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ECONOMIC IMPACT OF LOWER QUALITY IRRIGATION WATER ON CITRUS PRODUCTION IN BREVARD AND INDIAN RIVER COUNTIES: PHASE II

BY

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EXECUTIVE SUMMARY

Lower quality irrigation water (LQIW) can be characterized as water with total dissolved solids (TDS) in excess of 500 PPM. Phase I of this research project found that most groves in the Brevard and Indian River County area are irrigated with water having TDS levels above this threshold, some exceeding 2,500 PPM. Through non-foliar irrigation, rootstock selection, fertilizer types, and other cultural practices, growers have tried to effectively manage this adverse situation. Sandy soil and high rainfall alleviate some of the concern. Most previous research has investigated this problem in more arid regions. Certainly, those findings cannot be directly transferable to the Florida citrus environment. Some research in Florida suggests upper boundaries for TDS in drip or micro-sprinkler irrigation systems to be between 1,500 and 2,000 ppm. The purpose of this phase is to investigate actual grower results in managing LQIW and identify thresholds at which LQIW becomes detrimental to grove productivity.

Complete data were obtained for 163 blocks of citrus. Water samples were collected during 1996 at regular intervals and analyzed for levels of sodium, chloride, sulfate, and TDS. Ninety-nine percent of the samples had TDS levels exceeding 500 ppm. Average TDS levels neared 1,300 ppm. Leaf tissue samples were gathered and tested for levels of sodium, chloride, macro-nutrients, and micro-elements. Growers were interviewed about their irrigation, fertility, and pest control management practices. Grove characteristic and data were also gathered.

For statistical evaluation purposes, citrus production was divided into three categories: conventional orange, organic orange, and grapefruit. Poor market conditions resulted in incomplete harvesting for many of the grapefruit blocks. All of the organic blocks observed for this study were converted from conventional orange production. Harvesting information was more complete for orange blocks.

On average, sodium leaf tissue levels were below established thresholds for all types of production. Organic oranges tended to have higher leaf tissue sodium levels. Chloride levels in leaf tissue were near or above recommended excess threshold levels for oranges, but were well below this level for grapefruit. Sodium leaf tissue levels were found to have significantly negative impacts on all citrus production, while chlorides did not demonstrate negative effects.

Significant differences in leaf tissue analysis were observed for citrus on different rootstocks. In conventional oranges, higher sodium tissue levels were observed for Milam and Rough Lemon rootstock as compared to Sour Orange. Sodium tissue levels were higher for Carrizo rootstock trees in organic production and the use of liquid fertilizer resulted in higher sodium levels for grapefruit. Chloride levels were higher for Carrizo rootstock trees in all three production practices, though not statistically significant for grapefruit.

Statistical models were developed to determine whether LQIW had influenced grower's choice of rootstocks in sampled groves. In conventional orange groves, it was found that higher TDS levels increased the likelihood of Sour Orange being used and decreased the likelihood of

Carrizo or Swingle being selected. Soil organic matter and TDS levels in irrigation water did not significantly effect rootstock selection for organic oranges. In grapefruit blocks, higher levels of organic matter were found to increase the likelihood of growers selecting Swingle, while higher TDS levels decreased the likelihood of this choice.

The elasticity (proportional impact) of TDS on citrus yield was estimated at –0.25 for conventional oranges. Translated, this means there is a 2.5 percent reduction in yield for each 10 percent increase in TDS above the sample mean, when all other variables are held constant. For organic oranges, the estimated proportional impact of TDS on yield was -0.38, meaning a ten percent increase in TDS level above the mean would reduce yield by 3.8 percent, all else being equal. The performance of the grapefruit model was hurt by incomplete harvest data.

LQIW effects for conventional oranges were evaluated at different TDS levels using incremental regressions. Results from this analysis suggest that significant reductions in yields are occurring when TDS levels are as low as 600 to 700 ppm. The results also show yields continuing to decline at a substantial rate for TDS levels below 1200 ppm. Above 1200 ppm, these negative impacts continue to reduce yields but at a smaller rate. This last finding implies that growers may not see substantial improvements in citrus yields from using better quality irrigation water until TDS levels are reduced below 1200 ppm. These findings were generally confirmed by class interval analysis. When TDS levels were classified as Low (500-1000 ppm), Medium (1000-1500 ppm), or High (>1500 ppm), average yields for conventional oranges dropped over 80 boxes per acre from Low to Medium and another 40 boxes from Medium to High.

In conclusion, LQIW does significantly impact yields. The producer's decision to use LQIW is based in economics. In the current market environment when very few new groves are being planted, producers may find it financially difficult to justify large expenditures for improving irrigation water quality, especially when they already face substantial sunk costs in land, trees, and equipment. Increasing supply forecasts will continue to put downward pressure on prices.

The use of better quality water may improve citrus yields and some growers have taken steps to access surface water, but the cost of access may be larger than the marginal benefit. Smaller growers are less likely to be able to justify or acquire the necessary capital for such investments. Without improvement in the marketplace, we foresee a decrease in the number of groves. Smaller producers will be more likely to quit production. Larger producers will probably reduce their acreage with LQIW being an important decision factor.

One recommendation is to study the costs and feasibility of access to surface water. The elasticity measures for conventional orange production should be helpful in determining the corresponding marginal benefit. We feel that growers are effectively managing LQIW situations, but they are not able to completely reduce its negative impacts.

The findings of this study should be actively shared with producers. Some caution needs to be exercised in the direct application of these results, since this is only one year of information. Still, the findings of the analyses indicate significant relationships that should be of interest to producers. Finally, controlled experimentation may help provide insights into the why's and how's of LQIW impacts. Further understanding of these areas should shed light on technologies that will combat the detrimental effects.

ECONOMIC IMPACT OF LOWER QUALITY IRRIGATION WATER ON CITRUS PRODUCTION IN BREVARD AND INDIAN RIVER COUNTIES: PHASE II

INTRODUCTION

A substantial number of citrus groves in Indian River and southern Brevard counties of Florida are irrigated with artesian water originating from the Floridan aquifer. This water is usually of lower quality and not suitable for human consumption with levels of Total Dissolved Solids (TDS) exceeding 500 ppm. With the evolution to drip and micro-sprinkler irrigation technology during the last 20 years, citrus producers have discovered that they can use water with several times this level of TDS for irrigation. Due to the sandy soils and average annual rainfall levels near 50 inches, salts and other minerals are less likely to accumulate in the soils of this area except during seasonal dry spells.

Previous research on the impacts of saline irrigation water on citrus has been predominantly focused on more arid regions of the world where soils are usually heavier and less porous. In Florida, Syvertsen et al. (1989 and 1993) and Alva and Syvertsen (1991) have conducted lysimeter tank studies on the effects of saline irrigation water on Valencia orange trees with two different rootstocks and sandy soils typical of south-central Florida. A more extensive experimental field study for grapefruit on the southeast coast of Florida was interrupted by a freeze in 1989 before observations could be collected on mature trees (Boman 1993). Consequently, many researchers and growers feel that there is inadequate scientific research to provide comprehensive guidelines for using saline water to irrigate citrus, and particularly grapefruit, in the region under consideration. Current guidelines for the state of Florida place the upper boundary for TDS in drip or micro-sprinkler applied irrigation water on citrus between 1500 to 2000 ppm (Syvertsen 1996). Phase I of this study found that there is a significant minority of groves in the area being irrigated with water having TDS levels in the vicinity of 2500 ppm. This leads to the question; do the physiological and economic benefits of irrigating citrus groves with water having TDS levels in excess of 1500 to 2000 ppm outweigh the harm or costs?

Phase II of this study represents the implementation stage of an investigation to evaluate the use and productiveness of lower quality irrigation water (LQIW) on citrus production in Indian River and Brevard counties, Florida. This stage was preceded by Phase I, where the relevancy and feasibility of conducting an empirical analysis of this issue were appraised. The objectives of this second phase are to describe the scope and distribution of the LQIW problem for citrus, determine whether grower perceptions about LQIW and citrus production are consistent with its actual use and impact on their groves, and identify the threshold values at which LQIW becomes detrimental to grove productivity. This study will also describe and evaluate how different grove management practices interact with LQIW on grove productivity.

Scope

Data collection and analysis for this investigation were limited to orange and grapefruit groves located in Indian River and southern Brevard counties. For the purposes of supporting a diversity of types and sizes of citrus operations, efforts were made to recruit a stratified sample of growers in the study area based on operation size in terms of acres under irrigation. Participating growers were selected from a database of consumptive use permits provided by the St. Johns River Water Management District (SJRWMD). The type and depth of data collected on grove production practices were generally qualitative in nature and limited to lessen the intrusiveness and reporting burden placed on participants. The primary focus of this analysis is to establish how effectively growers are managing LQIW. This type of research is beneficial because it deals with actual grower activity and results; however there are limitations to information that is not gathered in a controlled environment. For instance, detailed data on the actual quantities and types of production inputs such as labor, fertilizers, pesticides, and irrigation water were not available for each block in the sample. As such, we assume that any differences here are not significantly impacting the targeted results of this study.

Organization of Report

In the following section, "**Procedures and Data**", the tasks and data used to carry out this research are discussed. This includes details on the methodology associated with the collection of water quality and leaf tissue samples, grove characteristics data, and management practices related to grove production and irrigation. The next section, "**Statistical Description of Data**", provides a descriptive evaluation of each of the types of data collected with respect to central tendencies and distributions over the sample base and within important subgroups of the sample base. The procedures and results of empirical analyses are presented in the section entitled "**Impact of LQIW on Citrus: Framework and Results**" The last section of this report, "**Summary, Conclusions, and Recommendations**", presents the overall results and implications of the empirical analysis. From these results, conclusions and recommendations are provided which address the overall objectives of the research.

PROCEDURES AND DATA

The principal tasks of Phase II were to sample irrigation water quality at three different times during the growing season, collect relevant data on physical and cultural grove characteristics, document cultural/management practices used on these groves, take leaf tissue samples, and collect yield data as they became available. These data were then statistically evaluated to identify and measure any relationships between grove yields, irrigation water quality, grove characteristics and cultural management practices. Details of the planned activities for each of these tasks were discussed in the "Proposed Scope of Work for Phase II". The actual procedures as they occurred are described below.

Recruiting Study Participants

The first task of the study was to recruit approximately 30 citrus producers from the two county area to participate in the study. The statistical sampling objective was to obtain between 120 and 175 observations units of citrus production, or blocks. This was based on a projected average block size of 40 acres. It was agreed with the SJRWMD that the selection of growers should be weighted more heavily to smaller operations since it was felt these types of operations would benefit more from the findings of this study. The proposed stratification consisted of 20 small operations of between 20 and 200 acres is size, five medium growers between 200 to 500 acres, and five large operations with greater than 500 acres.

Potential participants were selected from a database of approximately 450 consumptive use permits (CUP) provided by SJRWMD. Since larger operations sometimes have multiple permits under different entities, this listing was consolidated to approximately 250 observations. This consolidated data set was then sorted in ascending order by acres and producers were contacted in that order for recruiting purposes. Altogether, about 80 grower/operations were contacted. A large majority of the smaller sized permits (less than 200 acres) were no longer in commercial operation or could not be contacted due to obsolete addresses and telephone numbers. Of the smaller growers still in business, only about one in four expressed any interest in being involved with the study. In contrast, the proportion of viable and interested grower/operations increased substantially as permit size increased above 200 acres. As a result, the distribution of size of operations participating in the study was not weighted as heavily for smaller operations as was originally intended and the number of operations included in the study was reduced (tables 1.1 and 1.2).

Table 1.1. Number of growers by Category for the Sample population, Proposed Sample Set, Original Sample Set.

	CUP list		Proposed		Original	
Size	**Number**	**Percent**	**Number**	**Percent**	**Number**	**Percent**
20 – 200	168	71%	20	67%	5	26%
200-500	38	16%	5	17%	4	21%
500+	29	12%	5	17%	10	53%
TOTAL	235	100%	30	100%	19	100%

Table 1.2. Sample Acreage by Size Category for Sample Population, Proposed Sample Set, and Original Sample Set.

	CUP list		Proposed		Original	
Size	Acres	Percent	Acres	Percent	Acres	Percent
20 – 200	13,917	20%	NA	NA	574	3%
200-500	11,663	17%	NA	NA	1,340	7%
500+	42,405	62%	NA	NA	16,163	89%
TOTAL	67,985	100%	NA	NA	18,077*	100%

* Acres represent the size of participating operations and not the actual number of acres included in the study.

Several factors contributed to a loss of sample blocks (particularly grapefruit) during the study. The most prominent cause was a deficiency of some form of critical data. This included the absence of yield data for groves or blocks which were not harvested or only partially harvested, or the unavailability of precise information on rootstocks or the trees counts for different varieties or types grown within a single block. Some growers did not record yield data for individual blocks within a large grove due to difficult harvesting conditions. Complete data was obtained for 163 of the 253 blocks of citrus initially recorded in the study. The overall number exceeds the original proposal level and complete observations are well within the desired range.

Irrigation Water and Leaf Tissue Sampling

Irrigation water quality sampling began as soon as enough participants had been recruited for the study. To account for any seasonal variation in irrigation water quality, three series of samples were collected during 1996 season. The first series was collected between late March and early May; the second during the late summer and early fall and; the third between late November and mid-December. The second sampling series was delayed from late spring until late summer due to higher than normal levels of rainfall and a corresponding lack of irrigation activity during the earlier period.
Samples were recorded based on time, date, location, and water source. Water samples were delivered to and analyzed by SJRWMD laboratories for Sodium (Na), Chloride (Cl), Sulfate (SO4) and TDS. Altogether approximately 450 water samples were collected. Other samples were taken as a check to compare water quality at different points in an irrigation distribution system or at different withdrawal rates. A small percentage of the sites were only sampled twice due to circumstances preventing access to the site or the water from that site. Laboratory results for sites that were sampled more than once were averaged for use in the empirical analysis.

Leaf tissue samples were taken simultaneously with the second series of water samples. Between forty and sixty leaves were taken from four to six month old non-fruiting twigs for each block. Block sizes ranged from ten to fifty acres. Blocks of citrus larger than fifty acres were usually subdivided and the results from the multiple samples averaged. Leaf tissue samples were delivered to and analyzed by a University of Florida laboratory for Carbon (C), Nitrogen (N), Phosphorus (P), Potassium (K), Sodium, Chloride, Aluminum (Al), Calcium (Ca), Copper (Cu), Iron (Fe), Magnesium (Mg), Manganese (Mn), and Zinc (Zn).

Grove Characteristics and Management Practices Data

Eighteen participating producers were successfully interviewed about their operation's management practices in the areas of irrigation, drainage, fertilization, and pest control. Most interviews were completed during the summer months, which is typically the slow season for citrus operations. Survey questions on these practices were directed mainly to the degree and form of monitoring efforts in each production area, the different types of strategies employed to manage them, and how these monitoring efforts and management strategies were related to or interacted with the use of LQIW. Data on grove characteristics was collected simultaneously with water and leaf tissue sampling, and during these interviews.

Soil types and characteristics for each block were determined from USDA, Soil Conservation Service, Soil Surveys. Over eighty percent of the blocks observed contained at least two soil types; more than 40 percent contained three or more. Up to three soil types were recorded for each block along with the approximate proportion each comprised. Numerical soil characteristics were recorded for each soil type. Rainfall data was compiled for five different locations in Indian River County and for one location in southern Brevard County. These data were obtained from participating growers, the NOAA NCDC, and the Indian River Mosquito Control District.

Yield Data Collection

Yield data were collected, as they became available. This was perhaps the most challenging aspect of the data collection effort due to a record crop yield and low prices. Harvests for most grapefruit blocks were delayed as producers held out for better prices. According to the USDA NASS, seasonal average grapefruit prices were the lowest since the late 1960's. One participant acknowledged their grove was not harvested at all. Other producers verified only selected blocks were harvested. This may have also been the case for two other producers who never responded to repeated requests for harvest data. Still other blocks of grapefruit were spot harvested. In this case, only the largest, highest grade fruit was picked from the trees, leaving lower quality fruit to drop off. For some of these blocks, producers were willing to provide estimates of total yields. Orange prices were relatively better for the season and collecting yield data for this fruit type was much more successful.

Data Entry and Organization

Data on water and leaf tissue samples and survey responses were imported into to IBM compatible PC spreadsheet software as they became available. The identity of producers, grove locations, and sampling sites were coded in order to maintain the confidentiality of study participants. Data on management practices and grove characteristics were hand entered into electronic spreadsheets. These data along with the laboratory sampling results were then collated and assembled into several databases. Associated observations within each database are identified by a common key index. In some cases observation units had to be aggregated or split. In these cases, data from water and leaf-tissue samples, as well as soil characteristics were averaged or duplicated.

Data Analysis and Modeling

Once these data were entered and organized onto computer spreadsheets they could then be used for descriptive and modeling purposes. Minimum, maximum, average and standard deviation statistics were calculated for each field value where applicable. Separate descriptive statistics were provided for a variety of different cultural categories. The framework for modeling this study was based on its primary objective of exploring relationships between water quality, grove characteristics and cultural practices to productivity. Considerable insight into this process was obtained from previous research. Given this knowledge and objective, hypotheses were formulated as a basis for conducting the empirical analysis. Sometimes important relationships within a biological model are found unexpectedly. One relatively simple means of identifying empirical relationships (and problems) is to compute correlation tables between the different variables of interest.

STATISTICAL DESCRIPTION OF DATA

This section summarizes the survey data and allows initial insight into the investigation of LQIW for the Indian River and Brevard county areas. Descriptive statistics and some correlation analysis are provided for water quality, leaf tissue analysis, grove and block characteristics, management practices, and yields.

Water Quality

The results from approximately 350 water samples collected from nearly 140 sites were assembled for use in analysis. Most of these sites were sampled on three different occasions since water quality is known to fluctuate seasonally. A small percentage of sites were only sampled twice due to circumstances preventing access to the site or to the water from that site. All samples were analyzed for levels of toxic ions (Sodium, Chlorides, and Sulfates) as well as TDS.

There are two basic types of water sources used for irrigation in the study area. The majority of water used for irrigation in this study originates from wells tapping the Floridan aquifer. There was one grove that used a horizontal well system for irrigation. This consists of a water collection pipe buried 15 to 18 feet deep under the grove that was several hundred feet long. Surface water sources consist primarily of water drainage and distribution canals. A small proportion of blocks was irrigated from private reservoirs or retention ponds. Table 3.1 presents descriptive statistics for water quality results from all the samples and samples from surface and subsurface sources. The most striking differences in quality between the two sources occurs in the levels of Sodium and

Chlorides. Average ion levels for surface water are over forty percent lower than those from underground sources. Sulfate levels are approximately 25 percent lower and TDS levels are about one third lower in surface water sources.

Table 3.1. Descriptive Statistics for LQIW Water Samples by Source

Sample Category	Statistic	Quality			
		Na	**Cl**	**SO4**	**TDS**
All sample sources					
	Count	346	347	347	347
	Minimum	41	62	35	369
	Maximum	762	1700	330	3110
	Average	261.15	569.75	150.31	1271.79
	Standard deviation	122.86	275.53	52.92	475.79
	Coefficient of variation	0.4704	0.4836	0.3521	0.3741
Surface water sources					
	Count	65	65	65	65
	Minimum	41	62	35	369
	Maximum	460	1050	248	2020
	Average	164.79	341.11	118.17	918.67
	Standard deviation	108.78	248.25	46.30	393.86
	Coefficient of variation	0.6601	0.7278	0.3918	0.4287
Subsurface water sources					
	Count	281	282	282	282
	Minimum	87	209	48	515
	Maximum	762	1700	330	3110
	Average	283.44	622.45	157.72	1353.19
	Standard deviation	114.91	253.74	51.57	455.45
	Coefficient of variation	0.4054	0.4076	0.3270	0.3366
Statistical tests for differences between surface and subsurface					
Average	Z-test	**7.8402**	**8.2027**	**6.0733**	**7.7765**
	P-value	**4.44E-15**	**2.22E-16**	**1.25E-09**	**7.55E-15**
Variance	F-test	1.1159	1.0447	1.2407	**1.3372**
	P-value	0.3032	0.4275	0.1491	**0.0801**

Statistical tests were performed to compare the mean and variance (square of the standard deviation) of the levels for the different ions and TDS from the two sources. The means of all ions and TDS were significantly higher for subsurface sources. Only the variance of TDS solids was statistically greater for subsurface sources. It should be remembered that the variance of water quality is across sites, or geographic in nature. The coefficient of variation equals the standard deviation normalized (divided) by the mean. This allows a more accurate comparison of the variability between different components of water quality. Thus it is more appropriate to state that the absolute variability of TDS for subsurface sources was greater than for surface sources since the coefficient of variation for subsurface TDS is considerably smaller than its counterpart.

Table 3.2 presents water quality statistics broken-down by the season in which they were sampled; spring, summer, or fall. Count numbers differ slightly due to sampling sites being unavailable at different times of the year or samples being lost. Average ion and TDS levels are remarkably similar between series. Average levels of Sodium and Chlorides are within one percentage point for the spring and summer series. Sulfate levels were significantly higher in the spring than in the summer and fall (table 3.3). This was true for the absolute and relative variability of sulfates as well. TDS variability was much greater in the spring, than in the summer and fall.

Although there was no significant differences in the average levels of Na, Cl, and TDS for all sampling sites between series, there was still considerable variability in water quality at individual sites over time. When evaluated across all sites, the seasonal variability of water quality at individual sites could have been washed out because quality might improve at one site during the second series while it declined at another. Table 3.4 compares the standard deviations and coefficients of variation at individual sites across time with those across sites at one time.

Table 3.2. Descriptive Statistics For Spring, Summer, And Fall Irrigation Water Quality Samples.

Sample Category Statistic	Quality			
	Na	Cl	SO4	TDS
Spring series of water samples				
Count	113	114	114	114
Average	263.20	566.64	160.15	1327.80
Standard deviation	117.76	270.48	56.93	804.50
Coefficient of variation	0.4474	0.4773	0.3555	0.6059
Summer series of water samples				
Count	117	117	117	117
Average	263.35	566.98	145.65	1279.36
Standard deviation	123.29	268.08	50.53	481.71
Coefficient of variation	0.4682	0.4728	0.3469	0.3765
Fall series of water samples				
Count	116	116	116	116
Average	256.93	575.61	145.34	1260.84
Standard deviation	127.10	287.50	49.75	494.29
Coefficient of variation	0.4947	0.4995	0.3423	0.3920

Table 3.3. Tests For Statistical Differences Between Averages And Variances Of Irrigation Water Quality Samples for Spring, Summer, And Fall Sampling Series.

Sample Category	Statistic	Quality			
		Na	Cl	SO4	TDS
Summer - Spring tests					
	Average: z-test	0.0095	0.0095	**-2.0459**	-0.5535
	P-val	0.9924	0.9924	**0.0408**	0.5799
	Variance: F-test	1.0962	1.0180	**0.7878**	**0.3585**
	P-val	0.3094	0.4616	**0.0983**	**0.0000**
Fall – Spring tests					
	Average: z-test	-0.3875	0.2437	**-2.1003**	-0.7589
	P-val	0.6984	0.8075	**0.0357**	0.4479
	Variance: F-test	1.1649	1.1298	**0.7637**	**0.3775**
	P-val	0.2042	0.2543	**0.0723**	**0.0000**
Fall – Summer tests					
	Average: z-test	-0.3915	0.2369	-0.0477	-0.2895
	P-val	0.6954	0.8127	0.9620	0.7722
	Variance: F-test	1.0309	1.0724	0.9846	1.0261
	P-val	0.4346	0.3524	0.4664	0.4444

The average standard deviation for within site water quality was from one-fifth to one-third as large as that found to occur across sites (geographically, table 3.1). As implied earlier in Table 3.3, the SO4 ion varied the most between series or across time relative to its average level and variability between sites.

Table 3.4. Comparison Of Variability Of Water Quality Across Sites And Within Sites Across Time.

Dimension	Statistics	Na	Cl	SO4	TDS
Within site	Avg. Standard Dev.	25.72	50.20	16.85	113.08
Across sites	Standard Dev.	122.86	275.53	52.92	475.79
Within site	Avg. Coeff. Of Var.	0.1064	0.0951	0.1198	0.0771
Across site	Coeff. Of Var.	0.4704	0.4836	0.3521	0.3741

Leaf Tissue Results

Statistics for leaf tissue analysis (LTA) results are compared for different fruit types and cultures, different rootstocks, and different water sources. This discussion will focus on the levels of macro-nutrients (N, P, and K) and toxic ions (Na and Cl). Results indicated that some blocks had been treated with micro-nutrient sprays near sampling events. Often "stickers" are added to these nutritional sprays so they don't wash off with the next rain. As a result, some micro-nutrient levels are as much as 100 times of what would be optimal.

Important differences are evident in the breakout of LTA results. Looking at Table 3.5, macro-nutrient levels are uniformly higher in oranges than in grapefruit. Although there are currently no individual guidelines available for grapefruit versus oranges, it has been recognized by researchers in the field that LTA levels for nitrogen are typically lower for grapefruit than for oranges. Average levels of Na and Cl are higher than those found in conventional oranges and grapefruit (table 3.6). Conventional orange leaves had levels of Cl approximately 50 percent higher on average than found in grapefruit.

Table 3.5. Mean Tissue Levels of Macro-Nutrient by Production Type.

Production Type	N	P	K
Conventional Orange	2.800	0.143	0.990
Organic Orange	2.755	0.160	1.243
Grapefruit	2.282	0.125	0.981

Table 3.6. Mean Tissue Levels of Sodium and Chloride by Production Type.

Production Type	Na	Cl
Conventional Orange	0.110	0.217
Organic Orange	0.186	0.349
Grapefruit	0.075	0.147

LTA salt levels differed considerably between organic and conventional cultural programs. Organic production avoids use of synthetic materials for fertilization and pest control. On average, sodium levels in leaves from organic blocks were almost seventy percent higher than conventionally produced blocks. Chloride levels were likewise elevated in organic blocks, on average being 60 percent higher than in leaves from conventional blocks. Upon closer investigation, it was learned that mined nutrients known as Chilean Nitrate were applied to many of the organic blocks. This is a naturally occurring nitrogen fertilizer mined in South America and consists primarily of Sodium Nitrate and may be contaminated with Sodium Chloride. Consequently, it appears that the salt content of fertilizers can be an important influence on leaf tissue levels of Na and Cl.

Comparing results for different rootstocks in Table 3.7, macro-nutrient levels seem to be quite similar, with the possible exception of higher nitrogen levels for Carrizo. Trees on Carrizo, which is known to be a salt sensitive rootstock, had the highest levels of toxic elements (table 3.8). Sodium and Chloride levels for Sour Orange, the most frequently used rootstock in the study, were mid-way between Swingle and Carrizo. According to Syvertsen et al. (1989), salt sensitive rootstocks tend to be those which are also considered "vigorous", because they support faster growth and larger trees. This vigor occurs to some extent because the rootstocks are more efficient or demanding in extracting water from the soil. Apparently the more water a rootstock is capable of extracting from the soil, the more nutrients and salts will also be extracted.

Table 3.7. Mean Tissue Levels of Macro-Nutrient by Rootstock.

Rootstock	N	P	K
Sour Orange	2.463	0.126	1.031
Swingle	2.455	0.154	0.921
Carrizo	2.819	0.153	0.977

Table 3.8. Mean Tissue Levels of Sodium and Chloride by Rootstock.

Rootstock	Na	Cl
Sour Orange	0.094	0.177
Swingle	0.069	0.146
Carrizo	0.152	0.362

Interestingly, there is a lack of substantial differences in macro-nutrient and toxic ion levels between water sources (tables 3.9 and 3.10). Given the significantly greater levels of toxic ions and TDS found in the analysis of sub-surface water (table 3.1), it is surprising how close the sodium and chloride levels are for this classification. This provides perhaps some evidence that growers are managing LQIW with some degree of effectiveness. Macro-nutrient levels were also similar, providing some indication that higher salt levels in sub-surface irrigation water apparently had little affect on nutrient uptake.

Table 3.9. Mean Tissue Levels of Macro-Nutrients by Water Source.

Source	N	P	K
Surface	2.533	0.141	1.016
Sub-Surface	2.537	0.134	1.030

Table 3.10. Mean Tissue Levels of Sodium and Chloride by Water Source.

Source	Na	Cl
Surface	0.106	0.204
Sub-Surface	0.102	0.197

A relatively simple method of evaluating an empirical relationship between continuous variables is to calculate correlation coefficients. It is important to this analysis whether ion levels in irrigation water are related to those found in LTA. Table 3.11 presents correlation coefficients between leaf tissue levels and TDS. No significant correlation between sodium tissue levels and TDS was noted for the sample, while chloride and sulfates were positively related to TDS. The consistently negative, although relatively small, correlations between water quality and N, P, K in leaf tissue may be an indication that low quality irrigation water impedes the uptake of these nutrients.

Table 3.11. Correlation between TDS and Leaf Tissue Analysis.

Element	TDS
Na	-0.06
Cl	0.24
SO4	0.76
N	-0.21
P	-0.11
K	-0.11

Grove and Block Characteristics

General grove characteristics are provided in this section including fruit type, variety, rootstock, age, density and soil type. This information can prove insightful when analyzing productivity and LQIW management. The blocks are fairly evenly distributed between oranges and grapefruit (table 3.12). Over half of the orange blocks are Valencia and over one-fourth are Hamlin. Grapefruit blocks are split fairly evenly between reds and whites. Approximately 83 percent of blocks sampled consisted of a single rootstock. The majority of primary rootstock blocks were Sour Orange (table 3.13). Rough Lemon was the most frequently observed secondary rootstock in mixed blocks.

Table 3.12. Distribution of Fruit Type and Tree Variety.

Fruit Type	Fruit Variety	No. of Blocks[1]	% Blocks
Oranges	Valencia	64	51%
	Hamlin	34	27%
	Pineapple	12	9.4%
	Navel	12	9.4%
	Red Navel	2	1.6%
	Amber Sweet	1	0.8%
	Sun Burst	1	0.8%
	Total	**128**	**49%**
Grapefruit	Red	69	52%
	White	63	48%
	Total	**133**	**51%**

Table 3.13. Distribution of Rootstocks.

Primary Rootstock	No. of Blocks	% of Blocks	Secondary Rootstock	No. of Blocks	% of Blocks
Sour Orange	146	59%	Sour Orange	7	17%
Carrizo	47	19%	Carrizo	4	10%
Swingle	37	15%	Swingle	8	19%
Milam	8	3%	Milam	2	5%
Cleo	5	2%	Cleo	3	7%
Rough Lemon	3	1%	Rough Lemon	18	43%

Tree ages ranged from five to seventy years with nearly 70 percent 20 years or younger (table 3.14). Tree densities ranged from 46 to 240 trees per acre. Higher density blocks were usually found in groves with older more widely spaced trees which had been inter-planted or stagger-planted with younger trees within the last 8 years. Tree densities in the majority of blocks range between 100 to 125 trees per acre.

As expected, most of the soil types were fine sand which is consistent with the region (table 3.15). The most frequently observed soil types were Riviera, Wabasso, Winder, and Pineda.

Table 3.14. Distribution of Tree Age and Density Groups.

Tree age Years	No. of Blocks	% of Blocks	Tree density per acre	No. of Blocks	% of Blocks
5	3	1%	50	25	9%
10	42	17%	75	38	14%
15	31	13%	100	64	24%
20	90	37%	125	76	29%
30	48	20%	150	35	13%
50	25	10%	175	11	4%
70	3	1%	200	8	3%
70+	0	0%	200+	8	3%

Correlation coefficients were estimated between block characteristics, water quality and LTA results (Table 3.16). Tree age and density have the greatest correlation in the table (-0.49). New grove sites are being planted at higher densities which is consistent with this result. Tree density is negatively correlated with all four measures of water quality, but density is positively correlated with leaf tissue levels. The direction of correlations between tree age, water quality measure and leaf tissue results are generally opposite those for density. Over time the move to higher tree densities increases the competition for nutrient uptake. As such, roots would more aggressively extract elements from the soil. Growers may then be less likely to increase density in areas of poor water quality. Still, leaf tissue analysis levels do appear to be higher for densely populated blocks.

Water quality appears to be better in younger groves. New grove selection appears to be moving to better water quality areas. Obviously, producers would prefer lower TDS levels for irrigation. Also, Phase I of this study did indicate grower preference for available surface water when choosing new grove sites. Sunk costs and asset fixity may override water quality concerns in long established groves.

Table 3.15. Distribution of Soil Types.

	Primary		**Secondary**	
Soil Name	**No. of Blocks**	**% of Blocks**	**No. of blocks**	**% of Blocks**
Canaveral fine sand	2	1%	0	0%
Chobee loamy fine sand	1	0%	5	3%
Eaugallie fine sand	3	1%	4	2%
Myakka fine sand	1	0%	1	1%
Oldsmar fine sand	9	4%	1	1%
Riviera fine sand	47	19%	48	25%
Archbold sand	0	0%	2	1%
Wabasso fine sand	73	29%	35	18%
Winder fine sand	45	18%	7	4%
Manatee loamy fine sand	2	1%	6	3%
Pineda fine sand	32	13%	51	26%
Captiva fine sand	0	0%	2	1%
Pomello sand	1	0%	0	0%
Jupiter fine sand	0	0%	2	1%
Floridana sand	0	0%	2	1%
Malabar fine sand	5	2%	0	0%
Canova muck	5	2%	2	1%
Riviera fine sand, depr.	2	1%	10	5%
Oldsmar fine sand, depr.	1	0%	1	1%
Floridana mucky fine sand, depr.	0	0%	2	1%
Holopaw fine sand, depr.	0	0%	2	1%
EauGallie sand, bedded	14	6%	0	0%
Felda sand	7	3%	0	0%
Felda sand, bedded	0	0%	2	1%
Pineda sand	0	0%	1	1%
Pineda sand, bedded	0	0%	7	4%
Wabasso sand (IR)	0	0%	2	1%
Total	250	100%	195	100%

Table 3.16. Correlation between Density, Age, Water Quality and Leaf Tissue Levels.

	Trees Per acre	Tree Age
Trees per acre	1.00	
Tree age	-0.49	1.00
Water, Na	-0.38	0.29
Water, Cl	-0.38	0.29
Water, SO4	-0.21	0.13
Water, TDS	-0.35	0.26
Leaf tissue, N	0.42	-0.15
Leaf tissue, P	0.31	-0.19
Leaf tissue, K	0.01	0.14
Leaf tissue, Na	0.12	0.12
Leaf tissue, Cl	0.22	-0.07

Monthly rainfall observations were collected from nine different locations. Rainfall during the 16 month period between January 1996 and March 1997 was above normal overall with some fluctuations from month to month (table 3.17). Observations between the sites were fairly consistent over the study period; however, we do not have information on individual rain events. Rate of rainfall may also be important in addition to monthly amounts. Based on the consistency between the observations, we do not feel that rainfall is an important determinant for the study period. This level and pattern is presented graphically in Figure 3.1. Relative levels and variability for Vero Beach Municipal Airport, the average of six sites in the study area and the long term chronological average for the Vero Beach airport are shown. There were several rainfall events in excess of three inches which is probably sufficient to flush sandy soils of any accumulated salts.

Table 3.17. Rainfall Data for Indian River and Brevard Counties.

Time		Location										Vero Beach
Mon-th	Year	VB MAP	SW9th &17th	I95 &60	60& 146th	60& 512	Wab. OI	SW17 &I95	60& 71st	Mel-borne	Geo. Avg.	Historical Avg.
Jan.	96	4.19	3.5	3.5	3.5	3.5	4.1	2.7	4.42	3.64	3.67	2.43
Feb.	96	0.86	0.6	1.1	0.8	1.1	0.7	0.8	0.99	0.81	0.86	2.86
Mar.	96	10.8	5.8	5.8	5.8	5.8	8.8	8.3	11.11	11.58	8.20	3.05
Apr.	96	1.41	1.5	1.5	1.5	1.7	3.3	4.6	1.9	0.95	2.04	2.59
May.	96	6.88	6.9	6.6	5.7	5.7	5.4	4.7	5.63	2.44	5.55	4.39
Jun.	96	10.54	9.1	10.5	12.5	12.5	5.5	8	10.02	8.98	9.74	6.52
Jul.	96	7.55	9.9	5.2	5.2	5.2	5	6.2	7.71	3.18	6.13	5.76
Aug.	96	1.73	5.5	3.3	5.3	6.7	3.2	5.9	3.07	5.58	4.48	5.39
Sep.	96	3.29	4.3	3.7	3.5	4.1	1.1	4.6	3.74	3.57	3.54	7.96
Oct.	96	8.55	13.5	14	10.4	9	4.4	10.4	10.26	5.07	9.51	5.94
Nov.	96	0.74	0	0	0	0	0	0	0.67	1.97	0.38	2.55
Dec.	96	2.41	2.6	1.7	1.7	1.7	1.6	2.2	2.14	1.75	1.98	1.97
Jan.	97	3.41	6.5	7.1	6.6	6.6	3.5	4.2	3.56	1.99	4.83	2.43
Feb.	97	2.73	2.4	2	2.6	2.6	0.8	1.1	2.8	1.78	2.09	2.86
Mar.	97	3.98	3.7	3.7	3.7	3.7	2.6	3.3	4.18	1.65	3.39	3.05
Total		69.07	75.8	69.7	68.8	69.9	50	67	72.2	54.94	66.38	59.75

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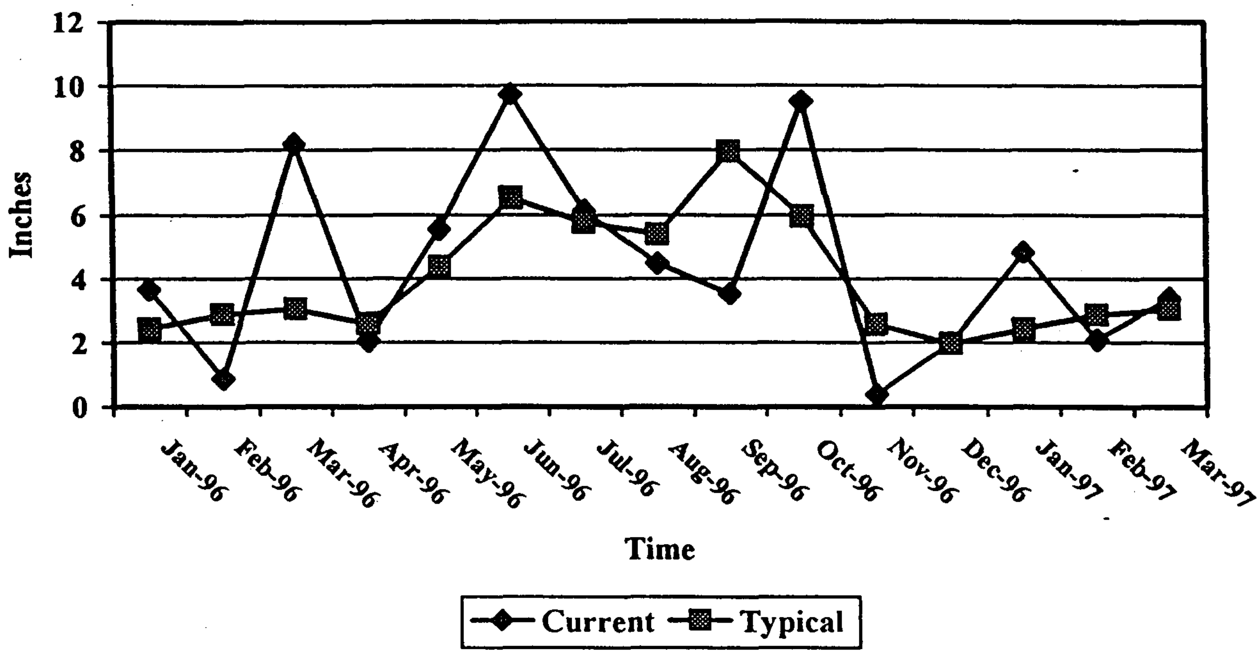
Figure 3.1 Rainfall for LQIW Study Area, 1996-97



Management Practices Data

The results of the management practices interviews are presented in Appendix A. Three areas of citrus management were evaluated: water management, fertility management, and pest management. With respect to water management, most growers test their irrigation water quality at least once per year. Based on interview comments, growers with lower quality water tend to test more frequently. Off site laboratories are used most frequently for this purpose and growers are most interested in TDS levels. Most growers use the visual appearance of soil and/or trees to determine the timing and duration of irrigation. Less than 25 percent use mechanical moisture or water table monitoring devices for this purpose. Most growers adjust the duration and frequency of irrigation depending on the soil type and quality of water they use. Generally for heavier soils and lower quality water, irrigation cycles are longer, i.e., lower frequency and longer duration. Approximate half of the initial participants indicated that they have made capital investments to improve water quality.

Many growers monitor their fertility programs by doing annual soil and/or leaf-tissue analysis. A smaller proportion of growers checks for salt levels in soil or trees, and they tend to do so less frequently. Most growers that do these tests apply fertilizers at or below the recommended rates. Dry granular fertilizers are widely used, but growers always use an additional type of fertilizer in their program as well. The application of dry fertilizers is most frequently used in combination with foliar sprays and/or sewage sludge. Only a small minority of participants apply fertilizers through their irrigation system, which is called fertigation. Usually this is done for very young trees. Over sixty percent of the participants indicated that they modify their fertilization program to reduce the salt content of the fertilizers.

Pest control strategies among the participants of this study were fairly sophisticated and varied. Growers tend to apply insecticides to treat existing problems, using a scout/spray or integrated pest management program. Over 40 percent apply fungicides (disease control materials) as a preventative measure. The "old" school of pest management dictated complete control whenever technically feasible. Survey results indicate that economic feasibility of pest/disease infestations drive their application decision today. Additional comments by growers suggested that pest and disease tolerance is increasing due to the poor citrus market, meaning the marginal benefit of application must be greater than the additional cost.

Overall, we get the sense that growers feel they are taking appropriate measures to minimize the potential impacts of LQIW use. As stated in Phase I, producers are more concerned with too much water (e.g., flooding) than the quality of water available for irrigation. Yet, they admit that this concern level is driven by recent events. A couple of dry years would renew concerns about the lack of quality water available.

An important issue in the analysis of management practices is how producers select rootstocks in relation to irrigation water quality. Interviewed growers were generally well informed of differences in salt tolerance associated with rootstock types. The selection of rootstocks for this purpose is borne out in the results of laboratory analysis of water quality and leaf tissue samples.

The generally accepted hierarchy of salt tolerance among rootstocks in descending order is Cleopatra, Sour Orange, Swingle, Rough Lemon, Milam and Carrizo (Syvertsen et al. 1989). There were 246 blocks of citrus surveyed in this study for which water quality, leaf tissue analysis and rootstock type were recorded. Sour orange was used in 143, or 59 percent, of these blocks, followed by Carrizo (19.5 percent) and Swingle (15 percent). Milam, Cleopatra, and Rough lemon composed the remaining 6.5 percent of the blocks surveyed (Sour orange is no longer a recommended choice of rootstock due to its susceptibility to citrus tristeza virus). By calculating the average and standard deviation of water quality and leaf tissue analysis results for the different rootstocks it is possible to calculate statistical tests to determine if growers are selecting rootstocks that are appropriate for the quality of their irrigation water.

Groves with Cleo rootstock have the highest average TDS level, supporting the notion of growers selecting salt tolerant rootstocks for high LQIW situations (table 3.18). The descending order for the other rootstocks is Sour Orange, Rough Lemon, Swingle, Carrizo, and Milam. This ranking is consistent with the earlier mentioned salt tolerance rankings providing evidence that TDS levels are an important determinant for rootstock selection.

Table 3.18. Average TDS Levels by Rootstock.

	Cleo	Sour Orange	Rough Lemon	Swingle	Carrizo	Milam
Count	5	143	3	37	48	8
Average	1501.6	1304.8	1234.9	1205.2	936.4	808.2
Std. Deviation	436.2	555.6	435.1	447.0	294.9	436.3
Std. Error	195.1	46.5	251.2	73.5	42.6	154.3

In fact, TDS levels for Cleo rootstock blocks are significantly higher than Swingle, Carrizo, and Milam but there is no significant TDS difference between Cleo and Sour Orange or Rough Lemon rootstocks (table 3.19). Rough Lemon was frequently used in conjunction with Sour Orange, which may influence this result. TDS levels for Sour Orange and Rough Lemon was significantly higher than Carrizo and Milam, while Swingle blocks had higher TDS levels than Carrizo and Milam. This finding is somewhat consistent but does suggest that other rootstock attributes contribute to the selection process as well.

Table 3.19. Significance Level for Ranking of Rootstocks by Average Irrigation Water Quality (1-tailed t-tests). *

	Cleo	Sour Orange	Rough Lemon	Swingle	Carrizo	Milam
Cleopatra.		0.214	0.217	0.085	0.000	0.009
Sour orange			0.414	0.157	0.000	0.007
Rough lemon				0.456	0.052	0.091
Swingle					0.001	0.014
Carrizo						0.147

* Darker shaded blocks are significant at better than the 0.05 level. Lighter shaded blocks are significant at better than the 0.1 level for a one-tailed test.

Not surprisingly, rankings of sodium levels in leaf tissue for different rootstocks are nearly the reverse of TDS with the exception of Swingle. Although Milam and Carrizo rootstocks were irrigated with water having the lowest average TDS levels, trees on these two rootstocks had the highest levels of sodium in their leaves; more than 50 percent higher than levels found in trees on Sour Orange (table 3.20). This result provides some confirmation to the salt tolerance rankings. Even though LQIW is being used, salt tolerant rootstock use results in lower sodium ion levels in the leaf tissue. Sodium levels for Milam and Carrizo are significantly higher than the other rootstocks (table 3.21). There was no significant difference between Cleo and Swingle.

Table 3.20. Average Sodium Leaf Tissue Levels by Rootstock.

	Milam	Carrizo	Rough Lemon	Sour Orange	Cleo	Swingle
Count	8	48	3	142	5	37
Average	0.1667	0.1508	0.0998	0.0932	0.0858	0.0685
Std. Deviation	0.0332	0.0574	0.0508	0.0418	0.0155	0.0378
Std. Error	0.0117	0.0083	0.0293	0.0035	0.0069	0.0062

Table 3.21. Significance Level for Ranking of Rootstocks by Leaf Tissue Sodium Levels (1-tailed t-tests). *

	Milam	Carrizo	Rough lemon	Sour Orange	Cleo	Swingle
Milam		0.225	0.014	0.000	0.000	0.000
Carrizo			0.070	0.000	0.008	0.000
Rough lemon				0.394	0.285	0.093
Sour orange					0.347	0.001
Cleo						0.162

* Darker shaded blocks are significant at better than the 0.05 level. Lighter shaded blocks are significant at better than the 0.1 level for a one-tailed test.

Trees on Carrizo rootstock had twice the average tissue levels of chlorides as the other rootstock (table 3.22). Cleo rootstock produced trees with the lowest levels of chloride despite being irrigated with water having the highest levels of TDS or chloride. Chloride tissue levels were significantly higher for Carrizo than all other rootstocks. Milam, Rough Lemon, and Swingle rootstocks had significantly higher TDS levels than Cleo.

Table 3.22. Average Chloride Leaf Tissue Levels by Rootstock.

	Carrizo	Sour Orange	Milam	Rough lemon	Swingle	Cleo
Count	48	142	8	3	37	5
Average	0.3591	0.1744	0.1693	0.1557	0.1456	0.0952
Std. Deviation	0.1669	0.1793	0.0721	0.0469	0.0869	0.0159
Std. Error	0.0241	0.0150	0.0255	0.0271	0.0143	0.0071

Table 3.23. Significance Level for Ranking of Rootstocks by Leaf Tissue Chloride Levels (1-tailed tests). *

	Carrizo	Sour Orange	Milam	Rough Lemon	Swingle	Cleo
Carrizo		0.000	0.001	0.021	0.000	0.000
Sour orange			0.468	0.429	0.173	0.163
Milam				0.386	0.239	0.024
Rough lemon					0.423	0.017
Swingle						0.104

* **Darker shaded blocks are significant at better than the 0.05 level. Lighter shaded blocks are significant at better than the 0.1 level for a one-tailed test.**

Management Practices, Water Quality, and Leaf Tissue Analysis Results

An important area of concern for this study is if and how certain production practices and inputs are associated with the use of LQIW. Growers may alter their irrigation practices based on tree and soil types. The purpose of the modification is to improve the quality of water, which in turn should lead to lower levels of toxic ions in the leaf tissue. Results do show that growers who modify irrigation practices based on soil and tree type have lower ion levels in the irrigation water and in the leaf tissue as a result (table 3.24). Positive test values indicate a reduction in tissue levels. Modifications based on water quality resulted in significantly lower chloride tissue levels.

Some growers have made capital investments to improve the quality of water they use for irrigation. It might be expected that these operations would have better quality water on average. Although the test results for water quality were all positively signed, none were significant (table 3.24). Despite the lack of significant difference in water quality, sodium and chloride ion levels in leaf tissue were significantly lower for operations that had made such investments. Approximately sixty percent of interviewed growers claimed to modify their fertilization practices in conjunction with LQIW use to reduce salt accumulation in soil and leaves. On average these growers had significantly lower levels of sodium and chloride ions in their irrigation water (table 3.24). The resulting improvement in irrigation water quality did not translate into significantly lower ion tissue levels. Leaf tissue levels may be a result of foliar fertilizer application, if this is the modification in the fertilizer program.

Table 3.24. Test Values for Associations of Selected Management Practices with Ion Levels in Irrigation Water and Leaf Tissue.*

	Modify irrigation practices for: Soil & tree type	Modify irrigation practices for: Water quality	Capital Improvements for: Water quality	Modify Fertilizer for: Water quality
Water	1	2	3	4
Na Test	2.023	-0.037	0.724	1.464
Cl Test	1.921	-0.075	0.529	1.683
TDS Test	3.210	0.799	0.808	0.811
Leaf tissue				
Na Test	1.465	-1.230	1.382	-1.287
Cl Test	3.716	2.046	1.888	-0.822

* shaded denotes significance at 0.10 level

A more important question is whether these modifications translate into higher yields. Yields were higher when modifications were made based on water, but there was no significant association demonstrated for modifications based on soil and tree type, capital improvements, or fertilizer modifications (table 3.25). Negative signs indicate a positive yield association.

Table 3.25. Test Values for Associations between Selected Management Practices and Citrus Yields.

	Modify irrigation practices for:		Capital Improve-ments for:	Modify Fertilizer for:
	Soil & tree type	Water quality	Water quality	Water quality
Boxes per acre				
Test	-1.252	-1.383	-0.192	0.817

With the major exception of foliar applications, there are few significant associations between different forms of fertilizer and ion levels (table 3.26). Dry fertilizer use is associated with lower phosphorous and sodium levels. Liquid fertilizer has no significant association with ion levels. Interestingly, foliar applications are associated with higher ion levels in the water and leaf tissue, suggesting this application is most common for high TDS areas. Use of compost is related to higher levels of potassium in the leaf tissue. Mined fertilizer use does not demonstrate any significant associations with ion levels.

Table 3.26. Test Values for Associations between Fertilizer Form and Ion Levels.

	Fertilizer Form				
Water	**Dry**	**Liquid**	**Foliar**	**Compost**	**Mined**
Na	0.960	0.082	-1.673	-0.664	0.121
Cl	1.037	0.075	-1.982	-0.313	0.251
TDS	0.228	0.071	-1.819	-0.665	0.258
Leaf Tissue					
N	-0.344	-0.495	-1.946	-0.174	-0.423
P	3.217	-0.357	-0.080	0.391	0.329
K	0.350	-0.208	-1.091	-1.618	0.462
Na	2.593	-0.321	-2.926	0.931	0.000
Cl	0.582	-0.021	-1.886	-1.032	0.282

Yields and Prices

Citrus yields for the state of Florida were excellent for the 1996-97 crop year. In aggregate, orange production achieved a record level of 226 million boxes, eleven percent higher than the previous year. Aggregate grapefruit production also set a record at 55.8 million boxes. This was seven percent higher than the previous season and nine percent higher than the previous record crop for the 1979-80 season. Economically, these strong supply increases have put downward pressure on prices. In fact, the value of production per acre for grapefruit and oranges actually declined from the previous season. This was substantial for white seedless and seedy grapefruit.

Average yields for the sample were similar to those estimated by the Florida Agricultural Statistics Service for the Indian River District (table 3.27). Yields for white grapefruit, Valencia, and Hamlin were slightly higher than the district average. Pineapple orange yields were more than one box per tree higher, but this average is based on very limited observations in the sample. Navel yields were somewhat lower but observations were again limited. Boxes per acre averages by variety show yields to be very similar between grapefruit varieties, while Hamlins were the top orange producers.

Overall, growers are usually more concerned with production per acre since land is a fixed input and trees are variable inputs. Navel and pineapple oranges demonstrated similar per tree yield as Hamlins, but per acre yield was considerably higher for Hamlins (table 3.28). Differences between the two yield measures result from differences in tree densities for the varieties.

Table 3.27. Boxes Per Tree Yield Statistics.

Variety	District Avg.	Sample Avg.	Std. Dev.	Min	Max
White	4.32	4.73	1.27	1.99	7.00
Red	3.95	3.92	2.00	0.90	8.03
Valencia	2.00	2.34	1.00	0.83	5.03
Hamlin	2.45	2.63	0.82	1.30	4.29
Navel	2.45	1.87	1.02	0.33	3.56
Pineapple	2.45	3.52	1.14	1.87	4.74

[1] Average of early and mid-season district yields for Hamlin, Navel, and Pineapple

Table 3.28. Boxes Per Acre Yield Statistics.

Variety	Sample Avg.	Std. Dev.	Min	Max
White	405	116	220	652
Red	410	175	112	757
Valencia	250	75	101	423
Hamlin	382	121	171	536
Navel	211	69	73	313
Pineapple	234	51	158	315

Prices for grapefruit were the lowest in several decades. By mid-spring of 1997, grapefruit prices dropped below the cost of picking and harvesting, thus on-tree prices became negative (table 3.29). These low prices resulted in delayed, partial, or abandoned harvesting. Hence, some grapefruit samples had to be dropped from empirical analysis, due to the unavoidable missing data. Estimates were used when feasible. Orange prices were approximately 17 percent lower than the previous season, but still significantly better than grapefruit prices. As a result, there is very little censoring of orange blocks from the data set.

When considering the costs of production, white grapefruit growers would have to produce about 450 boxes per acre at an average price of $2.21 to break even (Muraro and Hebb). This price and yield are above the sample means, which suggests that many growers who were able to sell grapefruit during the 1997/97 season lost money. If orange production occurred at the average yield and average unweighted price reported in table 3.29, then financial returns to land, trees, and ownership would be about ten percent, according to published cost information (Muraro, Oswalt, and Still). Obviously, citrus growers are in a very sensitive situation, especially smaller growers that lack strong market channel connections due to volume.

Table 3.29 On Tree Florida Orange and Grapefruit prices for the 1996-1997 season.

Month	Year	$/box Oranges	$/box Grapefruit
November	96	3.41	2.28
December	96	3.33	1.91
January	97	3.46	1.81
February	97	3.35	2.06
March	97	3.13	0.28
April	97	4.38	0.59
May	97	3.66	-0.25
June	97	4.28	2.27
Average		3.63	1.37

Correlation analysis provides a general overview of relationships between two variables. Unlike regression analysis, correlation estimates do not hold all other variables constant. Consequently, correlation estimates are best used to understand directional relationships (i.e., positive or negative) as opposed to putting too much credence in the specific measure. Correlation estimates between yields and grove characteristics, water quality and leaf tissue results are provided in table 3.30. Production types are conventional oranges, organic oranges, and grapefruit. Conventional orange yields are positively associated with tree density but a negative correlation exists for tree age. For example, a year increase in tree age for the block would be correlated with drop of 0.48 boxes per acre for our sample. Yields are also negatively associated with TDS and sodium tissue levels, while higher levels of nitrogen and phosphorous reflect positively with yield. For example, a one percentage point increase over the average of sodium in the water is correlated with a drop in yield of 0.45 boxes per acre

Yields for organic oranges are not significantly associated with TDS element values and tree density; however, there is an inverse association with sodium and chloride ions. Correlation differences between organic and conventional production are most likely due to the differences in cultural practices, but LQIW does not seem to have a lower negative impact on organic oranges.

As mentioned earlier, grapefruit yield data are of questionable quality. Higher leaf tissue levels for all of the elements are negatively associated with yield. Older trees are positively associated with yield while density did not have a strong correlation.

The next section provides more sophisticated analyses for determining the effects of LQIW. The initial correlation numbers do suggest that LQIW will impact citrus yield, but the specific effects and their magnitudes need to be investigated through empirical analysis.

Table 3.30. Correlation Coefficients between Boxes/Acre and Grove Characteristics, Water Quality, and Leaf Tissue Levels.

	Conventional Oranges	**Organic Oranges**	**Grapefruit**
Boxes per acre	1.00	1.00	1.00
Tree age	-0.48	-0.35	0.23
Trees per acre	0.45	-0.04	-0.09
Water, Na	-0.45	0.00	0.12
Water, Cl	-0.44	0.00	0.13
Water, SO4	-0.42	-0.13	0.19
Water, TDS	-0.42	-0.07	0.14
Leaf tissue, N	0.34	0.40	-0.27
Leaf tissue, P	0.12	-0.13	-0.35
Leaf tissue, K	-0.35	0.34	-0.29
Leaf tissue, Na	-0.22	-0.48	-0.34
Leaf tissue, Cl	0.20	-0.34	-0.26

ESTIMATING THE IMPACT OF LQIW ON CITRUS: FRAMEWORK AND RESULTS

The purpose of this section is to analyze the effects lower quality irrigation water (LQIW) has on citrus production in Indian River and Brevard Counties. Certainly, LQIW is not a new phenomenon being faced by area producers. In fact, TDS sample values range from 532 to 2,533 with a mean of 1,130. As a result, growers have altered cultural practices and root stocks to address the problem. With this in mind, we want to investigate how successful growers have been in their attempts to minimize negative effects of LQIW for their region. We have undertaken five objectives to address the issue.

Objectives

1. Based on leaf tissue samples, determine the effects of potentially toxic ions (Na, Cl) and beneficial ions (N, P, K) on production. Strong correlation coefficients were not noted for other ions.
2. Determine the effects of rootstock, TDS, and fertilization practices on the level of toxic ions in the leaf tissue.
3. Determine the effects of soil organic matter and TDS levels on the likelihood of selecting a rootstock.
4. Determine the effects of TDS on yield allowing for differences in tree age, tree density, variety, and rootstock.
5. Examine mean yield comparisons based on TDS levels for citrus production.

Based on our sample, we have segmented citrus production practices into three categories: conventional fresh and processed orange production, organic orange production, and grapefruit production. This segmentation is based on our previous focus group work indicating sufficient differences in yield measurement and culture practices exist to warrant separate investigation.

Leaf Tissue Analysis and Citrus Yield

While soil sampling is a common practice for many agricultural operations, leaf tissue analysis provides more useful information with respect to citrus nutrition (Obreza, Alva, Hanlon, and Rouse). The first objective of this section deals with understanding relationships between certain ions and citrus yields and will be satisfied in two separate steps.

The first step investigates the relationships between macro-nutrients (nitrogen (N), phosphorous (P), and potassium (K)) and production levels. Leaf tissue levels for these elements are potentially derived from fertilization practices, water quality, pest management programs, and soil condition. Optimal levels have been determined in previous research to be 2.6% for nitrogen, 0.14% for phosphorous, and 1.45% for potassium (Obreza et al). Actual leaf tissue levels are normalized (observed value divided by suggested optimal level) by the optimal values to determine the effects of variations from the optimums for citrus production.

Nitrogen mean values are slightly above the optimum (e.g., optimum = 100) for orange production and the mean is lower for grapefruit (table 4.1). Since the predetermined values are not specific for citrus type, these average values do appear to be within a reasonable range of the guidelines. As in all tables, N refers to the number of observations.

Table 4.1. Descriptive Statistics for Normalized Nitrogen Leaf Tissue Levels for Conventional Oranges (CO), Organic Oranges (OO), and Grapefruit (G) (Optimal = 100).

Type	N	Mean	Std. Dev.	Min	Max
Conventional orange	70	108.60	8.34	86.54	133.85
Organic Orange	34	107.00	7.30	88.08	121.92
Grapefruit	57	88.49	6.99	73.85	103.81

Mean levels for phosphorous are similar to those found for nitrogen, but the observed ranges appear to be larger for phosphorous (table 4.2). Leaf tissue analysis shows how effectively the nutrients are absorbed by the citrus tree. These wide ranges may have interesting consequences on production levels.

Table 4.2. Descriptive Statistics for Normalized Phosphorous Leaf Tissue Levels for Conventional Oranges (CO), Organic Oranges (OO), and Grapefruit (G).

Type	N	Mean	Std. Dev.	Min	Max
Conventional orange	70	102.94	18.72	57.86	180.71
Organic Orange	34	111.04	11.00	91.43	142.14
Grapefruit	57	86.81	24.37	26.43	214.29

For each type of citrus production, potassium levels were observed to be below the optimal values and exhibited considerable variation (table 4.3). This result suggests that growers in the Indian River and Brevard County area are using lower amounts of potassium in their fertilization practices. These lower levels appear to be beneficial for this area based on the earlier reported coefficient estimates between potassium levels and yield (table 3.21). The estimates for both conventional orange and grapefruit production show a negative relationship for higher potassium levels, -0.35 and –0.29 respectively.

Table 4.3. Descriptive Statistics for Normalized Potassium Leaf Tissue Levels for Conventional Oranges (CO), Organic Oranges (OO), and Grapefruit (G).

Type	N	Mean	Std. Dev.	Min	Max
Conventional orange	70	65.16	17.93	37.72	125.38
Organic Orange	34	86.90	21.16	45.10	123.59
Grapefruit	57	68.84	18.23	36.00	137.03

Yields are regressed on these normalized leaf tissue values to determines the effects of suggested excesses or deficiencies of the nutrients. As mentioned earlier, heavy supplies of citrus resulted in downward price pressures which effected harvesting decisions. Only harvested blocks are used for our analysis.

All regression models were statistically significant based on F-test results. The models for conventional and organic orange production had similar explanatory power as measured by Adjusted R2 statistics (table 4.4). This statistic represents the proportion of variation in the yield variable that is explained or predicted by changes in leaf tissue levels. R2 statistics are usually lower for cross-sectional data like those used in this study as compared to time series data. Leaf tissue levels above the suggested optimum for nitrogen had a positive impact on orange yields, but were negative for grapefruit production. These results indicate a higher optimum may be warranted for oranges in this region while the grapefruit level should probably be lower. Higher phosphorous levels negatively impacted organic orange production. Potassium had opposite effects for the different orange growing methods. Grapefruit did not appear to be adversely effected by excess levels of phosphorous or potassium.

Table 4.4. Regression Results for Normalized Leaf Tissue Level Effects on Citrus Yield (absolute values of t-ratios).

Variable	Conventional Orange	Organic Orange	Grapefruit
Intercept	-76.875 (0.47)	-159.10 (1.03)	**1195.5** **(4.43)**
Nitrogen	**4.6641** **(2.81)**	**5.1241** **(3.51)**	**-7.3136** **(2.16)**
Phosphorous	0.4843 (0.63)	**-2.4268** **(2.49)**	-0.3086 (0.31)
Potassium	**-2.5432** **(3.57)**	**1.2349** **(2.64)**	-1.5349 (1.52)
Adjusted R^2	0.34	0.34	0.15

bold denotes statistical significance at the 0.10 level

Our second step is to analyze the effects of sodium (Na) and chloride (Cl) leaf tissue levels, which are ordinarily considered to be toxic ions. Levels are also expected to be derived from the same factors as the nutritional elements with a greater emphasis perhaps on water quality. Additionally, rootstocks are often known to have an impact on the toxin levels in the leaf tissue. Due to the potential toxicity, we are more concerned here with excess levels as opposed to optimal levels. In both cases, leaf tissue levels exceeding 0.25% are considered excessive. For this analysis, leaf tissue ion values are normalized by this threshold.

Sodium levels are well below the threshold for all three practices on average (table 4.5). Grapefruit demonstrated the lowest mean values while all conventional orange values were below the threshold. Organic oranges had the highest levels, which may result from differences in types of fertilizers and pest control agents.

Table 4.5. Descriptive Statistics for Normalized Sodium Leaf Tissue Levels for Conventional Oranges (CO), Organic Oranges (OO), and Grapefruit (G).

Type	N	Mean	Std. Dev.	Min	Max
Conventional Orange	70	43.42	12.55	24.40	86.40
Organic Orange	34	74.58	16.20	33.20	116.40
Grapefruit	57	26.54	16.25	8.80	106.80

Chloride levels were observed to be excessive for organic oranges on average with a range of 38 percent to 338 percent of threshold levels (table 4.6). Again, these higher levels are thought to be indicative of differences in cultural practices for organic production. Grapefruit chloride levels were significantly lower than the threshold value, while levels for conventional oranges were slightly below. Assuming water quality for each type of production is similar, it would appear that toxic ions do not readily accumulate in the grapefruit as compared to oranges.

Table 4.6. Descriptive Statistics for Normalized Chloride Leaf Tissue Levels for Conventional Oranges (CO), Organic Oranges (OO), and Grapefruit (G).

Type	N	Mean	Std. Dev.	Min	Max
Conventional Orange	70	87.98	39.58	40.00	244.00
Organic Orange	34	137.33	80.24	38.40	338.00
Grapefruit	57	45.15	22.07	24.00	138.40

Yields were regressed on the normalized tissue levels for sodium and chloride. Excessive levels would be expected to have a negative impact on yield, assuming the previously suggested threshold levels are still appropriate in this area.

Excessive levels of sodium are shown to negatively impact yields for each of the production types; however, chloride levels did not have a significant impact on organic orange or grapefruit production (table 4.7). These results may result from modifications in growing practices over time. For example, growers have altered irrigation methods and root stocks to alleviate concerns from the ions. Blending with or switching to surface water reduces exposure to toxic ions, while changes in root stock and variety result in higher tolerances for the ions. In summary, growers should still be concerned with sodium levels, but they appear to be having success with respect to chloride.

Table 4.7. Regression Results for Normalized Leaf Tissue Level Effects on citrus Yield (absolute values of t-ratios).

Variable	Conventional Orange	Organic Orange	Grapefruit
Intercept	**365.28** **(7.41)**	**375.55** **(7.18)**	**495.21** **(11.18)**
Sodium	**-2.9938** **(2.71)**	**-1.8371** **(2.27)**	**-2.0198** **(1.46)**
Chloride	**0.8926** **(2.55)**	-0.0833 (0.51)	-0.5712 (0.56)
Adjusted R^2	0.11	0.19	0.05

bold denotes statistical significance at the 0.10 level

Leaf Tissue Analysis and Rootstocks, Fertilizer, and Water Quality

This section deals with understanding relationships between certain rootstocks, fertilizer form, and water quality with leaf tissue levels of sodium and chloride. We hypothesize that differences in these cultural characteristics impact the toxic ion levels. Investigation will be again done separately for the three different production types.

Rootstock selection is a common practice for managing LQIW situations; however, other factors such as climate, soil, and economics drive the selection decision as well (table 4.8). Sour Orange and Carrizo were the dominant rootstocks for conventional orange production in our sample, while Carrizo was the top choice for organic oranges. The majority of grapefruit rootstocks were sour orange with some Swingle as well.

Table 4.8. Sample Use of Sour Orange (SOr), Carrizo (CZ), Swingle (SW), Milam (MI), Rough Lemon (RL), and Cleo (CL) Citrus Rootstocks in Percent.

Type	N	SOr	CZ	SW	MI	RL	CL
Conventional Orange	70	46.64	27.14	9.14	7.14	9.93	0.00
Organic Orange	34	14.71	70.59	0.00	14.71	0.00	0.00
Grapefruit	57	66.22	2.89	25.75	0.00	1.75	3.51

Dry fertilizer was the overwhelming preference among conventional orange and grapefruit growers (table 4.9). Liquid fertilizer was most frequently used in conventional orange production. Organic production included the sole use of dry mined fertilizer. Liquid fertilizer is assumedly taken up by the tree quicker than dry fertilizer. General beliefs in the literature are that slower release is better. All observations of liquid fertilizer use were used for fertigation.

Table 4.9. Means for Fertilizer Use in Percent.

Type	N	Liquid Fertilizer	Dry Fertilizer	Dry Mined Fertilizer
Conventional Orange	70	52.86	100.00	0.00
Organic Orange	34	0.00	0.00	100.00
Grapefruit	57	3.51	96.49	0.00

LQIW is present for virtually every sample in the study. TDS levels are very similar for both conventional production of oranges and grapefruit, but TDS levels were substantially lower for organic production on average (table 4.10). Since most organic production is for specialty markets, this may be an indication of perceived LQIW effects on fruit quality. Using a TDS value of 500 as the cutoff for LQIW, all blocks are faced with lower water quality.

Table 4.10. Descriptive Statistics for TDS Levels.

Type	N	Mean	Std. Dev.	Min	Max
Conventional Orange	70	1209.8	456.91	616	2533
Organic Orange	34	849.59	214.92	616	1337
Grapefruit	57	1215.4	437.37	532	2423

Regressions are estimated to determine what effects rootstock selection, fertilizer form, and TDS (proxy for water quality) have on the normalized ion levels separately. Certainly, these are three key areas that may be important when considering citrus production using LQIW. The base rootstock is sour orange, meaning coefficient estimates for other rootstock types are in comparison to sour orange.

As mentioned earlier, growers have been aware of potentially negative effects associated with LQIW. Consequently, we may assume that growers have educated themselves on the proper practices for irrigating with LQIW. In all three instances, TDS did not have a significant impact on the sodium leaf tissue levels even though irrigation water quality is low (table 4.11). Milam and rough lemon rootstocks did significantly impact sodium levels for conventional oranges, while Carrizo had a significantly positive effect for organic oranges. The only significant effect in the grapefruit model was for fertilizer form. Here, liquid fertilizer is associated with higher observed sodium levels in the leaf tissue, but we should remember that the actual sodium levels were comparatively lower than for oranges.

Table 4.11. Regression Results for Rootstock, Fertilizer Form, and TDS Effects on Normalized Sodium Leaf Tissue Levels (absolute values of t-ratios).

Variable	Conventional Orange	Organic Orange	Grapefruit
Intercept	**35.851** **(6.32)**	**62.429** **(3.76)**	**24.911** **(3.34)**
Carrizo	-2.0004 (0.53)	**16.717** **(2.10)**	9.2752 (0.65)
Swingle	-7.7237 (1.40)	Na	-7.8794 (1.53)
Milam	**21.568** **(3.42)**	5.2378 (0.46)	Na
Rough Lemon	**20.646** **(2.35)**	Na	Na
Liquid Fertilizer	2.0185 (0.54)	Na	**33.792** **(2.93)**
TDS	0.0034 (1.03)	-0.0005 (0.03)	0.0017 (0.31)
Adjusted R^2	0.25	0.09	0.12

bold denotes statistical significance at the 0.10 level "na" denotes no or insufficient observations.

Carrizo rootstock was associated with higher chloride tissue levels for conventional and organic types or production (table 4.12). Liquid fertilizer also positively affected chloride tissue levels for conventional orange production. The grapefruit model was not statistically significant, but the expected signs were observed for Carrizo rootstock and liquid fertilization practices. Certainly, higher TDS levels do impact the tissue levels for citrus production; however, the more immediate impacts of rootstock selection and fertilizer type have outweighed these effects. Later, we will look at the specific effects of TDS with regard to actual yields.

Table 4.12. Regression Results for Rootstock, Fertilizer Form, and TDS Effects on Normalized Chloride Tissue Levels (absolute values of t-ratios).

Variable	**Conventional Orange**	**Organic Orange**	**Grapefruit**
Intercept	**49.639** **(3.09)**	83.322 (1.20)	**44.575** **(4.08)**
Carrizo	**40.710** **(3.81)**	**100.37** **(3.01)**	29.199 (1.39)
Swingle	-25.061 (1.60)	Na	5.1811 (0.68)
Milam	18.542 (1.04)	-21.126 (0.44)	Na
Rough Lemon	25.332 (1.02)	Na	Na
Liquid Fertilizer	**32.528** **(3.08)**	Na	1.9038 (0.11)
TDS	0.0071 (0.75)	-0.0162 (0.26)	-0.0012 (0.15)
Adjusted R^2	0.40	0.35	0.00

bold denotes statistical significance at the 0.10 level "na" denotes no or insufficient observations

Rootstock Selection

Selection of rootstock appears to be one key area for managing LQIW, though certainly not the only reason (i.e., disease resistance, cold tolerance, marketing issues). This section deals with the impacts that water-related factors may have on the grower's rootstock selection. TDS is used as a measure for water quality. Additionally, we also look at organic matter content for the soil which was estimated using soil maps. It is assumed that higher organic matter may reduce the likelihood of sodium or chloride entering the tree through the root system. Consequently, higher organic matter may offset some LQIW concerns. Additionally, many growers periodically apply sludge which may raise their organic matter levels above the value from the soil survey report.

In the sample, blocks in Grapefruit production had the highest average level of organic matter as well as the greatest variation (table 4.13). Descriptive statistics for rootstock and TDS levels were given earlier (tables 4.8 and 4.10 respectively).

Table 4.13. Descriptive Statistics for Organic Matter Levels.

Type	N	Mean	Std. Dev.	Min	Max
Conventional Orange	70	1.88	0.83	0.76	5.50
Organic Orange	34	2.02	0.71	1.00	3.18
Grapefruit	57	2.43	3.27	1.00	25.35

Some blocks have a combination of rootstocks while others have just one type. These types of values do not perform well in ordinary least squares (OLS) regressions resulting in bias and expectations outside the realm of possibilities (Kmenta). Tobit regressions are used for the selection likelihood models for handling this type of censored limited dependent variable. Previous research indicates that sour orange is more salt tolerant than Swingle, which in turn is more salt tolerant than rough lemon and Milam. Carrizo is considered the least salt tolerant of the rootstocks. Cleo is considered the most salt tolerant, but our sample lacked sufficient Cleo observations to estimate selection likelihood. Finally, orange trees generally appear more salt tolerant than grapefruit (Boman).

For higher TDS levels, growers are more likely to choose sour orange rootstocks (table 4.14). Growers are less likely to choose Carrizo or Swingle in higher TDS areas while TDS did not significantly impact the selection likelihood of Milam or Rough Lemon. Rough Lemon observations were frequently observed in conjunction with Sour Orange, which may explain the organic matter effect. The coefficients associated with Sour Orange, Carrizo, and Milam were of the anticipated sign but they were not statistically significant.

Table 4.14 Tobit Regression Results for Rootstock Selection in Conventional Orange Production (asymptotic absolute values of t-ratios).

Variable	Sour Orange	Carrizo	Swingle	Milam	Rough Lemon
Intercept	-0.4090 (0.73)	-0.0319 (0.48)	0.2093 (0.20)	**-2.3108** **(2.76)**	1.4030 (1.30)
Organic Matter	-0.0882 (0.55)	0.2290 (1.23)	-0.0768 (0.27)	0.3910 (1.60)	**-1.8978** **(3.94)**
TDS	**0.0008** **(2.68)**	**-0.0007** **(1.89)**	**-0.0011** **(1.85)**	0.0002 (0.47)	0.0007 (1.26)
Own	**1.5347** **(7.91)**	**0.9966** **(5.56)**	**0.7626** **(3.20)**	**0.7793** **(2.96)**	**2.6671** **(5.24)**
Mean Square Error	0.16	0.17	0.07	0.01	0.02

bold denotes statistical significance at the 0.10 level

The organic orange models did not perform as well as those for conventional production (table 4.15). This result is likely linked to the notion that organic production is driven more by the market environment and compatibility with organic practices. Also, most organic blocks were likely converted to this production type after the original planting. Coefficient signs do suggest that sour orange rootstocks are more likely with higher TDS and lower organic matter.

Table 4.15. Tobit Regression Results for Rootstock Selection in Organic Orange Production (asymptotic absolute values of t-ratios).

Variable	Sour Orange	Carrizo	Milam
Intercept	-1.9525 (1.13)	0.5408 (0.48)	**57.685** **(0.01)**
Organic Matter	-0.3988 (0.88)	0.0141 (0.05)	-0.3231 (0.50)
TDS	0.0019 (1.41)	0.0005 (0.53)	-0.0893 (0.01)
Own	**0.7193** **(2.55)**	**1.6050** **(6.27)**	**2.3085** **(2.97)**
Mean Square Error	0.11	0.21	0.02

bold denotes statistical significance at the 0.10 level

The sour orange model did not perform well, but the signs do indicate an increased likelihood for selection with lower organic matter and higher TDS levels (table 4.16). The results significantly indicate the inverse for the Swingle selection model. The Carrizo model also suggested increase selection likelihood for higher organic matter and lower TDS values, though the coefficients were not statistically significant. In summary, it appears that some growers have implemented sour orange rootstocks as one method to minimize potentially negative impacts of LQIW.

Table 4.16. Tobit Regression Results for Rootstock Selection in Grapefruit Production (asymptotic absolute values of t-ratios).

Variable	Sour Orange	Carrizo	Swingle
Intercept	0.5771 (1.26)	-0.9164 (0.79)	0.7122 (1.30)
Organic Matter	-0.0896 (1.44)	0.1111 (0.34)	**0.0808** **(1.87)**
TDS	0.0004 (1.32)	-0.0004 (0.54)	**-0.0012** **(2.63)**
Own	**1.6142** **(7.98)**	**0.8101** **(1.92)**	**0.9540** **(4.73)**
Mean Square Error	0.20	0.02	0.15

bold denotes statistical significance at the 0.10 level

TDS and Citrus Yield

The general motivation for the whole research undertaking is to determine the level of impact that TDS has on actual grower production. Many production practices are quite similar for the data sample. Significant variations are present for variety, tree age, and density. The functional form for the model is double log (natural logs are taken for both dependent and independent variables if they are continuous) which allows for nonlinear relationships to exist. This functional form was based on plotting the actual relationships of the continuous variables with the dependent variable yield. Conveniently, coefficient estimates for the model represent elasticities at the sample means. Elasticities are the proportional (rather than level) effects of the independent variable with respect to the dependent variable.

The conventional orange model is specified as:

$$LTBX = \beta_0 + \beta_1 LTDS + \beta_2 LAGE + \beta_3 LDEN + \beta_4 RSSO + \beta_5 VAL + e$$

where LTBX is the log of total boxes of oranges per acre, LTDS is the log of TDS, LAGE represents the age of the trees, LDEN is the number of trees per acre, RSSO is the proportion of trees with sour orange rootstock, and VAL is the proportion of trees that are Valencia in the block. Samples were not considered to be completely harvested if the total number of boxes per acre was less than 200. This reduced the sample size from 70 to 60 observations for the model. Valencias represent the majority of the sample with over 50 percent of the blocks planted to this variety (table 4.17). Almost one-third of the blocks was planted in Hamlins. Even with the censoring of the yield variable for harvesting, considerable variations still exist for yield, TDS levels, tree age, and tree population for the observed samples. The coefficient associated with TDS estimates the significance and relative effect of LQIW levels on observed citrus yield. Obviously, we hypothesize TDS to have an inverse relationship with production levels.

Table 4.17. Descriptive Statistics for Conventional Orange Yield Model.

Type	Mean	Std. Dev.	Min	Max
TBX	342.23	95.57	201.26	530.52
TDS	1197.4	464.78	616.00	2533.00
AGE	22.18	10.76	7.00	70.00
DEN	121.71	48.97	53.60	241.00
Valencia	0.53*	NA	0	1
Hamlin	0.32*	NA	0	1
PA	0.10*	NA	0	1
Navel	0.03*	NA	0	1

*** Variety variables are zero or one so that standard deviation statistics are not meaningful. Mean statistics for tree varieties represent frequencies or percentage of observations of that variety.**

The regression model demonstrates good explanatory power (adjusted R2) considering the cross-sectional nature of the data (table 4.18). All coefficient estimates except for tree density are statistically significant. The coefficient estimate for TDS suggests that a level 10 percent above the mean will result in a 2.5 percent loss in yield, all other things being equal. Hence, observed TDS levels that are twice the mean (e.g., almost 2400) yield over 25 percent less than areas with average TDS levels, all else being equal. Producers have certainly made progress in their efforts to manage LQIW, but the results show that higher TDS levels do have a significantly negative impact on production.

Table 4.18. Estimated Coefficients (absolute t-statistic values) for the Double Log yield Model for Conventional Orange Production.

Variable	Est. Coefficient
Intercept	**7.4363** **(8.88)**
LTDS	**-0.2545** **(3.87)**
LAGE	**-0.1662** **(2.26)**
LDEN	0.1419 (1.55)
RSSO	**0.1055** **(1.73)**
Valencia	**-0.1590** **(3.17)**
Adjusted R^2	0.65

bold denotes statistical significance at the 0.10 level

A closer investigation is undertaken to ascertain when TDS values become a significant detriment to conventional orange yield. To accomplish this task, the data observations are arrayed based on ascending TDS levels (i.e., the first observation has the lowest TDS level of the samples). We then estimate the regression by using only the first ten observations and subsequent regressions using an additional five observations until we reach seventy, the total number of conventional orange observations.

Table 4.18a provides the estimated coefficients for TDS only, since this is the area of interest. As shown, TDS is a significant factor from the very beginning. The first observations had TDS levels of 616 to 715, indicating that yield is significantly affected by this TDS difference. Glancing through the table, most of the estimated coefficients (elasticities) are about –0.35 which is slightly higher than the absolute value reported in the earlier regression. This result indicates that the negative impact may taper off as TDS levels continue to climb.

Table 4.18a. Estimated TDS Coefficients (absolute t-statistic values) for the Double Log Yield Model for Conventional Orange Production.

Observations Used	**Est. Coefficient**
1 to 10	**-1.2374** **(2.22)**
1 to 15	**-0.77832** **(3.35)**
1 to 20	**-1.0956** **(3.27)**
1 to 25	**-0.7601** **(3.65)**
1 to 30	**-0.3500** **(2.05)**
1 to 35	**-0.3930** **(2.48)**
1 to 40	**-0.3394** **(2.81)**
1 to 45	**-0.3081** **(2.80)**
1 to 50	**-0.3740** **(3.50)**
1 to 55	**-0.3863** **(3.87)**
1 to 60	**-0.3906** **(3.85)**
1 to 65	**-0.3491** **(3.84)**
1 to 70	**-0.2545** **(3.87)**

bold denotes statistical significance at the 0.10 level

To check this result, regressions were incrementally estimated in descending order to determine when the TDS coefficients become significant. Table 4.18b provides these results for the TDS coefficients. TDS is statistically significant until we work halfway down into the sample, which corresponds, with a TDS value of 1,230.

These results suggest that TDS levels have a significantly negative impact on conventional orange yield at 715 or lower since this is the first observed increase for our sample; however, the negative impact of TDS is similar for blocks with TDS values between 1,230 and 2,533, the sample high. This result would suggest that blending surface water with LQIW sub-surface water would not be yield effective unless the blending brings the blended TDS level below 1,200.

Table 4.18b Estimated TDS Coefficients (absolute t-statistic values) for the Double Log Yield Model for Conventional Orange Production.

Observations Used	**Est. Coefficient**
60 to 70	-0.0152 (0.02)
55 to 70	0.1912 (0.20)
50 to 70	-0.3549 (0.92)
45 to 70	-0.2056 (0.65)
40 to 70	-0.2065 (0.93)
35 to 70	**-0.3472** **(2.18)**
30 to 70	**-0.3527** **(2.29)**

bold denotes statistical significance at the 0.10 level

The organic orange model is specified as:

$$LTBX = \beta_0 + \beta_1 LTDS + \beta_2 LDEN + \beta_3 RSSO + \beta_4 VAL + e$$

where variables are defined in the previous model. There is not enough age variation among the organic samples to include it in the model. While there is considerable variation among varieties, these variables do not add significantly to the model explanatory power and so were dropped from the model as well (table 4.19). As earlier, samples were not considered to be completely harvested if the total number of boxes per acre was less than 200. This reduced the sample size from 34 to 21 observations for the model.

Table 4.19. Descriptive Statistics for Organic Orange Yield Model.

Type	Mean	Std. Dev.	Min	Max
TBX	259.45	68.51	201.08	536.24
TDS	841.29	211.54	616.00	1337.00
DEN	131.21	16.12	94.00	163.00
Valencia	0.38	0.50	0	1
Hamlin	0.48	0.51	0	1
Navel	0.14	0.36	0	1

The adjusted R2 statistics for the organic orange model indicates that this model does not have the same level of explanatory power as the conventional orange model (table 4.20). This may be due to the limited number of observations which restricts model efficiency. Still, TDS again shows to have a significantly negative impact on organic orange yield with a higher elasticity level. Levels that are 10 percent above the organic orange TDS mean (which is already lower than the observed level for conventional oranges) will result in a 3.8 percent reduction in yield. TDS levels nearing 1700 would have 38 percent lower yields, ceteris paribus (all other variables being equal). As in the conventional model, blocks with sour orange rootstock yield higher than the other types in general.

Table 4.20. Estimated Coefficients (absolute t-statistic values) for the Double Log Yield Model for Organic Orange Production.

Variable	Est. Coefficient
Intercept	**7.7678** **(3.16)**
LTDS	**-0.3831** **(1.64)**
LDEN	0.0563 (0.14)
RSSO	**0.2569** **(1.74)**
Valencia	0.0056 (0.05)
Adjusted R^2	0.26

bold denotes statistical significance at the 0.10 level

The grapefruit model is specified as:

$$LTBX = \beta_0 + \beta_1 LTDS + \beta_2 LAGE + \beta_3 LDEN + \beta_4 RSSO + \beta_5 RED + e$$

where RED represents blocks planted with the red grapefruit variety and other variables are as defined earlier. For grapefruit, samples were not considered to be fully harvested if the total number of boxes per acre was less than 250, since grapefruit tends to produce more boxes of fruit than oranges. This reduced the sample size from 56 to 49 observations for the model. The two varieties, red and white, are nearly equal in use for the sample (table 4.21). Acceptable variations are noted for the other model variables.

Table 4.21. Descriptive Statistics for Grapefruit Yield Model.

Type	Mean	Std. Dev.	Min	Max
TBX	448.24	128.40	253.07	756.67
TDS	1270.9	420.37	532.00	2423.00
AGE	19.78	11.43	5.00	70.00
DEN	97.06	25.49	60.20	197.80
White	0.51	0.51	0	1
Red	0.49	0.51	0	1

Only tree age and density significantly affected grapefruit production (table 4.22). Low prices had a larger impact on the grapefruit harvest compared to oranges, which may explain the poor performance of the model. However, further censoring of yield data did not improve model performance. Another speculation would be that grower practices have been more effective in managing LQIW for grapefruit production, but this speculation is suspect since grapefruits are considered to be less salt tolerant than their orange counterpart. The coefficient estimates for TDS and sour orange rootstock do have the expected signs, though they are not statistically significant. We feel that the low performance of the model is due to the quality of the grapefruit data, which is anticipated to be low due to the unfortunate market conditions in 1997.

Table 4.22. Estimated Coefficients (absolute t-statistic values) for the Double Log Yield Model for Grapefruit Production.

Variable	Est. Coefficient
Intercept	**2.8767** **(1.85)**
LTDS	-0.0077 (0.05)
LAGE	**0.1856** **(1.90)**
LDEN	**0.5714** **(2.40)**
RSSO	0.1531 (1.27)
Red	0.0318 (0.33)
Adjusted R^2	0.23

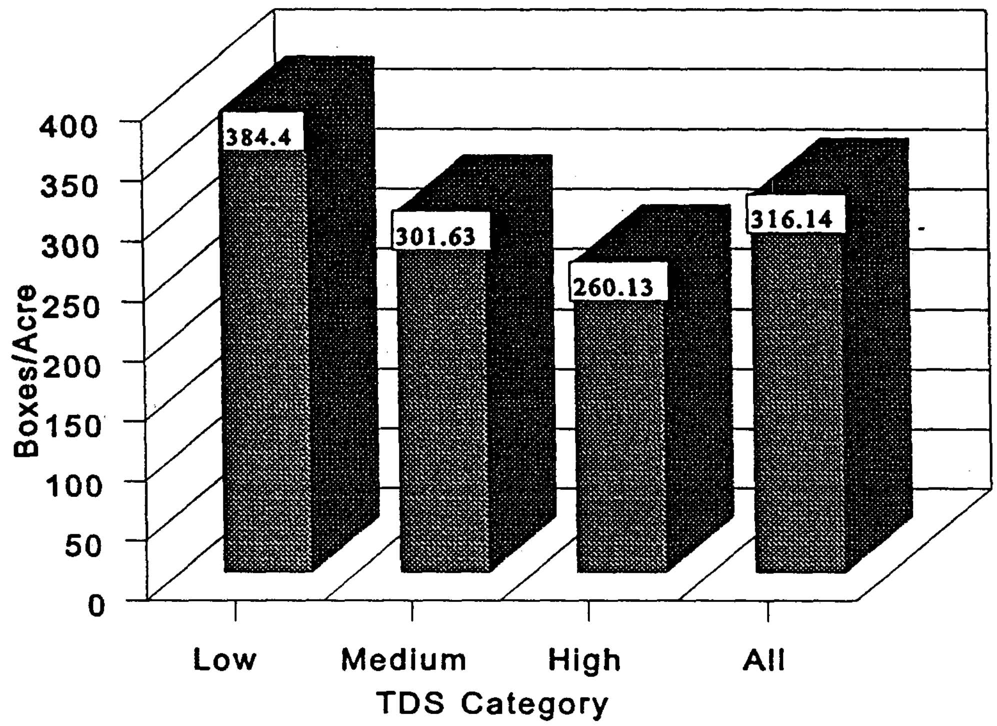
bold denotes statistical significance at the 0.10 level

Citrus Yield by TDS Category

The final objective of this section is to examine mean yield comparisons based on TDS levels for citrus production. This descriptive overview provides insights into average yield expectations for different categories of TDS levels. All of the samples can be considered LWIQ, but the question remains as to the overall effect that this situation poses to producers. The three TDS categories for LQIW are: Low (500-1000 TDS), Medium (1000-1500 TDS), and High (>1500TDS). Expectations are that the higher TDS categories will have lower yields.

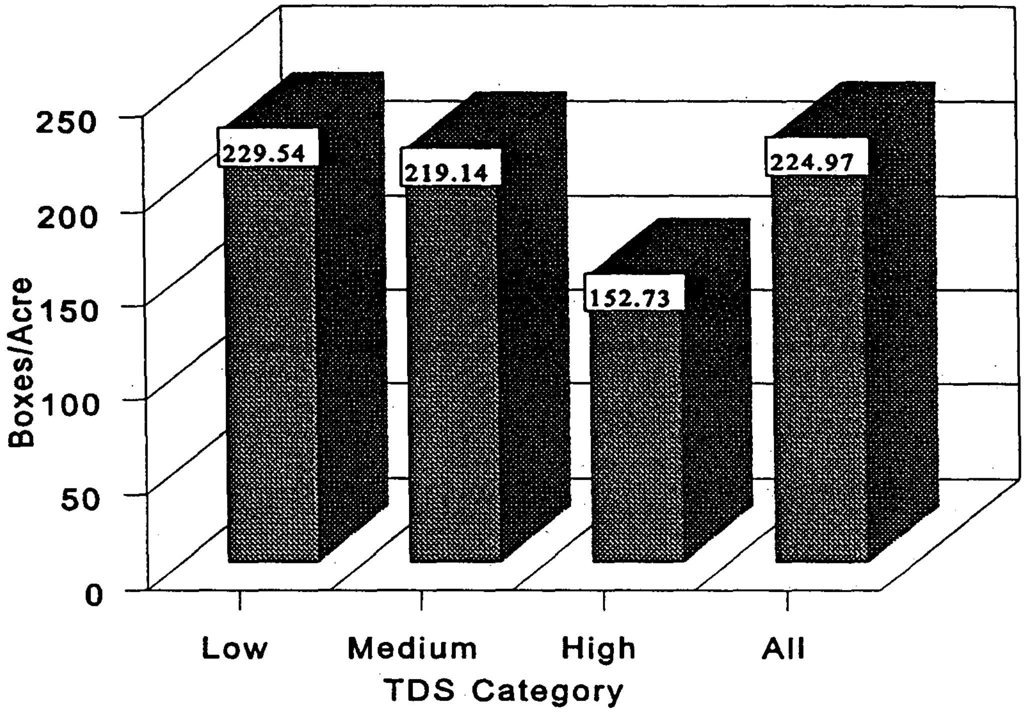
Yields for conventional oranges follow expectations (figure 4.1). Statistically speaking, the Low category yields are significantly higher than the sample mean, while the higher categories have significantly lower yields. The high category average yield is over 56 boxes less than the sample mean and nearly 125 boxes below the Low category. These effects would indicate revenue differences of several hundred dollars between the categories.

Fig. 4.1 Conventional Orange Yield by TDS Category



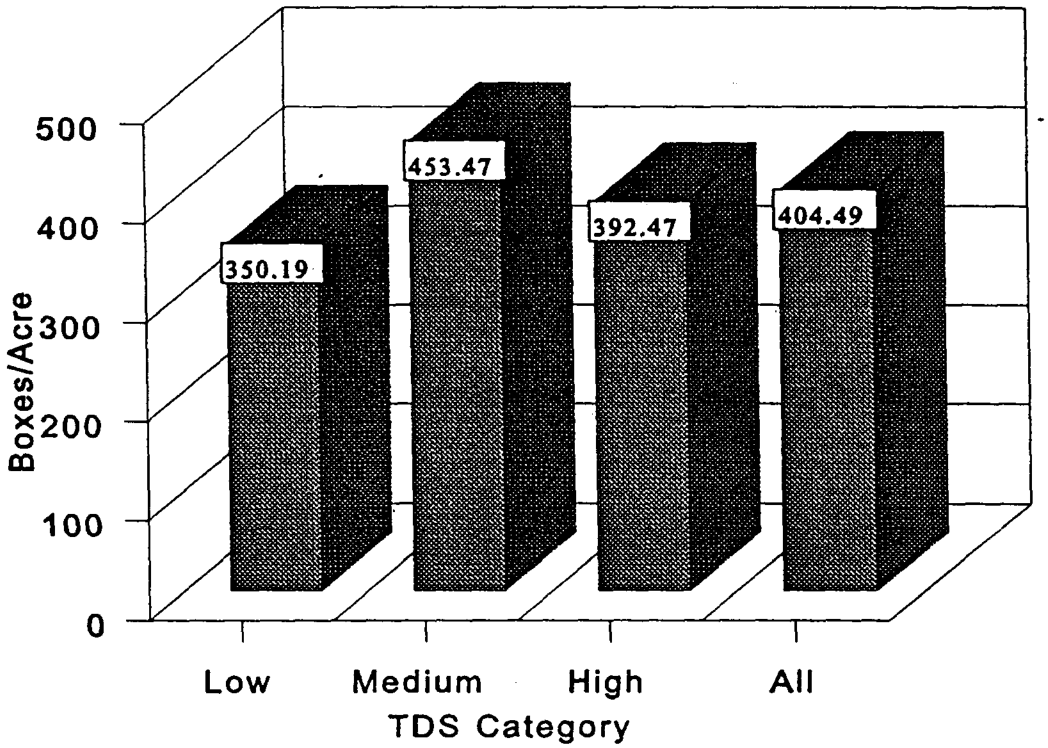
Organic orange yields also followed expectations with the Low category averaging more than 75 boxes more than the high category (fig. 4.2). Both the Medium and the High categories were significantly lower than the sample mean, while the Low category did not have significantly different average yield. Differences between organic categories may not be as large as those found for conventional production, but successful niche marketing may generate higher prices which could erode the difference in dollar terms.

Fig. 4.2 Organic Orange Yield by TDS Category



Grapefruit yields did not follow expectations (fig. 4.3). In fact, the lowest average mean was for the Low category; however, the means were not statistically different. As previously mentioned, the unfortunate market for grapefruit over the study period strongly impacted the respective harvesting decisions. We attempted to censor out the obvious situations where the block was not harvested. Still, we expect that there are blocks that were 50 to 90 percent harvested which may still yield above the 250 box censor threshold. Since we treat these blocks as fully harvested, the quality of the information becomes unavoidably tainted. In some situations, growers tried to estimate yields from partially harvested blocks which may have resulted in ineffective measures.

Fig. 4.3 Grapefruit Yield by TDS Category



SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Lower quality irrigation water is noted for the entire sample, where TDS levels ranged from about 500 to 2,600. Since the blocks were not pre-selected based on TDS, we feel that this is representative of the Indian River County and Brevard County area. Grower perceptions indicate that LQIW is a production concern, but they can manage the detrimental effects to some degree. Over-the-top irrigation is practically non-existent. Additionally, growers may select rootstocks, fertilizer types, and other cultural practices to alleviate some of the concern. Currently, growers seem more concerned with too much water rather than with the quality of water. This perception is most likely a result of higher rainfalls and major rain events in the area during the study period.

Sodium leaf tissue levels are below established thresholds on average. Organic oranges tend to have higher sodium levels. Chlorides near or surpass recommended excess threshold levels for oranges but are well below for oranges. Sodium leaf tissue levels have significantly negative impacts on all citrus production, while chlorides did not demonstrate negative effects.

In conventional orange production, higher sodium tissue levels were observed for Milam and Rough Lemon rootstock trees compared to Sour Orange. Sodium tissue levels were higher for Carrizo rootstock trees in organic production and the use of liquid fertilizer resulted in higher sodium levels for grapefruit. Chloride levels were higher for Carrizo rootstock trees in all three production practices, though not statistically significant for grapefruit. TDS did not have a significant relation to leaf tissue levels, because different rootstocks and fertilizer type effects appear to have a stronger influence on these levels.

Higher TDS levels increase the likelihood of Sour Orange selection in conventional orange groves, but they lower the likelihood for Carrizo or Swingle selection. Organic matter and TDS levels did not significantly effect the rootstock selection likelihood for organic oranges. Organic matter was positively associated with Swingle selection in grapefruit while TDS was negatively associated with selection likelihood of Swingle rootstock.

Poor market conditions resulted in several sample blocks going out of business, not harvested, or partially harvested. This was especially true for grapefruit blocks. TDS coefficient levels showed an elasticity of –0.25 for conventional orange yield, meaning a TDS level ten percent above the mean would have a yield 2.5 percent lower, all else being equal. The elasticity for organic orange yield with respect to TDS levels was larger at -0.38, meaning a TDS level ten percent above the mean would have a yield 3.8 percent lower, all else being equal. Yields were higher with Sour Orange rootstock compared to the other rootstock types, perhaps counterbalancing the negative effects of higher TDS levels. Performance of the grapefruit model is effected by the poor harvest season, which translates into poor quality harvest data. Though not significant, the TDS coefficient sign is negative in the grapefruit yield model.

TDS is demonstrated to significantly impact yield. The lowest TDS level in the final sample was 616 with the next lowest being 715 ppm. Using a step-wise sampling format for regression estimation, yields were significantly less between these two TDS levels for conventional oranges. However, there was no significant difference observed for yields between 1,230 and 2,533 ppm.

TDS effects can also be demonstrated categorically: Low (500-1000 TDS); Medium (1000-1500 TDS); and High (>1500 TDS). For conventional oranges, yields drop over 80 boxes per acre from Low to Medium and another 40 boxes from Medium to High. Organic oranges only dropped 10 boxes from Low to Medium, but the number fell by almost 70 boxes from Medium to High. Categorically, little could be seen with grapefruit yields. Accurate harvest information was difficult to obtain. As such, we believe some of the data represents only a partial harvest, but we are unable to identify these situations. With today's current market prices and cost of production, it seems doubtful that growers can profitably operate with High LQIW, and perhaps not even with Medium LQIW.

In conclusion, we demonstrated that LQIW does significantly impact yields. Specifically, sodium leaf tissue levels have a stronger association with yield reduction than chloride levels. Use of LQIW is an economic decision for the producer. Investment in land, equipment, and trees make it difficult for the grower to cease operating the grove. Yet, with today's market conditions, it would appear that many growers may be forced to make that decision. Yield forecasts point to even higher production levels in the future, which may make it difficult for the price to rebound. Farm subsidy programs have provided growers of certain crops some risk reduction for downside price movements. Currently, the federal government is phasing out these programs. Citrus growers have never been eligible for these programs and cannot count on their possibility for the future. Access to better quality water may ease the economic stress on growers. Some growers are taking steps to gain access to surface water, but the cost of access may be larger than the marginal benefit. Smaller growers are more likely to lack the necessary capital for surface water access. Without improvement in the marketplace, we foresee a decrease in the number of groves. Smaller producers will be more likely to quit production. Larger producers will probably reduce their acreage with LQIW being an important decision factor.

One recommendation is to study the costs and feasibility of access to surface water. The elasticity measures for conventional orange production should be helpful in determining the corresponding marginal benefit. We feel that growers are effectively managing LQIW situations, but they are not able to completely reduce the negative effects.

Another recommendation is to actively share the findings of this study with the producers. Some caution needs to be exercised in direct application of the results, since this is only one year of information. Still, the findings of the analyses indicate significant relationships that should be of interest to producers.

Finally, controlled experimentation may help provide insights into the why's and how's of LQIW impacts. Further understanding of these areas should shed light on technologies that will combat the detrimental effects.

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Appendix A
Results of Lower Quality Irrigation Water Management Practices Survey

A. Water management

1. Frequency of irrigation water testing.

	Times per year						
	Value	Freq.	%Freq.				
	0	3	16.67%				
	0.25	1	5.56%				
	0.33	3	16.67%				
	0.5	2	11.11%				
	1	7	38.89%				
	2	1	5.56%				
	4	1	5.56%				

2. Method of irrigation water testing.

	Choice	Freq.	%Freq.				
	Don't test	2	11.11%				
	Electrical conductivity	9	50.00%				
	On-site chemical test kit	3	16.67%				
	Off-site lab. Analysis	12	66.67%				

3. Aspects of irrigation water quality tested or considered.

	Choice	Freq.	%Freq.				
	Don't test	2	11.11%				
	Specific minerals or ions	7	38.89%				
	Total dissolved solids	14	77.78%				
	Electrical conductivity	9	50.00%				
	pH	10	55.56%				

4. Criteria used to determine the timing and amount of irrigation.

	Choice	Freq.	%Freq.				
	Plant appearance	17	94.44%				
	Soil appearance	17	94.44%				
	Tensiometer	2	11.11%				
	Observation wells	8	44.44%				
	Other mechanical system	2	11.11%				
	Water level in canals	5	27.78%				
	Other	1	5.56%				

Appendix A
Results of Lower Quality Irrigation Water Management Practices Survey

5. Modifies irrigation system or practices for different soil types or tree characteristics.							
	Choice	Freq.	%Freq.				
	No	3	16.67%				
	Yes	15	83.33%				

6. Modifies irrigation system or practices depending on the quality of water.							
	Choice	Freq.	%Freq.				
	No	6	33.33%				
	Yes	12	66.67%				

7. Has made capital investments in water quality during the last 10 years							
	Choice	Freq.	%Freq.				
	No	8	44.44%				
	Yes	10	55.56%				

8. Does regular maintenance or improvements on drainage in groves.							
	Choice	Freq.	%Freq.				
	No	1	5.56%				
	Yes	17	94.44%				

9. Uses irrigation system for freeze protection							
	Choice	Freq.	%Freq.				
	No	1	5.56%				
	Yes	17	94.44%				

B Fertility management

1. Frequency of soil tests.							
	Nutrients:			Salts			
	X times per year			X times	per year		
	Value	Freq.	%Freq.	Value	Freq.	%Freq.	
	0	1	5.56%	0	3	16.67%	
	0.33	0	0.00%	0.33	1	5.56%	
	0.5	2	11.11%	0.5	2	11.11%	
	1	13	72.22%	1	10	55.56%	
	1.5	1	5.56%	1.5	1	5.56%	
	2	1	5.56%	2	1	5.56%	

Appendix A
Results of Lower Quality Irrigation Water Management Practices Survey

2. Frequency of leaf tissue tests.							
	Nutrients:			Salts			
	X times per year			X times	per year		
	Value	Freq.	%Freq.	Value	Freq.	%Freq.	
	0	2	11.11%	0	5	27.78%	
	0.33	4	22.22%	0.33	4	22.22%	
	0.5	1	5.56%	0.5	2	11.11%	
	1	10	55.56%	1	6	33.33%	
	1.5	1	5.56%	1.5	1	5.56%	
3. Follows recommendations from soil and leaf tissue tests.							
	Choice	Freq.	%Freq.				
	Not applicable	1	5.56%			-	
	Below recommendations	5	27.78%				
	at recommendations	13	72.22%				
	Above recommendations	1	5.56%				
	other?	1	5.56%				
4. Predominant form(s) of macro-nutrient fertilizers applied to groves.							
	Choice	Freq.	%Freq.				
	Dry / granular	15	83.33%				
	liquid	2	11.11%				
	fertigation	3	16.67%				
	foliar	12	66.67%				
	organic	5	27.78%				
	Manure, compost, sludge	11	61.11%				
	mined nutrients	5	27.78%				
5. Applies plant nutrients in foliar sprays.							
	Choice	Freq.	%Freq.				
	No	1	5.56%				
	Yes	17	94.44%				
6. Applies fertilizer through micro irrigation systems (fertigate).							
	Choice	Freq.	%Freq.				
	No	16	88.89%				
	Yes	2	11.11%				

Appendix A
Results of Lower Quality Irrigation Water Management Practices Survey

7. Modifies the formulation of fertilizer applications depending on salt concerns.							
	Choice	Freq.	%Freq.				
	No	7	38.89%				
	Yes	11	61.11%				

C Pest management

1. Groves are regularly scouted for pests and diseases.							
	Choice	Freq.	%Freq.				
	No	0	0.00%				
	Yes	18	100.00%				
2. Who performs pest scouting.							
	Choice	Freq.	%Freq.				
	Never scout	0	0.00%				
	Owner	5	27.78%				
	Manager	11	61.11%				
	Outside consultant	6	33.33%				
	Trained employee	6	33.33%				
	Other	0	0.00%				
3. Basic pest control strategy.							
		for insects		for diseases			
	Choice	Freq.	%Freq.	Freq.	%Freq.		
	None	0	0.00%	0	0.00%		
	Preventative	3	16.67%	14	77.78%		
	Scout & spray as needed	10	55.56%	8	44.44%		
	Integrated pest management	10	55.56%	7	38.89%		
	Organic	4	22.22%	3	16.67%		

Appendix A
Results of Lower Quality Irrigation Water Management Practices Survey

4. Apply economic thresholds for pest control decisions.							
	Insects						
	Choice	Freq.	%Freq.				
	No	2	11.11%				
	Yes	16	88.89%				
	Diseases						
	Choice	Freq.	%Freq.				
	No	4	22.22%				
	Yes	14	77.78%				
5. Subjective evaluation of tolerance for diseases, insects, and weeds.							
	Disease						
	Choice	Freq.	%Freq.				
	zero	1	5.56%				
	low	7	38.89%				
	Low to medium	2	11.11%				
	Medium	7	38.89%				
	high	1	5.56%				
	Insects						
	Choice	Freq.	%Freq.				
	zero	0	0.00%				
	low	6	33.33%				
	Low to medium	3	16.67%				
	Medium	7	38.89%				
	high	2	11.11%				
	Weeds						
	Choice	Freq.	%Freq.				
	zero	1	5.56%				
	low	2	11.11%				
	Low to medium	1	5.56%				
	Medium	12	66.67%				
	high	2	11.11%				

Appendix A
Results of Lower Quality Irrigation Water Management Practices Survey

6. Certification for restricted use pesticides.							
	Decisions makers or supervisors.						
	Choice	Freq.	%Freq.				
	No	1	5.56%				
	Yes	17	94.44%				
	Handlers.						
	Choice	Freq.	%Freq.				
	No	10	55.56%				
	Yes	8	44.44%				
	Applicators.						
	Choice	Freq.	%Freq.				
	No	9	50.00%				
	Yes	9	50.00%				

APPENDIX B

ECONOMIC IMPACT OF LOWER QUALITY IRRIGATION WATER ON CITRUS IN BREVARD AND INDIAN RIVER COUNTIES: PHASE I, FOCUS GROUP REPORT.

An Interim Report for a Research Project Conducted by the Food and Resource Economics Department of the University of Florida in Cooperation with the St. Johns River Water Management District, State of Florida.

by

Thomas J. Stevens III, Patrick J. Byrne and Richard N. Weldon

December 29, 1995

Economic Impact of Lower Quality Irrigation Water on Citrus in Brevard and Indian River Counties: Phase I, Focus Group Report.

Two focus groups were conducted as the first phase of an effort to obtain information about the use, impact, and management of low quality irrigation water on citrus in Brevard and Indian River counties. The specific objective of the focus groups was to yield insights, attitudes, and technical information on these issues. The knowledge gained from these meetings will be used determine the feasibility of conducting a survey to accurately assess the scope and distribution of this problem within each county. If a survey is deemed feasible, this information will also be used to develop a questionnaires for the second phase of this project.

Each session was moderated by Patrick Byrne. Richard Weldon and Tom Stevens provided occasional comments, but primarily observed and took notes during the meeting. The sessions were recorded by audio tape and later transcribed. To protect confidentiality, access to the tape and transcripts are limited to Byrne, Weldon, and Stevens. Growers were asked to provide some general information in a written form at the beginning of the meeting. The moderator encouraged free and easy discussion and directed the discussion as summarized below.

Indian River County

The focus group for Indian River county, Florida was held on November 9th, at 8:00 am., at the Indian River Citrus League offices in Vero Beach. It lasted approximately one hour and 30 minutes. For the convenience of the growers, this session was scheduled immediately preceding the League's board of directors meeting.

Out of 17 telephone contacts, nine individuals from the area participated in this focus group. Only one Indian River grower indicated he was not interested in participating because water quality was not a concern. Four of the participants in this group served exclusively as managers for citrus operations in Indian River and other nearby counties in the state. Two individuals indicated they were both owners and managers, and a third indicated he owned and managed groves for himself and others. One participant was a consulting engineer who designed, installed, and maintained irrigation systems for growers in the area. All firms were organized as corporations except for one individual proprietorship. The groves under control of these individuals ranged from 440 to 14,000 acres in size, and averaged 5120 acres. Five growers indicated that they used water from both subsurface and surface sources for irrigation. Two growers relied exclusively on surface water sources. Only one of the seven identified growers did not produce both fresh and processed fruit.

Discussion Content Summary.

The session began with the moderator describing the purpose of the meeting, and how it fit into the objectives of the project and the overall research effort being funded by the Saint Johns Water Management District. The moderator emphasized that the purpose for this discussion was to ascertain the grove manager's viewpoint with respect to low quality irrigation water.

Concern Priorities.

Participants were first asked about their current most pressing concerns with respect to citrus production in the area. Presently, grower's primary interest is in maintaining profitability for their operations. The next most important issue revolved around the managerial burden of government regulation. Specific issues with respect to regulation (in order of importance) are worker protection standards, pesticide safety, water regulation, and illegal immigration.

Current Water Quality Concerns.

None of the participants in this group seemed reluctant to express their concerns about the quality of irrigation water. They were obviously well acquainted with this issue, and not just from a production technology or management perspective. One grower characterized water as one of the most important growth regulators for citrus production. By exercising a relatively high degree of control over how much water is available to their trees on a day-to-day basis, growers are able to significantly influence the productivity and health of their groves. By comparison, growers have relatively little day-to-day control over other important inputs such as soil type, root stock, tree variety, and sunshine.

Most participants use surface water either exclusively or blended with well water for irrigating their groves. Currently, the best source of high quality irrigation water is rainwater stored in either natural or man-made surface retention structures. If your only source of irrigation water is from subsurface wells, then as one grower put it, "you're in deep trouble". But there are groves being successfully managed with very low quality well water. Blending of water usually takes place by allowing water from artesian wells to flow directly into surface water storage or distribution structures. Water from these structures is then pumped into groves either through flood or low volume irrigation systems. When this occurs, the quality of the water in the canals or reservoirs becomes dynamic.

There are considerable geographic differences in the quality of well water. Water quality also fluctuates seasonally within the year depending how much pumping takes place. This in turn depends on the amount of rainfall. Generally, water quality in wells and surface structures gets worse the longer a drought continues. There was considerable speculation on the causes of the geographic variation in water quality, but most growers believed that water quality declined during droughts due to significantly increased withdrawals and use of artesian well water.

Several participants were eager to point out the beneficial effects that citrus groves can have on area water quality. Reference was made to prior studies which had shown that irrigation water (presumably in flood systems) was cleaner when it left groves than when it was first applied. One grower proposed that citrus groves could be considered to function as a "flow-way", much like some natural systems do, to clean and recycle water.

Current Water Quantity Concerns.

The biggest concern with respect to quantity or availability of water is with regulatory agencies. Although growers profess to have sufficient supplies of water now, they are struggling to retain their rights to use these supplies as consumption permits come up for renewal. Water management district regulators are applying water use guidelines and classifications too broadly, they say. This system is based on commodities or commodity groups. Consequently, some growers are not able to get or retain water use rights for groves that have unique needs or conditions that demand above average amounts of water. The commodity system doesn't account for local differences or cyclical trends in rainfall, soil type, and other grove characteristics, the growers contend.

A current pressing problem is too much water. This has resulted from above normal rainfall during the past six months. Growers try to store as much excess rainfall as they can, but when storage structures become filled, they have to pump excess water "to tide" (the Indian River or Atlantic Ocean). Currently, growers are losing more trees and production to excess water and insufficient drainage than drought or poor water quality. Growers state that in general they would rather have good drainage than good irrigation.

It was also pointed out that the net quantity of water used by flood irrigation systems is not that much greater than micro-jet or drip because a significant proportion of this water is put back into "the system". In other words, flood systems may require more water to be pumped, but actual water consumption by the grove is not much higher than with micro-jet or other low volume systems.

Future Direction of Water Quality.

There was disagreement among the participants as to the past and current direction of water quality over the long term. Several growers stated that the problem of chlorides and salinity has been getting worse for 40 to 50 years, particularly near the coast. Some believed this was a consequence of these areas being "over-stressed" by urban development. Another individual, who talked very knowledgeably on the topic, disagreed. He cited a water quality study from the 1960s that mapped well water salinity levels in Indian River, St. Lucie and Martin counties. Based on his own tests, he claimed that salinity levels in these wells today are no higher than when they were tested in that study.

Another grower described his experiences six or seven years ago when he tested some of his wells frequently over a three year period. He found that during droughts TDS levels would increase steadily as growers continued to pump or allow artesian wells to flow. Once it rained and the wells were shut down, TDS content would go down, but not as low as it had been before the drought. Thus there was a "ratcheting up" of TDS levels over the years. However, he characterized these years as a dry period.

A previous study by a Dr. Reitz was referenced. It was described as showing that TDS levels had increased over a 20 to 30 year period in parts of south Florida. Another grower commented that water quality was highly dependent on the specifics of the well: how deep it was, how much water was used, its location, etc. For a particular field, a grower described how one well had very low TDS while another immediately next to it was virtually unusable for irrigation. "There doesn't seem to be any rhyme or reason" as to why the quality differs from one to the other, said one grower. Another participant stated that he didn't believe the salinity levels of the aquifer itself were really changing, and that we should be able to continue to use this water for a long time.

One individual described how many of the old wells in the area were encased with steel pipe only though the upper soil layers. During drilling, once the limerock layer was reached encasement was no longer necessary. He speculated that the salinity in some of these old wells originates from water in the upper layers of limerock and not from the bottom of the wells where they are presumably tapping into the deep Floridan aquifer. This grower testified that many of the newer wells were encased to their full depth and this eliminated much of the problem with salinity. This was supported by a reference to a Brantley Sherrard study conducted some 30 years ago on the "old Georgeville property".

How does Low Quality Irrigation Water Affect the Quantity and Quality of Fruit?

This question was not asked directly, but comments were made to these effects through the course of the discussion. Growers referred to the effects of salts on the trees mainly in terms of leaf loss and appearance, but not yields. Some growers speculated that the salts from low quality irrigation water build up in the soil and trees over time, possibly over a period of years. The effects from salinity can continue in the trees even after heavy rains have flushed the accumulated salts out of the soil. One growers believes that chlorides are more deleterious to citrus trees than sodium. Thus "chloride excluder" type root stock should be used.

Importance of Irrigation in Citrus Production.

Growers confirmed that irrigation is an important component of their production program, but they stressed that good drainage is actually more crucial to grove productivity.

How Frequently Do You Irrigate?

In sand soils found in south-west, growers may irrigate weekly during the winter months. But schedules can vary from every three to four days to two weeks depending on weather conditions and soil characteristics. For many groves, there is no pure indicator of when to irrigate. This is impossible because soil types change so frequently within groves or even individual blocks. One grower suggests that you should under-irrigate for your worst soil and over-irrigate for your best soil. Another grower said you should irrigate for your best trees. Smaller operations are better able to micro-manage irrigation for different soil types since they are usually dealing with smaller blocks of trees. Irrigation can be adjusted within a grove or even a row of trees by changing from drip to micro-jet systems and adjusting emitter sizes.

Types of Irrigation Systems in Use.

Growers indicated that they were using flood, micro-jet and drip irrigation systems in their groves. One grower was careful to distinguished between a "good" flood and a "bad" flood system. A good flood irrigation system is designed so that water flows through the grove in a timely and uniform manner. A seepage irrigation system was said to be just another name for a bad flood system. A few growers had groves with old overhead systems, but none were in operating condition. One grower is using a traveling "rainbird" system (in St. Lucie county) which is fed by surface water reservoirs.

Desired or Ideal Irrigation Systems, System Pros and Cons.

The ideal irrigation system for a particular grove depends on a number of cultural, geographic, and institutional factors. The type of system you can install today is dictated in large part by institutional constraints, mainly in the form of water management regulations. Water use allocations make low-volume systems the only option in many instances. Particular conditions exist for the 298 district. If a grove is boxed in by urban development it may be difficult or impossible to build reservoirs. A lot depends on the size of the grove. Soil type is a major consideration, particularly in terms of its water holding capacity. According to one participant, when you have to use highly saline water, a good flood system will work better than micro-jet on soils with a high water holding capacity. Since good drainage is more often associated with flood irrigation systems, many growers expressed a preference for this type. The age of grove was also mentioned as a consideration.

How Do You Determine or Measure Water Quality?

The group was not forthcoming when directly queried about how they determined water quality. Later, when discussing another issue, one participant described how he use to carry a "hot chloride" test kit around in his car and tested numerous wells that way. Growers indicated that they are aware of the TDS levels in their wells, but they don't always maintain records on this. One grower interjected that he didn't believe it was possible to determine anything meaningful from taking a "snap shot" of water quality. The water quality in the canals and surface storage structures is going to be quite dynamic as droughts progress and low quality well water is introduced into the system.

Criteria for Determining Suitability of Water for Irrigation.

The primary criteria growers claimed to use for evaluating the suitability of irrigation water is the response from the trees. A wide range of TDS levels were quoted throughout the discussion. One grower stated that he is profitably managing a grove using 2000 ppm TDS water. Another grower claimed to profitably grow citrus using straight well water with 3500 ppm TDS. Growers readily admitted that using water with these high levels of salinity caused noticeable effects on the trees. There is a perception problem though, because the salinity and its effects in the soil and trees can build up so gradually that growers get used to it. There was no dispute with one grower's statement that management was "critical" anytime that TDS levels exceed 1500 ppm, regardless of irrigation system.

Frequency of Sampling for Water Quality.

Growers do not test their water quality on a regular basis. Many sample their wells when they begin using them (seasonally), and will continue doing so throughout the dry periods. Those growers that have switched to surface reservoirs for irrigation water have quit testing their wells.

At What Levels Does TDS Begin to Negatively Impact the Tree?

Prior and current production practices have to be taken into consideration when evaluating whether a certain quality of water will adversely impact a grove. In the words of one participant, "You have to define the age of the grove." Apparently, the most critical pre-existing condition is the level of salts which may have build up in the soil and/or trees from prior irrigation practices over a period possibly as long as several years. One participant believes that you can safely use 1300 to 1400 TDS water across the board. Another said he has no problem with 400 to 500 ppm TDS water.

How do Grove and Tree Characteristics Influence Water Quality Problems?

Soil type is the most important consideration with respect to water and irrigation practices; specifically the water holding capacity of the soil. As one grower stated, "You can do many things with ball bearing sand that will not work on flatwood soils". With the heavier soils found near the east coast, growers don't have to irrigate as frequently but they must irrigate "properly". Another factor is the existence and level of perched water tables.

Size and location must be taken into consideration when deciding how to develop water sources for a grove. Generally, it is more difficult to build surface water holding structures for smaller groves or groves located near the coast. Also different water management districts (WMDs) have different rules on the use of stormwater runoff. The South Florida WMD doesn't allow reuse of stormwater without a difficult permitting process.

Root stock can be adjusted to help deal with water quality if you are starting out with a new grove. There were no definitive responses to inquires about fruit type or variety being a consideration with respect to water quality. Likewise growers were not too specific when asked about age or life cycle of the grove. Trees and groves are not recycled because of age, but due to diminished productivity. Therefore trees of all ages can be found in many groves.

Another characteristic which growers thought might be relevant was the age of the trees. Younger trees were considered to be more resilient to any kind of stress than older trees by one grower. Another participant thought that the existence of water control structures in reservoirs or canals have helped maintain water table levels so that groves are not as dependent on well water as in the past. Finally, a grower reiterated the opinion that the most important consideration was what had happened to the soil under the tree since it had been in production.

Management or Cultural Practices that Mitigate Problems with Low Quality Irrigation Water

Low quality water can be effectively managed. However, yields are probably lower compared to groves irrigated with high quality water (TDS < 500 ppm). You must use a different irrigation schedule with low quality water. When you have salt in the water, it is best to irrigate so that a constant moisture level is maintained in the soil. This will prevent the salts from precipitating out and damaging tree roots. Consequently, once irrigation with low quality water is initiated, it is necessary to continue until sufficient rainfall occurs to flush out the accumulated salts in the soil. Fertilizer management may also be adjusted to avoid compounding the deleterious effects of saline irrigation water.

One grower who claimed to use water straight from wells with 3500 ppm TDS, says that during dry spells he irrigates "hydroponically". He described this as maintaining a steady flow of water through the soil once irrigation was begun. This is accomplished with a micro-jet system on soil with a shallow hard pan. The trees are on beds with the furrows cut down almost to the hard pan. Typically, he will irrigate during periods of high water use: bloom time, beginning in February, on through to June, or until the rainy season starts. Last year, the summer rains in his area didn't begin until July. He reiterated that irrigation management is highly dependent on soil type. In the grove he spoke of, the soil is relatively porous and the trees are on a tolerant root stock. This block produces a high solids, early variety fruit, he said. In summary, high TDS irrigation water can be used when "properly managed", but there was little talk of negating its effects on tree health or productivity.

Do you Blend Water?

Growers in Indian River county do blend surface and subsurface water, particularly for flood irrigated groves. The 298 district was mentioned specifically as an area where flood irrigation is still used a lot and growers blend water. In areas where water is blended, wells are usually turned on as soon as growers begin pumping water from the canals. As irrigation continues through a dry spell, typically in the spring, the salinity of the surface/canal water will rise hand-in-hand with the addition of Floridan well water. One grower testified that toward the latter stages of a drought the quality of canal water will approach TDS levels found in the local wells, but never quite equal it. Once it rains, water quality returns to normal levels.

Practices on the Horizon which May Help Manage this Problem.

Growers do not believe there is anything that can be done to reduce their reliance on irrigation water. In fact, the more intensely trees are managed the more water they will need, since water is an essential ingredient for tree growth and fruiting. Groves can survive on low quality irrigation water up to a point, provided it is properly managed.

How Do You Think Different Interests Impact Water Quality in the Area?

There were differences of opinion on this issue. Some growers felt that by taking saline water from underground and putting it on top of the ground, there was no avoiding an unnatural environmental impact on the area's water quality. Other participants felt that agriculture's impact on the areas water supply was minor compared to that from businesses, residents, or municipalities. Some acknowledged that agriculture was the area's largest water user as measured by consumptive use permits, but this was due to a misconceived measurement system. Growers dispute the WMD's definition of water consumption versus water use. For example, in many flood irrigation systems growers are able to recycle their own or each others water from one grove to another. In effect the management districts are not crediting growers for pumping water back into the "system". In addition, growers claim that the quality of the water they return to the "system" is much better than that which has been used for residential, municipal and industrial purposes. Another grower declared that he pumps off more water than he uses in those groves with low volume irrigation systems.

Political Issues.

Political and regulatory issues related to water use came up numerous times during the session. Growers perceive that many of their water related issues arise from a political - demographic rivalry between themselves and other interest groups in the area and state. They view themselves as a more historically vested but minority concern that now has to do battle and compete against residential newcomers for water resources which they (the growers) originally developed.

Growers feel that the majority interests of residents, commerce, and municipalities are being subsidized by state, regional, and local governments at agriculture's expense. One grower contended that there was plenty of high quality water available in south-east Florida, but it was not cheap. Residents and municipalities don't want to pay the true price for this water, but growers, by building the reservoirs and other retention structures necessary to capture and store rainwater, are paying for it.

The feelings of political and economic injustice are intensified for growers when the WMDs take actions to restrict their use of the water from their own canal systems and reservoirs. This is part of a larger issue of property and mineral rights. As non-agricultural constituents and interests of the state have increased, and environmental concerns mounted, various regulatory actions of the government have effectively eroded the property and mineral rights of land owners. Consequently, growers feel they are losing control over resources in which they are significantly invested.

Growers feel that they suffer from regulatory discrimination because their is little or no differentiation of water use or consumption for fundamentally different user groups by the WMDs. As discussed in the previous section, growers contend that significant portions of the water used to flood irrigate citrus groves is recycled from one grove to another. Growers are not credited for the unused water they pump back into public reservoirs. Also, as previously brought up, the quality of water after it has been used for irrigating citrus is reported to be much better than that discarded by residential and municipal users.

Willingness to Participate in Detailed Survey and Water Sampling.

Grower's interest in participating in a survey on water quality was conditional. They wanted to know how this information was going to be used by the WMD. Is the WMD going to regulate water based on quality too? Will they require or prohibit growers to use 3500 ppm water for irrigation, now that they know that this is feasible and being practiced?

The information gathering objective of this project was reminiscent to some growers who were involved in the early development of the consumptive use permitting process. Growers are not enthusiastic about new areas of regulation. They admitted that there are gaps in the data base on water quality and grove management, and that they could benefit from more accurate information on the issue. But many were not convinced that this project is needed, believing that considerable information has already been collected on this matter. One individual claimed that five or more different agencies had tested his water over the past ten years. Others talked about the extensive information requirements of the consumptive use permitting process, and having to send in water quality samples to management districts every quarter for the past 15 years. Growers did state that if IFAS was involved in such a survey, the reception would likely be friendlier than for agencies such as the US Geological Service or the WMDs directly.

Brevard County.

The focus group for Brevard county was held at 1:00 pm. on November 9th, at the Indian River Citrus League offices in Vero Beach. This was immediately following a complimentary lunch provided to all participants at the nearby "Surf" restaurant. The group met for approximately one hour.

Out of 24 telephone contacts, only four growers from the area attended this meeting. Two primary reasons for not participating were: 1) growers did not irrigate; and 2) growers did not feel irrigation water quality was a major issue. All four participating growers worked as managers for citrus operations in Brevard and other nearby counties in the state. The firms with whom they worked were all organized as corporations. Acreages managed by these individuals ranged from 1100 to 3000, and averaged 2050. Three growers used water from both wells and canals for irrigation. One grower relied exclusively on well water. Likewise, three growers produced both fresh and processed fruit, with one grower producing only processed.

<u>Discussion Content Summary.</u>

The session was begun with an explanation of the purpose of the meeting, and how this fit into the objectives of the project and the overall research effort being funded by the Saint Johns Water Management District. It was made clear that the viewpoint for this discussion was from the management side of commercial citrus production.

Concern Priorities.

Participants were first asked to express their current most pressing concerns with respect to citrus production in the area. The responses included: the over abundance of water; the overall profitability or economics in producing and marketing citrus; and government regulation and taxation. Compliance with governmental regulations was the over-riding topic during this discussion. Particular issues in this regard included: worker protection and safety; property value appraisal for tax purposes; and environmental protection rules and inspections. The general feeling was that greater amounts of managerial time and expense are being required to comply with an increasing array of governmental regulations. As a result, operating costs are increasing and profits declining.

Current Water Quality Concerns.

There appeared to be some initial reluctance among the participants of this group to openly admit that water quality was a specific problem for them. One grower recounted a series of problems he had experienced recently with a substantial number of resets (trees that have been recently transplanted) that he thought might have been related to water quality. He and his associates knew there was salt in the irrigation water and also possibly in the soil, but they were uncertain as to how much and what its impact was on their trees. No other growers immediately responded to this inquiry. Comments made later, on more specific matters, substantiated that water quality was in fact a production concern for all participants. This not only applied to irrigation, but also to having good quality water for mixing and applying pesticides or other water-based spray applications.

Current Water Quantity Concerns.

Two issues were brought up with respect to the quantity of water available for irrigating citrus. The first was a problem with inadequate water volume from shallow wells in the northern part of the county, near the coast or on Merritt Island. One grower described how most of the wells in that area that were more than 100 feet deep had very poor quality water, "all salt". On the other hand, wells to depths less than 100 feet did not produce sufficient volume to perform any meaningful irrigation. Consequently there is little irrigation in this area, and the few groves that are irrigated are done with micro-jet or drip (low volume) systems. The respondent indicated that this was "hammock" type land that was actually quite productive without irrigation. The grower was probably referring to an area north of Titusville and east of U.S. Highway 1 near the town of Mims, which has a high water table and shallow soils (Myakka-Bradenton association).

The drainage of excess rain water compounded by increasing storm water run-off from suburban development was the second problem identified with respect to water quantity. One grower described how water drainage problems in his area were being aggravated by run-off from streets and subdivisions which was "filling up the canals instead of percolating back down to the aquifer". Citrus tree roots can only tolerate submersion for a limited time before they begin to die. The problem with drainage has been a recent critical concern for many growers in the area due to unusually high rainfall in the past six months. In fact, growers ranked the drainage/excess quantity issue more important than water quality at this point in time.

Future Direction of Water Quality.

Growers think the water quality problem has gotten progressively worse over a ten to forty year period. They are not sure whether this is a local phenomenon or if the quality of the whole Floridan aquifer has deteriorated over time due to salt water intrusion or other causes. The quantity and quality issues were difficult to separate in this discussion. Regardless of whether this is a local or regional happening, most growers feel that the decline in quality is linked to the increasing demands for water from residential and commercial development. On the other hand, as another grower pointed out, it may be just a perception issue. Community sensitivity to the impacts of heavy agricultural water usage during droughts has escalated as the number of small residential wells in the county has increased over time. One grower recalled his experiences with wells cavitating and significantly drawing down the water level during dry periods. He wondered if this happened back when they were originally installed (many of the wells used by growers were drilled decades ago by previous owners).

In speculating on the direction of the problem over time, growers shared many diverse experiences with water quality from different parts of the county and state. Water quality can vary tremendously with location, and there doesn't seem to be any intuitive pattern to its distribution. Sometimes wells close to the ocean have less salt than those further inland. One grower related how most new wells are encased to their full depth in order to improve the quality of water obtained. The rationale behind this is that saltier water in the limerock layers is often perched on top of deeper fresh water. The full-depth encasement keeps this saltier water from mixing in the deeper fresh water as it flows up the well.

How does Low Quality Irrigation Water Affect the Quantity and Quality of Fruit?

Low quality water can contribute to a reduction in yields and/or quality. Often though, salt from irrigation water is not the sole source or cause of salt related problems in grove production. Injury could occur in conjunction with or as a result of salt in the air, in the soil, or from fertilizers. Most growers believe that with adequate information and proper management the problems associated with salt can be "managed". Obviously, rainfall, temperature, and wind direction can be important contributing or mitigating factors, and these should be monitored closely by the grower. Overall, saline irrigation water is not a "real big" factor in reducing yields or quality, but it could be in the future. One grower expressed the hope that new "mangrove" root stocks would be developed in the near future. These would be more salt and water tolerant than existing stocks.

The Importance of Irrigation in Citrus Production.

Irrigation is of dubious value for citrus production in Brevard county. More than one grower expressed the belief that more harm was done to many groves in the area from over irrigation than from a lack of moisture. Irrigation is more valuable to young trees than older ones, claimed one grower, but in either case, it is not critical. As trees get older and their root systems develop, they are better able to obtain moisture from the water table during dry periods. When asked how prevalent irrigation was in their county, growers said the majority of groves in

Brevard were not irrigated and none on Merritt Island were. Irrigation is not widespread in this area because most groves are on soils with a high water table, only 2 to 3 feet below the surface. Currently, drainage of excess water is a much bigger problem for growers in Brevard county.

How Frequently Do You Irrigate?

There are a number of variables that determine the frequency of irrigation in citrus. Both seasonal and annual variations in weather conditions are perhaps the primary determining factor. Obviously, in dry years irrigation will be more frequent, where it is an option. Seasonally, groves are irrigated mostly in the spring and fall, due to diminished rainfall at those times of the year. The spring season tends to be the driest. It is important for citrus trees to have adequate moisture during certain stages of their production cycle, such as during bloom and fruit set. In contrast, irrigation may be reduced in October and November to allow trees to dry out and go dormant prior to cold weather. Soil type, root stock, tree variety, and the type of irrigation system are some of the grove characteristics that influence the timing of irrigation. During winter months irrigation can be used to prevent or reduce damage from freezing temperatures. One grower uses a tensionometer to determine when to flood irrigate a grove. Another grower decides when to irrigate by the number of days since the last rainfall of at least one-half inch and by kicking up the soil around the drip line of the trees.

Types of Irrigation Systems in Use.

Micro-jet and flood irrigation were the systems most frequently cited by participants. Overhead "Rainbird" systems exist in some groves, but they are not currently in use. There was some mention of converting old overhead systems to micro-jet or drip systems.

Desired or Ideal Irrigation Systems, System Pros and Cons.

Depending on the soil type, size, and layout of grove, growers would choose either micro-jet or flood type irrigation systems. One grower stated that he had fewer disease problems using flood systems. Another grower pointed out the advantages of managing a new grove or a grove with numerous resets with micro-jet irrigation. Micro-jet systems can also be used to apply macro and micro-nutrients to the groves. For mature groves, flood systems were considered superior by one grower because he didn't have to worry about tearing up irrigation equipment every time he did mechanical work in these groves. Micro systems are expensive to install and maintain. It was also noted that flood systems have advantages for freeze protection. An important side benefit of flood irrigation systems is the improved drainage of excess water that comes from the precise land grading required for these systems to work correctly.

How Do You Determine or Measure Water Quality?

Most growers are taking water, leaf, and soil samples and sending them to laboratories on an annual basis. The ones that have not been doing this are planning on starting. Again the issue of water quality and its use for applying chemicals or pesticides to groves came up. One grower gave testimony to the importance of testing the pH of water before using it in chemical spray applications. Pesticide applications represent a significant production expense.

Criteria for Determining Suitability of Water for Irrigation.

When asked what criteria they used to decide if water was suitable for irrigating citrus, one participant said he would not use water with total dissolved solids (TDS) greater than 1300 ppm, but water with 700 to 800 ppm TDS could be used without any problems. Citrus cannot take as much salt in a foliar spray. Anther grower indicated he had used water as high as 1500 to 1800 ppm TDS through both micro-jet and flood irrigation systems with no apparent adverse effects. He was quick to add though, that 1500 ppm in an overhead spray would defoliate the trees.

At What Levels Does TDS Begin to Negatively Impact the Tree?

Growers were non-committal in responding to this question directly, although one grower had previously divulged that 700 ppm. could be used in foliar sprays with no problems. Some participants thought it would be easy to find out and joked that they had some trees that they would be happy to let us use in an experiment for this purpose.

How do Grove and Tree Characteristics Influence Water Quality Problems?

Growers did not think fruit type was a factor in a grove's response to saline irrigation water. Since most groves in the area are on Sour root stock, they really could not comment on this, other than to say that Sour was a "pretty tough root stock" anyway. In general, younger trees are considered to be more sensitive to everything than older trees, and salt is no exception.

Soil type is an important consideration when it comes to many water and irrigation issues. Salts will accumulate or leach out of some soils faster than others depending on sand, clay, and organic matter content in addition to other physical or chemical characteristics. There was some question about how shallow layers of limerock, found in some soils of Brevard county, influences grove performance relative to water quality.

Management or Cultural Practices that Mitigate Problems with Low Quality Irrigation Water.

One grower was quite definitive in recommending that when irrigating with saline water, soil moisture must be maintained at a level that will keep the salts from precipitating out and consequently damage tree roots. In other words, once you begin irrigating, you must continue to do so until sufficient rainfall occurs to flush out any accumulated salts in the soil. Consequently, higher salt content in irrigation water results in higher water usage.

Do you Blend Water?

Some blending is done. Growers only admitted to mixing small amounts of well water with canal water, when it is available.

Practices on the Horizon which May Help Manage this Problem.

The only nonpolitical response to this inquiry was the hope that salt tolerant root stocks could be developed in the near future.

Political Issues.

Although participants were not directly solicited for their ideas concerning the politics of water use and quality, this came up frequently during the discussion. There were basically four different types of concerns. First, some participants felt oppressed by the general level of government intrusion into their business affairs. The WMDs are just one among many agencies with which they have to contend. Second, growers do not believe the WMDs fully understand or appreciate how water functions within the ecosystem and within various agricultural enterprises. Growers don't agree with the WMD's definition of water consumption. The WMDs don't take into consideration the significant volumes of irrigation water that growers recycle or contribute to the ecosystem. The third political issue that concerns growers involves vested rights. Simply put, growers got here first. They purchased the land and planted their groves under the rules and regulations of that day. Now that a multitude of residents have arrived, these new residents and the state want to change the rules. Of course from the growers perspective, these changes are designed to accommodate the new residents and development, and not citrus producers. Finally, citrus growers feel like they are out-numbered and effectively overpowered by the popular majority and the government officials they elect. Growers have become a political minority and feel like they are getting beat up. Consequently, there are strong feelings of frustration and bitterness.

Willingness to Participate in Detailed Survey and Water Sampling.

The participants in this group appreciated and concurred with the general premise of this research, but they expressed doubts as to its relevance for Brevard county given the comparatively few number irrigation wells located there. Water quality is definitely a concern for these growers on at least some of their groves. They considered any research which could lead to a better understanding and management of this problem worthwhile, but they stressed the need for accuracy in the information and recommendations generated. Growers viewed IFAS's involvement in the study a positive factor. One participant recommended we take advantage of the cooperative extension service to notify and explain to the growers what was taking place and why. Overall the Brevard group could be characterized as cautiously receptive to participating in a survey the water quality issues.

Summary and Recommendations

Overview.

Water quality is an important concern for the growers who attended these two focus groups. It must be recognized though, that there was an inherent selection bias to this focus group procedure, since there was little or no motivation for growers to attend these sessions if water quality was not a concern. Based on the lower turnout and comments made for that session, there are substantially fewer problems with water quality in Brevard county than in Indian River county. This appears to be simply and primarily due to the relatively small number of irrigated groves in Brevard county. To put this issue in a general perspective, participants in both groups didn't consider irrigation to be as critical to grove health and productivity as adequate drainage for excess water. This attitude may be in part due to the excess rainfall growers have experienced in recent months and the absence of a serious drought for several years. Growers also seemed more concerned about possibility of future regulatory constraints on the use of low quality water than they were about using low quality water in and of itself.

There are a wide range of conditions and situations that are relevant to citrus irrigation and water quality in both counties. Some growers have effectively precluded any problems with low quality well water by building rain-water retention structures in or near their groves. Other growers regularly blend water from underground and surface sources when they irrigate. A few growers manage to successfully irrigate their groves using only well water with levels of TDS considered to be quite high. The three biggest factors which appear to influence a grower's strategy and success in using low quality irrigation water are soil type, institutional constraints, and managerial skill. This last attribute underlies the fact that there are a multitude of other factors which must also be considered and monitored when irrigating with this type of water. Management is complicated by the dynamic behavior and interaction of salts in the water, soil, and trees and an evolving regulatory environment.

Growers appear to be very knowledgeable about their own particular situations with respect to water quality and how to best handle them. There was considerable uncertainty and disagreement over the causes or sources of the low quality water as well as the direction of change in water quality over time. Water quality from artesian wells varies substantially across both counties, and often within distances of less than a mile. Some growers claim to have experienced long term declines in water quality while others say that only temporary seasonal changes occur.

Growers Interest in Participating with this Research.

The participants were cautious and somewhat skeptical of the WMD's motives for conducting this study. Understandably, citrus producers are not positively inclined toward additional regulatory overhead, and they suspect that this study is a precursor to some form of water quality regulation. As for their willingness to participate in more extensive data collection efforts, growers were somewhat tentative and some questioned the necessity of this activity given the quantity of information they claim to have already supplied the WMDs and other government agencies. Growers would appreciate more accurate information and a better understanding of what is happening with water quality in their area. It was suggested that a well planned public relations effort be conducted prior to implementing any survey.

Feasibility of Empirical Analysis.

There are a number of potential data inadequacies and complications which could interfere with efforts to empirically analyze or evaluate the impacts of low quality irrigation water on citrus production. First there may be difficulties in determining how much TDS a grove or tree has received over its relevant production history. This is due to the changes in both underground and surface water quality that occur when growers irrigate. Consideration must also be given to the accumulation of salts in the soil and trees over a period of months and probably years. It may also be difficult to accurately account for the effects of soil type on yields since it is not uncommon for groves and production blocks to have more than one type of soil. Comparing yields between different groves or production blocks will likewise be complicated by the diversity of tree ages that can be found throughout many groves in the area. These and other factors must be carefully considered when determining what kinds and how much information must be obtained in order to accurately model the practical impact of saline water on citrus production.

Recommendations.

- There is evidence that substantial unpublished data may exist on the quality of well water in Brevard and Indian River counties. In order to avoid duplicating any data collection activities, it is recommended that a thorough search be undertaken to locate and compile these data. There can be considerable costs in terms of goodwill when survey participants are burdened with redundant data requests. If sufficient data can be found, these should be analyzed for seasonal and long term trends. The publication or distribution of any findings on water quality trends could bolster grower cooperation and goodwill for subsequent data collection efforts.

- Various procedures for aggregating data on soil types, tree age, and water quality should be evaluated prior to beginning any collection of data on grove characteristics or management activities. Consultation with agronomists, citrus experts, and the Florida Agricultural Statistics Service should be made in order to ascertain the best methods of comparing yields between groves with significantly different physical and cultural characteristics. These precautions will help insure that citrus yields can be accurately modeled without having to collect excessively detailed data from growers.

- Based on: information obtained from the focus group discussions; a review of published literature; the availability and review of unpublished data on water quality in the two counties, and; the ability to aggregate certain types of data on grove characteristics the remaining tasks (4 - 8) for Phase 1 of this research project should be carried out as originally described in the "Scope of Work".