Sutter Mutual Water Company (WMWC)

Proposed Salinity Management Program

(For Crop Management and Improved Irrigation District Operation)

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Prepared by

ITRC

IRRIGATION TRAINING AND RESEARCH CENTER
California Polytechnic State University
San Luis Obispo, CA 93407

Phone: (805) 756-2423
FAX: (805) 756-2433

ATTACHMENT 5

Table of Contents

List of Figures

List of Tables

Executive Summary

Purpose of Study

Approximately 45 percent of the total delivery for Sutter Mutual Water Company is pumped from Karnak Pumping Plant during the summer. This water can not be recycled due to its high salt content. The salt content of the drains is higher due to the influx of what is known as connate water into the drains. This connate water is contained in a localized area of the district. The drains pick up the connate water as they pass through this area. If the salt water can be removed the district can implement a drain water recirculation program. A recirculation program will provide the following benefits for the district:

1. Increase district flexibility making district operation easier.

2. Help maintain the flow in the river by reducing diversions.

3. Reduce pumping at both Karnak and Tisdale Pumping Plants (this will be offset by increased pumping in other areas).

The purpose of this study is to look at options for removing the connate water in order to make a recirculation program feasible.

Estimation of the Volume of Connate water

The volume of connate water to be used in calculations was estimated using three methods:

1. Water balance.

2. Salt balance.

3. Using estimates made by Dr. Tanji of UC Davis.

A comparison of the estimates made by each method can be found below.

Comparison of methods to estimate volume of connate water.

	Estimate of volume of connate water (acre-feet)	
	1993	**1999**
Water Balance	58,422	56,755
Salt Balance	18,946	8,058
Tanji's estimate	55,081	55,081

The range of values for the volume was from about 8,000 ac-ft to 58,000 ac-ft. An estimated value of 25,000 acre-feet was determined to be a reasonable value to use in further calculations.

Potential Solutions

Two potential solutions were explored in this report. The options are:

1. Use wells to relieve the artesian pressure and remove the connate water.

2. To re-route the drainage ditches in the connate area so the connate water never reaches the main drain.

Each option was explored for feasibility and costs. In both options the water being removed will discharge into the Nelson Slough which leads back to the Feather River.

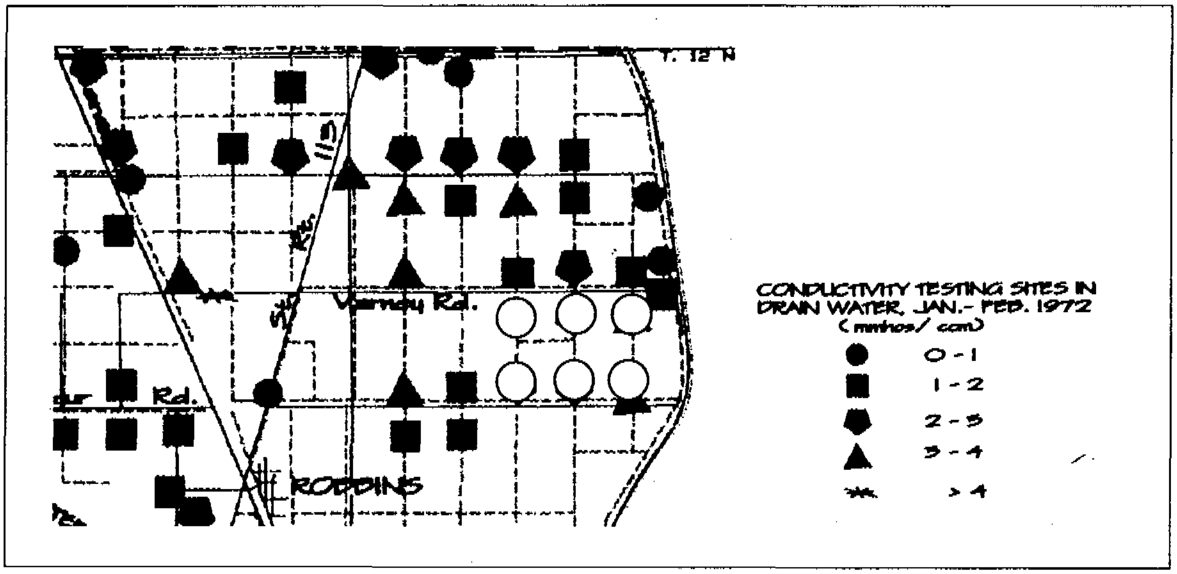
<u>Well Option</u>

Determining the Number of Wells to Use

From the water and salt balance it was estimated that the volume of connate water to be removed is 25,000 acre-feet. The flow each well can produce was estimated to be 500 gpm from a geological engineering report conducted by William Gianelli in 1962. By dividing the volume to be removed by the flow from each well it was determined that 30 wells would be required to relieve the connate water problem. From geological reports it was estimated that the wells would be required to be drilled to a depth of 500 feet.

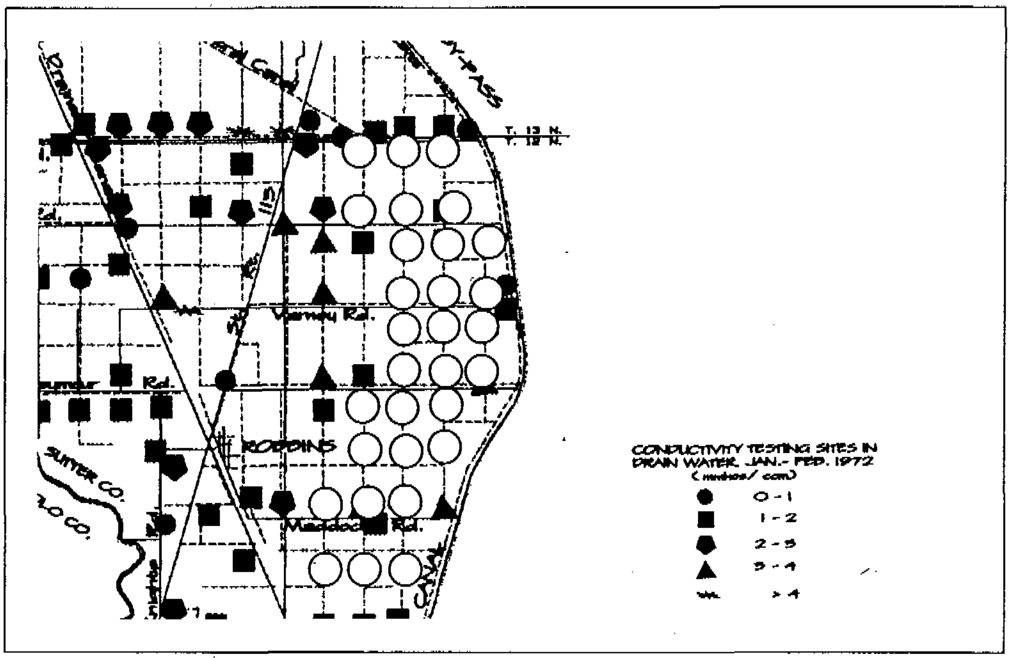
Seems low.

In order to determine if drilling wells will help relieve the pressure an initial design of one-fifth the number of wells (six wells) was made. The location of the six test wells is shown below.



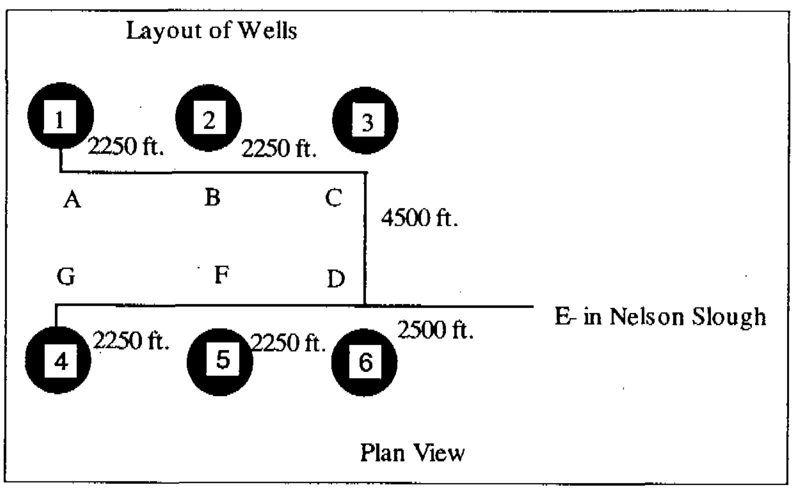
Location of the initial six test wells

The location of all thirty wells is shown below.



Location of all thirty wells

The layout of the initial six test wells can be seen below.



Layout of the initial six test wells (not to scale)

The final cost estimations for the initial six test wells and for all thirty wells are shown below. A cost per acre was determined for comparison purposes. The cost per acre is based on 68,000 acres since the whole district will benefit from the removal of the connate water.

Total cost estimates for the initial six wells.

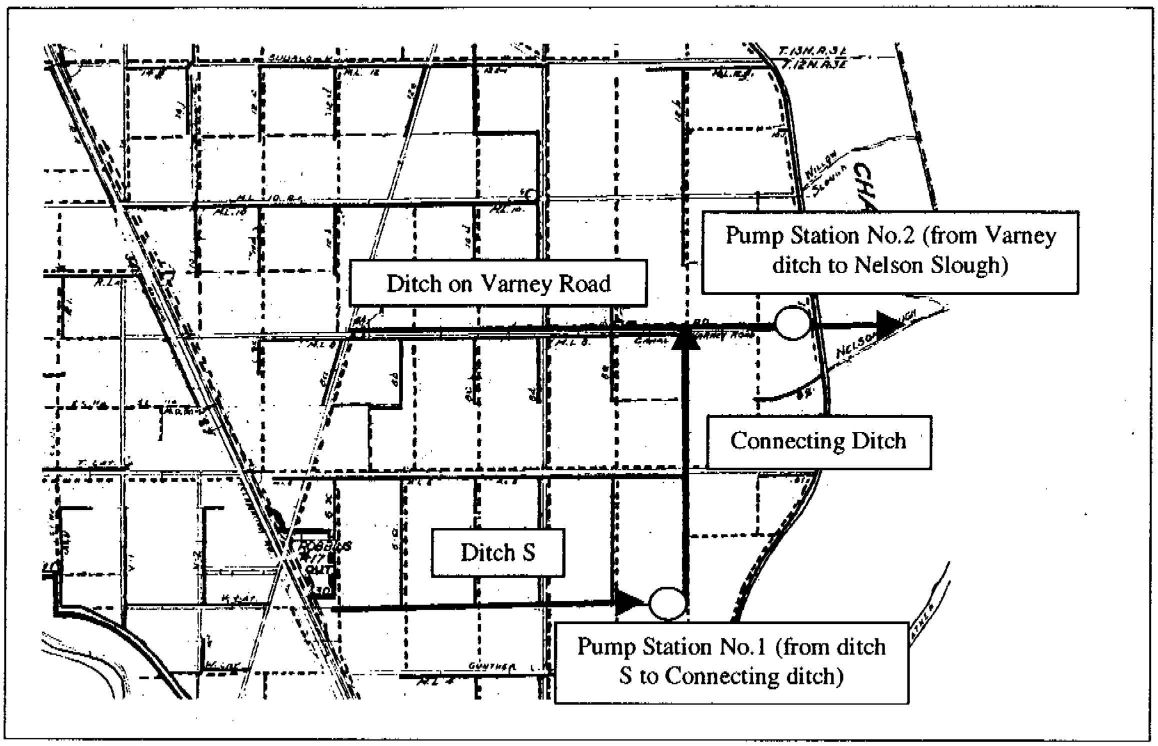
Cost of Project (initial 6 wells):			
Item	Initial Costs ($)	Subtotal	Annualized Costs
Well installation	$ 144,960		
Pump installation	$ 60,000		
PVC pipe installation	$ 264,046		
Total Fixed costs		$ 469,006	$ 69,896
Power costs			$ 95,481
Total Annualized costs			$ 165,377
Annualized cost per acre (68,000 acres)			$ 2

Total cost estimates for all thirty wells.

Cost of Project (all 30 wells):			
Item	Initial Costs ($)	Subtotal	Annualized Costs
Well installation	$ 724,800		
Pump installation	$ 300,000		
PVC pipe installation	$ 1,320,229		
Total Fixed costs		$ 2,345,029	$ 349,478
Power costs			$ 477,407
Total Annualized costs			$ 826,886
Annualized cost per acre (68,000 acres)			$ 12

Re-Routing Drainage Ditches Option

For this option the ditches in the connate area were surveyed to find changes in water level. A detail of the ditches surveyed in the connate area along with the proposed direction of flow and location of pump stations is shown below.



Ditches surveyed in connate area, showing proposed direction of flow and pumps.

Flows for each ditch were estimated and backwater curves developed to estimate the water depth with the new flow directions. An elevation profile was then developed to find the location of pumps required and the volume of excavation.

The final cost estimate for this option can be found below.

Total cost estimates for the ditch re-routing option.

Cost of Project (Re-Routing ditches):			
Item	Initial Costs ($)	Subtotal	Annualized Costs
Excavation	$ 249,333		
Pump installation	$ 273,000		
PVC pipe installation	$ 650,000		
Total Fixed costs		$ 1,172,333	$ 174,712
Power costs			$ 244,706
Total Annualized costs			$ 419,418
Total cost per acre (68,000 acres)			$ 6

Discussion and Final Recommendation

Cost Comparison

A cost comparison of the two options can be found below.

Cost comparison of options.

Life of Project (yrs)	10	assumed			
Interest rate	0.08	assumed			
CRF	0.15	CRF =[i*(1+i)^n]/[(1+i)^n-1]			
Option	Total Fixed Costs	Annualized Costs	Power costs	Total Annual Costs	Annual cost per acre
Initial six test wells	$ 469,006	$ 69,896	$ 95,481	$ 165,377	$ 2
All thirty wells	$ 2,345,029	$ 349,478	$ 477,407	$ 826,885	$ 12
Re-routing of Ditches	$ 1,172,333	$ 174,712	$ 244,706	$ 419,418	$ 6
Cost per acre is based on 68,000 acres					

While the re-routing option appears to cost less than the well option it actually may not. The well option may be the most cost effective for the following reasons:

1. All thirty wells may not be necessary to achieve the desired result. The estimation of the volume of connate water is not known to a definitive level and may be over estimated. When the drain water at Karnak reaches desired EC levels no more wells need be installed. The least expensive option is actually to install the six test wells and determine if this is enough to relieve the connate problem.

2. The flow each well can produce is not clear. If the wells can produce 1000 gpm rather than 500 gpm half the wells may be necessary. Flow tests must be conducted to determine the actual flow the wells can produce.

3. The well option will eventually remove the connate water and pumping will no longer be necessary. The re-routing option will take much longer to remove the connate water leading to higher overall pumping costs.

Advantages of the Well Option Over the Re-Routing Option

The main advantage of the well option is that it is treating the source of the problem and not just the symptom. The well option will remove the source of the connate water permanently from the district. Over time the connate water will be completely removed from the area. However, with the re-routing option the water is being removed after it has reached the surface. For this option it will take much more time to completely remove the water, if ever. For this reason the well option is recommended over the re-routing option.

Final Recommendation

The well option is recommended over the re-routing option for the following reasons:

1. This option may actually cost less for reasons described above.
2. This option will remove the source of the water eliminating connate water problems in the future.

The final recommendation is to install one test well as soon as possible to determine the flow capabilities. After this has been determined the remaining five test wells should be installed and their effectiveness monitored. In order to determine the effectiveness of the wells the EC of the drain water in the drain on Varney Road and the drain directly south should be monitored to look for improvements. If improvements are seen within the first year six more wells should be installed and monitored. Once the drain water at Karnak reaches levels suitable for recirculation during the summer, no more wells need to be installed.

Background of Problem

History of District

In 1911 Reclamation District No. 1500 formed to provide flood protection and drainage for the Sutter Basin. The Sutter Mutual Water Company (SMWC) was formed soon after in 1919 to meet the irrigation needs of the Sutter Basin. SMWC is located northwest of Sacramento City. The Sacramento and Feather Rivers and Tisdale and Sutter Bypasses surround SMWC. The two major crops are rice and processing tomatoes grown in rotation with wheat, corn, safflower, and beans (USDA, 1996).

SMWC provides irrigation water to 68,000 irrigated acres. Most of the irrigation water is diverted from the Sacramento River under appropriative rights that date back to 1917 (USDA, 1996). In 1964, the Company and several individual landowners secured water under a contract with the U.S. Bureau of Reclamation (BOR) (USDA, 1996). Concerns over possible water cuts in contract renegotiations have prompted SMWC to look for alternative sources of water.

The location and layout of Reclamation District 1500 can be seen in Figure 1.

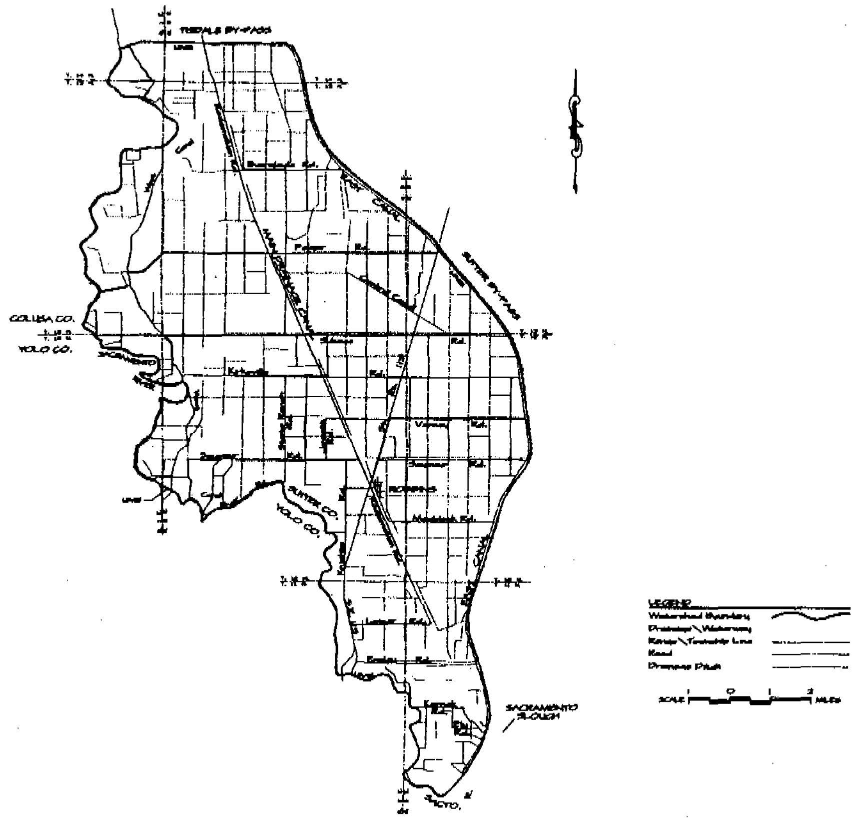


Figure 1. Layout of Reclamation District 1500 (USDA, 1996).

Connate Water Issues

One option is to implement a drainage water recirculation program. However, the difficulty with this option is the saline water problems in the area. As the drainage ditches run through the district they encounter a high salt area known as the connate area. Here the subsurface connate water, having a high salt content, is apparently under artesian pressure. This pressure forces the water up through the soil and into the drainage ditches. Therefore, the drainage water in this area has a high salt content. The high salt content has restricted SMWC's ability to recirculate drainage water. Recirculation would improve district efficiency and allow SMWC to make more flexible deliveries. SMWC is interested in developing a long-term management program to reduce the salt content in the drainage water that can then be recirculated.

The location of the connate area was determined by Dr. Tanji during a study conducted in 1972. A conductivity test site map created as a result of this study can be found in figure 2 below. The location of the connate area was determined to be on the east side of the main drainage canal between Subaco and Maddock Roads.

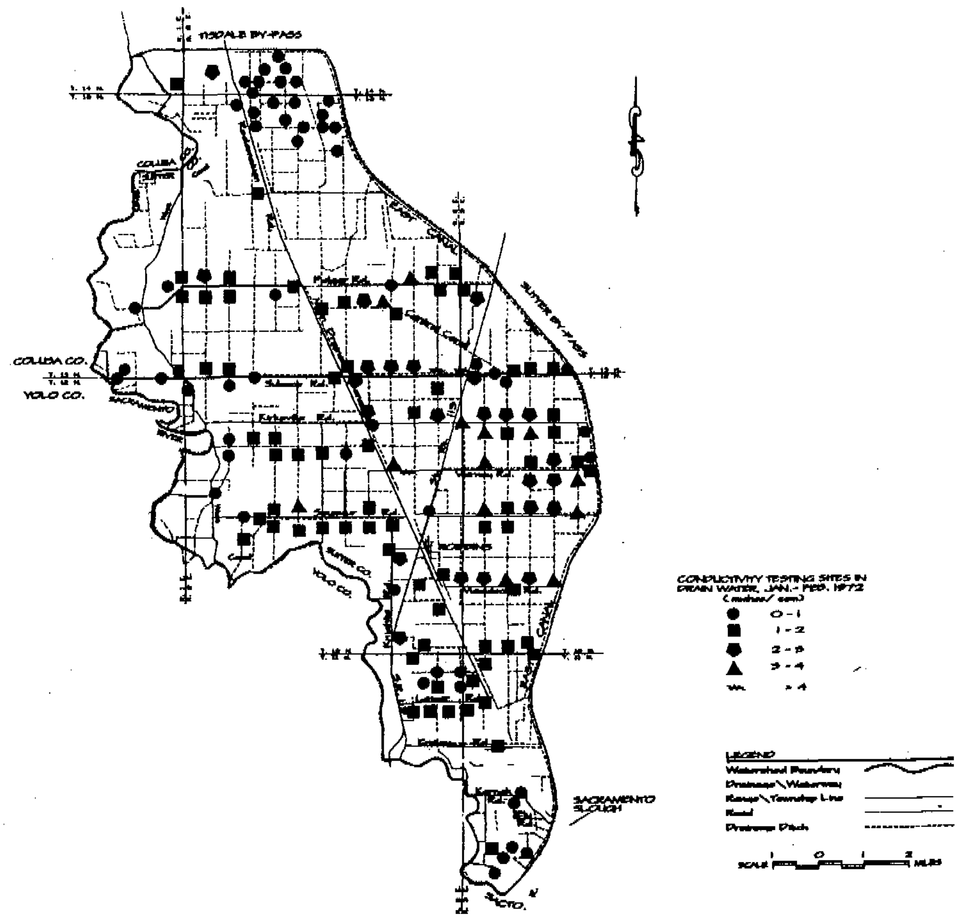


Figure 2. Conductivity testing sites in drainage water (USDA, 1996).

A search was initiated to find any studies of the area that would give an idea of the salt-water issues and possible solutions.

In order to determine alternative solutions to the salt-water problem in the Sutter Basin it is important to first understand the problem of the connate water. According to Tanji et al. (1975) there is an excess of water and salts being discharged from Sutter Basin, California- more than can be accounted for by surface water and salt inputs. The relatively large quantity of salt being discharged in the drainage water comes in part from saline underground water intercepted by the drains (Wilcox, 1947). This high salt content water is called connate water. It is believed that this connate water, containing principally sodium and chloride, rises upward through the Sutter Basin Fault under artesian pressure (USDA, 1996). The pressure is created by inflows of fresh water into the Kione sand formation at Sutter Buttes (USDA, 1996).

According to Tanji et al. (1975) the concentration of salts in the soil increases with the depth below ground in the connate area. Ten to 20 feet below the surface the EC ranges from 1 to 4 dS/m while 100 to 300 feet below surface the EC range increases from 8 to 13 dS/m (Tanji et al., 1975). This area coincides with a saline ground water mound lying at a depth of approximately 1,968 feet in alluvial and non-marine sediments (USDA, 1996). According to Tanji et al. (1975) an inland sea is believed to have been trapped during the Late Paleocene Period leaving a mound of connate water in the Kione Formation, Upper Cretaceous. According to a 1996 study by the USDA, NRCS it is believed that the excavation of the drainage ditches through the layer of sandstone is the cause of the connate water seeping into the drainage ditches.

After having a better understanding of where the connate water comes from it is important to understand how this water affects the drainage water. The salt-laden ground water seeps into the drain ditches and causes an increase in EC in the drains (USDA, 1996). The EC of the main drain is higher in the winter when there is no irrigation water to dilute the salt content of the water. The irrigation season runs from April to October (USDA, 1996). During this season from 1987 to 1992 the EC of the main drain at Karnak varied from 0.38 to 0.78 dS/m and in winter the measured EC ranged from 0.42 to 1.5 dS/m (USDA, 1996). The water supply from the river is of excellent quality and averages 0.13 dS/m electric conductivity (EC) (USDA, 1996). According to the USDA, NRCS study, in order to maintain high quality of water all reused water should follow the standard of a maximum EC of 0.75 dS/m. This can become difficult as the levels of salt increase in the drain water during reuse.

Purpose of Study

Approximately 45 percent of the total delivery for the district is pumped from Karnak pumping plant during the summer. This water can not be recycled due to its high salt content. The salt content of the drains is higher due to the influx of what is known as connate water into the drains. This connate water is contained in a localized area of the district. The drains pick up the connate water as they pass through this area. If the salt water can be removed the district can implement a drain water recirculation program. A recirculation program will provide the following benefits for the district:

1. Increase district flexibility making district operation easier.
2. Help maintain the flow in the river by reducing diversions.
3. Reduce pumping at both Karnak and Tisdale pumping plants (this will be offset by increased pumping in other areas).

The purpose of this study is to look at options for removing the connate water in order to make a recirculation program feasible. According to Burt (1999) in a site visit study of the area there are three main options; (i) reduction of the artesian pressure that drives the connate water upward, by installing wells that extend into the salty area, (ii) accelerate the leaching of connate water and residual salts during the winter, and (iii) maintain higher drain water levels in the summer.

Potential Solutions

Two options for controlling the connate water problem have been explored. The options are:

1. Use wells to relieve the artesian pressure and remove the connate water.

2. Re-route the drainage ditches in the connate area so the connate water never reaches the main drain.

Estimation of the Volume of Connate Water

In order to determine the severity of the connate problem an estimate of the volume of connate water to be removed must be made. The volume of connate water was estimated using three methods.

- The first method was a water balance. The water balance was conducted for the years 1993 and 1999. The water balance looked at the water coming into the district versus the amount of water leaving the district. The difference between these two amounts is the estimated volume of connate water.

- The second method was a salt balance. The salt balance was conducted for the years 1993 and 1999 as well. The EC of the incoming volume of water was compared to the EC of the volume of water leaving the district. Using an estimate of the EC of the connate water, the volume of connate water was determined.

- The final method was to consider an estimate made by Dr. Tanji of the University of California at Davis. Dr. Tanji has conducted several studies of the area and has made an estimate using an average of several years of data.

Option #1 to Estimate Connate Water Volume: Water Balance

Sources of Data

District Diversions

Water pumped from the Sacramento River is measured at the Tisdale Pumping Plant using a series of pump rating tables. Water is also diverted from the Portugese Bend Pumping Plant and is measured using a series of pump rating tables. The total diversions are calculated by the Bureau of Reclamation and provided to the district in tabular form for their records. The district provided these totals for this study. The total diversions for the years 1993 and 1999 are shown in Table 1.

Table 1. Total diversions made by SMWC in 1993 and 1999.

Year	Total diversions (acre-feet)
1993	192,910
1999	213,165

Karnak Pumping Plant Discharge

The Department of Water Resources (DWR), Northern District calculates flows out of Karnak Pumping Plant using data collected by the district and a program developed by their office. There are three possible flow conditions out of Karnak Pumping Plant; (i) from gravity flow, (ii) from Auxillary Pumping Plant No. 2 and (iii) from the main pumping plant. The district collects daily data on the head levels in the Pumping Plant and in the Sutter Bypass. Data is also collected on which pumps are operating and for how long. In the case of gravity flow, data is collected on how long the gates are left open for water to flow out and how far the gate is opened in feet.

Each flow condition requires special equations to determine the flow. The equations used by the DWR are empirical and were developed using data collected by the DWR. The exact date these equations were developed or the methods used to develop them could not be determined.

In order to verify the program used by the DWR raw data was obtained from the district and a spreadsheet was developed to determine the flow out of Karnak. The equations used by the DWR were also used in the spreadsheet program. The amount of flow given by the DWR was slightly larger than the volume determined by the spreadsheet program. This may be due to a discrepancy in the program developed by the DWR or in data entry. The equations used can be found in Appendix A.

The total flow for each day was calculated by adding the flow from Auxillary Pumping Plant No. 2, gravity flow and the Main Pumping Plant. The totals for each month were added and a final total for the year was found. The total discharge for 1993 and 1999 can be found in Table 2.

Table 2. Flows out of Karnak for 1993 and 1999.

Year	Total discharge (acre-feet)
1993	201,891
1999	127,934

Evapotranspiration Data

Farmer Surveys

The district provided approximate planting and harvesting dates for each crop. In order to more accurately develop crop coefficient curves phone surveys were conducted to determine irrigation patterns and typical planting/harvesting dates. A total of six farmers were contacted. Information was collected about the following crops; wheat, melons, tomatoes, rice and safflower. Additionally, rice farmers were interviewed about their pre-flooding and decomposition practices. Sample surveys and a summary of data collected can be found in Appendix B.

Crop Areas

The district provided the cropping acreage for 1993. The same cropping pattern was used in the 1999 calculations.

Rain and Reference ET Data

The Nichols CIMIS station was used to provide the rain and reference ET data. The data was accessed through the University of California at Davis web site. Directions on using the web site can be found in Appendix C.

Formulation of Crop Coefficient Curves and Crop ET

Crop coefficient curves were developed using appropriate K_{cb} and K_c values found in FAO Paper 56. The curves were adjusted according to information provided through the farmer surveys. According to the farmer surveys the ground remains wet during the rainy season which is approximately from January through April and November through December. During these times the K_c value was increased to 1.2 to account for a wet soil surface. In between the rainy times the K_c values were found using the planting, harvesting and emergence dates provided from the surveys along with the Kc and Kcb

EC of Connate Water

The EC of the connate water was estimated to be 5000 ppm. This is close to the value estimated by Dr. Tanji in his studies.

EC of River Water

The EC of the river water is known to be low. Reports from the USDA, NRCS show the EC to be around 0.13 dS/m. This number was used in the calculations. A conversion factor of 700 ppm = 1 dS/m was assumed for the water in this region. In order to calculate pounds of salt coming in from river water the following equation was used:

$$\text{lbs. of salt} = \frac{\text{dS}}{\text{m}} \times \frac{700\text{ ppm}}{\text{dS/m}} \times \frac{1\text{ lb salt}}{10^6\text{ lb solution} - \text{ppm}} \times \frac{\text{Total diverions(AF)}}{\text{year}} \times \frac{43{,}560\text{ ft}^3}{\text{AF}} \times \frac{62.4\text{ lb}}{\text{ft}^3}$$

EC of Karnak Discharge

The EC of the water at Karnak Pumping Plant is measured by the district on a weekly basis. The EC is measured in mmhos/cm. The EC for each day was found using a linear approximation between readings. These values were then added to the spreadsheet created to calculate the daily flow out of Karnak Pumping Plant. The daily EC values were multiplied by the daily flow values along with the appropriate conversion factors to yield pounds of salt per day. The daily values were summed to determine the total pounds of salt leaving the district through Karnak.

<u>Equation Used</u>

To determine the volume of connate water from the salt balance the following equation was used:

$$\text{Vol of connate water (AF)} = (\text{lbs. from Karnak} - \text{lbs. from diversions}) \times \frac{10^6\text{ lb. solution} - \text{ppm}}{\text{lb. salt}} \times \frac{1}{5000\text{ ppm}} \times \frac{\text{ft}^3}{62.4\text{ lb.}} \times \frac{\text{ac} - \text{ft}}{43{,}560\text{ ft}^2}$$

Final Salt Balance

The final salt balance for 1993 and 1999 can be found in Table 5.

Table 5. Salt balance for 1993 and 1999.

Salt Balance		
1993		
Out:		
lbs from Karnak		
305,201,813		
In:		
EC of River water (dS/m)	Total Diversions (ac-ft)	Lbs of salt from diversions
0.13	192,910	47,716,501
EC of connate water (ppm)	**Ac-ft of connate**	
5,000	**18,946**	
Salt Balance		
1999		
Out:		
lbs from Karnak		
162,246,447		
In:		
EC of River water (dS/m)	Total Diversions (ac-ft)	Lbs of salt from diversions
0.13	213,165	52,726,598
EC of connate water (ppm)	**Ac-ft of connate**	
5,000	**8,058**	

Confidence Intervals

The confidence intervals for the diversions and discharge from Karnak are the same as for the water balance (± 20 percent and ± 15 percent respectively). The confidence in the salt content of the connate water (5000 ppm) is ± 10 percent. There have not been any definitive tests of the connate water to give an exact number.

Option #3 to Estimate Connate Water Volume: Tanji's estimate

In a 1972 report titled "Water and Salt Transfers in Sutter Basin, California", Dr. Tanji made estimates of the volume connate water for years 1964 to 1972. An average of these years was used.

Summary of Volume Estimation of Connate Water

Using Water Balance

For the year 1993 the water balance yielded a volume of connate water equal to 58,422 acre-feet. For the year 1999 the water balance yielded a volume of connate water equal to 56,755 acre-feet.

Using Salt Balance

For the year 1993 the salt balance yielded a volume of connate water equal to 18,946 acre-feet. For the year 1999 the salt balance yielded a volume of connate water equal to 8,058 acre-feet.

Using Estimates Made By Dr. Tanji

In a 1972 report titled "Water and Salt Transfers in Sutter Basin, California", Dr. Tanji made estimates of the volume connate water for years 1964 to 1972. The average of all these years gives a volume of 55,081 acre-feet.

Table 6 gives a comparison of the volume estimates made using each method.

Table 6. Comparison of methods to estimate volume of connate water.

	Estimate of volume of connate water (acre-feet)	
	1993	**1999**
Water Balance	58,422	56,755
Salt Balance	18,946	8,058
Tanji's estimate	55,081	55,081

Final Estimate to be used in Calculations

The range of values for the volume was from about 8,000 acre-feet to 58,000 acre-feet. An estimated value of 25,000 acre-feet was determined to be a reasonable value to use in further calculations.

Potential Solutions

Using Wells to Relieve Artesian Pressure

Determining the Number of Wells to use

From the water and salt balance it was estimated that the volume of connate water to be removed is 25,000 acre-feet. The flow each well can produce was estimated to be 500 gpm from a geological engineering report conducted by William Gianelli in 1962. By dividing the volume to be removed by the flow from each well it was determined that 30 wells would be required to relieve the connate water problem. In order to determine the feasibility of using wells research was conducted on the nature of the soil layers in the connate area. During the search for information on the nature of the soil profile in the connate area a geological engineering report conducted by William Gianelli in 1962 for SMWC was found. The report included a detail of the soil profile in the area. This detail can be found in Figure 3.

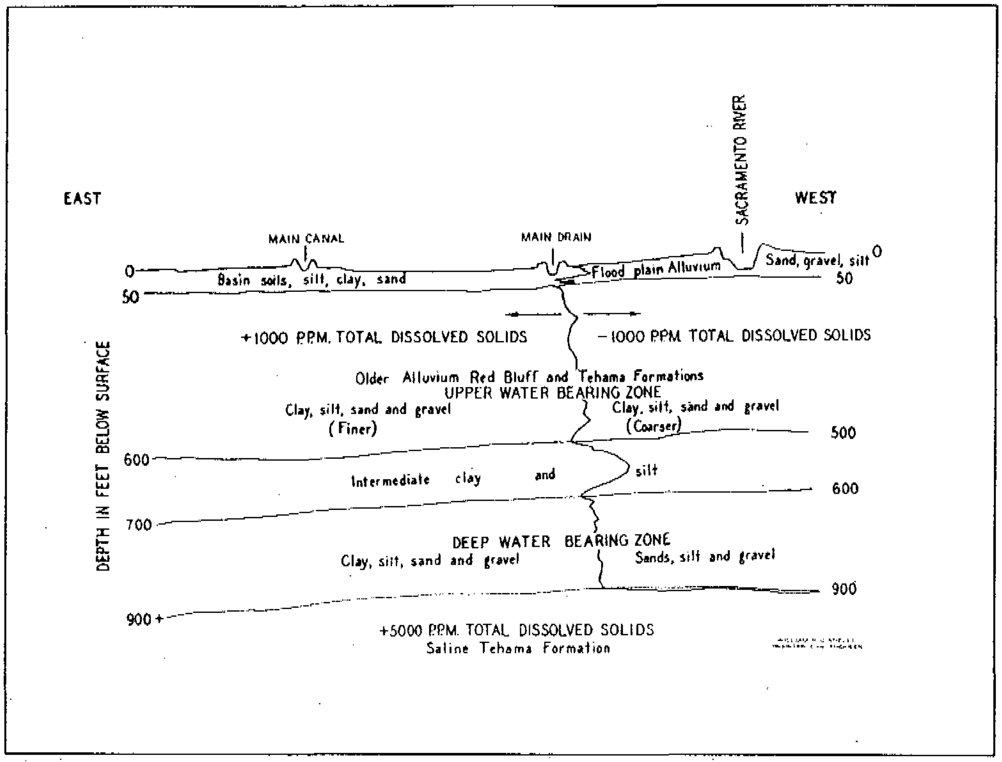


Figure 3. Soil profile of SMWC (Gianelli, 1962).

The connate area is located in the east part of the district. The above profile reveals that a gravel layer is present at a depth of approximately 500 feet below ground surface. With a gravel layer present the option of installing wells is feasible. The wells must be drilled to a depth of 500 feet to be effective.

Initial Design

In order to determine if drilling wells will help relieve the connate problem one-fifth the number of wells (six wells) should be installed and monitored. It is recommended that the remaining 24 wells not be installed until results from the initial six wells can be determined.

Determining the Location of the Wells

The six test wells were placed to be close to the levee to minimize the amount of pipe used. The wells were placed in the area with the highest EC values that were closest to the levee. A detail of where the initial six wells would be placed can be found in figure 4 below.

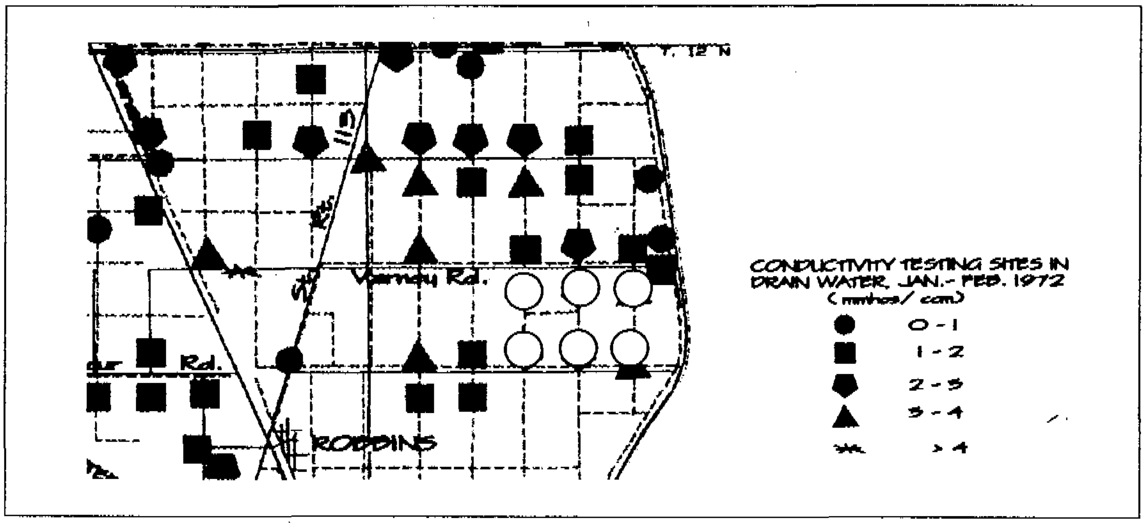


Figure 4. Detail of where the initial six wells would be placed.

A detail of where all 30 wells should eventually be placed can be seen in Figure 5.

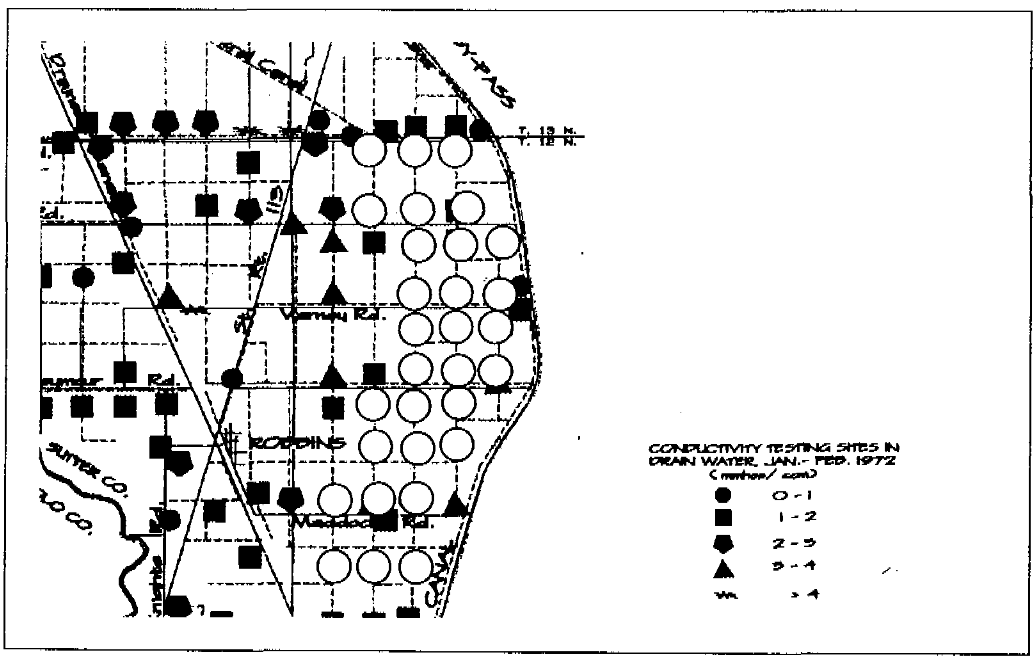
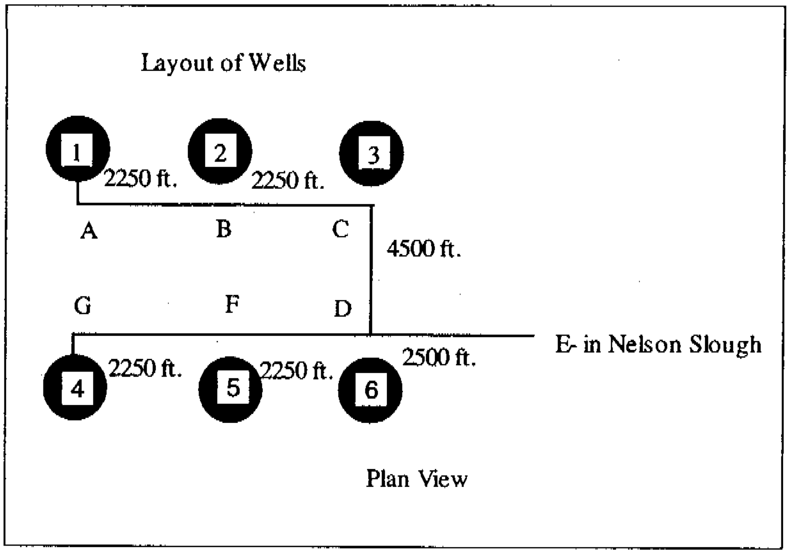


Figure 5. The location of all 30 wells.

The layout of the initial six wells can be seen in Figure 6. The wells will discharge into the Nelson Slough.



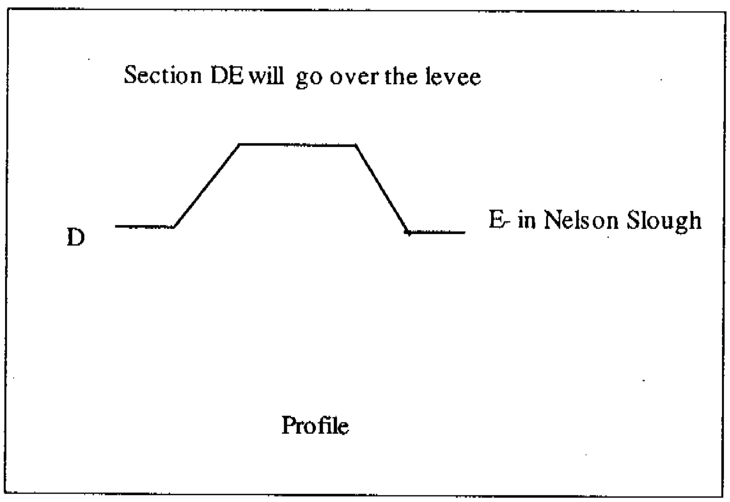


Figure 6. Layout of the initial six wells (not to scale).

PVC Pipe Design

The selection of PVC pipe sizes came from an economic pipe sizing analysis. To perform the economic analysis the following assumptions were made:

1. The price of PVC pipe was assumed to be $1.30 per pound, including fittings.
2. The total cost of the PVC pipe was assumed to come from 60% PVC pipe cost and 40% installation costs.
3. To determine the annual cost of the pipe installation a project life of 10 years and an interest rate of 8% were assumed.
4. Power costs were assumed to be $0.13 per kW-hr.
5. Pump efficiency was assumed to be 80%.
6. Motor efficiency was assumed to be 92%
7. Pump was assumed to be operating 24 hours each day, 365 days per year for a total of 8760 hours per year.

The economic pipe sizing analysis was performed using the procedure outlined in the Surface Irrigation Manual (Burt, 1995). The pipe size with the lowest total annual cost was selected. The analysis was done for each section with a different flow. The economic pipe sizing analysis can be found in Appendix E.

<u>Pump Selection</u>

In order to determine which pump to use the pump Total Dynamic Head (TDH) must first be found. The TDH was determined using the following equation:

$$\text{TDH} = \text{Depth to standing water(ft)} + \text{Column friction loss(ft)} + \text{Discharge pressure(ft)} + \text{Drawdown(ft)}$$

Where: Depth to standing water = 10 feet (change estimated over time)

Column friction loss = 1.1 ft/100 ft

(From Floway TDH book, 8" column and 1.5" shaft)

Discharge pressure = found in pressure analysis (Appendix F)

Drawdown = 25 feet (estimated from well drillers)

The final design TDH for each well can be found in table 7 below. The discharge pressures were found assuming the use of a Harris siphon breaker and air relief valve at the top of the pipe going over the levee. A complete analysis of the discharge pressures used in the TDH calculation can be found in Appendix F.

Table 7. TDH calculation for each well.

TDH = Discharge P + Drawdown + Column Friction Loss + Standing Water Level		
Drawdown (ft)	25	estimate given by well driller
Standing water level (ft)	10	estimate may increase over time
Column Friction loss (ft/100')	1.10	from Floway TDH book
Depth of well (ft)	500.00	
Total friction loss (ft)	5.50	
Well	Discharge P (ft)	TDH (ft)
1	51.4	92
2	42.6	83
3	32.0	73
4	34.7	75
5	23.9	64
6	11.3	52

The final pump selection for each well was made using Floway pumps keeping the efficiencies around 80 percent. The final pump selection for each well can be found in table 8 below.

Table 8. Final pump selection for each well

Total BHP = (Bowl BHP x # of Stages) + Shaft losses + Thrust bearing losses								
Thrust bearing losses are ignored								
Shaft losses (for 1 1/2' shaft) (BHP/100')		1.14						
Total shaft losses (BHP)		5.7						
Well	GPM	TDH (ft)	No. of stages	TDH/Stage (ft)	Floway Pump Selected	Diameter (in)	Bowl BHP	Total BHP
1	500	92	3	31	10 DKL	5.90	5.40	21.90
2	500	83	3	28	10 DKM	5.40	4.00	17.70
3	500	73	2	36	10 DKM	6.10	5.60	16.90
4	500	75	2	38	10 DKM	6.20	5.80	17.30
5	500	64	2	32	10 DKM	5.70	5.20	16.10
6	500	52	2	26	10 DKM	5.30	3.90	13.50

Cost Estimation of Well Option

The cost estimate of this option consists of the following components: PVC pipe installation, well installation, pump installation, and annual power costs.

The same price, project life, interest rate, power costs, pump and motor efficiencies and pump operation assumptions as used in the economic pipe sizing analysis were used in the economic analysis of the project.

The capital recovery factor for the project was found using the following equation:

$$\mathrm{CRF} = \left[\frac{i \times (1+i)^n}{(1+i)^n - 1} \right]$$

Where: i = interest rate

n = life of the project

The annualized costs were found by multiplying the total cost by the CRF.

<u>PVC Pipe Installation Costs</u>

The cost of installing the pipe was found by multiplying the total cost per pound by the total weight of the pipe. The costs for installing the PVC pipe are summarized in Table 9.

Table 9. Costs for installing the PVC pipe.

Pipe costs								
Price of PVC ($/lb)	$ 1.30	estimate (including fittings)						
Installation costs ($/lb)	$ 0.87							
Total Fixed costs ($/lb)	$ 2.17	Using 60% of cost is pipe						
		40% of cost is installation						
Life of Project (yrs)	10	assumed						
Interest rate	0.08	assumed						
CRF	0.15	CRF =[i*(1+i)^n]/[(1+i)^n-1]						
Max velocity (ft/sec)	3.5		from economic analysis					
Section	Length of section	GPM	Nominal Diameter to use	ID	Weight/Ft	$/100 ft	Cost ($)	Annualized costs
	(ft)		(in)	(in)	(lb/100')		Installed pipe	
AB	2250	500	8	8.205	363.3	$ 787	$ 17,711	$ 2,639
BC	2250	1000	10	10.23	565	$1,224	$ 27,544	$ 4,105
CD	4500	1500	12	12.13	795.4	$1,723	$ 77,552	$ 11,557
GF	2250	500	8	8.205	363.3	$ 787	$ 17,711	$ 2,639
FD	2250	1000	10	10.23	565	$1,224	$ 27,544	$ 4,105
DE	2500	3000	18	18.701	1772.03	$3,839	$ 95,985	$ 14,305
						Total	$ 264,046	$ 39,351

Well Installation

Estimates on installing a well in the area were made by calling a few local well drillers in Yuma and Marysville. The prices given are for a well with 188-wall steel casing of 16-inch diameter to a depth of 500 feet. The estimates given by the well drillers (Herr, 2000) can be found in Table 10 below. The wells are 16 inches in diameter and 500 feet deep.

Table 10. Cost estimates for installing initial six wells.

Life of Project (yrs)	10	assumed
Interest rate	0.08	assumed
CRF	0.15	CRF =[i*(1+i)^n]/[(1+i)^n-1
Cost of installing 1 well	$ 20,000	
24 hour flow test cost ($) ($90/hr)	$ 2,160	
Cost to put in and take out pump for flow test	$ 2,000	
Total cost per well	$ 24,160	
Cost for 6 wells	$ 144,960	
Annualized cost of 6 wells	$ 21,603	

Pump Installation

Cal-West Rain (Martin, 2000) was contacted for an estimate on installing a pump. The costs for installing pumps can be found in Table 11.

Table 11. Cost estimates for installing pumps.

Life of Project (yrs)	10	assumed
Interest rate	0.08	assumed
CRF	0.15	CRF =[i*(1+i)^n]/[(1+i)^n-1]
Cost of installing one pump w/panel	$ 10,000	
Cost of installing 6 pumps	$ 60,000	
Annualized cost of 6 pumps	$ 8,942	

Power Costs

Power costs were determined assuming a power cost of $0.13 per kW-hour. The input horsepower for the pumps were determined using an estimated 92% motor efficiency and the 80% pump efficiency found in pump selection. A summary of the power costs can be found below in Table 12.

Table 12. Power costs for operating pumps 365 days/year for 24 hrs. each day.

Power costs					
$/input kW-hr	$ 0.13	assumed electric costs			
Hours of op/year	8760	operating 24 hrs/day for 365 days			
Motor Efficiency	0.92	assumed efficiency			
Total BHP = (Bowl BHP x # of Stages) + Shaft losses + Thrust bearing losses					
Thrust bearing losses are ignored					
Input HP = Total BHP/ Motor Eff.					
Input kW = Input HP * 0.746					
Input kW-hrs/year = Input kW x Hours of op/year					
Well	Total BHP	Input HP	Input kW	Input kW-hrs/year	Cost/year
1	21.90	23.80	17.76	155,560	$ 20,223
2	17.70	19.24	14.35	125,727	$ 16,345
3	16.90	18.37	13.70	120,044	$ 15,606
4	17.30	18.80	14.03	122,886	$ 15,975
5	16.10	17.50	13.06	114,362	$ 14,867
6	13.50	14.67	10.95	95,893	$ 12,466
				Total cost/year	$ 95,481

Cost Per Acre

A cost per acre has also been calculated for the project. Because the entire district will see the benefit of reducing the connate water problem, the overall acreage of 68,000 was used rather than just the acreage of the connate area.

Annual Costs

The combined annual costs for the initial six wells can be found in Table 13 below. The total cost estimates for the well option with all thirty wells can be found in Table 14. A cost per acre has been calculated for reference.

Table 13. Total cost estimates for the initial six wells.

Cost of Project (initial 6 wells):			
Item	Initial Costs ($)	Subtotal	Annualized Costs
Well installation	$ 144,960		
Pump installation	$ 60,000		
PVC pipe installation	$ 264,046		
Total Fixed costs		$ 469,006	$ 69,896
Power costs			$ 95,481
Total Annualized costs			$ 165,377
Annualized cost per acre (68,000 acres)			$ 2

Table 14. Total cost estimates for the well option (all thirty wells).

Cost of Project (all 30 wells):			
Item	Initial Costs ($)	Subtotal	Annualized Costs
Well installation	$ 724,800		
Pump installation	$ 300,000		
PVC pipe installation	$ 1,320,229		
Total Fixed costs		$ 2,345,029	$ 349,478
Power costs			$ 477,407
Total Annualized costs			$ 826,886
Annualized cost per acre (68,000 acres)			$ 12

Special Considerations for Well Option

For this option it is important to monitor the effectiveness of the six test wells in order to determine if more wells should be installed. The EC of the drain water in the drain on Varney Road and the drain directly south should be monitored to look for improvements. The EC of the drain water at Karnak pumping plant should also be monitored. However, it should be noted that improvements at Karnak might not be observed from just the six test wells. For this reason it is important to monitor the drains in the area directly effected by the six test wells. The EC of the drains should be taken before the wells are installed for comparison purposes.

Re-routing Drainage Ditches Option

The second solution to be explored is to re-route the drainage ditches in the connate area to discharge into the Sutter Bypass instead of the main drain. The idea is to prevent the connate water from ever reaching the main drain. Without the connate water polluting the main drain this drainage water may be used for re-circulation.

The layout of the drains in the connate area can be seen in Figure 7 below.

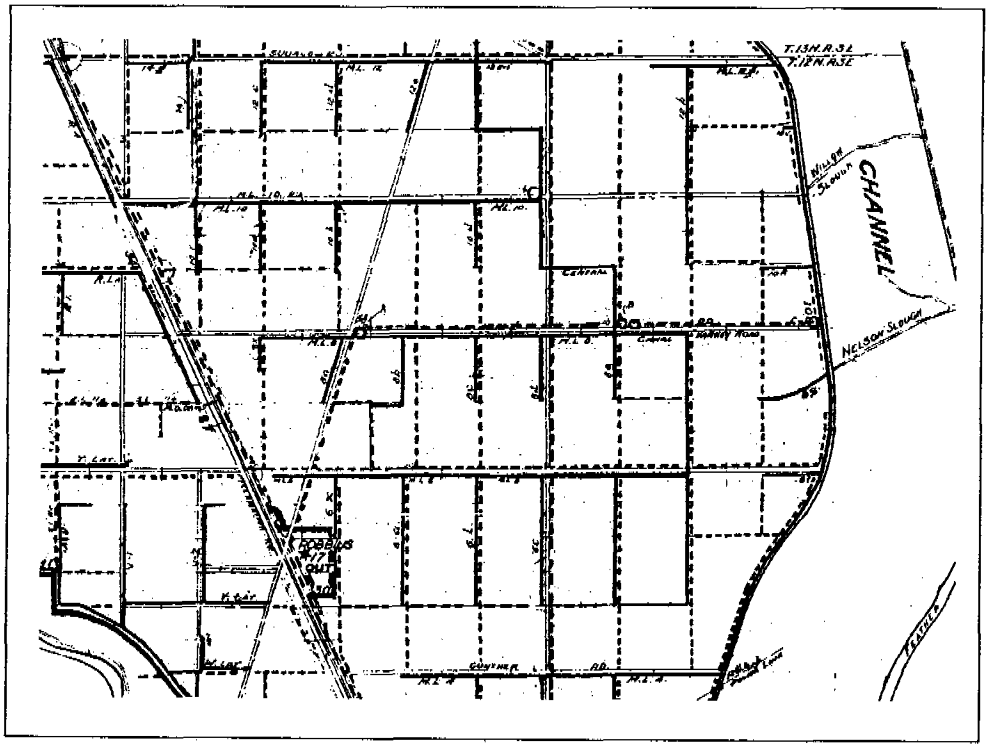


Figure 7. Detail of drainage layout in connate area.

The initial plan was to re-route the ditches in the area to the ditch along Varney Road. This ditch is comparably large and can handle the flow from several ditches. The drain water would then be pumped out to the Nelson Slough which leads into the Feather River.

Surveying of Drainage Ditches in the Connate Area

In order to determine the feasibility of this solution the drains in the connate area needed to be surveyed to find the water level profile. The main drains to be used in the plan were surveyed using a Trimble Global Positioning System (GPS) with accuracy up to a centimeter. This system uses satellites to find the exact position of a point. The GPS equipment was used to find the elevation of the ground surface of the drainage ditch. The depth to the water surface was found by extending a rod with a string and weight attached to the end until the weight hit the top of the water. The distance the string had to be extended was then measured. The elevation of the water surface was found by subtracting the distance to the water surface from the elevation of the ground surface. A water profile was created for each ditch surveyed. A total of three ditches were surveyed: the ditch along Varney road, a ditch south of Varney road and a ditch connecting the two. The ditches surveyed with the proposed direction of flow are shown in Figure 8 below.

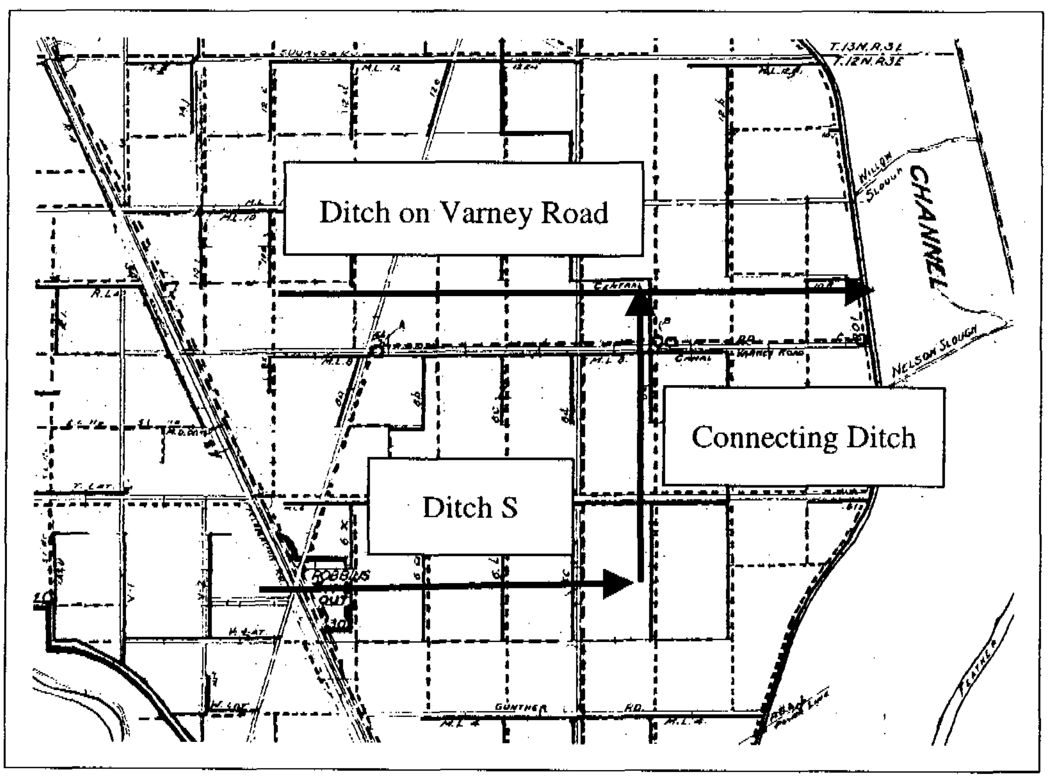


Figure 8. Ditches surveyed in connate area with proposed direction of flow.

The water level profiles for each ditch surveyed can be found in Appendix G. The water profiles were used to determine the feasibility of pumping into the slough.

Determining Flows Into Each Ditch

A ratio of area served by the ditch to the overall area of the district was used to find the percentage of area served by each ditch. The maximum flow out of Karnak Pumping Plant was found for the year 1993. The maximum flow used occurs during the summer (July) when the salinity problems are significant. The actual maximum flow occurs during the winter due to heavy rainfall. However, during that time the salinity problems are not as significant and will not require the removal of the drainage water. A multiplier of two was used in the calculations to account for spikes in flow. The flows for each ditch surveyed can be found in Table 15 below.

Table 15. Flows for each ditch surveyed.

Total area (acres)	68,000		cfs = Max Q (cfs) x % of total area x Multiplier
Ditch	**Area covered (acres)**	**% of total area**	**cfs**
Varney	3,500	5%	60
S	2,000	3%	34
Connecting	930	1%	16
Connecting ditch + Ditch S			50
Total flow			111
Total Flow ditch = section of Varney ditch which will carry the flow from all three ditches out to the levee			
Flows out of Karnak			
Max Q (cubic feet/day)	50,600,000.00		
Max Q (cubic feet/sec)	586		
Multiplier	2		

Determining Depth of Flow For Each Ditch

The depth of the water at the downstream end (Y) for each ditch was estimated using Mannings equation. A bottom width of 15 feet, a roughness factor of 0.035, a bottom slope of 0.0001 and a side slope of 0.5 were used in Mannings equation. The depth at the head of the ditch (Y') was then estimated from backwater curves developed for each ditch. In developing the backwater curves a bottom slope of zero was assumed for ditch S and the connecting ditch, as these will be excavated. The bottom profile of the Varney ditch will remain the same. The water depth at the head and end of each ditch can be found in Table 16 below.

Table 16. Water level depths for each ditch.

Ditch	Y (ft)	Y' (ft)
Varney	6	12.7
S	3	3.9
Connecting Ditch	4	4.5
Y = depth of water at the downstream end of the ditch, estimated from Mannings equation		
Y' = depth of water at the head of the ditch, estimated from backwater curves		
Varney Ditch contains the flow from all three ditches		

Elevation Profile

A profile of existing elevations of the ground surface and invert versus distance was constructed using AutoCAD®. This profile was used to determine where excavation and pumping would be necessary. The profile shows the excavation and water surface profiles once excavation and pumping has occurred. This profile can be found in Appendix H.

Excavation of Ditches

From the elevation profile it was determined that Ditch S and the connecting ditch would have to be excavated to level the bottom. This is necessary in order to change the direction of flow. The other option for changing flow is to put a structure in that will back up the water in the ditch. The problem with this option is that it will effect the drainage from the fields. In order to minimize effects on drainage the ditches will be excavated. The approximate volume of excavation was determined using the following equation:

$$\text{Vol. of Excavation (ft}^3) = \Delta \text{ Elevation along the ditch invert (ft)} \times \text{width of ditch (ft)} \times \text{length of ditch (ft)} \times \frac{1}{2}$$

The volume of excavation for each ditch can be found in Table 17.

Table 17. Approximate volumes of excavation for each ditch.

Ditch	Change in elevation (ft)	Width of ditch (ft)	length of ditch (ft)	Vol. of excavation (ft^3)	Vol. of excavation (yd^3)
S	1.8	17	16,000	489,600	18,133
Connecting Ditch	5.6	17	9,000	856,800	31,733

Pump Selection

From the elevation profile analysis it was determined that two pumps would be necessary. One pump would transfer water from ditch S to the connecting ditch. The second pump would transfer the water over the levee and into the Nelson Slough. The location of the pumping stations can be found in Figure 9.

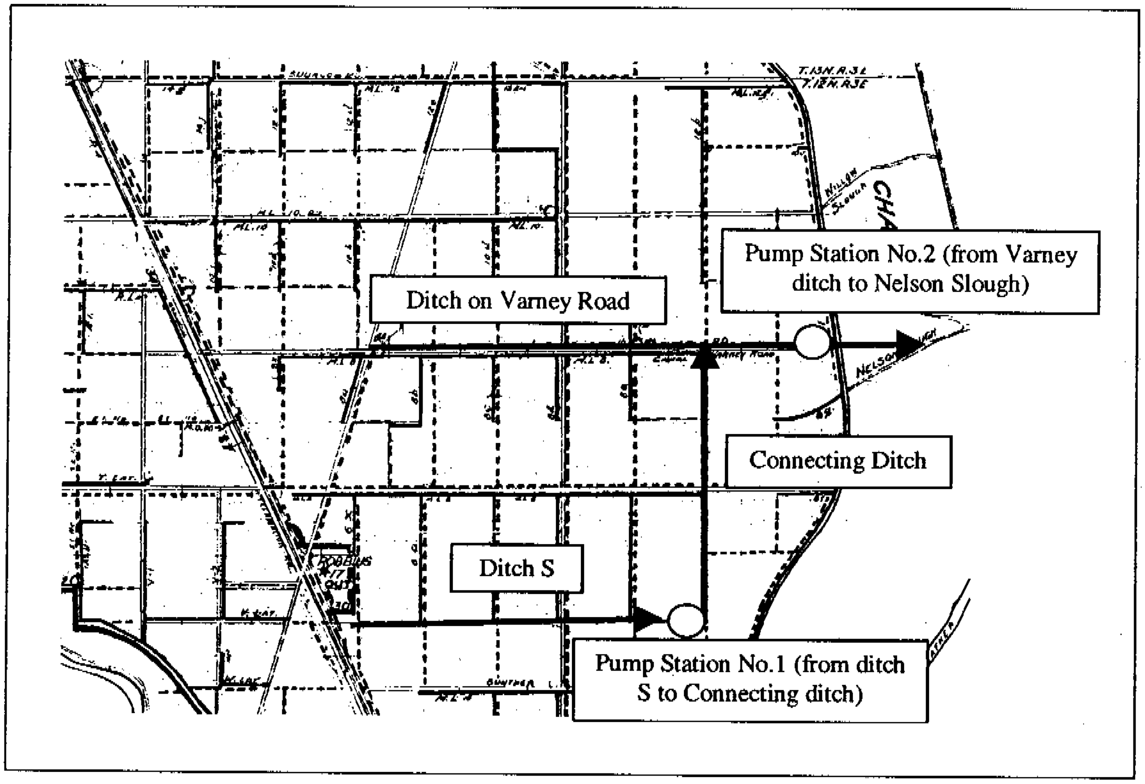


Figure 9. Proposed location of pumping stations.

In order to find the horsepower requirement for each pump the following equation was used:

$$HP = \frac{(\Delta \text{ in Water surface elevation (ft)} + 2 \text{ ft to pipe}) \times Q \text{ (gpm)}}{3960}$$

The pump transferring water to the connecting ditch has a change in water surface elevation of 2.3 ft. and a flow of 15,300 gpm. The HP requirement for this pump is 16.6 HP. A pump of 30 HP will be used. The pump transferring water over the levee has a change in elevation of 33.8 ft. and a flow of approximately 50,000 gpm. The horsepower requirement for this pump is 430 HP. Two pumps of 250 HP each will be used.

PVC Pipe Design

The pipe required to transfer the water over the levee must handle a flow of 50,000 gpm. A simple economic analysis using the same assumptions as in the well design shows that using a pipe 60 inches in diameter is most economical.

Cost Estimation of Re-Routing Option

The cost estimate of this option consists of the following components: excavation of ditches, PVC pipe installation, pump installation and annual power costs.

The following assumptions were used:

1. The price of PVC pipe was assumed to be $1.30 per pound including fittings:
2. The total cost of the PVC pipe was assumed to come from 60% PVC pipe cost and 40% installation costs.
3. To determine the annual cost of the pipe installation a project life of 10 years and an interest rate of 8% were assumed.
4. Power costs were assumed to be $0.13 per kW-hr.
5. Pump efficiency was assumed to be 80%.
6. Motor efficiency was assumed to be 92%.
7. Pumps were assumed to be operating 24 hours each day for 6 months out of the year (when salinity is highest) for a total of 4380 hours per year.

The capital recovery factor for the project was found using the following equation:

$$CRF = \left[\frac{i \times (1+i)^n}{(1+i)^n - 1}\right]$$

Where: i = interest rate

n = life of the project

The annualized costs were found by multiplying the total cost by the CRF.

Excavation of Ditches.

The price for excavating the ditches was found by calling a contractor in Marysville for a quote (Eckbert, 2000). A summary of the costs for excavating can be found in Table 18 below.

Table 18. Excavation costs.

Life of Project (yrs)	10	assumed		
Interest rate	0.08	assumed		
CRF	0.15	CRF =[i*(1+i)^n]/[(1+i)^n-1]		
Ditch	Vol. of excavation (yd^3)	Cost ($/yd^3)	Cost ($)	Annual Cost
S	18,133	$ 5	$ 90,667	$ 13,512
Connecting Ditch	31,733	$ 5	$ 158,667	$ 23,646
Total initial Cost			$ 249,333	
Total annual cost				$ 37,158

PVC Pipe Installation Costs

The cost of installing the pipe to transfer the water over the levee was found by multiplying the total cost per pound by the total weight of the pipe. The costs for installing the PVC pipe are summarized in Table 19.

Table 19. Summary of Pipe Installation Costs.

Pipe costs								
Price of PVC ($/lb)	$ 1.30	estimate (including fittings)						
Installation costs ($/lb)	$ 0.87							
Total Fixed costs ($/lb)	$ 2.17	Using 60% of cost is pipe						
		40% of cost is installation						
Life of Project (yrs)	10	assumed						
Interest rate	0.08	assumed						
CRF	0.15	CRF =[i*(1+i)^n]/[(1+i)^n-1]						
Pipe section	Length of section	GPM	Nominal Diameter	ID	Weight/Ft	$/100 ft	Cost ($)	Annualized costs
	(ft)		(in)	(in)	(lb/100')		Installed pipe	
from end of Varney ditch over the levee	2500	50,000	60	59.589	12,000	$ 26,000	$ 650,000	$ 96,869

Pump Installation

Pump costs were estimated based on rough estimates from Stockton Pumps and Flo-Systems. The costs include the cost of a concrete base and pipe. A summary of pump costs can be found in Table 20.

Table 20. Costs for installing pumps.

Life of Project (yrs)	10	assumed
Interest rate	0.08	assumed
CRF	0.15	CRF =[i*(1+i)^n]/[(1+i)^n-1]
Pump	Cost	Annualized costs
Pump Station No.1		
from ditch S to connecting ditch	$ 33,000	$ 4,917.97
Pump Station No. 2		
from Varney ditch over the levee (1)	$ 120,000	$ 17,883.54
from Varney ditch over the levee (2)	$ 120,000	$ 17,883.54
Total initial costs	$ 273,000	
Total annual costs		$ 40,685.05

Power Costs

Power costs were determined assuming a power cost of $0.13 per kW-hour. The input horsepower was determined using an estimated motor efficiency of 92%. The hours of operation were estimated to be 4380 hours. This is assuming that the removal of the connate water will occur during approximately half the year when salinity problems are highest. A summary of power costs can be found in Table 21.

Table 21. Power costs for operating pumps for 6 months out of the year.

Power costs					
$/input kW-hr	$ 0.13	assumed electric costs			
Hours of op/year	4380	operating 24 hrs/day for 1/2 a year			
Motor Efficiency	0.92	assumed efficiency			
Input HP = Total BHP/ Motor Eff.					
Input kW = Input HP * 0.746					
Input kW-hrs/year = Input kW x Hours of op/year					
Pump	Total HP	Input HP	Input kW	Input kW-hrs/year	Cost/year
from ditch S to connecting ditch	30	32.61	24.33	106,548	$ 13,851
from Varney ditch over the levee	500	543.48	405.43	1,775,804	$ 230,855
				Total cost/year	$ 244,706

Cost Per Acre

A cost per acre has also been calculated for the project. Because the entire district will see the benefit of reducing the connate water problem the overall acreage of 68,000 was used rather than just the acreage of the connate area.

Annual Costs

The combined annual costs for the re-routing option can be found in Table 22 below. A cost per acre has been calculated for reference.

Table 22. Total cost estimates for the ditch re-routing option.

Cost of Project (Re-Routing ditches):			
Item	Initial Costs ($)	Subtotal	Annualized Costs
Excavation	$ 249,333		
Pump installation	$ 273,000		
PVC pipe installation	$ 650,000		
Total Fixed costs		$ 1,172,333	$ 174,712
Power costs			$ 244,706
Total Annualized costs			$ 419,418
Total cost per acre (68,000 acres)			$ 6

Special Consideration for Re- Routing Option

In order to prevent an increase in flows from those calculated the spills from the east canal must be eliminated. The spills may increase the flows in the ditches and change the effectiveness of this option. Spills should be reduced as much as possible before implementing this option.

Discussion and Recommendations

Comparison of Options

Cost Comparison

A comparison of total costs for each option can be found in table 23 below.

Table 23. Cost comparison of options.

Life of Project (yrs)	10	assumed			
Interest rate	0.08	assumed			
CRF	0.15	CRF =[i*(1+i)^n]/[(1+i)^n-1]			
Option	Total Fixed Costs	Annualized Costs	Power costs	Total Annual Costs	Annual cost per acre
Initial six test wells	$ 469,006	$ 69,896	$ 95,481	$ 165,377	$ 2
All thirty wells	$ 2,345,029	$ 349,478	$ 477,407	$ 826,885	$ 12
Re-routing of Ditches	$ 1,172,333	$ 174,712	$ 244,706	$ 419,418	$ 6
Cost per acre is based on 68,000 acres					

While the re-routing option appears to cost less than the well option it actually may not. The well option may be the most cost effective for the following reasons:

1. All thirty wells may not be necessary to achieve the desired result. The estimation of the volume of connate water is not known to a definitive level and may be over estimated. When the drain water at Karnak reaches desired EC levels no more wells need be installed. The least expensive option is to install the six test wells and determine if this is enough to relieve the connate problem.

2. The flow each well can produce is not clear. If the wells can produce 1000 gpm rather than 500 gpm half the wells may be necessary. Flow tests must be conducted to determine the actual flow the wells can produce.

3. The well option will eventually remove the connate water and pumping will no longer be necessary. The re-routing option will take much longer to remove the connate water leading to higher overall pumping costs.

Advantages of the Well Option Over the Re-Routing Option

The main advantage of the well option is that it is treating the source of the problem and not just the symptom. The well option will remove the source of the connate water permanently from the district. Over time the connate water will be completely removed from the area. However, with the re-routing option the water is being removed after it has reached the surface. For this option it will take much more time to completely remove the water, if ever. For this reason the well option is recommended over the re-routing option.

Final Recommendation

The well option is recommended over the re-routing option for the following reasons:

1. This option may actually cost less for reasons described above.
2. This option will remove the source of the water eliminating connate water problems in the future.

The final recommendation is to install one test well as soon as possible to determine the flow capabilities. After this has been determined the remaining five test wells should be installed and their effectiveness monitored. In order to determine the effectiveness of the wells the EC of the drain water in the drain on Varney Road and the drain directly south should be monitored to look for improvements. If improvements are seen within the first year six more wells should be installed and monitored. Once the drain water at Karnak reaches levels suitable for recirculation during the summer, no more wells need to be installed.

Improving Quality of Data Collection

Lost Data

One of the most difficult aspects of this project was finding all the data necessary to perform all calculations. The district has only recently been putting data on computer and backing it up. Some data, such as the engineering data on the canals and ditches in the district, were permanently lost in a fire.

Data from Tisdale, Portugese Bend and Karnak

Another difficulty was determining the methods of data collection and processing. This is particularly true of the flow coming into the district from Tisdale and the flow leaving the district from Karnak. The district does not have on recorded the methods used to find either flow. The DWR, Northern District personnel also does not seem to remember how the equations they use were developed. The pump rating curves used to determine the flow at Tisdale and Portugese Bend Pumping Plants are an inaccurate way to determine the flow.

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Appendix A

Equations Used To Determine Flow Out Of Karnak Pumping Plant

Equations Used To Determine Flow Out of Karnak Pumping Plant:

Gravity Flow

1. Determine the area of flow:

   The area of flow is determined by using the following equation:

   $$A = R \times 6.5 \quad (1)$$

   Where: A = Gate Area in square feet
   R = Gate opening in feet (from data collected by district)
   Gate width is 6.5 feet

2. Determine the Velocity Coefficient, Cv, for gravity flow. The Cv is in terms of feet per second. To best fit the rating curve, a series of computer generated curves of velocity coefficient versus head were developed to best-fit segment of the original curve. Below are the equations developed and their ranges:

   Range 0.0 ft < H ≤ 0.5 ft

   $$Vc = -2.0985\times10^{-3} + 12.880\times H - 11.985\times H^2 - 39.631\times H^3 + 136.89\times H^4 - 116.3\times H^5 \quad (2)$$

   Range 0.5 ft < H ≤ 1.5 ft

   $$Vc = 0.25982 + 9.7875\times H - 9.4295\times H^2 + 5.72\times H^3 - 1.74\times H^4 + 0.18551\times H^5 \quad (3)$$

   Range 1.5 ft < H ≤ 3.0 ft

   $$Vc = 1.8828 + 4.1818\times H - 1.5323\times H^2 + 0.31640\times H^3 - 2.8405\times10^{-2}\times H^4 \quad (4)$$

3. Flow is calculated using the following equation:

   $$Q = A \times Vc \quad (5)$$

   Where: Q = flow in cubic feet per second
   A = gate opening area in square feet
   Vc = Velocity coefficient in feet per second

4. Volume of flow in acre-feet was determined by multiplying the flow calculated using the above by the number of hours the gate was opened and appropriate conversion factors.

   $$Q\,(\text{acre-feet}) = Q\,(\text{ft}^3/\text{sec}) \times \text{Hrs.} \times 3600\ \text{sec}/\text{hr.} \times \text{acre-feet}/43560\text{ft}^2 \quad (6)$$

Auxillary Pumping Plant No. 2

1. Determine the Head between the Reclamation Canal and the Sutter Bypass as follows:

   Head = H = Sutter Bypass Head - RD 1500 Head (as recorded by the district) (7)

2. Determine the rate of discharge in cubic feet per second per hour. To best fit the rating curve, a series of computer generated curves of rate of discharge versus head were developed to best-fit segment of the original curve. Below are the equations developed and their ranges:

   Range $H < 0.00$ ft.

   $$q = 8.2587 \quad (8)$$

   Range $0.00 \text{ ft} < H \leq 21.5$ ft

   $$q = 8.257 - 1.0935\times10^{-2}\times H - 2.8737\times10^{-3}\times H^2 + 1.3633\times10^{-4}\times H^3 - 2.7698\times10^{-6}\times H^4 \quad (9)$$

   Range $21.5 \text{ ft} < H < 22.27$ ft

   $$q = -0.08\times H + 9.17 \quad (10)$$

   Range $22.28 \text{ ft} < H < 23.71$ ft

   $$q = -0.2308\times H + 12.53 \quad (11)$$

   Range $23.72 \text{ ft} < H < 26.23$ ft

   $$q = -0.2679\times H + 13.41 \quad (12)$$

   Range $26.24 \text{ ft} < H < 27.90$ ft

   $$q = -0.3750\times H + 16.22 \quad (13)$$

   Range $27.9 \text{ ft} < H$

   $$q = -0.1364\times H + 9.56 \quad (14)$$

3. Determine the total hours pumped (P) by Auxillary Plant No. 2. This is found in the data sheets given by the district.

4. Determine the total flow in cubic feet per second by multiplying q (CFS/hr) by the number of hours (P).

5. Volume of flow in acre-feet was determined by multiplying the flow calculated using the above by the number of hours the pumps were on and appropriate conversion factors.

$$Q\,(\text{acre-feet}) = Q\,(\text{ft}^3/\text{sec}) \times \text{Hrs.} \times 3600\,\text{sec}/\text{hr.} \times \text{acre-feet}/43560\text{ft}^2 \qquad (15)$$

Main Pumping Plant

1. Determine the Head between the Reclamation Canal and the Sutter Bypass as follows:

Head = H = Sutter Bypass Head - RD 1500 Head (as recorded by the district) (16)

Where: Sutter Bypass Head = reading if above 35.0 feet
Sutter Bypass Head = 35.0 feet if below 35.0 feet

2. Determine the rate of discharge in cubic feet per second per hour. To best fit the rating curve, a series of computer generated curves of rate of discharge versus head were developed to best-fit segment of the original curve. The range of head for pump rating was 18.0 feet to 28.0 feet. Below are the equations developed and their ranges:

Unit 1

$$q = 13.003 - 0.31294 \times H \qquad (17)$$

Unit 2

$$q = 14.271 - 0.31749 \times H \qquad (18)$$

Unit 3

$$q = 13.120 - 0.31217 \times H \qquad (19)$$

Unit 4

$$q = 14.432 - 0.31114 \times H \qquad (20)$$

Unit 5

$$q = 14.691 - 0.31489 \times H \qquad (21)$$

Unit 6

$$q = 12.820 - 0.31392 \times H \qquad (22)$$

3. Determine the total flow in cubic feet per second by multiplying q (CFS/hr) for each unit by the number of hours (P) each unit is on.

4. Volume of flow in acre-feet was determined by multiplying the flow calculated using the above by the number of hours each unit was on and appropriate conversion factors.

$$Q\,(\text{acre-feet}) = Q\,(\text{ft}^3/\text{sec}) \times \text{Hrs.} \times 3600\ \text{sec}/\text{hr.} \times \text{acre-feet}/43560\text{ft}^2 \qquad (23)$$

Appendix B

Summary Of Data From Farmer Surveys

A summary of the results from the farmer surveys can be found below:

Farmer	A	B	
Crop	Wheat	Wheat	
Soil Type:	sandy loam	heavy clay	
Event			
Planting	November	Dec-Jan	
Emergence	15-20 days	2-4 weeks	
Full Cover	90 days	60 days	
Harvest	June	mid June	
How long does ground stay wet			
in summer	1 day	1-2 days	
in winter	stays wet	stays wet	

Farmer	A	B	C
Crop	Tomatoes	Tomatoes	Tomatoes
Soil Type:	sandy loam	heavy clay	silt loam
Event			
Planting	Feb-May	March-April	March 20-April 25
Emergence	March1-15	10-30 days	9 days
Full Cover	80 days	75 days	40-50 days
Harvest	130-135 days	120 days	August 1-Spet 25
How long does ground stay wet			
in summer	2 days	1-2 days	1-2 days
in winter	stays wet	stays wet	stays wet

Farmer	D
Crop	Safflower
Soil Type:	sandy loam
Event	
Planting	May 15-Apr 15
Emergence	10-12 days
Full Cover	30 days
Harvest	August-September
How long does ground stay wet	
in summer	2 days
in winter	stays wet

Farmer	E	F
Crop	Melons	Melons
Soil Type:	heavy clay	adobe clay
Event		
Planting	Apr-June	May 10- July 1
Emergence	7-10 days	10 days
Full Cover	50 days	45 days
Harvest	90 days	Aug 1-Oct 1
How long does ground stay wet		
in summer	2 days	2 days
in winter	stays wet	stays wet

Farmer	A	B	C
Crop	rice	rice	rice
Soil Type:	sandy loam	heavy clay	silt loam
Event			
Planting	May 1-15	late Apr-May	late Apr-May 3
Emergence	15-20 days	10-14 days	20 days
Full Cover	70 days	60 days	50-60 days
Harvest	Sept-Oct.	120 days	Sept 1 - late Oct.
How long does ground stay wet			
In summer	2 days	1-2 days	1-2 days
in winter	stays wet	stays wet	stays wet
How long before planting do you flood?	5 days	5-7 days	3-6 days
Is the ground wet when you plant?	Yes	Yes	Yes
How long before harvest do you cutoff water?	30 days	30 days	3 weeks
When you harvest how wet is the ground?	can be muddy	can be if it rains	muddy
When does decomp water start?	mid Nov.	No decomp	1-Nov
When do youstop decomp water?	Feb.		1-Feb

Irrigation Practices Survey

Name of Farmer______________________________

Phone Number______________________________

Annual Crop:______________________________

Soil type:______________________________

Event	**Date**
Planting	
Emergence	
10% cover	
Full Cover	
Harvest	
Plow down	

Cultural Practices

Irrigation	**Date**	**Hr/set**	**Method**	**How long after stopping irrigation does the soil look brown?**	**Discussion**
1					
2					
3					
4					
5					
6					
7					
8					

Survey about Rice

Preflood:

How long before planting do you flood?:

Does the ground remain flooded when you plant?:

Cutoff water:

How long before harvest do you cutoff the water?:

When you harvest how wet is the ground?:

Decomposition:

When does decomposition water start?:

When do you take off the decomposition water?:

Appendix C

Directions To UC Davis CIMIS Web Site

Accessing CIMIS Data through the UC Davis IPM Website

1. Go to http://www.ipm.ucdavis.edu
2. Click on "Weather Data."
3. Click on "Retrieve daily weather data."
4. Choose desired County.
5. Choose desired Station (NCDC is the NOAA stations for precipitation data and CIMIS stations for evaporation and other crop related weather parameters).
6. Select the time interval for the desired data.
7. Select what data parameters are desired.
8. Select output format and units (English or Metric). Comma delimited output is typically used for data analysis in spreadsheets.
9. Highlight the data and copy it. Paste the data into a spreadsheet. Highlight the column with the data and go to, Tool- Text to Column. Click delimited, next, comma, next and finish. The data should be separated into individual columns.

Appendix D

Crop Coefficient Curves

The dates used to formulate the crop coefficient curves and the Kc and Kcb values used can be found in the tables below. The dates were taken from the farmer surveys and the Kc and Kcb values were taken from FAO No. 56.

Crop	Date Plant	Days to incline	Date Harvest	Date Full Canopy	Date Start Decline
Rice	15-Apr	10	30-Aug	25-May	30-Jul
Tomato	15-Apr	9	30-Aug	25-May	15-Jul
Safflower	30-Apr	10	15-Oct	9-Jun	15-Aug
Melons	1-May	10	1-Sep	31-May	1-Sep
Beans	15-May	10	1-Nov	14-Jun	2-Oct
Sunflowers	30-Apr	10	15-Oct	9-Jun	15-Aug
Milo	1-May	20	1-Sep	31-May	2-Aug
Corn	1-Apr	10	1-Sep	1-May	2-Aug
Wheat	11/01/92	20	1-Jul	1-Jan	1-Jun

		Kc				Kcb	
Crop	Plant	Full	End		Plant	Full	End
Rice	1.05	1.2	0.75		1	1.15	0.7
Tomato	0.25	1.1	0.6			1.1	0.6
Safflower		1.1	0.25			1.1	0.25
Melons		1.05	0.75			1	0.7
Beans	0.5	1	0.9			1.1	0.25
Sunflowers		1.1	0.35		0.5	1.1	0.3
Milo	0.4	1.15	0.25			1.1	0.25
Corn		1.2	0.6		0.4	1.15	0.25
Wheat	0.4	1.15	0.25			1.1	1
Canals/ditches	1.2	1.2	1.2				
Roads							
Other							

The crop coefficient values for each day in 1993 can be found on the following pages. The same values were used in the 1999 analysis. The curves generated from this data are on the pages following that.

		ETo grass in/day	Precip in/day	Rice KC	Tomatoes KC	Safflower KC	Melons KC	Beans KC	Sunflowers KC	Milo KC	Corn KC	Wheat KC	Canals/ Ditches KC = 1.2
Date	Julian Day												
1/1/93	1	0.07	0.65	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/2/93	2	0.04	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/3/93	3	0.03	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/4/93	4	0.04	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/5/93	5	0.02	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/6/93	6	0.03	0.18	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/7/93	7	0.03	2.14	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/8/93	8	0.03	0.52	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/9/93	9	0.05	0.02	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/10/93	10	0.03	0.11	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/11/93	11	0.03	0.01	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/12/93	12	0.03	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/13/93	13	0.03	1.45	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/14/93	14	0.07	0.91	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/15/93	15	0.03	0.09	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/16/93	16	0.05	0.86	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/17/93	17	0.03	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/18/93	18	0.05	0.87	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/19/93	19	0.05	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/20/93	20	0.06	0.24	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/21/93	21	0.06	0.73	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/22/93	22	0.07	0.36	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/23/93	23	0.05	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/24/93	24	0.07	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/25/93	25	0.03	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/26/93	26	0.04	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/27/93	27	0.02	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/28/93	28	0.03	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/29/93	29	0.10	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/30/93	30	0.10	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
1/31/93	31	0.05	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/1/93	32	0.05	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/2/93	33	0.05	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/3/93	34	0.04	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/4/93	35	0.06	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/5/93	36	0.05	0.28	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/6/93	37	0.06	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/7/93	38	0.05	0.28	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/8/93	39	0.04	0.99	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/9/93	40	0.05	0.04	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/10/93	41	0.07	0.12	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/11/93	42	0.07	0.08	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/12/93	43	0.06	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/13/93	44	0.06	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/14/93	45	0.08	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/15/93	46	0.09	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/16/93	47	0.07	0.04	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/17/93	48	0.03	0.87	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/18/93	49	0.04	0.67	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/19/93	50	0.09	0.63	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/20/93	51	0.07	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/21/93	52	0.07	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/22/93	53	0.04	0.28	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/23/93	54	0.04	0.91	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/24/93	55	0.08	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/25/93	56	0.06	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/26/93	57	0.05	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/27/93	58	0.10	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
2/28/93	59	0.07	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/1/93	60	0.07	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/2/93	61	0.10	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/3/93	62	0.07	0.12	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/4/93	63	0.09	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/5/93	64	0.09	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/6/93	65	0.10	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/7/93	66	0.12	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/8/93	67	0.10	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/9/93	68	0.09	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20

3/10/93	69	0.11	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/11/93	70	0.12	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/12/93	71	0.10	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/13/93	72	0.10	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/14/93	73	0.14	0.04	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/15/93	74	0.08	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/16/93	75	0.06	0.63	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/17/93	76	0.10	0.43	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/18/93	77	0.11	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/19/93	78	0.08	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/20/93	79	0.12	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/21/93	80	0.11	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/22/93	81	0.13	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/23/93	82	0.04	0.71	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/24/93	83	0.12	0.35	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/25/93	84	0.06	0.04	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/26/93	85	0.07	0.08	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/27/93	86	0.07	0.16	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/28/93	87	0.10	0.04	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/29/93	88	0.10	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/30/93	89	0.13	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
3/31/93	90	0.12	0.08	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
4/1/93	91	0.10	0.00	1.19	1.18	1.18	1.19	1.17	1.18	1.17	1.00	1.15	1.20
4/2/93	92	0.10	0.00	1.17	1.16	1.16	1.17	1.15	1.15	1.15	1.00	1.15	1.20
4/3/93	93	0.11	0.00	1.16	1.14	1.14	1.16	1.13	1.13	1.12	1.00	1.15	1.20
4/4/93	94	0.13	0.00	1.14	1.12	1.12	1.14	1.10	1.10	1.09	1.00	1.15	1.20
4/5/93	95	0.15	0.00	1.13	1.10	1.10	1.13	1.08	1.08	1.07	1.00	1.15	1.20
4/6/93	96	0.12	0.00	1.11	1.08	1.08	1.11	1.06	1.05	1.04	1.00	1.15	1.20
4/7/93	97	0.16	0.00	1.10	1.06	1.06	1.10	1.03	1.03	1.01	1.00	1.15	1.20
4/8/93	98	0.12	0.00	1.08	1.05	1.03	1.08	1.01	1.00	0.99	1.00	1.15	1.20
4/9/93	99	0.14	0.00	1.20	1.03	1.01	1.07	0.98	0.98	0.96	1.00	1.15	1.20
4/10/93	100	0.15	0.00	1.20	1.01	0.99	1.05	0.96	0.95	0.93	1.01	1.15	1.20
4/11/93	101	0.19	0.00	1.20	0.99	0.97	1.04	0.94	0.93	0.91	1.02	1.15	1.20
4/12/93	102	0.19	0.00	1.20	0.97	0.95	1.02	0.91	0.90	0.88	1.03	1.15	1.20
4/13/93	103	0.13	0.00	1.20	0.95	0.93	1.01	0.89	0.88	0.85	1.04	1.15	1.20
4/14/93	104	0.15	0.00	1.20	0.93	0.91	0.99	0.87	0.85	0.83	1.05	1.15	1.20
4/15/93	105	0.15	0.00	1.20	0.91	0.89	0.98	0.84	0.83	0.80	1.05	1.15	1.20
4/16/93	106	0.14	0.00	1.20	0.89	0.87	0.96	0.82	0.80	0.77	1.06	1.15	1.20
4/17/93	107	0.09	0.63	1.20	0.87	0.85	0.95	0.80	0.78	0.75	1.07	1.15	1.20
4/18/93	108	0.15	0.00	1.20	0.85	0.83	0.93	0.77	0.75	0.72	1.08	1.15	1.20
4/19/93	109	0.14	0.00	1.20	0.83	0.81	0.92	0.75	0.73	0.69	1.09	1.15	1.20
4/20/93	110	0.16	0.00	1.20	0.81	0.79	0.90	0.73	0.70	0.67	1.10	1.15	1.20
4/21/93	111	0.16	0.00	1.20	0.79	0.77	0.89	0.71	0.68	0.64	1.11	1.15	1.20
4/22/93	112	0.17	0.00	1.20	0.77	0.75	0.87	0.68	0.65	0.61	1.12	1.15	1.20
4/23/93	113	0.08	0.04	1.20	0.75	0.73	0.86	0.66	0.63	0.59	1.13	1.15	1.20
4/24/93	114	0.13	0.00	1.20	0.74	0.70	0.84	0.64	0.60	0.56	1.14	1.15	1.20
4/25/93	115	0.13	0.00	1.20	0.75	0.68	0.83	0.61	0.58	0.53	1.15	1.15	1.20
4/26/93	116	0.17	0.00	1.20	0.76	0.66	0.81	0.59	0.55	0.51	1.15	1.15	1.20
4/27/93	117	0.19	0.00	1.20	0.77	0.64	0.80	0.57	0.53	0.48	1.16	1.15	1.20
4/28/93	118	0.18	0.00	1.20	0.78	0.62	0.78	0.54	0.50	0.45	1.17	1.15	1.20
4/29/93	119	0.25	0.00	1.20	0.80	0.60	0.77	0.52	0.48	0.43	1.18	1.15	1.20
4/30/93	120	0.31	0.00	1.20	0.81	0.58	0.75	0.50	0.45	0.40	1.19	1.15	1.20
5/1/93	121	0.23	0.00	1.20	0.82	0.56	0.75	0.50	0.43	0.40	1.20	1.15	1.20
5/2/93	122	0.21	0.00	1.20	0.83	0.54	0.75	0.50	0.40	0.40	1.20	1.15	1.20
5/3/93	123	0.16	0.00	1.20	0.84	0.52	0.75	0.50	0.38	0.40	1.20	1.15	1.20
5/4/93	124	0.19	0.00	1.20	0.86	0.50	0.75	0.50	0.35	0.40	1.20	1.15	1.20
5/5/93	125	0.20	0.00	1.20	0.87	0.48	0.75	0.50	0.35	0.40	1.20	1.15	1.20
5/6/93	126	0.20	0.00	1.20	0.88	0.46	0.75	0.50	0.35	0.40	1.20	1.15	1.20
5/7/93	127	0.20	0.00	1.20	0.89	0.44	0.75	0.50	0.35	0.40	1.20	1.15	1.20
5/8/93	128	0.23	0.00	1.20	0.91	0.42	0.75	0.50	0.35	0.40	1.20	1.15	1.20
5/9/93	129	0.20	0.00	1.20	0.92	0.39	0.75	0.50	0.35	0.40	1.20	1.15	1.20
5/10/93	130	0.27	0.00	1.20	0.93	0.37	0.75	0.50	0.35	0.40	1.20	1.15	1.20
5/11/93	131	0.16	0.00	1.20	0.94	0.35	0.75	0.50	0.35	0.40	1.20	1.15	1.20
5/12/93	132	0.17	0.00	1.20	0.95	0.33	0.75	0.50	0.35	0.40	1.20	1.15	1.20
5/13/93	133	0.18	0.00	1.20	0.97	0.31	0.75	0.50	0.35	0.40	1.20	1.15	1.20
5/14/93	134	0.18	0.00	1.20	0.98	0.29	0.75	0.50	0.35	0.40	1.20	1.15	1.20
5/15/93	135	0.17	0.00	1.20	0.99	0.27	0.75	0.50	0.35	0.40	1.20	1.15	1.20
5/16/93	136	0.20	0.00	1.20	1.00	0.25	0.77	0.50	0.38	0.40	1.20	1.15	1.20
5/17/93	137	0.22	0.00	1.20	1.01	0.26	0.79	0.50	0.41	0.40	1.20	1.15	1.20
5/18/93	138	0.20	0.00	1.20	1.03	0.29	0.81	0.50	0.44	0.40	1.20	1.15	1.20
5/19/93	139	0.19	0.00	1.20	1.04	0.33	0.83	0.50	0.47	0.40	1.20	1.15	1.20
5/20/93	140	0.18	0.00	1.20	1.05	0.37	0.84	0.50	0.50	0.40	1.20	1.15	1.20
5/21/93	141	0.20	0.00	1.20	1.06	0.40	0.86	0.50	0.53	0.40	1.20	1.15	1.20

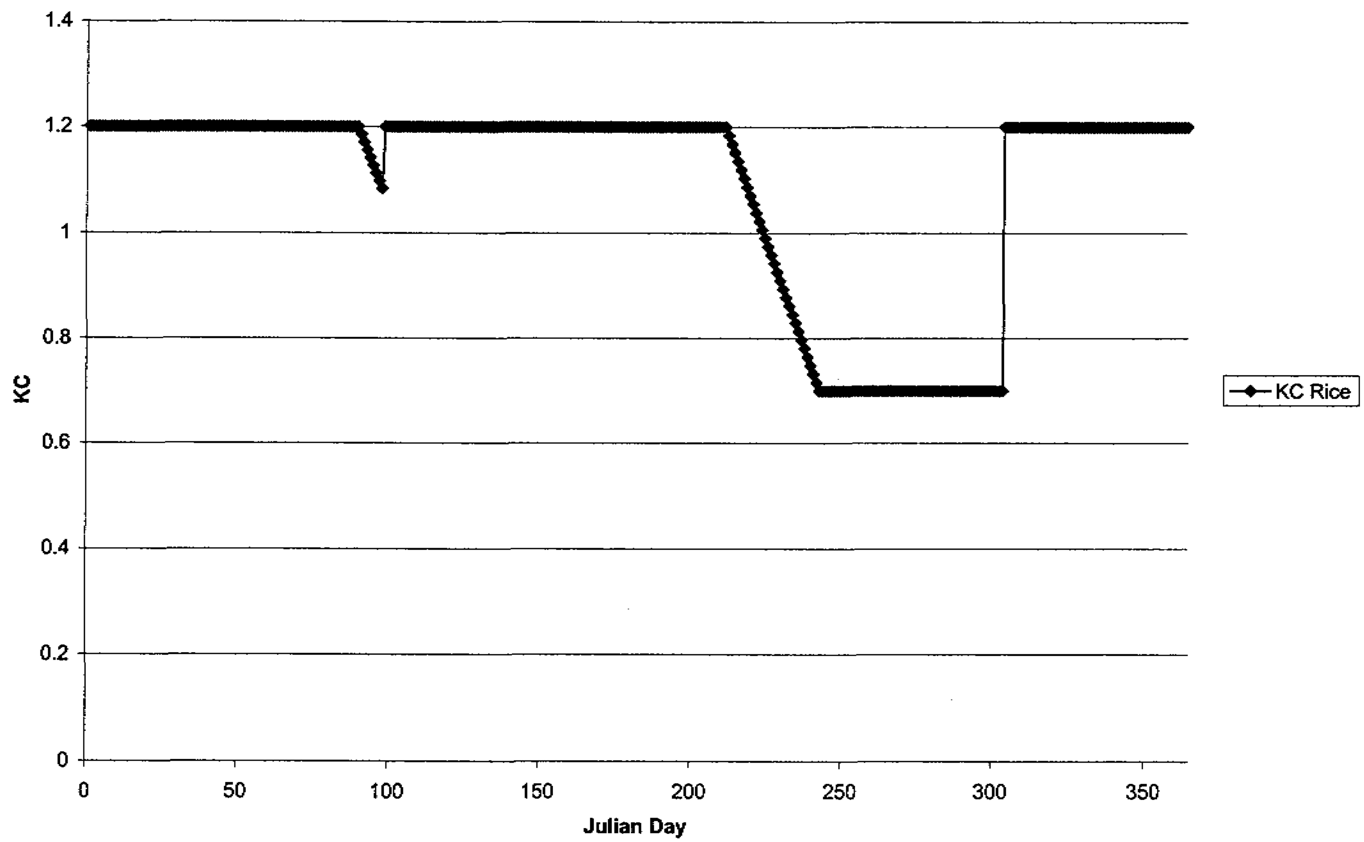
5/22/93	142	0.24	0.00	1.20	1.08	0.44	0.88	0.50	0.56	0.48	1.20	1.15	1.20
5/23/93	143	0.25	0.00	1.20	1.09	0.48	0.90	0.50	0.59	0.55	1.20	1.15	1.20
5/24/93	144	0.09	0.71	1.20	1.10	0.51	0.92	0.50	0.62	0.63	1.20	1.15	1.20
5/25/93	145	0.14	0.20	1.20	1.10	0.55	0.94	0.50	0.65	0.70	1.20	1.15	1.20
5/26/93	146	0.17	0.00	1.20	1.10	0.59	0.96	0.53	0.68	0.78	1.20	1.15	1.20
5/27/93	147	0.16	0.00	1.20	1.10	0.62	0.98	0.55	0.71	0.85	1.20	1.15	1.20
5/28/93	148	0.19	0.00	1.20	1.10	0.66	0.99	0.58	0.74	0.93	1.20	1.15	1.20
5/29/93	149	0.13	0.00	1.20	1.10	0.70	1.01	0.60	0.77	1.00	1.20	1.15	1.20
5/30/93	150	0.08	0.12	1.20	1.10	0.73	1.03	0.63	0.80	1.08	1.20	1.15	1.20
5/31/93	151	0.17	0.20	1.20	1.10	0.77	1.05	0.65	0.83	1.15	1.20	1.15	1.20
6/1/93	152	0.20	0.00	1.20	1.10	0.81	1.05	0.68	0.86	1.15	1.20	1.15	1.20
6/2/93	153	0.21	0.00	1.20	1.10	0.84	1.05	0.70	0.89	1.15	1.20	1.12	1.20
6/3/93	154	0.16	0.00	1.20	1.10	0.88	1.05	0.73	0.92	1.15	1.20	1.09	1.20
6/4/93	155	0.07	0.55	1.20	1.10	0.92	1.05	0.75	0.95	1.15	1.20	1.07	1.20
6/5/93	156	0.16	0.59	1.20	1.10	0.95	1.05	0.78	0.98	1.15	1.20	1.04	1.20
6/6/93	157	0.07	0.04	1.20	1.10	0.99	1.05	0.80	1.01	1.15	1.20	1.01	1.20
6/7/93	158	0.14	0.00	1.20	1.10	1.03	1.05	0.83	1.04	1.15	1.20	0.98	1.20
6/8/93	159	0.20	0.00	1.20	1.10	1.06	1.05	0.85	1.07	1.15	1.20	0.95	1.20
6/9/93	160	0.20	0.00	1.20	1.10	1.10	1.05	0.88	1.10	1.15	1.20	0.92	1.20
6/10/93	161	0.26	0.00	1.20	1.10	1.10	1.05	0.90	1.10	1.15	1.20	0.90	1.20
6/11/93	162	0.23	0.00	1.20	1.10	1.10	1.05	0.93	1.10	1.15	1.20	0.87	1.20
6/12/93	163	0.24	0.00	1.20	1.10	1.10	1.05	0.95	1.10	1.15	1.20	0.84	1.20
6/13/93	164	0.23	0.00	1.20	1.10	1.10	1.05	0.98	1.10	1.15	1.20	0.81	1.20
6/14/93	165	0.27	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.78	1.20
6/15/93	166	0.25	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.75	1.20
6/16/93	167	0.32	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.73	1.20
6/17/93	168	0.36	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.70	1.20
6/18/93	169	0.26	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.67	1.20
6/19/93	170	0.26	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.64	1.20
6/20/93	171	0.32	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.61	1.20
6/21/93	172	0.26	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.58	1.20
6/22/93	173	0.24	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.56	1.20
6/23/93	174	0.33	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.53	1.20
6/24/93	175	0.33	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.50	1.20
6/25/93	176	0.26	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.47	1.20
6/26/93	177	0.29	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.44	1.20
6/27/93	178	0.29	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.41	1.20
6/28/93	179	0.24	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.39	1.20
6/29/93	180	0.27	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.36	1.20
6/30/93	181	0.28	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.33	1.20
7/1/93	182	0.24	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/2/93	183	0.27	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/3/93	184	0.23	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/4/93	185	0.27	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/5/93	186	0.28	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/6/93	187	0.29	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/7/93	188	0.25	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/8/93	189	0.26	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/9/93	190	0.25	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/10/93	191	0.26	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/11/93	192	0.25	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/12/93	193	0.19	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/13/93	194	0.22	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/14/93	195	0.23	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/15/93	196	0.20	0.00	1.20	1.10	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/16/93	197	0.21	0.00	1.20	1.09	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/17/93	198	0.22	0.00	1.20	1.08	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/18/93	199	0.25	0.00	1.20	1.07	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/19/93	200	0.28	0.00	1.20	1.06	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/20/93	201	0.22	0.00	1.20	1.05	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/21/93	202	0.20	0.00	1.20	1.03	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/22/93	203	0.21	0.00	1.20	1.02	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/23/93	204	0.25	0.00	1.20	1.01	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/24/93	205	0.27	0.00	1.20	1.00	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/25/93	206	0.26	0.00	1.20	0.99	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/26/93	207	0.25	0.00	1.20	0.98	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/27/93	208	0.25	0.00	1.20	0.97	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/28/93	209	0.25	0.00	1.20	0.96	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/29/93	210	0.22	0.00	1.20	0.95	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/30/93	211	0.22	0.00	1.20	0.94	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
7/31/93	212	0.24	0.00	1.20	0.93	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
8/1/93	213	0.24	0.00	1.18	0.92	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20
8/2/93	214	0.27	0.00	1.17	0.90	1.10	1.05	1.00	1.10	1.15	1.20	0.30	1.20

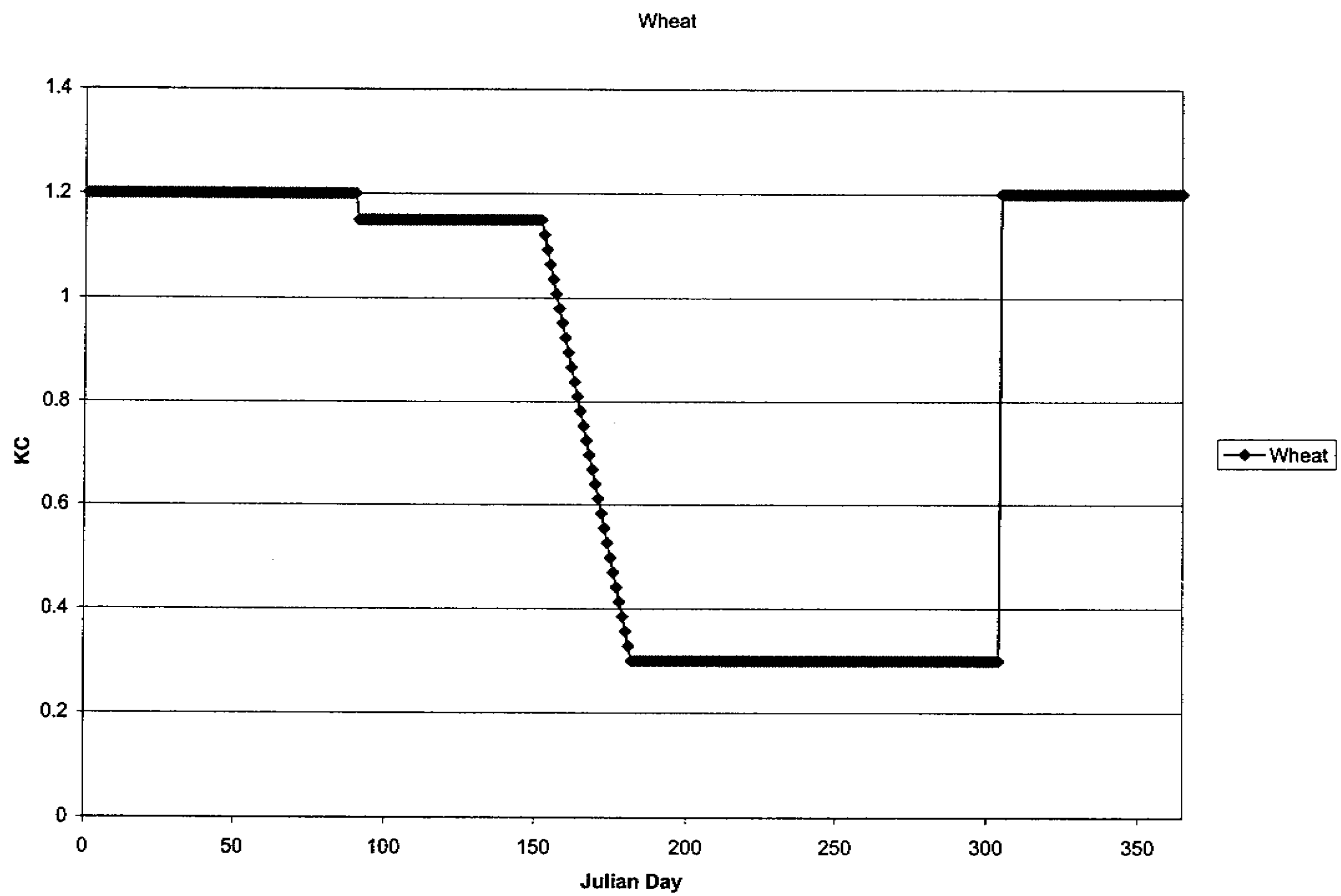
8/3/93	215	0.28	0.00	1.15	0.89	1.10	1.05	1.00	1.10	1.12	1.18	0.30	1.20
8/4/93	216	0.26	0.00	1.14	0.88	1.10	1.05	1.00	1.10	1.09	1.16	0.30	1.20
8/5/93	217	0.24	0.00	1.12	0.87	1.10	1.05	1.00	1.10	1.06	1.14	0.30	1.20
8/6/93	218	0.24	0.00	1.10	0.86	1.10	1.05	1.00	1.10	1.03	1.12	0.30	1.20
8/7/93	219	0.22	0.00	1.09	0.85	1.10	1.05	1.00	1.10	1.00	1.10	0.30	1.20
8/8/93	220	0.22	0.00	1.07	0.84	1.10	1.05	1.00	1.10	0.97	1.08	0.30	1.20
8/9/93	221	0.23	0.00	1.05	0.83	1.10	1.05	1.00	1.10	0.94	1.06	0.30	1.20
8/10/93	222	0.23	0.00	1.04	0.82	1.10	1.05	1.00	1.10	0.91	1.04	0.30	1.20
8/11/93	223	0.19	0.00	1.02	0.81	1.10	1.05	1.00	1.10	0.88	1.02	0.30	1.20
8/12/93	224	0.22	0.00	1.01	0.80	1.10	1.05	1.00	1.10	0.85	1.00	0.30	1.20
8/13/93	225	0.22	0.00	0.99	0.78	1.10	1.05	1.00	1.10	0.82	0.98	0.30	1.20
8/14/93	226	0.22	0.00	0.97	0.77	1.10	1.05	1.00	1.10	0.79	0.96	0.30	1.20
8/15/93	227	0.23	0.00	0.96	0.76	1.10	1.05	1.00	1.09	0.76	0.94	0.30	1.20
8/16/93	228	0.20	0.00	0.94	0.75	1.09	1.05	1.00	1.08	0.73	0.92	0.30	1.20
8/17/93	229	0.20	0.00	0.93	0.74	1.07	1.05	1.00	1.06	0.70	0.90	0.30	1.20
8/18/93	230	0.22	0.00	0.91	0.73	1.06	1.05	1.00	1.05	0.67	0.88	0.30	1.20
8/19/93	231	0.19	0.00	0.89	0.72	1.04	1.05	1.00	1.04	0.64	0.86	0.30	1.20
8/20/93	232	0.18	0.00	0.88	0.71	1.03	1.05	1.00	1.03	0.61	0.84	0.30	1.20
8/21/93	233	0.22	0.00	0.86	0.70	1.02	1.05	1.00	1.01	0.58	0.82	0.30	1.20
8/22/93	234	0.23	0.00	0.85	0.69	1.00	1.05	1.00	1.00	0.55	0.80	0.30	1.20
8/23/93	235	0.22	0.00	0.83	0.68	0.99	1.05	1.00	0.99	0.52	0.78	0.30	1.20
8/24/93	236	0.20	0.00	0.81	0.67	0.97	1.05	1.00	0.98	0.49	0.76	0.30	1.20
8/25/93	237	0.22	0.00	0.80	0.65	0.96	1.05	1.00	0.96	0.46	0.74	0.30	1.20
8/26/93	238	0.20	0.00	0.78	0.64	0.95	1.05	1.00	0.95	0.43	0.72	0.30	1.20
8/27/93	239	0.21	0.00	0.76	0.63	0.93	1.05	1.00	0.94	0.40	0.70	0.30	1.20
8/28/93	240	0.19	0.00	0.75	0.62	0.92	1.05	1.00	0.93	0.40	0.68	0.30	1.20
8/29/93	241	0.20	0.00	0.73	0.61	0.90	1.05	1.00	0.91	0.40	0.66	0.30	1.20
8/30/93	242	0.19	0.00	0.72	0.60	0.89	1.05	1.00	0.90	0.40	0.64	0.30	1.20
8/31/93	243	0.20	0.00	0.70	0.60	0.88	1.05	1.00	0.89	0.40	0.62	0.30	1.20
9/1/93	244	0.19	0.00	0.70	0.60	0.86	1.05	1.00	0.88	0.40	0.60	0.30	1.20
9/2/93	245	0.21	0.00	0.70	0.60	0.85	1.04	1.00	0.86	0.40	0.60	0.30	1.20
9/3/93	246	0.20	0.00	0.70	0.60	0.84	1.03	1.00	0.85	0.40	0.60	0.30	1.20
9/4/93	247	0.24	0.00	0.70	0.60	0.82	1.02	1.00	0.84	0.40	0.60	0.30	1.20
9/5/93	248	0.20	0.00	0.70	0.60	0.81	1.01	1.00	0.83	0.40	0.60	0.30	1.20
9/6/93	249	0.18	0.00	0.70	0.60	0.79	1.00	1.00	0.81	0.40	0.60	0.30	1.20
9/7/93	250	0.18	0.00	0.70	0.60	0.78	0.99	1.00	0.80	0.40	0.60	0.30	1.20
9/8/93	251	0.19	0.00	0.70	0.60	0.77	0.98	1.00	0.79	0.40	0.60	0.30	1.20
9/9/93	252	0.19	0.00	0.70	0.60	0.75	0.97	1.00	0.78	0.40	0.60	0.30	1.20
9/10/93	253	0.23	0.00	0.70	0.60	0.74	0.96	1.00	0.76	0.40	0.60	0.30	1.20
9/11/93	254	0.21	0.00	0.70	0.60	0.72	0.95	1.00	0.75	0.40	0.60	0.30	1.20
9/12/93	255	0.20	0.00	0.70	0.60	0.71	0.94	1.00	0.74	0.40	0.60	0.30	1.20
9/13/93	256	0.26	0.00	0.70	0.60	0.70	0.93	1.00	0.73	0.40	0.60	0.30	1.20
9/14/93	257	0.20	0.00	0.70	0.60	0.68	0.92	1.00	0.71	0.40	0.60	0.30	1.20
9/15/93	258	0.15	0.00	0.70	0.60	0.67	0.91	1.00	0.70	0.40	0.60	0.30	1.20
9/16/93	259	0.18	0.00	0.70	0.60	0.65	0.90	1.00	0.69	0.40	0.60	0.30	1.20
9/17/93	260	0.14	0.00	0.70	0.60	0.64	0.89	1.00	0.68	0.40	0.60	0.30	1.20
9/18/93	261	0.16	0.00	0.70	0.60	0.63	0.88	1.00	0.66	0.40	0.60	0.30	1.20
9/19/93	262	0.14	0.00	0.70	0.60	0.61	0.87	1.00	0.65	0.40	0.60	0.30	1.20
9/20/93	263	0.19	0.00	0.70	0.60	0.60	0.86	1.00	0.64	0.40	0.60	0.30	1.20
9/21/93	264	0.15	0.00	0.70	0.60	0.58	0.85	1.00	0.63	0.40	0.60	0.30	1.20
9/22/93	265	0.13	0.00	0.70	0.60	0.57	0.84	1.00	0.61	0.40	0.60	0.30	1.20
9/23/93	266	0.14	0.00	0.70	0.60	0.56	0.83	1.00	0.60	0.40	0.60	0.30	1.20
9/24/93	267	0.15	0.00	0.70	0.60	0.54	0.82	1.00	0.59	0.40	0.60	0.30	1.20
9/25/93	268	0.15	0.00	0.70	0.60	0.53	0.81	1.00	0.58	0.40	0.60	0.30	1.20
9/26/93	269	0.16	0.00	0.70	0.60	0.51	0.80	1.00	0.56	0.40	0.60	0.30	1.20
9/27/93	270	0.15	0.00	0.70	0.60	0.50	0.79	1.00	0.55	0.40	0.60	0.30	1.20
9/28/93	271	0.14	0.00	0.70	0.60	0.49	0.78	1.00	0.54	0.40	0.60	0.30	1.20
9/29/93	272	0.15	0.00	0.70	0.60	0.47	0.77	1.00	0.53	0.40	0.60	0.30	1.20
9/30/93	273	0.15	0.00	0.70	0.60	0.46	0.76	1.00	0.51	0.40	0.60	0.30	1.20
10/1/93	274	0.14	0.00	0.70	0.60	0.45	0.75	1.00	0.50	0.40	0.60	0.30	1.20
10/2/93	275	0.13	0.00	0.70	0.60	0.43	0.75	1.00	0.49	0.40	0.60	0.30	1.20
10/3/93	276	0.16	0.00	0.70	0.60	0.42	0.75	1.00	0.48	0.40	0.60	0.30	1.20
10/4/93	277	0.05	0.21	0.70	0.60	0.40	0.75	0.99	0.46	0.40	0.60	0.30	1.20
10/5/93	278	0.08	0.00	0.70	0.60	0.39	0.75	0.99	0.45	0.40	0.60	0.30	1.20
10/6/93	279	0.10	0.00	0.70	0.60	0.38	0.75	0.99	0.44	0.40	0.60	0.30	1.20
10/7/93	280	0.11	0.00	0.70	0.60	0.36	0.75	0.98	0.43	0.40	0.60	0.30	1.20
10/8/93	281	0.14	0.00	0.70	0.60	0.35	0.75	0.98	0.41	0.40	0.60	0.30	1.20
10/9/93	282	0.09	0.00	0.70	0.60	0.33	0.75	0.98	0.40	0.40	0.60	0.30	1.20
10/10/93	283	0.08	0.01	0.70	0.60	0.32	0.75	0.97	0.39	0.40	0.60	0.30	1.20
10/11/93	284	0.05	0.07	0.70	0.60	0.31	0.75	0.97	0.38	0.40	0.60	0.30	1.20
10/12/93	285	0.09	0.02	0.70	0.60	0.29	0.75	0.97	0.36	0.40	0.60	0.30	1.20
10/13/93	286	0.09	0.00	0.70	0.60	0.28	0.75	0.96	0.35	0.40	0.60	0.30	1.20
10/14/93	287	0.06	0.26	0.70	0.60	0.26	0.75	0.96	0.35	0.40	0.60	0.30	1.20

10/15/93	288	0.10	0.16	0.70	0.60	0.25	0.75	0.96	0.35	0.40	0.60	0.30	1.20
10/16/93	289	0.08	0.01	0.70	0.60	0.25	0.75	0.95	0.35	0.40	0.60	0.30	1.20
10/17/93	290	0.08	0.00	0.70	0.60	0.25	0.75	0.95	0.35	0.40	0.60	0.30	1.20
10/18/93	291	0.09	0.00	0.70	0.60	0.25	0.75	0.95	0.35	0.40	0.60	0.30	1.20
10/19/93	292	0.10	0.00	0.70	0.60	0.25	0.75	0.94	0.35	0.40	0.60	0.30	1.20
10/20/93	293	0.09	0.00	0.70	0.60	0.25	0.75	0.94	0.35	0.40	0.60	0.30	1.20
10/21/93	294	0.07	0.00	0.70	0.60	0.25	0.75	0.94	0.35	0.40	0.60	0.30	1.20
10/22/93	295	0.10	0.00	0.70	0.60	0.25	0.75	0.93	0.35	0.40	0.60	0.30	1.20
10/23/93	296	0.11	0.00	0.70	0.60	0.25	0.75	0.93	0.35	0.40	0.60	0.30	1.20
10/24/93	297	0.09	0.00	0.70	0.60	0.25	0.75	0.93	0.35	0.40	0.60	0.30	1.20
10/25/93	298	0.15	0.00	0.70	0.60	0.25	0.75	0.92	0.35	0.40	0.60	0.30	1.20
10/26/93	299	0.18	0.00	0.70	0.60	0.25	0.75	0.92	0.35	0.40	0.60	0.30	1.20
10/27/93	300	0.10	0.00	0.70	0.60	0.25	0.75	0.92	0.35	0.40	0.60	0.30	1.20
10/28/93	301	0.08	0.00	0.70	0.60	0.25	0.75	0.91	0.35	0.40	0.60	0.30	1.20
10/29/93	302	0.15	0.00	0.70	0.60	0.25	0.75	0.91	0.35	0.40	0.60	0.30	1.20
10/30/93	303	0.10	0.00	0.70	0.60	0.25	0.75	0.91	0.35	0.40	0.60	0.30	1.20
10/31/93	304	0.08	0.00	0.70	0.60	0.25	0.75	0.90	0.35	0.40	0.60	0.30	1.20
11/1/93	305	0.18	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/2/93	306	0.17	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/3/93	307	0.09	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/4/93	308	0.08	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/5/93	309	0.09	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/6/93	310	0.08	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/7/93	311	0.08	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/8/93	312	0.07	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/9/93	313	0.08	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/10/93	314	0.03	0.86	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/11/93	315	0.06	0.28	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/12/93	316	0.05	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/13/93	317	0.05	0.01	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/14/93	318	0.16	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/15/93	319	0.08	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/16/93	320	0.05	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/17/93	321	0.05	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/18/93	322	0.07	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/19/93	323	0.06	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/20/93	324	0.06	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/21/93	325	0.03	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/22/93	326	0.06	0.04	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/23/93	327	0.05	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/24/93	328	0.08	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/25/93	329	0.05	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/26/93	330	0.05	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/27/93	331	0.04	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/28/93	332	0.04	0.38	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/29/93	333	0.02	1.06	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
11/30/93	334	0.06	0.01	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/1/93	335	0.03	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/2/93	336	0.07	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/3/93	337	0.03	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/4/93	338	0.06	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/5/93	339	0.04	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/6/93	340	0.05	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/7/93	341	0.05	0.10	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/8/93	342	0.06	0.57	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/9/93	343	0.03	0.11	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/10/93	344	0.04	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/11/93	345	0.05	0.35	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/12/93	346	0.03	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/13/93	347	0.06	0.16	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/14/93	348	0.04	0.88	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/15/93	349	0.03	0.65	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/16/93	350	0.02	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/17/93	351	0.02	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/18/93	352	0.03	0.02	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/19/93	353	0.01	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/20/93	354	0.01	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/21/93	355	0.02	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/22/93	356	0.02	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/23/93	357	0.03	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/24/93	358	0.01	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/25/93	359	0.01	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/26/93	360	0.02	0.05	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20

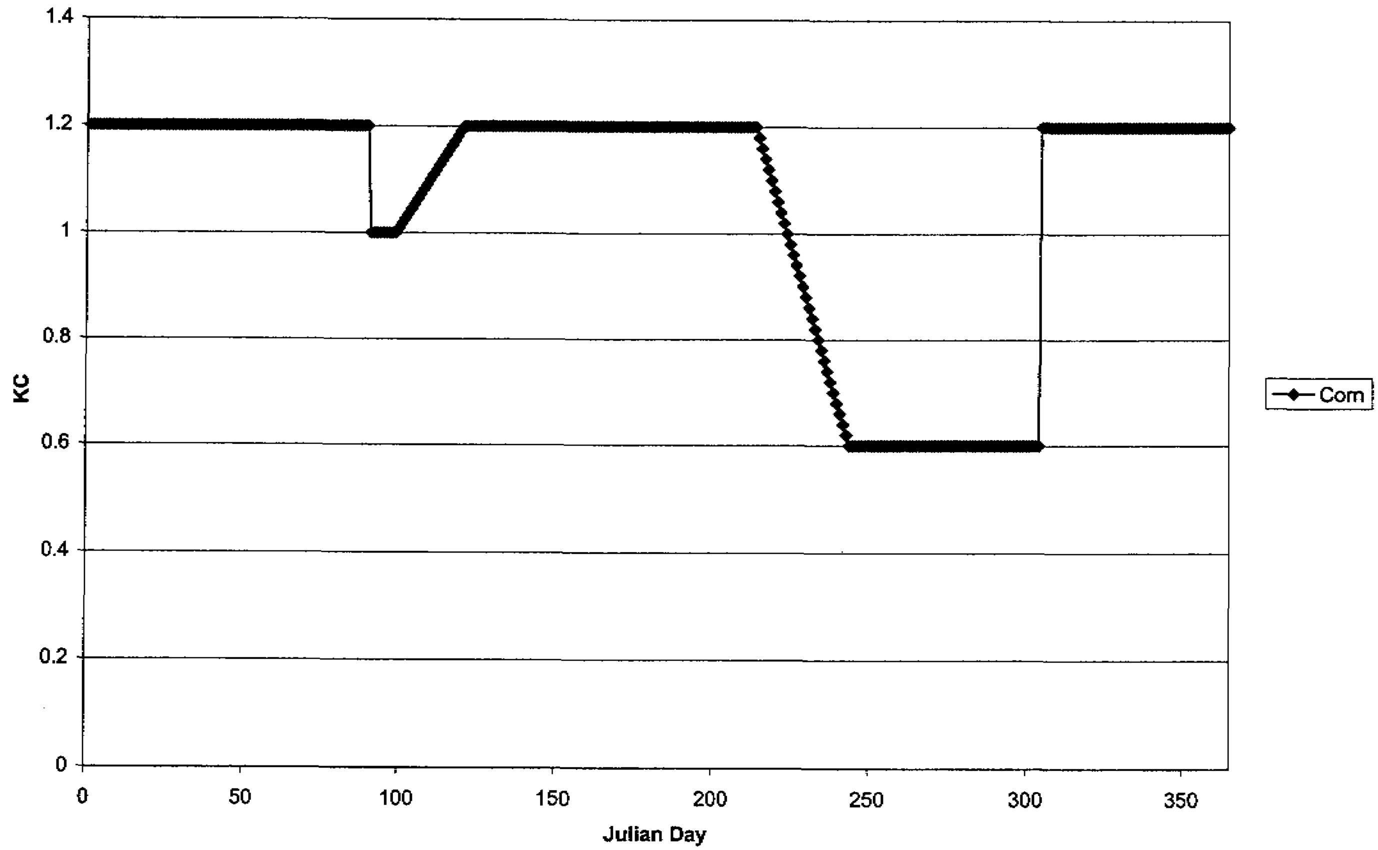
12/27/93	361	0.04	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/28/93	362	0.03	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/29/93	363	0.03	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/30/93	364	0.02	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
12/31/93	365	0.04	0.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20

KC Rice

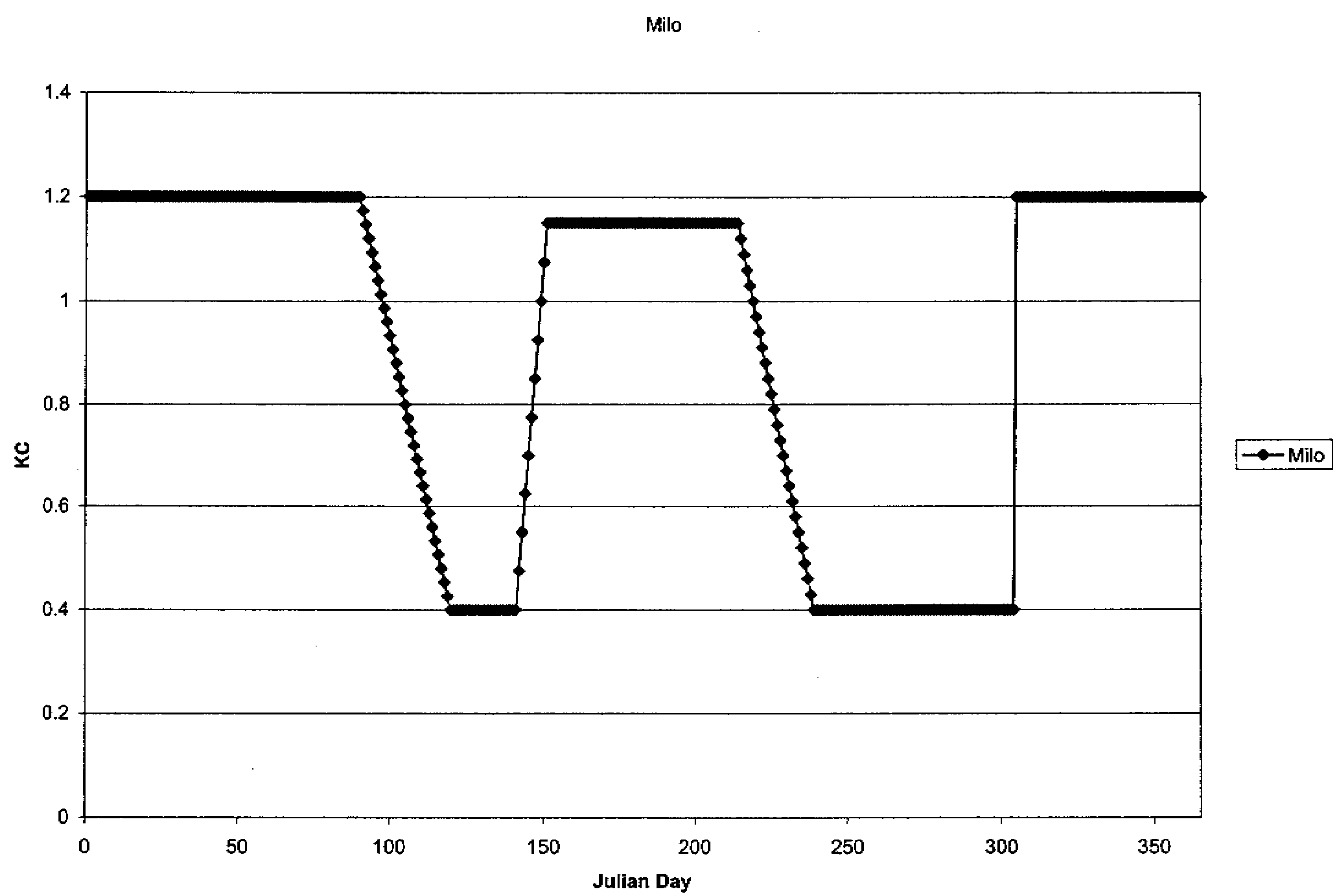

1.4
1.2
1
0.8
0.6
0.4
0.2
0
KC
0
50
100
150
200
250
300
350
Julian Day
KC Rice

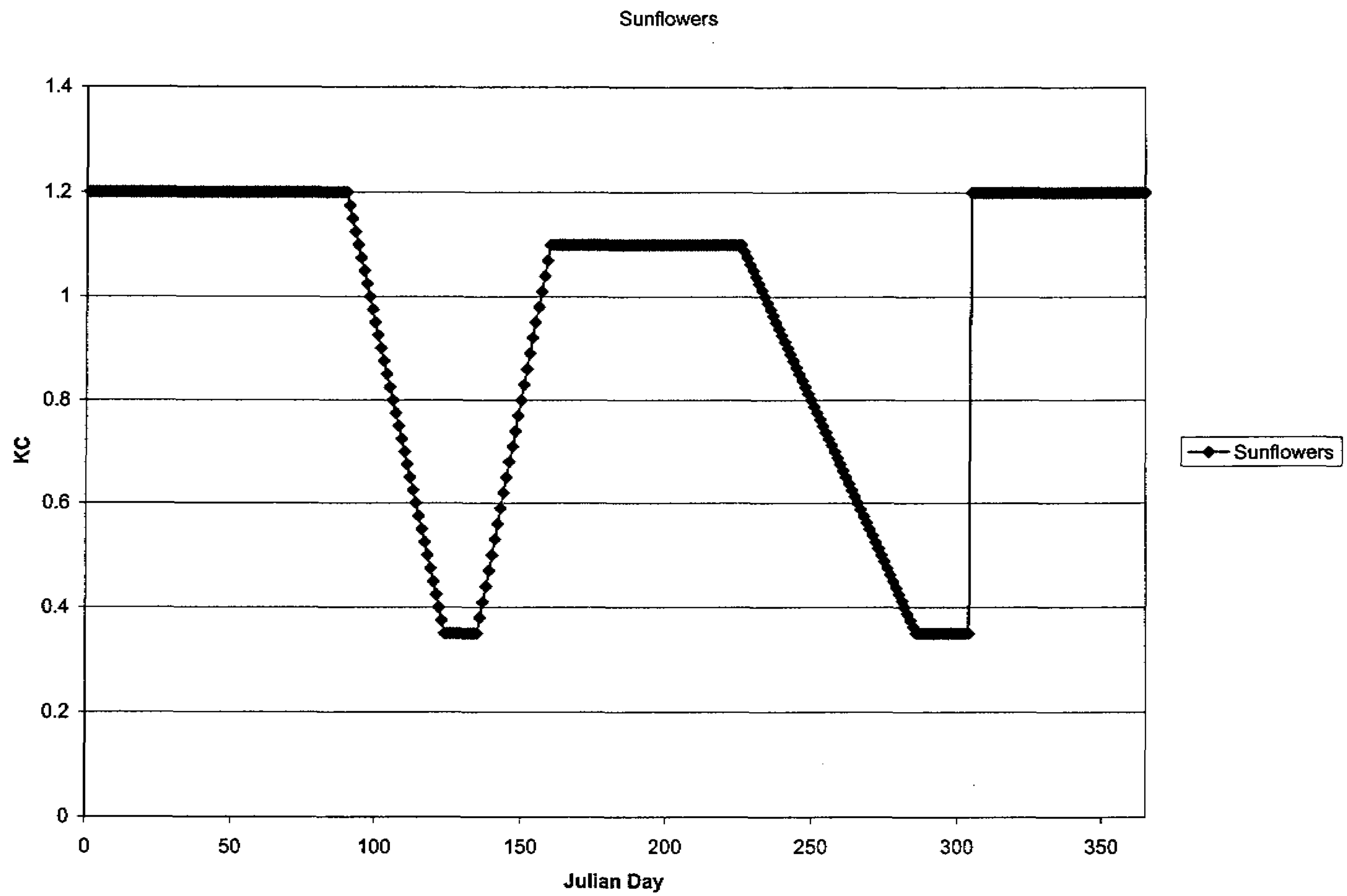

Wheat
1.4
1.2
1
0.8
0.6
0.4
0.2
0
KC
0
50
100
150
200
250
300
350
Julian Day
Wheat

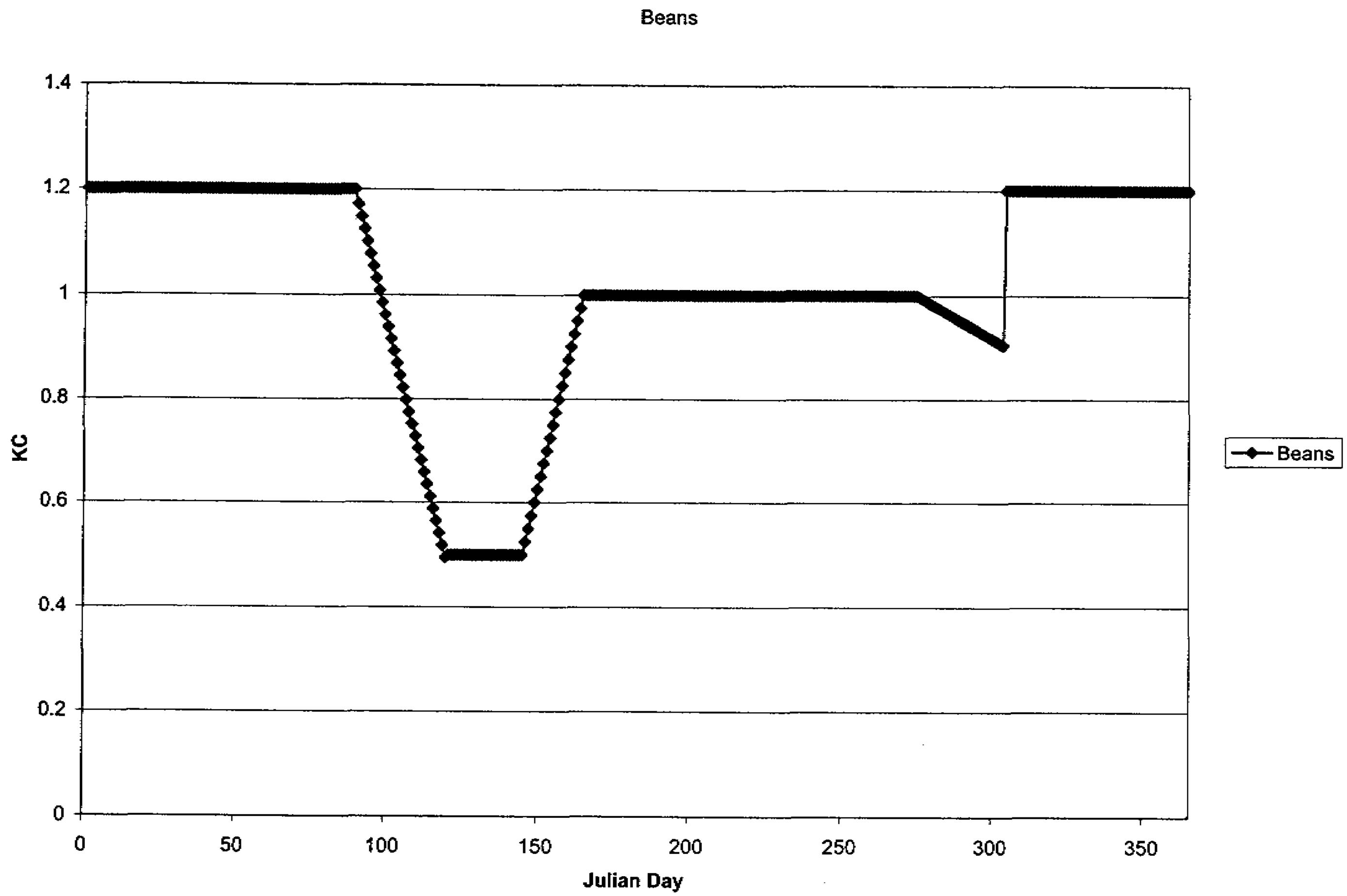
Corn



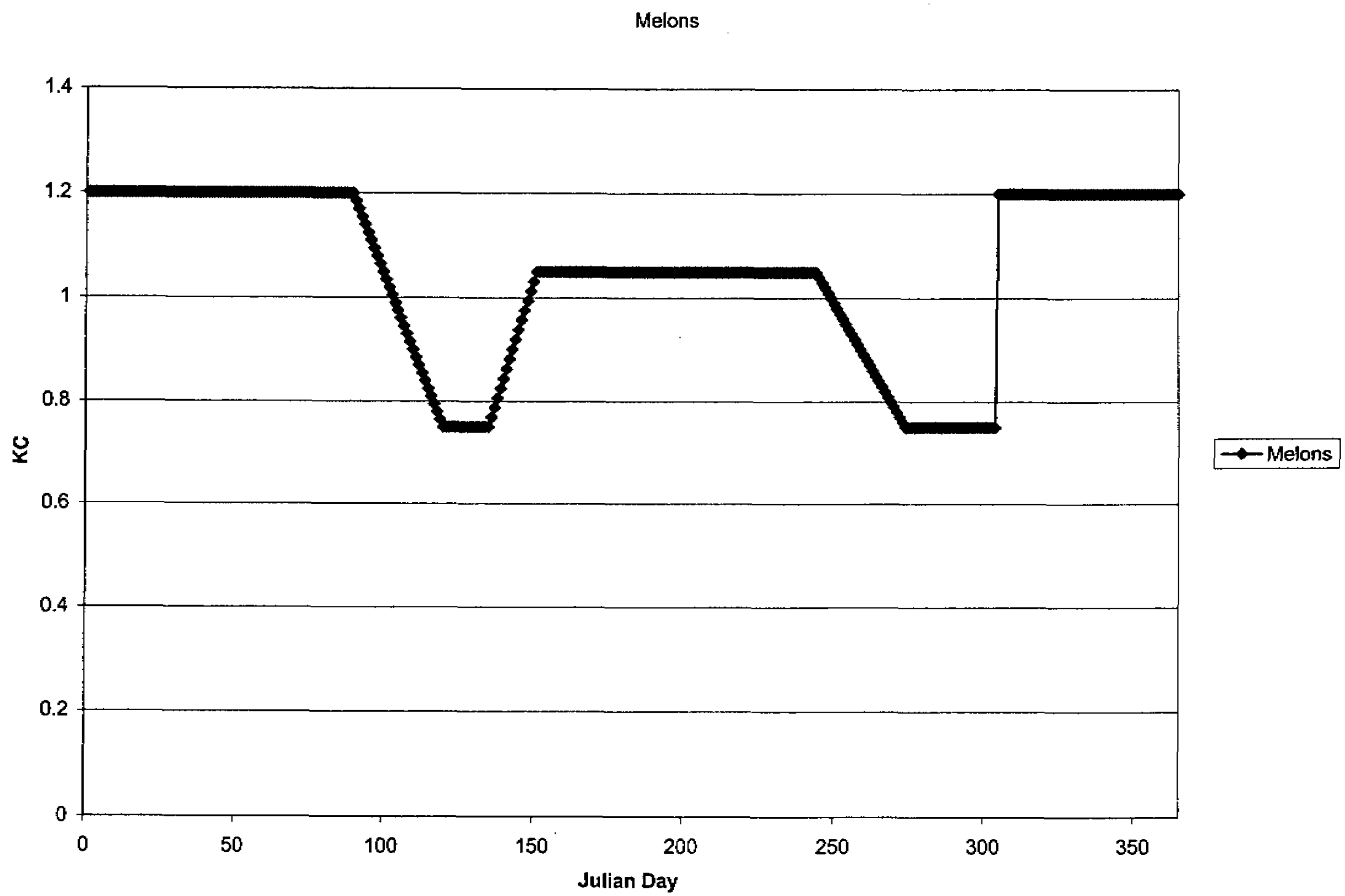
KC
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250
300
350
Julian Day
Corn


Milo
1.4
1.2
1
0.8
0.6
0.4
0.2
0
KC
0
50
100
150
200
250
300
350
Julian Day
Milo

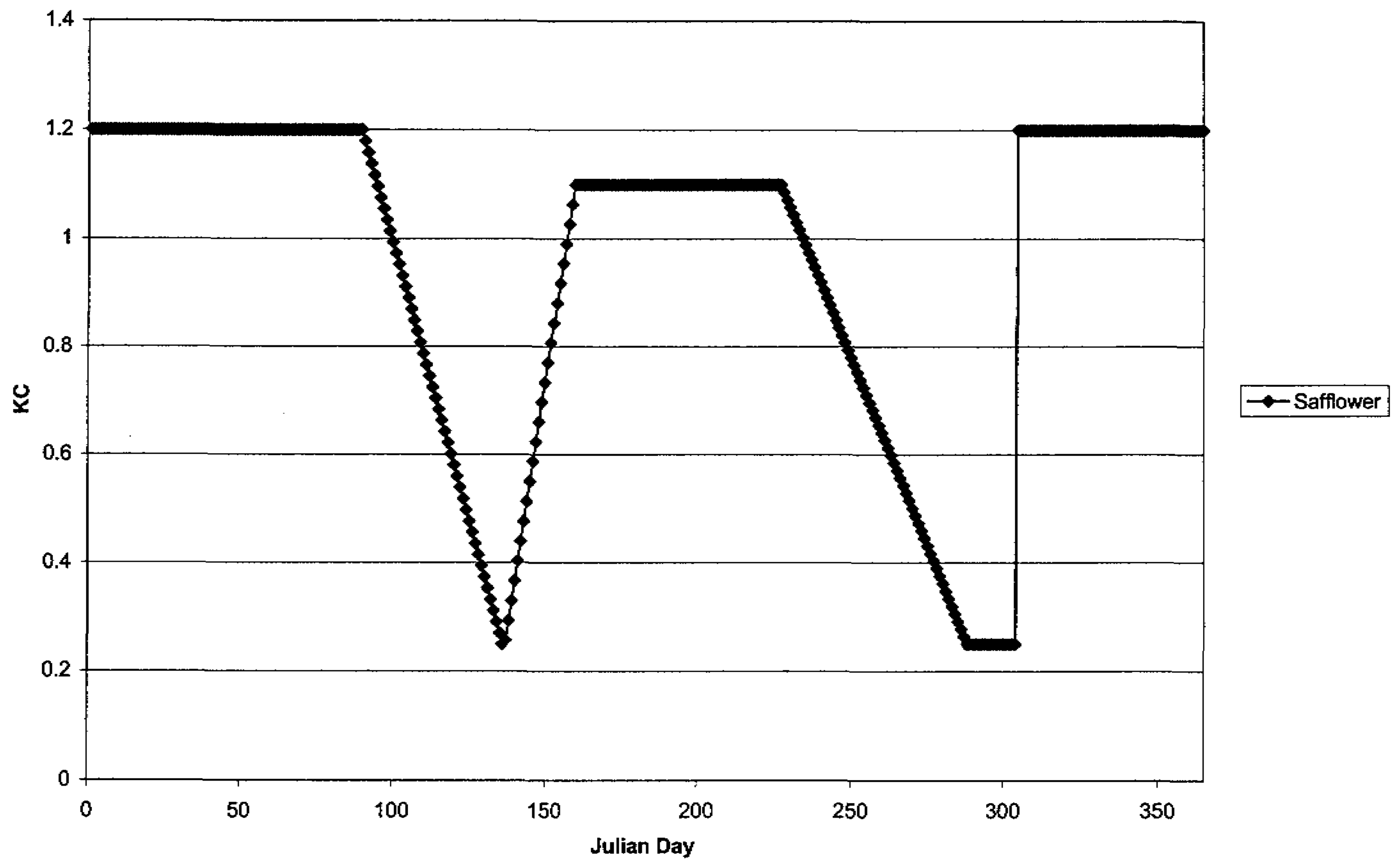

Sunflowers
KC
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250
300
350
Julian Day
Sunflowers

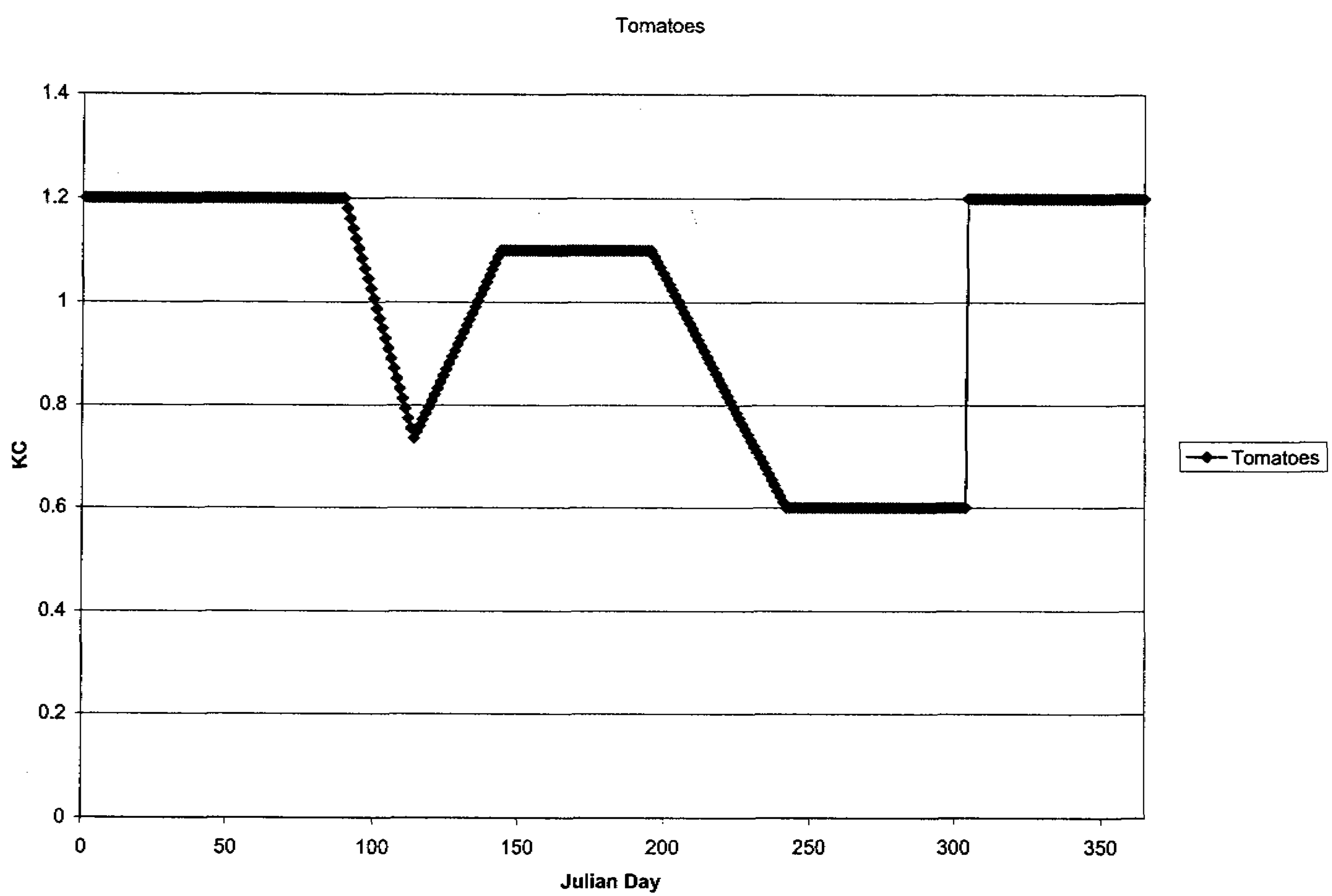


Beans
1.4
1.2
1
0.8
0.6
0.4
0.2
0
KC
0
50
100
150
200
250
300
350
Julian Day
Beans


Melons
1.4
1.2
1
0.8
0.6
0.4
0.2
0
KC
0
50
100
150
200
250
300
350
Julian Day
Melons

Safflower


KC
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250
300
350
Julian Day
Safflower


Tomatoes
1.4
1.2
1
0.8
0.6
0.4
0.2
0
KC
0
50
100
150
200
250
300
350
Julian Day
Tomatoes

Appendix E

Economic Pipe Sizing

The economic pipe sizing analysis can be found below.

The following equations were used in the analysis. All equations not listed here are listed in the spreadsheet shown below.

$$\text{Friction (Hf) in ft/100ft} = 1050 \times \left(\frac{\text{GPM}}{150}\right)^{1.852} \times (\text{ID})^{-4.87} \times \left(\frac{100'}{100}\right)$$

Where: GPM = 500, 1000, 1500, or 3000 gpm
ID = inside diameter of pipe in inches

$$\text{WHP} = \frac{\text{Hf} \times \text{GPM}}{3960}$$

Where: Hf = friction in (ft/100 ft)
GPM = 500, 1000, 1500, or 3000 gpm

Annualized Fixed Cost = CRF x ($/100 ft.)

Annual Power Costs = ($/WHP) x WHP

Total Annual Costs = Annualized Fixed Costs + Annual Power Costs

The pipe diameter with the lowest total annual cost was selected for each flow.

Pipe costs		
Price of PVC ($/lb)	$ 1.30	estimate (including fittings)
Installation costs ($/lb)	$ 0.87	
Total Fixed costs ($/lb)	$ 2.17	Using 60% of cost is pipe
		40% of cost is installation
Life of Project (yrs)	10	assumed
Interest rate	0.08	assumed
CRF	0.15	CRF =[i*(1+i)^n]/[(1+i)^n-1]

Power costs		
$/input kW-hr	$ 0.13	assumed electric costs
Hours of op/year	8760	operating 24 hrs/day for 365 days
Pump Eff.	0.8	from Floway TDH book
Motor Eff.	0.92	assumed efficiency
Total annual $/WHP	$ 1,154.27	$/WHP = ($/input kW-hr)*1/(Pump Eff * Motor Eff)*0.746 kW/HP*hrs. of operation per year

For pipe sections with 500 gpm

GPM	Nominal Diameter (in)	ID (in)	Hf ft/100	Weight/Ft (lb/100')	$/100ft	Annualized Fixed costs ($/100')	WHP	Annual power costs	Total annual cost
500	6	6.301	1.25	215.3	$ 466.48	$ 69.52	0.16	$ 181.98	$ 251.50
500	8	8.205	0.35	363.3	$ 787.15	$ 117.31	0.04	$ 50.30	$ 167.61
500	10	10.23	0.12	565	$ 1,224.17	$ 182.44	0.01	$ 17.18	$ 199.62
500	12	12.13	0.05	795.4	$ 1,723.37	$ 256.83	0.01	$ 7.49	$ 264.33
500	15	15.3	0.02	1181.12	$ 2,559.09	$ 381.38	0.00	$ 2.42	$ 383.80
500	18	18.701	0.01	1772.03	$ 3,839.40	$ 572.18	0.00	$ 0.91	$ 573.09

For pipe sections with 1000 gpm

GPM	Nominal Diameter (in)	ID (in)	Hf ft/100	Weight/Ft (lb/100')	$/100ft	Annualized Fixed costs ($/100')	WHP	Annual power costs	Total annual cost
1000	6	6.301	4.51	215.3	$ 466.48	$ 69.52	1.14	$ 1,313.89	$ 1,383.40
1000	8	8.205	1.25	363.3	$ 787.15	$ 117.31	0.31	$ 363.18	$ 480.49
1000	10	10.23	0.43	565	$ 1,224.17	$ 182.44	0.11	$ 124.05	$ 306.48
1000	12	12.13	0.19	795.4	$ 1,723.37	$ 256.83	0.05	$ 54.11	$ 310.94
1000	15	15.3	0.06	1181.12	$ 2,559.09	$ 381.38	0.02	$ 17.47	$ 398.85
1000	18	18.701	0.02	1772.03	$ 3,839.40	$ 572.18	0.01	$ 6.57	$ 578.76

For pipe sections with 1500 gpm

GPM	Nominal Diameter (in)	ID (in)	Hf ft/100	Weight/Ft (lb/100')	$/100ft	Annualized Fixed costs ($/100')	WHP	Annual power costs	Total annual cost
1500	6	6.301	9.55	215.3	$ 466.48	$ 69.52	3.62	$ 4,176.09	$ 4,245.61
1500	8	8.205	2.64	363.3	$ 787.15	$ 117.31	1.00	$ 1,154.33	$ 1,271.64
1500	10	10.23	0.90	565	$ 1,224.17	$ 182.44	0.34	$ 394.28	$ 576.71
1500	12	12.13	0.39	795.4	$ 1,723.37	$ 256.83	0.15	$ 171.99	$ 428.82
1500	15	15.3	0.13	1181.12	$ 2,559.09	$ 381.38	0.05	$ 55.52	$ 436.90
1500	18	18.701	0.05	1772.03	$ 3,839.40	$ 572.18	0.02	$ 20.89	$ 593.07

For pipe sections with 3000 gpm

GPM	Nominal Diameter (in)	ID (in)	Hf ft/100	Weight/Ft (lb/100')	$/100ft	Annualized Fixed costs ($/100')	WHP	Annual power costs	Total annual cost
3000	6	6.301	34.48	215.3	$ 466.48	$ 69.52	26.12	$ 30,151.38	$ 30,220.90
3000	8	8.205	9.53	363.3	$ 787.15	$ 117.31	7.22	$ 8,334.29	$ 8,451.60
3000	10	10.23	3.26	565	$ 1,224.17	$ 182.44	2.47	$ 2,846.67	$ 3,029.11
3000	12	12.13	1.42	795.4	$ 1,723.37	$ 256.83	1.08	$ 1,241.74	$ 1,498.57
3000	15	15.3	0.46	1181.12	$ 2,559.09	$ 381.38	0.35	$ 400.85	$ 782.23
3000	18	18.701	0.17	1772.03	$ 3,839.40	$ 572.18	0.13	$ 150.82	$ 723.00

Appendix F

Discharge Pressure Analysis

The following is an analysis of the discharge pressures at points in the well design. The point names refer back to the layout of the initial six wells in figure 6.

Discharge pressure analysis:

Assumptions:

- Pipe is flowing full
- A Harris siphon breaker and air relief valve is used at the top of the levee.
- The pressure at point E is 0

Section	Length of section	GPM	from economic analysis Nominal Diameter to use	ID	Hf	Hf
	(ft)		(in)	(in)	(ft/100')	ft
AB	2250	500	8	8.205	0.35	7.77
BC	2250	1000	10	10.23	0.43	9.58
CD	4500	1500	12	12.13	0.39	17.70
GF	2250	500	8	8.205	0.35	7.77
FD	2250	1000	10	10.23	0.43	9.58
DE	2500	3000	18	18.701	0.17	4.31

Path #1 goes from Pt. E in the Nelson Slough to Pt. A

P = Change in Elev + P at d/s point + Hf + 2 feet for valve losses

Pt	Approximate Elev (ft)	Change in Elev (ft)	Hf along section	P at point (ft)	P at point (psi)
E	35		(ft)	0	0
D	30	5	4.31	11.31	5
C	27	3	17.70	32.01	14
B	26	1	9.58	42.59	18
A	25	1	7.77	51.35	22

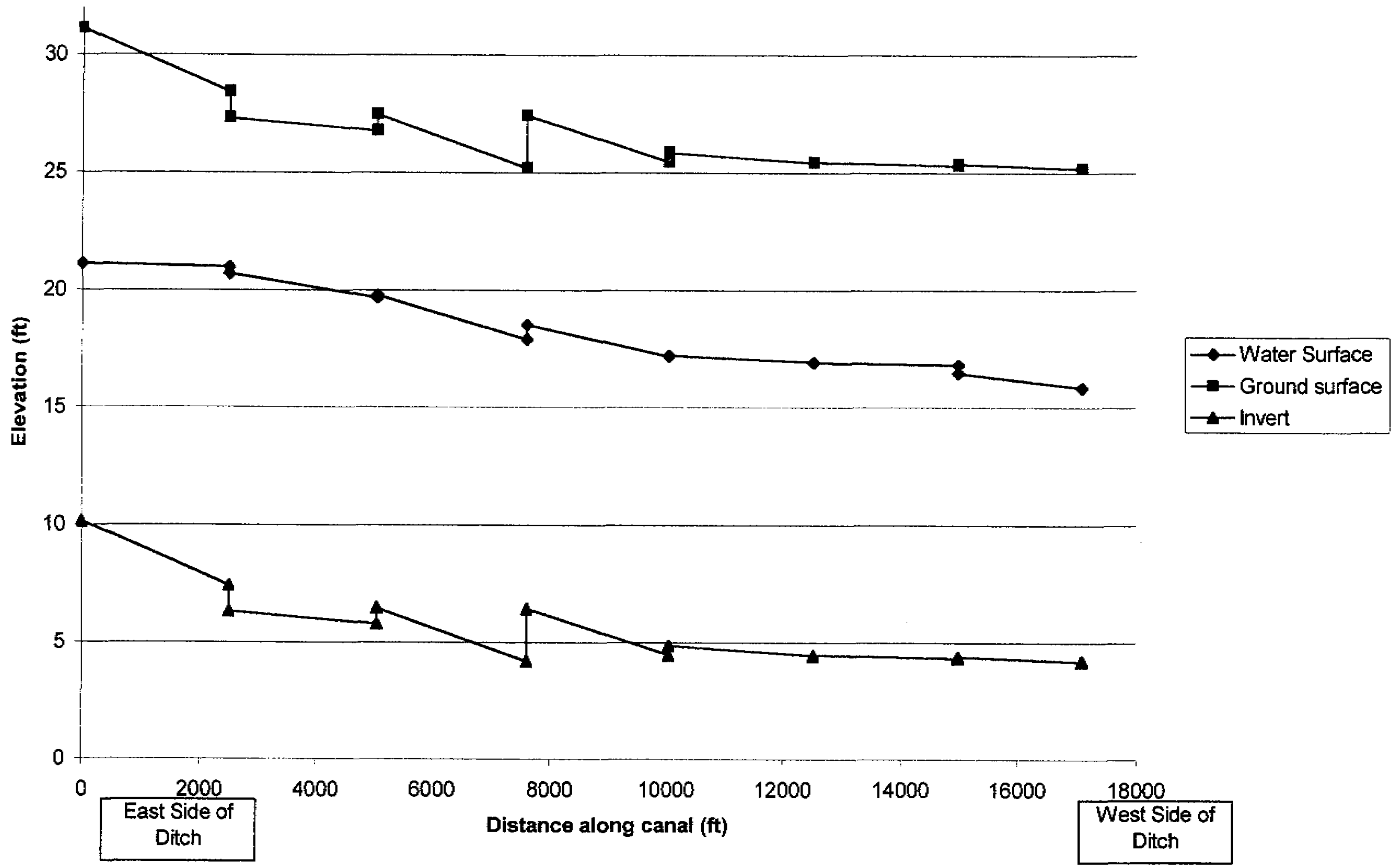
Path #2 goes from Pt. E in the Nelson Slough to Pt. G

Pt	Approximate Elev (ft)	Change in Elev (ft)	Hf along section	P at point (ft)	P at point (psi)
E	35			0	0
D	30	5	4.31	11.31	5
F	29	1	9.58	23.89	10
G	28	1	7.77	34.65	15

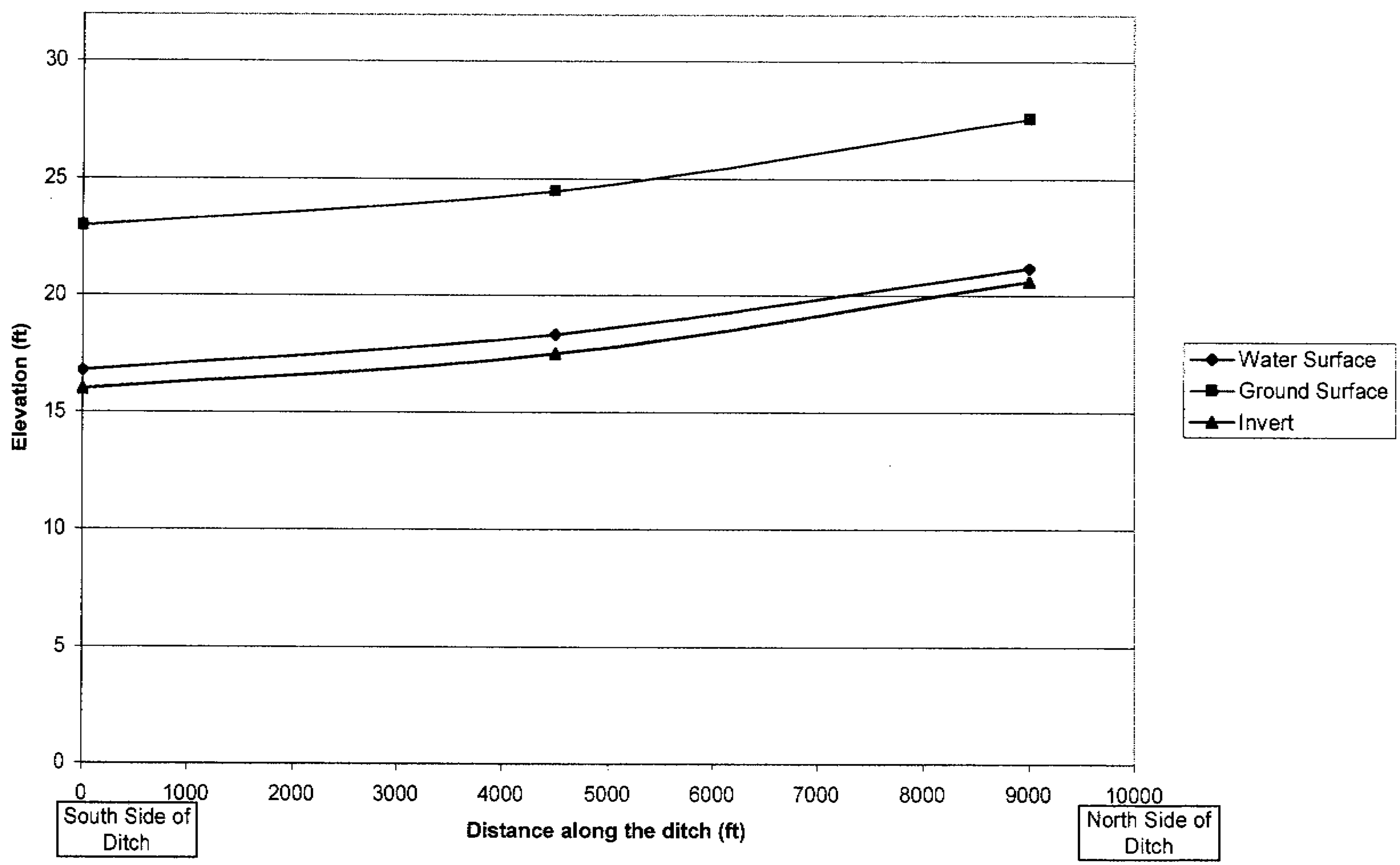
Appendix G

Water Level Profiles For Each Ditch Surveyed

Water Level Changes on Varney Road

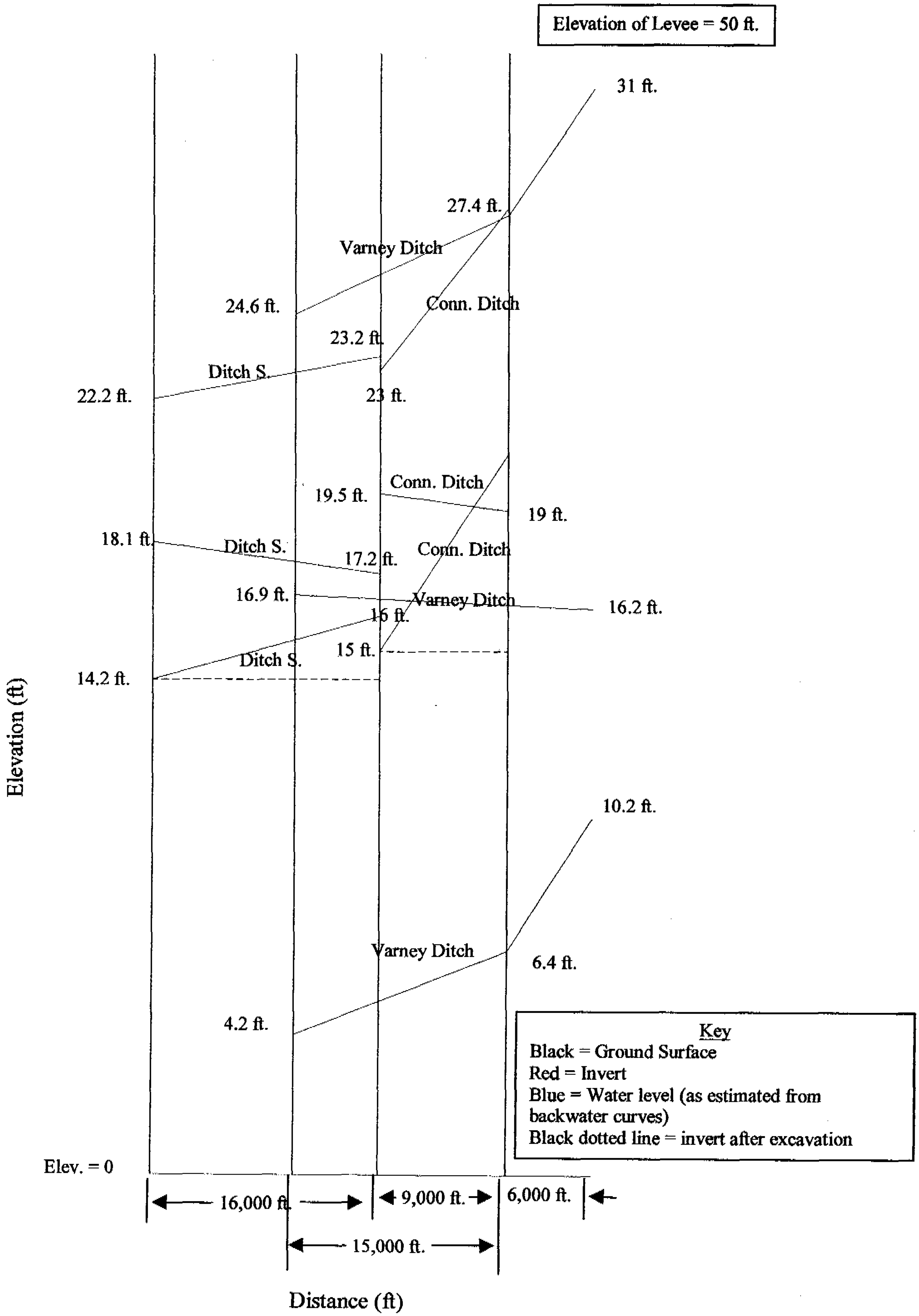


Connecting Ditch



Appendix H

Elevation Profile of Ditches


Elevation of Levee = 50 ft.
31 ft.
27.4 ft.
Varney Ditch
24.6 ft.
Conn. Ditch
23.2 ft.
Ditch S.
22.2 ft.
23 ft.
19.5 ft.
Conn. Ditch
19 ft.
18.1 ft.
Ditch S.
17.2 ft.
Conn. Ditch
16.9 ft.
Varney Ditch
16.2 ft.
16 ft.
15 ft.
Ditch S.
14.2 ft.
Elevation (ft)
10.2 ft.
Varney Ditch
6.4 ft.
4.2 ft.
Key
Black = Ground Surface
Red = Invert
Blue = Water level (as estimated from backwater curves)
Black dotted line = invert after excavation
Elev. = 0
16,000 ft.
9,000 ft.
6,000 ft.
15,000 ft.
Distance (ft)