BUREAU OF SUGAR EXPERIMENT STATIONS

BRISBANE, AUSTRALIA

FINAL REPORT SRDC PROJECT BS148S
AN ECONOMIC EVALUATION OF IRRIGATION METHODS AND PROGRAMS

by

T G Willcox

SD97007

Project Supervisor: **Mr Trevor Willcox**
District Productivity Coordinator
C/- CANEGROWERS Bundaberg
PO Box 953
BUNDABERG Q 4670
Phone: (071) 512 555

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CONTENTS

1.0 NON-TECHNICAL SUMMARY

The aim of the project was to produce economic and financial information to promote the adoption of more efficient irrigation practices in the Bundaberg district.

The project was developed through workshops convened by the Bundaberg Cane Productivity Committee (BCPC). Irrigation consultants Sinclair Knight Merz (SKM) were engaged to conduct the investigation with assistance from BSES, Bundaberg Sugar Limited and QDPI.

The first activity was a workshop to confirm project objectives and determine the scope of the investigations. Parameters selected were: four irrigation methods, three farm sizes, three soil categories, three announced water allocations, three system capacities, three water sources, one water use efficiency factor, two cultivation practices, two electricity tariffs and three sugar prices.

Water balance modelling was conducted for the 24 year period 1969 to 1993 using daily time steps. The model's ability to simulate irrigation schedules at various supply flow rates improved knowledge of effective rainfall, irrigation water requirements and benefits of increased system capacity for different soil types. The modelling results provided a better understanding of the constraints on, and performance of, irrigated sugarcane in the Bundaberg Irrigation Area (BIA).

The economic analysis showed that best practice furrow (BPF) irrigation was generally the most profitable and had the highest benefit-cost ratios of the irrigation methods considered. However, trickle irrigation was superior to BPF with 50% allocation for 30, 50 and 70 ha farms and also for 30 ha farms on medium soils with 100% allocation. Trickle irrigation generally gave higher profits and benefit/cost ratios than winch irrigation, despite the high capital cost of trickle irrigation. The exceptions were on soils of high readily available soil water (RASW) with unlimited water supplies when winch irrigation was more profitable than trickle in some cases. However, the unlimited water scenario is unlikely in Bundaberg as demand exceeds the yield of the BIA in most years.

The economics of converting to more efficient irrigation methods were calculated for 15% and 100% conversion scenarios. Profit generally decreased after converting to trickle irrigation. The exceptions were 30 ha farms on soils with low and medium RASW and water supplies of 100% allocation or higher, when profits increased. On 50 ha and 70 ha farms and the 50% allocation scenario on 30 ha farms, profit decreased after conversion to trickle.

Benefit-cost ratios calculated over a 30 year period increased after conversion to trickle or best practice furrow irrigation from winch irrigation with limited water supplies, but decreased with unlimited water.

The quantity of irrigation water available influenced farm profit more than irrigation method. For example, at 100% allocation (5.3 ML/ha) for a 50 ha farm on medium soils, farm profit with trickle irrigation was 15% higher than with winch irrigation. However, lifting the allocation to 150% increased farm profit by a further 107%, highlighting the value of increased water storage to the viability of the district.

SKM presented their report to a workshop at CANEGROWERS Bundaberg in October 1996. SKM also prepared an Excel spreadsheet containing the economic model for the project.

A brochure summarising the results was prepared by BSES in October and forwarded to all cane growers in the Bundaberg and Isis districts in November 1996. Papers were also prepared for the Irrigation and Drainage Course for Cane Protection and Productivity Boards (CPPBs) at Proserpine, the BSES Bulletin, ASSCT, CANEGROWER magazine and local media.

2.0 BACKGROUND

BCPC developed this project after a lengthy study of the issues limiting productivity at Bundaberg. The study identified irrigation as a major factor (Smith et al, 1994). Workshops hosted to consider the findings of the study identified a lack of credible financial information as a barrier to the adoption of more efficient irrigation practices. Cane growers and financiers required information to justify the capital expenditure required to improve irrigation systems.

In 1993, the Bundaberg district average water use efficiency was 8 t cane/ML, well below the benchmark figure of 12.2 t cane/ML (Kingston 1994), indicating an opportunity to improve water application efficiency. Improved water application efficiency is essential for the long term sustainability of irrigation to optimise economic returns and minimise runoff and deep percolation of irrigation water.

Consultants Sinclair Knight Merz were engaged for the project due to their expertise in water resource assessment, water balance modelling, irrigation design and economic evaluation. Relevant projects recently undertaken by SKM in the sugar industry include: Preliminary design and Economic Assessment Study for a Water Management Scheme for the Russell and Mulgrave Rivers; Eli Creek Effluent Irrigation Study; Burdekin River Irrigation Area Environmental Review. Other relevant projects include: The Dawson Valley 1990 Irrigation Study; The Emerald 1993 Irrigation Study for QDPI Water Resources.

3.0 PROJECT OBJECTIVES

1. Identify the most efficient and profitable irrigation method for representative soil types, topography, water supply source, quantity applied, instantaneous application rates and electricity tariff scenarios.
2. Collate information on existing irrigation methods on representative farms.
3. Identify resulting system requirements to provide optimum irrigation capacity and irrigation management.
4. Calculate costs and benefits of changing from the present to the optimum method.
5. Present the information in a readily assimilated form.
6. Extend the information to cane growers, agribusiness, banks and accountants as part of Project BS127S and through specific workshops and information brochures.

4.0 INTRODUCTORY TECHNICAL INFORMATION AND RESEARCH NEED

The need for this project was identified by a workshop hosted by BCPC to discuss the results of a survey undertaken by QDPI Economic and Financial Services for BCPC entitled 'Factors affecting cane farm productivity and profitability in the Bundaberg district'. The workshop identified the need for key economic data to support the extension of appropriate irrigation methods and optimum irrigation programs.

Information from the QDPI survey provided some of the base financial data for this project. Additional information from BS91S 'Determining the relationship between on-farm decision-making and profitability' and the QDPI Financial Counsellor were used to verify cost of production figures.

Technical data was also available from BS62S 'Efficient use of irrigation water in sugarcane', BS64S 'Management strategies for drip irrigation systems in sugarcane' and BS127S 'Increased adoption of efficient, sustainable irrigation practices by Australian cane growers'.

5.0 RESEARCH METHODOLOGY

1. The project was developed through consultation with Bundaberg sugar industry representatives, technical staff, agribusiness and financiers. This consultation process was critical, as the success of the project depended on the credibility of the results. Involvement of opinion leaders in the project secured ownership of the results and credibility. The project began with a workshop to initiate the project, confirm project objectives and set base economic assumptions. People involved were from agribusiness, banks, BSES, Bundaberg Sugar Company, CANEGROWERS, Cane Protection and Productivity Boards, QDNR, QDPI and SKM.
2. Consultants SKM then:
   - collected technical information from BSES, QDPI and Project BS127S,
   - collected financial information from agribusiness, QDPI, BCPC and Project BS91S,
   - collected daily rainfall and evaporation data for the period 1969 to 1993 from QDPI RAINMAN and BSES Bundaberg.
   - developed the SKM Irrigation Water Balance Model to determine crop growth water use and cane yield for different irrigation methods, soil types, water supply quantities and delivery flow rates,
   - outputs of the SKM model were used to identify potential crop growth limitations imposed by the design of the Bundaberg irrigation scheme and on-farm distribution systems and identify options to optimise use of the existing scheme,
   - SKM carried out preliminary designs for each irrigation method for 30, 50 and 70 ha farms on surface water, groundwater and river water supplies. Capital and operating costs were calculated for each system. Capital costs of changing from one irrigation method to another were also calculated.
   - SKM developed an Economic Model operating on an Excel spreadsheet to examine gross margins, profit and benefit-cost ratios for each case.

3. SKM presented a draft report to the BCPC and project participants.
4. A workshop was held with project participants to present the final report.
5. A brochure summarising the project was prepared by BSES and mailed to all cane growers in the Bundaberg/Isis area as well as BSES and CPPB centers throughout the State.
6. An electronic copy of the Economic Model was provided to BSES, CANEGROWERS and QDPI at Bundaberg and forwarded to BSES centers in other irrigation areas.
7. Publicity concerning the project's findings included a BSES Bulletin article in January 1997, two ASSCT papers at the 1997 conference, a module of the BSES Irrigation and Drainage Course in October 1996 and media releases published in the Bundaberg NewsMail, CANEGROWER magazine and ABC radio interviews. The findings were also presented at the Fairymead harvest breakfast, Agrotrend and Fairymead, Bingera and Millaquin/Qunaba cell group meetings.

Details of the research methodology used by SKM are shown in Section 2 of their report on the project 'Bundaberg Irrigation Economic Assessment Report -Volume 1' in the Appendix.

6.0 RESULTS

Results of the project are detailed in SKM's report 'Bundaberg Irrigation Economic Assessment Report - Volumes 1 & 2'. (Attached)

Findings were also summarised in the brochure 'Economics of irrigation methods and programs at Bundaberg' produced by BSES. (Attached)

7.0 DISCUSSION OF RESULTS IN RELATION TO OBJECTIVES

7.1 Objective 1: Identify the most efficient and profitable irrigation method for representative soil types, topography, water supply source, quantity applied, instantaneous application rates and electricity tariff scenarios.

The most efficient irrigation methods were identified by the water balance model. The model simulated crop growth water use from which cane yields were calculated (Table 1). The model also calculated effective rainfall (Table 2) and the quantity of irrigation water required at different delivery flow rates (Table 3) for four irrigation methods: trickle, winch, best practice furrow (BPF) and standard furrow. Water Use Efficiency (WUE) expressed as tonnes cane per megalitre of water (effective rain plus irrigation) was calculated for each irrigation method (Table 4).

Trickle irrigation was the most efficient method. As modelled, crop WUE increased with the moisture holding capacity of the soil. The quantity of irrigation water appeared to have little effect. Crop WUE increased with higher delivery flow rates with trickle irrigation but tended to decrease when flow rates were increased for other irrigation methods. However, it is important to note that the crop growth model used a linear relationship between yield and crop growth water use, and at low soil water levels assumed zero growth. A more refined model may have produced different results.

Farm profits for 30, 50 and 70 ha farms for each irrigation method, soil type, water source and water quantity are shown for green field development, 100% conversion and 15% conversion with sugar at $330 per tonne and CCS at 14.3 in Tables 5, 6 and 7. Gross benefit-cost ratios are shown in Tables 8, 9 and 10.

Tables 5 to 10 show that best practice furrow (BPF) irrigation was generally the most profitable and had the highest benefit-cost ratios of the irrigation methods considered. However, trickle irrigation had superior benefit-cost ratios to BPF with 50% allocation for 30, 50 and 70 ha farms (Tables 8 to 10) and also for 30 ha farms on medium soils with 100% allocation (Table 8). Trickle irrigation generally gave higher profits and benefit/cost ratios than winch irrigation, despite the high capital cost of trickle irrigation (Tables 5 to 10). The exceptions were for 50 and 70 ha farms on high RASW soils with unlimited water supplies when winch irrigation was more profitable than trickle in some cases (Tables 6 and 7). However, the unlimited water scenario is unlikely in Bundaberg as demand exceeds the yield of the BIA in most years.

Table 1. Calculated Cane Crop Yields (t cane/ha)

Irrigation	Low RASW			Medium RASW			High RASW		
Capacity:	A	B	C	A	B	C	A	B	C
50% Allocation									
Trickle	63.0	63.4	61.1	71.8	74.1	73.3	80.5	82.2	82.1
Winch	56.3	53.5	50.4	63.9	61.7	59.7	73.8	73.2	71.6
BPF	-	-	-	63.9	61.7	60.1	74.5	73.8	72.2
Standard Furrow	-	-	-	58.8	58.4	56.1	68.6	68.0	67.5
100% Allocation									
Trickle	81.7	85.7	85.8	92.0	99.6	102.3	101.6	107.6	111.1
Winch	75.4	72.2	69.0	84.7	83.4	81.5	95.6	95.9	95.7
BPF	-	-	-	85.1	84.0	81.5	97.0	97.6	96.5
Standard Furrow	-	-	-	74.6	75.2	73.1	85.5	85.5	86.0
Unlimited supply									
Trickle	110.4	125.7	131.2	113.5	128.5	134.8	116.0	130.2	135.8
Winch	107.9	116.3	120.9	111.5	120.3	126.6	116.3	123.6	129.5
BPF	-	-	-	111.5	120.3	126.6	117.1	124.7	129.9
Standard Furrow	-	-	-	101.0	111.2	119.7	108.5	116.7	124.2
Dryland		38.5			42.1			48.2	

Where: A = Design flow rate
B = Design flow rate + 30%
C = Design flow rate + 30% + 30%

The economics of converting to more efficient irrigation methods were calculated for 15% and 100% conversions (Tables 5 to 10). Profit generally decreased after converting to trickle irrigation (Tables 5 to 7). The exceptions were 30 ha farms on soils with low and medium RASW and water supplies of 100% allocation or higher, where profits increased (Table 5). Small farms usually have access to higher flow rates which increase crop yields by supplying more water during peak demand periods. On 50 ha and 70 ha farms and the 50% allocation scenario on 30 ha farms, profit decreased after conversion to trickle (Tables 5 to 7). The decrease in profit was largely due to higher depreciation which included the residual value of the old equipment such as high pressure pipelines and/or tailwater-return dams.

Benefit-cost ratios calculated over a 30 year period increased after conversion to trickle or best practice furrow irrigation from winch irrigation with limited water supplies, but decreased with unlimited water (Tables 8 to 10).

The quantity of irrigation water available influenced farm profit more than irrigation method. For example, at 100% allocation (5.3 ML/ha) for a 50 ha farm on medium soils, farm profit with trickle irrigation was 15% higher than with winch irrigation (Table 6). However, lifting the allocation to 150% increased farm profit by a further 107%, highlighting the value of increased water storage to the viability of the district.

Table 2. Effective rainfall (mm/year)

Irrigation	Low RASW			Medium RASW			High RASW		
Capacity:	A	B	C	A	B	C	A	B	C
50% Allocation									
Trickle	386	390	390	390	448	450	518	517	516
Winch	404	409	413	413	456	459	515	513	513
BPF	-	-	-	-	456	459	513	511	512
Standard Furrow	-	-	-	-	461	465	522	520	520
100% Allocation									
Trickle	363	365	364	364	428	430	499	497	493
Winch	377	380	385	385	429	429	481	480	483
BPF	-	-	-	-	428	429	479	477	480
Standard Furrow	-	-	-	-	439	439	497	498	500
Unlimited supply									
Trickle	335	326	323	323	403	404	491	486	481
Winch	327	315	309	309	366	356	457	444	435
BPF	-	-	-	-	366	356	457	441	434
Standard Furrow	-	-	-	-	382	367	472	459	442
Dryland		434			489			552	

Where: A = Design flow rate
B = Design flow rate + 30%
C = Design flow rate + 30% + 30%

Table 3. Average Gross Yearly Water Demand (ML/ha) with Unlimited Water Supply

Irrigation	Low RASW			Medium RASW			High RASW		
Capacity:	A	B	C	A	B	C	A	B	C
Trickle	8.89	9.76	10.24	7.79	8.33	8.42	6.82	7.25	7.36
Winch	9.93	11.93	13.39	8.87	10.21	11.48	7.69	8.54	9.25
BPF	-	-	-	8.80	10.12	11.39	7.48	8.40	9.06
Standard Furrow	-	-	-	9.86	11.65	13.39	8.73	9.91	11.11

<u>Where:</u> A = Design flow rate
B = Design flow rate + 30%
C = Design flow rate + 30% + 30%

Table 4: Water Use Efficiency for four irrigation methods for different water supply, soil type and flow rate cases.

	Low RASW			Medium RASW			High RASW		
Irrigation Method	A	B	C	A	B	C	A	B	C
50% Allocation									
Trickle	9.68	9.68	9.33	10.06	10.39	10.25	10.28	10.51	10.51
Winch	8.42	7.94	7.43	8.90	8.56	8.25	9.46	9.41	9.20
BPF				8.90	8.56	8.30	9.58	9.51	9.29
Standard Furrow				8.10	8.04	7.68	8.72	8.66	8.60
100% Allocation									
Trickle	9.15	9.58	9.60	9.60	10.40	10.66	9.87	10.48	10.86
Winch	8.31	7.93	7.54	8.90	8.70	8.50	9.46	9.50	9.45
BPF				8.95	8.77	8.50	9.61	9.69	9.55
Standard Furrow				7.69	7.76	7.54	8.33	8.32	8.35
Unlimited supply									
Trickle	9.02	9.65	9.74	9.54	10.40	10.82	9.89	10.75	11.16
Winch	8.17	7.71	7.34	8.79	8.67	8.42	9.49	9.52	9.52
BPF				8.84	8.73	8.47	9.72	9.73	9.69
Standard Furrow				7.29	7.19	7.02	8.07	8.05	8.00
Dryland		8.87			8.61			8.73	

<u>Where:</u> A = Design flow rate
B = Design flow rate + 30%
C = Design flow rate + 30% + 30%

Table 5. Profit ($ p.a.) from 30 ha farms for different soil types, irrigation methods and water supply sources with sugar price of $330 per tonne at design BIA delivery capacity.

	Profit ($ p.a.) for:								
	Low RASW			Medium RASW			High RASW		
	Surface	River	Bore	Surface	River	Bore	Surface	River	Bore
50% Allocation									
Green Field Development									
Trickle	-174	807	-2 004	6 636	7 617	4 806	11 880	12 861	10 051
Winch	-2 906	-1 927	-5 620	2 338	3 317	-375	9 696	10 675	6 983
BPF				4 954	5 827	2 659	12 703	13 576	10 408
Standard Furrow				3 799	4 671	1 504	9 982	10 855	7 687
100% Conversion									
Winch to BPF				670	1 081	-2 266	8 427	8 838	5 491
Winch to Trickle	-5 472	-4 879	-7 897	1 338	1 931	-1 087	6 583	7 176	4 158
BPF to Trickle				5 235	6 182	3 521	10 479	11 426	8 766
15% Conversion									
Winch +15%BPF				1 095	1 799	-1 618	8 531	9 235	5 818
Winch+15%Trickle	-3 556	-2 826	-6 161	1 924	2 654	-682	8 969	9 699	6 363
BPF +15%Trickle				4 569	5 582	2 468	11 927	12 940	9 826
100% Allocation									
Green Field Development									
Trickle	11 135	13 449	11 047	20 068	22 382	19 980	25 225	27 539	25 137
Winch	4 691	7 041	3 757	11 874	14 224	10 940	19 886	22 236	18 952
BPF	-	-	-	15 887	18 195	15 449	24 636	26 944	24 197
Standard Furrow	-	-	-	11 228	13 536	10 790	17 858	20 166	17 420
100% Conversion									
Winch to BPF	-	-	-	11 612	13 458	10 520	20 360	22 206	19 268
Winch to Trickle	5 440	7 367	4 757	14 373	16 299	13 690	19 530	21 456	18 847
BPF to Trickle	-	-	-	18 269	20 550	18 298	23 426	25 707	23 455
15% Conversion									
Winch +15% BPF	-	-	-	10 723	12 797	9 789	18 826	20 901	17 893
Winch+15%Trickle	4 461	6 562	3 636	11 921	14 022	11 095	19 472	21 573	18 646
BPF +15% Trickle	-	-	-	15 842	18 176	15 511	24 130	26 464	23 799
Unlimited Water									
Green Field Development									
Trickle	32 058	36 518	34 774	35 398	39 143	37 179	37 663	40 886	38 762
Winch	22 471	28 119	25 818	27 767	32 561	30 006	32 603	36 542	33 732
BPF	-	-	-	33 260	37 953	35 917	38 274	42 092	39 795
Standard Furrow	-	-	-	26 762	32 229	30 425	32 420	37 013	34 948
100% Conversion									
Winch to BPF	-	-	-	29 317	33 547	31 320	34 222	37 578	35 090
Winch to Trickle	25 724	29 796	27 844	29 277	32 634	30 463	31 697	34 532	32 201
BPF to Trickle	-	-	-	33 173	36 884	35 071	35 594	38 783	36 810
15% Conversion									
Winch +15% BPF	-	-	-	26 571	31 090	28 810	31 485	35 150	32 615
Winch+15%Trickle	22 539	27 780	25 789	27 638	32 043	29 803	32 121	35 712	33 229
BPF +15% Trickle	-	-	-	32 948	37 567	35 584	37 588	41 352	39 114

Table 6. Profit ($ p.a.) from 50 ha farms for different soil types, irrigation methods and water supply sources with sugar price of $330 per tonne at design BIA delivery capacity.

	Profit ($ p.a.) for:								
	Low RASW			Medium RASW			High RASW		
	Surface	River	Bore	Surface	River	Bore	Surface	River	Bore
50% Allocation									
Green Field Development									
Trickle	-6 108	-4 333	-6 889	3 285	5 060	2 504	12 678	14 453	11 897
Winch	-5 867	-4 061	-7 498	2 352	4 158	721	12 919	14 725	11 288
BPF				5 124	6 889	3 989	16 474	18 239	15 339
Standard Furrow				645	2 409	-491	11 082	12 846	9 946
100% Conversion									
Winch to Best PF				-587	618	-2 474	10 763	11 968	8 876
Winch to Trickle	-12 795	-11 408	-14 171	-3 402	-2 015	-4 778	5 991	7 378	4 615
BPF to Trickle				1 182	2 922	517	10 575	12 315	9 910
15% Conversion									
Winch +15%BPF				522	2 053	-1 109	11 220	12 751	9 589
Winch+15%Trickle	-7 238	-5 680	-8 761	1 112	2 669	-411	11 548	13 106	10 025
BPF +15%Trickle				3 884	5 675	2 856	14 973	16 764	13 946
100% Allocation									
Green Field Development									
Trickle	8 965	12 962	11 088	20 015	24 013	22 139	30 299	34 296	32 422
Winch	7 488	11 580	8 823	17 465	21 556	18 800	29 129	33 221	30 464
BPF	-	-	-	22 307	26 356	24 137	35 046	39 095	36 876
Standard Furrow	-	-	-	12 103	16 152	13 933	23 767	27 816	25 598
100% Conversion									
Winch to BPF	-	-	-	16 694	20 281	17 871	29 433	33 020	30 610
Winch to Trickle	1 774	5 384	3 302	12 825	16 435	14 353	23 108	26 718	24 636
BPF to Trickle	-	-	-	17 409	21 372	19 648	27 692	31 656	29 932
15% Conversion									
Winch +15% BPF	-	-	-	15 789	19 605	17 124	27 607	31 423	28 942
Winch+15%Trickle	6 237	10 079	7 680	16 367	20 209	17 810	27 725	31 567	29 168
BPF +15% Trickle	-	-	-	21 056	25 131	22 994	33 488	37 563	35 426
Unlimited Water									
Green Field Development									
Trickle	33 301	40 160	39 162	38 698	44 647	43 371	43 069	48 226	46 707
Winch	30 507	38 413	36 794	37 115	44 127	42 241	45 258	51 277	49 095
BPF	-	-	-	43 681	50 591	49 226	52 300	58 098	56 400
Standard Furrow	-	-	-	31 567	39 372	38 272	41 842	48 693	47 310
100% Conversion									
Winch to BPF	-	-	-	38 305	44 753	43 196	46 877	52 213	50 324
Winch to Trickle	25 464	31 935	30 729	31 066	36 628	35 144	35 616	40 386	38 659
BPF to Trickle	-	-	-	35 649	41 565	40 440	40 200	45 323	43 955
15% Conversion									
Winch +15% BPF	-	-	-	35 322	42 058	40 448	43 670	49 393	47 481
Winch+15%Trickle	29 216	36 734	35 431	35 636	42 259	40 689	43 373	49 023	47 163
BPF +15% Trickle	-	-	-	42 019	48 856	47 542	53 699	57 754	55 611

Table 7. Profit ($ p.a.) from 70 ha farms for different soil types, irrigation methods and water supply sources with sugar price of $330 per tonne at design BIA delivery capacity.

	Profit ($ p.a.) for:								
	Low RASW			Medium RASW			High RASW		
	Surface	River	Bore	Surface	River	Bore	Surface	River	Bore
<u>50% Allocation</u>									
Green Field Development									
Trickle	-18 489	-15 994	-18 739	-5 339	-2 844	-5 589	7 811	10 306	7 562
Winch	-20 947	-18 394	-22 197	-9 440	-6 887	-10 690	5 354	7 907	4 104
BPF				-2 866	-364	-3 522	13 024	15 526	12 368
Standard Furrow				-9 495	-6 993	-10 151	5 116	7 619	4 461
100% Conversion									
Winch to BPF				-12 320	-10 509	-13897	3 570	5 381	1 993
Winch to Trickle	-29 692	-27 663	-30 657	-16 542	-14 512	-17 506	-3 392	-1 362	-4 356
BPF to Trickle				-8 432	-5 978	-8 543	4 718	7 172	4 608
15% Conversion									
Winch +15%BPF				-11 543	-9 321	-12 793	3 434	5 656	2 183
Winch+15%Trickle	-22 733	-20 480	-23 854	-11 044	-8 790	-12 165	3 567	5 821	2 446
BPF +15% Trickle				-4 553	-2 020	-5 099	10 971	13 505	10 425
<u>100% Allocation</u>									
Green Field Development									
Trickle	2 612	8 219	6 428	18 083	23 690	21 899	32 480	38 087	36 296
Winch	-2 604	3 148	298	11 363	17 115	14 265	27 694	33 445	30 596
BPF	-	-	-	20 835	26 536	24 331	38 669	44 370	42 166
Standard Furrow	-	-	-	6 191	11 892	9 687	22 521	28 222	26 018
100% Conversion									
Winch to BPF	-	-	-	11 517	16 664	14 230	29 352	34 499	32 064
Winch to Trickle	-9 597	-4 455	-6 495	5 874	11 016	8 976	20 271	25 413	23 373
BPF to Trickle	-	-	-	13 984	19 550	17 940	28 380	33 947	32 336
15% Conversion									
Winch +15%BPF	-	-	-	9 475	14 896	12 377	26 020	31 441	28 922
Winch+15%Trickle	-4 170	1 282	-1 139	10 012	15 464	13 043	25 912	31 365	28 944
BPF +15% Trickle	-	-	-	19 185	24 917	22 811	36 590	42 322	40 216
<u>Unlimited Water</u>									
Green Field Development									
Trickle	36 692	46 301	45 736	44 256	52 588	51 632	50 358	57 588	56 295
Winch	29 017	40 113	38 857	38 407	48 251	46 622	49 962	58 416	56 372
BPF	-	-	-	50 286	60 001	58 993	62 533	70 678	69 202
Standard Furrow	-	-	-	32 969	43 935	43 300	47 500	57 135	56 103
100% Conversion									
Winch to BPF	-	-	-	41 447	50 607	49 369	53 598	61 189	59 483
Winch to Trickle	23 190	32 333	31 519	31 166	39 033	37 828	37 624	44 389	42 847
BPF to Trickle	-	-	-	39 275	47 567	46 792	45 734	52 924	51 811
15% Conversion									
Winch +15% BPF	-	-	-	36 378	45 891	44 593	48 246	56 329	54 604
Winch+15%Trickle	27 452	38 070	37 189	36 620	45 967	44 707	47 543	55 539	53 876
BPF +15% Trickle	-	-	-	48 149	57 756	56 804	59 619	67 676	66 263

Table 8. Gross Benefit-Cost Ratio of 30 ha farms for different soil types, irrigation methods and water supply sources with sugar price of $330 per tonne at design BIA delivery capacity.

	Gross Benefit-Cost Ratio for:								
	Low RASW			Medium RASW			High RASW		
	Surface	River	Bore	Surface	River	Bore	Surface	River	Bore
50% Allocation									
Green Field Development									
Trickle	1.19	1.23	1.19	1.34	1.38	1.34	1.45	1.48	1.45
Winch	1.07	1.10	1.05	1.19	1.22	1.17	1.35	1.39	1.34
BPF				1.25	1.28	1.24	1.43	1.46	1.41
Standard Furrow				1.22	1.25	1.21	1.37	1.40	1.36
100% Conversion									
Winch to BPF				1.22	1.24	1.22	1.39	1.42	1.40
Winch to Trickle	1.14	1.16	1.15	1.28	1.31	1.30	1.39	1.41	1.40
BPF to Trickle				1.31	1.35	1.34	1.42	1.46	1.45
15% Conversion									
Winch +15%BPF				1.21	1.24	1.22	1.38	1.41	1.39
Winch+15%Trickle	1.09	1.12	1.11	1.22	1.25	1.24	1.38	1.41	1.39
BPF +15% Trickle				1.29	1.33	1.31	1.46	1.50	1.48
100% Allocation									
Green Field Development									
Trickle	1.39	1.47	1.45	1.55	1.63	1.61	1.64	1.72	1.70
Winch	1.21	1.28	1.24	1.35	1.42	1.39	1.49	1.57	1.53
BPF	-	-	-	1.44	1.53	1.50	1.60	1.69	1.66
Standard Furrow	-	-	-	1.35	1.44	1.41	1.48	1.57	1.54
100% Conversion									
Winch to BPF	-	-	-	1.62	1.77	1.79	1.73	1.86	1.87
Winch to Trickle	1.58	1.71	1.73	1.65	1.77	1.78	1.71	1.81	1.82
BPF to Trickle	-	-	-	1.69	1.81	1.83	1.74	1.85	1.87
15% Conversion									
Winch +15% BPF	-	-	-	1.37	1.44	1.43	1.51	1.59	1.58
Winch+15%Trickle	1.24	1.31	1.30	1.38	1.46	1.45	1.52	1.60	1.59
BPF + 15% Trickle	-	-	-	1.48	1.57	1.57	1.64	1.73	1.73
Unlimited Water									
Green Field Development									
Trickle	1.66	1.81	1.81	1.74	1.87	1.86	1.79	1.90	1.89
Winch	1.41	1.56	1.55	1.51	1.65	1.64	1.62	1.74	1.72
BPF	-	-	-	1.64	1.80	1.80	1.75	1.89	1.88
Standard Furrow	-	-	-	1.53	1.70	1.71	1.65	1.81	1.80
100% Conversion									
Winch to BPF	-	-	-	1.41	1.49	1.48	1.57	1.65	1.64
Winch to Trickle	1.33	1.39	1.39	1.48	1.55	1.55	1.57	1.64	1.64
BPF to Trickle	-	-	-	1.51	1.59	1.60	1.60	1.68	1.69
15% Conversion									
Winch + 15%BPF	-	-	-	1.53	1.67	1.68	1.64	1.76	1.77
Winch+15%Trickle	1.44	1.59	1.61	1.54	1.68	1.70	1.64	1.76	1.77
BPF + 15% Trickle	-	-	-	1.68	1.84	1.86	1.78	1.93	1.94

Table 9. Gross Benefit-Cost Ratio of 50 ha farms for different soil types, irrigation methods and water supply sources with sugar price of $330 per tonne at design BIA delivery capacity.

	Gross Benefit-Cost Ratio for:								
	Low RASW			Medium RASW			High RASW		
	Surface	River	Bore	Surface	River	Bore	Surface	River	Bore
50% Allocation									
Green Field Development									
Trickle	1.09	1.12	1.11	1.21	1.24	1.22	1.32	1.35	1.33
Winch	1.02	1.05	1.03	1.13	1.17	1.14	1.27	1.30	1.28
BPF				1.17	1.20	1.19	1.32	1.35	1.33
Standard Furrow				1.11	1.14	1.12	1.25	1.28	1.26
100% Conversion									
Winch to BPF				1.15	1.18	1.17	1.29	1.32	1.32
Winch to Trickle	1.06	1.08	1.08	1.17	1.20	1.19	1.28	1.31	1.30
BPF to Trickle				1.17	1.20	1.20	1.28	1.31	1.31
15% Conversion									
Winch +15% BPF				1.15	1.18	1.17	1.28	1.32	1.31
Winch+15%Trickle	1.05	1.08	1.08	1.17	1.20	1.19	1.30	1.33	1.32
BPF +15% Trickle				1.21	1.24	1.24	1.35	1.39	1.38
100% Allocation									
Green Field Development									
Trickle	1.25	1.31	1.31	1.36	1.43	1.43	1.47	1.54	1.54
Winch	1.17	1.24	1.23	1.28	1.35	1.34	1.40	1.47	1.46
BPF	-	-	-	1.35	1.42	1.42	1.48	1.56	1.56
Standard Furrow	-	-	-	1.23	1.30	1.30	1.37	1.44	1.44
100% Conversion									
Winch to BPF	-	-	-	1.50	1.62	1.64	1.59	1.70	1.72
Winch to Trickle	1.40	1.50	1.53	1.46	1.56	1.58	1.52	1.60	1.62
BPF to Trickle	-	-	-	1.46	1.56	1.58	1.52	1.60	1.62
15% Conversion									
Winch +15% BPF	-	-	-	1.30	1.37	1.37	1.42	1.49	1.50
Winch+15%Trickle	1.20	1.27	1.27	1.31	1.38	1.39	1.43	1.50	1.51
BPF +15% Trickle	-	-	-	1.38	1.46	1.47	1.51	1.60	1.61
Unlimited Water									
Green Field Development									
Trickle	1.45	1.57	1.58	1.51	1.62	1.63	1.56	1.66	1.66
Winch	1.35	1.46	1.47	1.42	1.53	1.53	1.51	1.61	1.61
BPF	-	-	-	1.51	1.64	1.65	1.61	1.72	1.73
Standard Furrow	-	-	-	1.39	1.52	1.54	1.50	1.63	1.64
100% Conversion									
Winch to BPF	-	-	-	1.33	1.40	1.40	1.46	1.54	1.54
Winch to Trickle	1.21	1.27	1.28	1.32	1.38	1.39	1.42	1.49	1.50
BPF to Trickle	-	-	-	1.32	1.39	1.40	1.42	1.49	1.50
15% Conversion									
Winch +15% BPF	-	-	-	1.43	1.54	1.57	1.53	1.63	1.65
Winch+15%Trickle	1.37	1.49	1.52	1.45	1.56	1.58	1.53	1.64	1.65
BPF +15% Trickle	-	-	-	1.54	1.67	1.70	1.71	1.79	1.81

Table 10. Gross Benefit-Cost Ratio of 70 ha farms for different soil types, irrigation methods and water supply sources with sugar price of $330 per tonne at design BIA delivery capacity.

	Gross Benefit-Cost Ratio for:								
	Low RASW			Medium RASW			High RASW		
	Surface	River	Bore	Surface	River	Bore	Surface	River	Bore
50% Allocation									
Green Field Development									
Trickle	0.99	1.01	1.00	1.10	1.12	1.11	1.20	1.23	1.22
Winch	0.91	0.93	0.92	1.01	1.04	1.02	1.13	1.16	1.15
BPF				1.06	1.08	1.07	1.19	1.22	1.21
Standard Furrow				0.99	1.02	1.01	1.12	1.15	1.14
100% Conversion									
Winch to BPF				1.04	1.06	1.06	1.17	1.20	1.19
Winch to Trickle	0.96	0.98	0.98	1.06	1.09	1.09	1.17	1.19	1.19
BPF to Trickle				1.08	1.10	1.10	1.18	1.21	1.21
15% Conversion									
Winch +15% BPF				1.03	1.05	1.05	1.15	1.18	1.18
Winch+15%Trickle	0.93	0.96	0.95	1.04	1.06	1.06	1.16	1.18	1.18
BPF +15% Trickle				1.07	1.10	1.10	1.20	1.23	1.23
100% Allocation									
Green Field Development									
Trickle	1.15	1.20	1.20	1.25	1.31	1.32	1.35	1.41	1.42
Winch	1.06	1.11	1.11	1.16	1.21	1.21	1.27	1.33	1.33
BPF	-	-	-	1.23	1.29	1.29	1.36	1.42	1.42
Standard Furrow	-	-	-	1.12	1.18	1.17	1.24	1.30	1.30
100% Conversion									
Winch to BPF	-	-	-	1.38	1.48	1.50	1.47	1.56	1.58
Winch to Trickle	1.29	1.38	1.40	1.35	1.43	1.45	1.40	1.47	1.49
BPF to Trickle	-	-	-	1.36	1.45	1.47	1.41	1.49	1.51
15% Conversion									
Winch +15% BPF	-	-	-	1.18	1.23	1.24	1.29	1.35	1.36
Winch+15%Trickle	1.08	1.13	1.14	1.18	1.24	1.25	1.29	1.35	1.36
BPF +15% Trickle	-	-	-	1.24	1.31	1.32	1.37	1.44	1.45
Unlimited Water									
Green Field Development									
Trickle	1.35	1.44	1.46	1.40	1.49	1.50	1.45	1.53	1.54
Winch	1.23	1.33	1.34	1.30	1.39	1.40	1.38	1.47	1.47
BPF	-	-	-	1.39	1.50	1.51	1.48	1.58	1.58
Standard Furrow	-	-	-	1.27	1.39	1.40	1.38	1.48	1.50
100% Conversion									
Winch to BPF	-	-	-	1.21	1.27	1.28	1.34	1.40	1.41
Winch to Trickle	1.10	1.15	1.16	1.21	1.26	1.27	1.31	1.36	1.37
BPF to Trickle	-	-	-	1.23	1.28	1.29	1.32	1.38	1.39
15% Conversion									
Winch +15% BPF	-	-	-	1.31	1.41	1.43	1.40	1.49	1.50
Winch+15%Trickle	1.25	1.35	1.37	1.32	1.41	1.43	1.40	1.48	1.50
BPF +15% Trickle	-	-	-	1.40	1.51	1.53	1.49	1.59	1.61

The effect of different electricity tariffs on farm profit was determined by modelling with delivery flow rates reduced to half system capacity to simulate night-only irrigation for winch systems at 100% allocation (Table 11). Profits increased on soils with low and medium RASW, but decreased on soils with high RASW due to not being able to use all the water allocated at half flow rate in 16 out of the 24 years modelled.

Table 11. Profit ($ p a) for two electricity tariffs (and therefore daily flow rates) for a 50 ha farm with 100% allocation and a sugar price of $330/t.

	Low RASW	Medium RASW	High RASW
Channel Supply			
Night only	12 335	18 474	25 074
Day and Night	7 488	17 465	29 129
River Supply			
Night only	16 727	22 866	29 466
Day and Night	11 580	21 556	33 221
Bore Supply			
Night only	14 030	20 170	26 769
Day and Night	8 823	18 800	30 464

7.2 Objective 2: Collate information on existing irrigation methods on representative farms.

The output of the model was validated by comparing simulated cane yields for winch irrigation on soils with medium RASW with the 1995 district average yields (Bundaberg Cane Productivity Committee, 1995) for equivalent levels of water use (Table 12).

Table 12. Simulated cane yield (t/ha) compared to 1995 district average yield (t/ha)

Water use (ML/ha)	Simulated cane yield	1995 District average yield
0 - Dryland	42	45
3	64	69
5	85	84
9	112	111

7.3 Objective 3: Identify resulting system requirements to provide optimum irrigation capacity and irrigation management.

System requirements to provide optimum irrigation capacity were examined in terms of flow rate and the quantity of water required to meet crop demand not satisfied by rainfall for each irrigation method.

Effective rainfall, the quantity of rainfall actually used by the plant, was calculated by the model for each scenario (Table 2). Average annual effective rainfall ranged from 552 mm for soils with high RASW in a dryland situation to 309 mm on soils with low RASW fully irrigated by winch.

The Bundaberg Irrigation Area (BIA) was designed with a flow rate sufficient to supply 100 mm of irrigation water to 80% of the assigned area in 15 days. To test whether this was adequate, model runs were made with flow rates increased in two steps of 30%. The effects of increased irrigation capacity are shown in Tables 1 to 4.

With limited water, increased flow rate had only marginal effects on crop growth water use and therefore cane yield. Yields tended to increase with trickle irrigation, but decrease for furrow and winch irrigation. The decrease with winch was most marked on soils with low RASW indicating a conservative use strategy (reduced flow rate) may be advantageous with limited water supplies on these soils. Increased flow rate increased yield for trickle irrigation on all soils with 100% allocation. Therefore, farms where pumping capacity is not limited by scheme flow rate obtain higher returns from trickle irrigation. Table 11 indicates a similar result.

With an unlimited water supply, the design flow rate of the BIA was grossly inadequate. As shown in Table 1, simulated crop yields increased markedly with the higher flow rates. Crop yields rose by approximately 20 t cane/ha with increased flow rate on all soil types. The quantity of irrigation water that may be effectively used by sugarcane at each flow rate for each soil category and irrigation method was calculated by the water balance model (Table 3). Gross yearly demand ranged from 6.82 ML/ha with trickle irrigation at design flow rate on soils with high RASW to 13.39 ML/ha for winch irrigation with high flow rates on soils with low RASW.

The irrigation requirement for optimum yield of sugar cane at Bundaberg exceeds allocation and varies considerably with irrigation method and soil type. An allocation of 100% amounts to 5.3 ML/ha when cane is grown on 85% of the 1970 assigned area and is less on many farms due to expansion since 1970. Therefore, an allocation of 100% provides, at best, only 68% of the water required by trickle irrigation for optimum yield on soils with medium RASW. This highlights the opportunity to increase cane yield by providing on-farm storage to harvest run-off and store out-of-allocation water. It also shows that any water saved by improvements in irrigation efficiency will be used in situ to meet crop requirements.

7.4 Objective 4: Calculate costs and benefits of changing from the present to the optimum method.

The costs and benefits for each irrigation method were calculated for different water supply sources, water supply quantities, flow rates, soil types and sugar price scenarios.

A summary of the capital costs for green field development, 15% conversion and 100% conversion are shown in Table 13. For detailed costing of the components see Table 3.2 of Volume 1 and Depreciation Schedules in Volume 2 of SKM’s report.

Table 13. Capital costs ($) for green field development, 15% and 100% conversion for 30, 50 and 70 ha farms.

	Capital Development Costs ($) for:								
	30 ha Farms on:			50 ha Farms on:			70 ha Farms on:		
	Surface	**River**	**Bore**	**Surface**	**River**	**Bore**	**Surface**	**River**	**Bore**
Green Field Development									
Trickle	97 071	97 520	116 074	154 754	155 203	173 757	206 700	207 239	229 504
Winch	47 906	48 921	75 035	67 605	70 979	94 733	100 647	101 865	133 201
BPF	45 744	46 193	64 747	73 015	74 390	95 897	89 077	90 727	116 536
Standard Furrow	36 244	36 693	55 247	63 015	64 390	85 897	78 577	80 227	106 036
100% Conversion									
Winch to B PF	30 471	34 789	31 826	51 033	52 992	52 388	70 894	64 596	61 041
Winch to Trickle	80 640	83 398	77 617	125 768	126 167	122 746	168 362	171 672	164 735
BPF to Trickle	54 445	54 734	53 447	121 818	121 181	116 941	123 118	122 354	117 265
15% Conversion									
Winch +15% BPF	11 839	14 199	11 839	18 151	18 151	18 151	20 717	23 549	20 717
Winch+15%Trickle	13 519	15 654	12 594	20 288	20 064	19 363	27 731	30 293	26 621
BPF +15% Trickle	13 518	14 221	16 474	20 288	20 064	19 363	28 730	28 462	27 622

Operating costs for each scenario are shown in the Economic Analysis spreadsheet printouts in Volume 2 of SKM's report. Table 14 shows annual irrigation operating costs for each irrigation method on 30, 50 and 70 ha farms on soils with medium RASW and a supply of 100% allocation of surface water.

Farm income for each scenario was calculated using the crop yields shown in Table 1 and a CCS of 14.3.

Table 14. Annual irrigation operating costs and depreciation ($) for each irrigation method on farms with medium RASW soils, on surface water at 100% allocation.

Farm size and Item	Trickle	Winch	Best Practice Furrow	Standard Furrow
30 ha Farms				
Water	5 113	5 113	5 113	5 113
Electricity	1 138	3 679	1 037	1 037
Additional Labour	-	935	935	935
Less fertiliser	(765)	-	-	-
Depreciation	7 531	3 536	2 641	2 158
Total	**13 017**	**13 263**	**9 726**	**9 243**
50 ha Farms				
Water	8 522	8 522	8 522	8 522
Electricity	1 778	5 773	1 618	1 618
Additional labour	-	1 183	1 183	1 183
Less fertiliser	(1 275)	-	-	-
Depreciation	11 821	4 448	3 950	3 450
Total	**20 846**	**19 926**	**15 273**	**14 773**
70 ha Farms				
Water	11 930	11 930	11 930	11 930
Electricity	2 481	8 074	2 258	2 258
Additional labour	-	2 367	2 367	2 367
Less fertiliser	(1 785)	-	-	-
Depreciation	16 068	7 388	4 956	4 439
Total	**28 694**	**29 759**	**21 511**	**20 994**

7.5 Objective 5: Present the information in a readily assimilated form.

The information gained from the analysis was presented by SKM in a comprehensive report. The report contains a number of tables and figures which enable readers to assimilate the results. A brochure highlighting the major findings of the study was also prepared by BSES for distribution to cane growers and industry service personnel.

The Economic Model developed by SKM is also available. The model runs on Microsoft Excel and allows the user to change inputs or assumptions and thereby examine a specific situation for a grower.

7.6 Objective 6: Extend the information to cane growers, agribusiness, banks and accountants as part of Project BS127S and through specific workshops and information brochures.

SKM presented their report on the project to a workshop of 40 local sugar industry representatives and staff of agribusiness, banks, BSES, Bundaberg Sugar Limited, CANEGROWERS, CPPBs, QDNR and QDPI. Copies of Volume 1 of SKM's report were supplied to each organisation. Copies of Volume 2 were restricted to BSES, Bundaberg Sugar Limited, CANEGROWERS, QDNR and QDPI.

Two thousand copies of an eight page brochure summarising the project findings were prepared by BSES. These brochures were forwarded to all Bundaberg and Isis district cane growers, all CPPB staff who attended the Irrigation and Drainage workshop at Proserpine, local agribusiness and BSES centers. The brochures were also available at the CRC display at the 1997 ASSCT Conference and the 1997 Agrotrend.

The findings of the project were presented to the CPPB Irrigation and Drainage workshop as well as in articles in the BSES Bulletin, CANEGROWER magazine, local media and newsletters. The information was also presented at all Bundaberg district cell group meetings, the Fairymead Harvest Breakfast, field days and Agrotrend. Two ASSCT papers were presented at the 1997 conference.

Reaction to the information to date has been very positive. Local industry recently used information from the study to support their application to Water Infrastructure Task Force for more water storages and there is little doubt that the report will become a major reference on crop irrigation requirements and the economics of irrigation at Bundaberg.

The report supports the trend to trickle irrigation, improvements to furrow irrigation by laser leveling and tailwater recycling, and more on-farm storage. Access to this financial information will assist cane growers and their financiers make informed decisions regarding capital investment in irrigation equipment to improve farm viability.

As a result of the participative approach taken in the conception and implementation of this project, extension agencies and financiers at Bundaberg are already aware of the findings, and the project has influenced the current improvements in irrigation efficiency. Crop water use efficiency (WUE) has risen from 8.0 t cane/ML in 1993 to 10.5 t cane/ML in 1996. While the improvement has been hastened by water shortages, this project has helped decision makers determine the best course of action. For some growers with very low water allocations, the project also emphasised that there was insufficient cash flow to make substantial investment.

8.0 IMPLICATIONS AND RECOMMENDATIONS

The outcomes of the project planned initially were:

- Increased water use efficiency and increased profitability from irrigated sugar cane production.
- Improved sustainability of irrigated sugar cane production through more effective and efficient irrigation minimising off-farm impacts.

Cane growers in the Bundaberg/Isis area are actively seeking ways to improve irrigation efficiency due to inadequate water supplies. For the 1996-97 water year allocations have been set at 65%. As this is about one third of crop requirements, it is imperative that cane growers achieve high irrigation efficiency to maximise farm profit.

An analysis of WUE for the 1996 crop accounted for 98 232 ML of irrigation water, applied to 28 017 ha of sugarcane in the Bundaberg district. This produced 2,410,172 t cane. Effective rainfall averaged 468 mm giving a crop WUE of 10.51 t cane/ML. Cane growers are therefore achieving close to the modelled crop WUE for trickle irrigation (Table 4). If the modelled crop WUE is correct, this indicates that further improvements in crop WUE are likely to be relatively small on many farms and these farms should focus on increasing on-farm storage. Extension efforts to increase farm WUE should focus on the farms significantly below average. The current high WUE has allowed the Bundaberg crop to be maintained despite reduced water supplies. If the WUE was still 8.0 as in 1993, the district would have produced 246,562 t cane less in 1996, reducing district income by $12 million.

The analysis shows that any moves local industry or individual farmers can make to restore water allocation to 100% and, if possible, improve it to 150%, would have major impacts on district production and profitability. From Table 1, improvements in water supply to 100% would increase yield by about 20 t cane/ha, and to 150% would further increase yield by another 20 t cane/ha.

This supports the industry’s case for the building of Walla Weir on the Burnett River and the current proposal to the Water Infrastructure Task Force for additional storages. The information also provides base data for growers wishing to carry out economic evaluations for increased water storage on their own properties.

Sustainability issues such as the containment of irrigation tailwater and reduced deep percolation of irrigation water are also addressed indirectly by the findings of this project. The installation of tailwater return systems for furrow irrigation will minimise tailwater runoff and restrict the off-farm movement of sediment, fertilisers and pesticides. Likewise, installation of trickle irrigation on porous soils will provide greater control over the quantity of water applied reducing deep drainage losses which may carry nutrients and pesticides into groundwater. Therefore, recommendations to cane growers to adopt these irrigation methods will assist the long term sustainability of the industry.

The project also identified several areas for further study. For the water balance modelling, assumptions were made regarding input data. For some of the assumptions there was very little substantiated information. Areas where further research is required to identify parameters are:

- Is the 3.0 mm interception loss used correct for sugarcane? What effect does a green cane trash blanket have on this?
- Measurements of irrigation distribution efficiencies are required for each method under a range of conditions, particularly for trickle irrigation.
- Do the DNR Farm Water Supplies Design manual recommendations for leaching losses apply to Bundaberg soils?
- What are the water holding capacities of Bundaberg soils? Soil RASW has a significant effect on effective rainfall and irrigation economics. There is some disagreement with CSIRO regarding the water holding capacities of Bundaberg soils. This needs to be resolved.
- A soil water level/crop growth algorithm for sugarcane needs to be developed and made available to all researchers in the industry. For the analysis, it was assumed that 12.2 t cane were produced for each megalitre of water consumed while soil moisture was above the crop stress soil moisture level or refill point. The model also assumed that there was no crop growth for water used when soil moisture levels were below the refill point. In practice, growth varies with the level of soil moisture. As the soil moisture approaches and drops below the refill point, growth slows. If this relationship between soil moisture and growth was available, SKM's water balance model would give a more accurate estimate of crop yield and irrigation efficiency for each scenario.
- To include a cultivation practice such as green cane trash blanketing in the water balance model, data is required on changes to irrigation efficiency and interception loss. For this project, an attempt was made to model green cane by reducing crop factors by 25% from June to November. This did not work as it simply reduced the water consumed by the crop and therefore yield. The effects of a green cane trash blanket are to increase irrigation efficiency by reducing evaporation losses from the soil surface. It does not reduce the water consumed by the plant for growth. Work needs to be done to measure the effects of green cane trash blankets on irrigation efficiency and effective rainfall.
- The water yields of storages serving the Bundaberg Irrigation Area have not been calculated using daily models. They were established in the 1960's using monthly rainfall and evaporation data. Modern computer technology allows hydrologic modelling using daily rainfall and evaporation data. Accurate system water yields will provide better information for investment decisions as the quantity of irrigation water has a major impact on farm profit.
- Reducing the flow rate to half the system flow rate increased yield on soils with low RASW but decreased yield on soils with high RASW with 100% allocation. This indicates there are optimum flow rates for different water allocations which depend on soil water holding capacity. Additional modelling to establish this relationship may assist to answer the question of how to use a limited water supply?

9.0 INTELLECTUAL PROPERTY

No patents or licenses have been applied for as a result of this research.

Although SKM carried out modifications to their WATBAL Model for this project, the model is their property and is not available commercially. However, if further use of the model is required, SKM are willing to conduct further model runs for a fee. SKM frequently contract irrigation projects for the sugar industry. The model is currently being used by SKM for a project for the Burdekin Water Board.

The economic model prepared for the project by SKM has been released to the Bundaberg Cane Productivity Committee. It runs on Excel and the files containing the model are available to extension officers and other farm advisers.

10.0 TECHNICAL SUMMARY

The aim of the project was to hasten the adoption of more efficient irrigation practices in the Bundaberg district by producing economic and financial information to support capital investment decisions.

The analysis considered four irrigation methods, three farm sizes, three soil categories, three water allocations, three system capacities, three water sources, one water use efficiency factor, two cultivation practices, two electricity tariffs and three sugar prices. The water balance modelling was conducted with 24 years of daily rainfall and evaporation records.

SKM developed their water balance model to simulate the water demand of sugarcane under various irrigation management scenarios. After some initial runs of the model, it was decided to calculate crop growth water use as well as total water use by the crop. Crop growth water use was a better parameter for the calculation of crop yield as it discounted any crop water use during stress periods. Cane yield was calculated from crop growth water use for each case. The calculated yields agreed closely with observed yields on district farms. This showed that SKM's WATBAL Model, as modified, was a useful research tool for determining irrigation requirements and yield of sugarcane with changing irrigation practices.

SKM carried out preliminary designs for each irrigation system and each farm size, irrigation method and water source. Capital and operating costs were also determined for each case. An economic model was set up to calculate benefit/cost ratios, farm gross margins and farm profit.

Effective rainfall, calculated using daily rainfall and crop use with simulated irrigation scheduling, produced interesting results. Average effective rainfall ranged from 552 mm in a dryland situation on soils with high Readily Available Soil Water (RASW) to 309 mm in a fully irrigated situation using winch irrigation on soils with low RASW. Effective rainfall was therefore between 30% and 50% of total rainfall, much lower than the 70% assumed previously. This difference in effective rainfall between soil types and irrigation intensity helps to explain the wide variation in yield for any level of water use in the district. The difference of 243 mm between the highest and lowest effective rainfall would result in a yield difference of 30 t cane/ha based on effective rainfall alone. The effect of soil type and irrigation intensity on effective rainfall therefore needs to be considered when benchmarking water use efficiency.

Irrigation water requirements for sugarcane at Bundaberg ranged from 6.82 ML/ha with trickle irrigation on soils with high RASW at design flow rate to 13.39 ML/ha with winch irrigation on soils with low RASW at high flow rates. This highlights that the original allocation of 6 ML/ha for the Bundaberg scheme did not allow for on-farm distribution efficiency and applied only to soils with high RASW.

Increases in system capacity also improve cane yield when water supplies are unlimited. Increasing the supply flow rate improved crop yield by approximately 20 t cane/ha for all irrigation methods and soil types. This showed that there are potential yield gains by providing on-farm storage to help meet crop requirements at peak demand periods.

The economic analysis showed that best practice furrow irrigation was generally the most profitable and had the highest benefit/cost ratios of the irrigation methods considered. However, trickle irrigation was superior to BPF for medium RASW soils on 30 ha farms. Also, trickle irrigation generally gave higher profits and benefit-cost ratios than winch irrigation, despite the high capital cost of trickle irrigation. The exceptions were on soils of high RASW with unlimited water supplies when winch irrigation was more profitable than trickle in some cases. However, the unlimited water scenario is unlikely in Bundaberg as demand exceeds the yield of the BIA in most years. Cane growers should examine BPF as first choice and consider trickle for all situations not suited to BPF.

The economics of converting to more efficient irrigation methods were also calculated for 15% and 100% conversion. Profit generally decreased after converting to BPF or trickle irrigation. Some exceptions where profits increased were 30 ha farms on medium RASW soils converting to trickle, and 50 and 70 ha farms on high RASW soils converting to BPF. On 30 ha farms, profits increased after conversion to trickle on soils with low to medium RASW for 100% allocation and unlimited water supplies, but decreased with 50% allocation The general decrease in profit after 100% conversion was the result of higher depreciation which included the residual value of the old equipment such as high pressure pipelines and tailwater-return dams.

Benefit-cost ratios calculated over a 30 year period generally increased after conversion to trickle or BPF irrigation from winch irrigation with limited water supplies, but decreased with unlimited water.

The quantity of irrigation water available influenced farm profit more than irrigation method. For example, at 100% allocation (5.3 ML/ha) for a 50 ha farm on medium RASW soils, farm profit with trickle irrigation was 15% higher than with winch irrigation. However, lifting the allocation to 150% increased farm profit by a further 107%. This highlights the value of increased water storage to the viability of the district.

11.0 REFERENCES

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Smith, M A, Willcox, T G, Culpitt, R and Bartholomew, B (1994). Identifying factors limiting cane farm productivity: results of a Bundaberg farm study. Proc Aust Soc Sugar Cane Technol. 16: 164-168.

Bundaberg Cane Productivity Committee (1995). Crop yield and water use, 4-5. Sugar Cane Yields & Varietal Performance Bundaberg District 1995. Bundaberg Sugar Limited.

12.0 APPENDICES

Appendix 1 Sinclair Knight Merz (1996) Bundaberg Irrigation Economic Assessment Report. Volumes 1 and 2.

Appendix 2 Bundaberg Cane Productivity Committee. Brochure 'Economics of Irrigation Methods and Programs at Bundaberg.'

Appendix 3 1997 ASSCT papers:

Willcox, T G, Kane, R and Smith, M A (1997) Determining irrigation requirements and crop yield using a water balance model. Proc Aust Soc Sugar Cane Technol. 19: 270-279.

Willcox, T G, Kane, R, Smith, M A and Mackson, J (1997) An economic evaluation of irrigation methods at Bundaberg. Proc Aust Soc Sugar Cane Technol. 19: 280-284.

Appendix 4 BSES Bulletin article:

Willcox, T G (1997) Economics of irrigation studied at Bundaberg. BSES Bulletin No.57 January 1997: 3-5.

Appendix 5 Extract from Irrigation and Drainage Course booklet:

Willcox, T G (1996) Economics of Irrigation, Bundaberg Case Study. BSES Irrigation and Drainage Course Workshop Manual, Laguna Quays Resort, Proserpine, October 24 & 25, pp 28-35.

Appendix 6 Article in Queensland Country Life:

Limited water resources focus of sugar industry. Queensland Country Life, May 1, 1997 p.113.

Appendix 7 Bundaberg Cane Productivity Committee newsletter, November 1996.

APPENDIX 1

SINCLAIR KNIGHT MERZ (1996)

BUNDABERG IRRIGATION ECONOMIC ASSESSMENT REPORT

VOLUMES 1 AND 2

Note: One copy of this report (Volumes 1 and 2) was supplied to SRDC for information.

Please refer to BSES for access to a copy of the report.

APPENDIX 2

BUNDABERG CANE PRODUCTIVITY COMMITTEE

BROCHURE

ECONOMICS OF IRRIGATION METHODS AND PROGRAMS AT BUNDABERG

APPENDIX 3

1997 ASSCT PAPERS

APPENDIX 4

BSES BULLETIN ARTICLE

APPENDIX 5

EXTRACT

FROM

IRRIGATION AND DRAINAGE COURSE BOOKLET

APPENDIX 6

ARTICLE IN QUEENSLAND COUNTRY LIFE

APPENDIX 7

BUNDABERG CANE PRODUCTIVITY COMMITTEE

NEWSLETTER, NOVEMBER 1996