BUREAU OF SUGAR EXPERIMENT STATIONS
QUEENSLAND AUSTRALIA

AN INVESTIGATION OF FACTORS AFFECTING ASH IN FIRST EXPRESSED JUICE IN THE ROCKY POINT MILL AREA

by

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Bundaberg

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SUMMARY

An investigation into factors affecting ash in the cane supply to the Rocky Point Sugar Mill was carried out following extensive sampling of first expressed juice in October 1979. The study was divided into two phases.

Phase I was a detailed study of the chemical composition of 110 juice samples and associated field data.

Phase II was a mill area survey of ash loadings in first expressed juice.

The detailed investigation of juice and soil composition clearly implicated soil salinity as the most important factor contributing to the high ash levels in first expressed juice and ultimately in raw sugar. Ash per cent juice and ash per cent impurities averaged 0.70 and 28.8 per cent during the study period. In the 110 juice samples the mean concentrations of cations were Ca^{++} (4.8 me/L), Mg^{++} (18.0 me/L), Na^{+} (4.7 me/L), K^{+} (64.6 me/L) and Fe^{++} (1.5 me/L). The mean potassium and chloride concentrations are well above average. Mean chloride and phosphorus levels were 42.0 me/L and 115 p.p.m. respectively.

Juice potassium levels were strongly correlated with soil salinity and soil potassium levels: salinity was the more important parameter. In this study usage of potassium fertilizer had no measurable influence on juice potassium or ash levels.

Ash, potassium and chloride concentrations in juice were highly significantly correlated with depressions in c.c.s.. The effect appeared more related to soil salinity than effects of specific ions.

The mill area study revealed that high ash farms (ash $>$ 0.7 per cent) were associated with areas of peaty and/or saline gley soils, while farms with ash levels below 0.7 per cent were generally located on fine and medium textured humic gley soils. The Phase II study also pointed to significant negative correlations between ash and c.c.s. within varieties. Ash levels of NCo310, Q90, H48-3116 and Pindar were not significantly different, but values were significantly lower than those of Q86.

It was concluded that before any significant reduction of ash levels in first expressed juice can be expected, major improvements to soil profile and farm drainage are necessary to promote leaching and to lower saline water-table levels. Further research on a number of aspects should be undertaken before large scale implementation of such drainage works is contemplated.

BUREAU OF SUGAR EXPERIMENT STATIONS

AN INVESTIGATION OF FACTORS AFFECTING ASH IN FIRST EXPRESSED JUICE IN THE ROCKY POINT MILL AREA

1. INTRODUCTION

The Rocky Point mill area has historically produced some of the highest ash raw sugars in Queensland. On average over five seasons 1976-1980 this mill was ranked highest in the State for ash per cent impurities in total sugar, with the figure varying between 44.6 and 51.8 per cent.

The high ash loading in raw sugar is having a direct effect on the miller through penalties imposed by ash in the net titre formula. Thus because of the effect on net titre ash will also be affecting the factory coefficient of work. A previous study by Kingston and Kirby (1979) at Qunaba Mill showed that potassium ions were present in high concentration in juice and represented the dominant cation in ash. Several authors including Irvine (1979) and Clarke (1981) have reported that potassium ion concentrations are largely unaffected by clarification and have an enhancing effect on solubility of sucrose. Thus potential exists for poorer recovery of sucrose from high potassium ash juices.

Because of a deep concern at the level of ash in Rocky Point sugars and the lack of information on inorganic composition of juices entering the factory the management of W.H. Heck and Sons requested BSES to undertake an investigation in 1979 which might assist in identification of factors which contribute to the ash problem at Rocky Point.

Accordingly a project was planned to allow identification of the major factors contributing to the ash loading in first expressed juice and to determine whether the ash levels in juice could be related to yield parameters affecting cane growers in the mill area.

2. METHODS

The data collection phase of the Rocky Point ash investigation was carried out from 1-17/10/79 after a preliminary investigation had been conducted from 28-31/8/79.

2.1 Mill laboratory

A conductivity electrode was mounted below the outfall of the discharge pipe from juice tubs in the laboratory. The electrode was connected to an industrial conductivity meter and chart recorder (Figure 1). With the above arrangement it was possible to obtain a conductivity reading for every juice sample analyzed by the laboratory for cane payment purposes.

Because of the bagacillo and dirt suspended in the first expressed juice it was necessary to flush the electrode with a jet of water at least three times during each eight hour shift in order to maintain electrode sensitivity.

Each day conductivity readings for c.c.s. samples were transferred from the recorder chart to data sheets along with the following information obtained from mill laboratory records:-

Farm No., Juice can No., Date of burning, Variety,
Crop class, Block No., Brix, Pol, C.C.S.

During the course of the investigation 110 juice samples were selected to cover the range of juice conductivities encountered. A one litre sample of each of these juices was immediately placed in the deep freeze for later chemical analysis.

2.2 Field investigations

The origin of all juice samples collected for chemical analysis was noted in terms of farm and block location. Where possible the block was inspected within 24 hours of sample collection and a field data sheet, Figure 2, was completed. A soil sample was taken from the 0-25 and 25-50 cm zones in parts of the field as close as possible to the area harvested to supply the juice sample. Cane yield was taken as the cane inspector's pre-season estimate for a block.

2.3 Soil analysis

Soil samples were air dried, prepared and analyzed at Bundaberg.

TABLE I

Assays performed on soils from Rocky Point ash investigation

Assay	Extractant	Analytical method
EC mS/cm	1:5 soil water extract	Conductivity meter.
Cl^- me/100 g soil	"	Potentiometric titration with $AgNO_3$.
Ca^{++} "	Exchangeable + soluble cations determined in 0.02 N HCl after 16 h shaking	Atomic absorption spectrophotometry.
Mg^{++}		
Na^+		Flame photometry on auto-analyzer.
K^+		

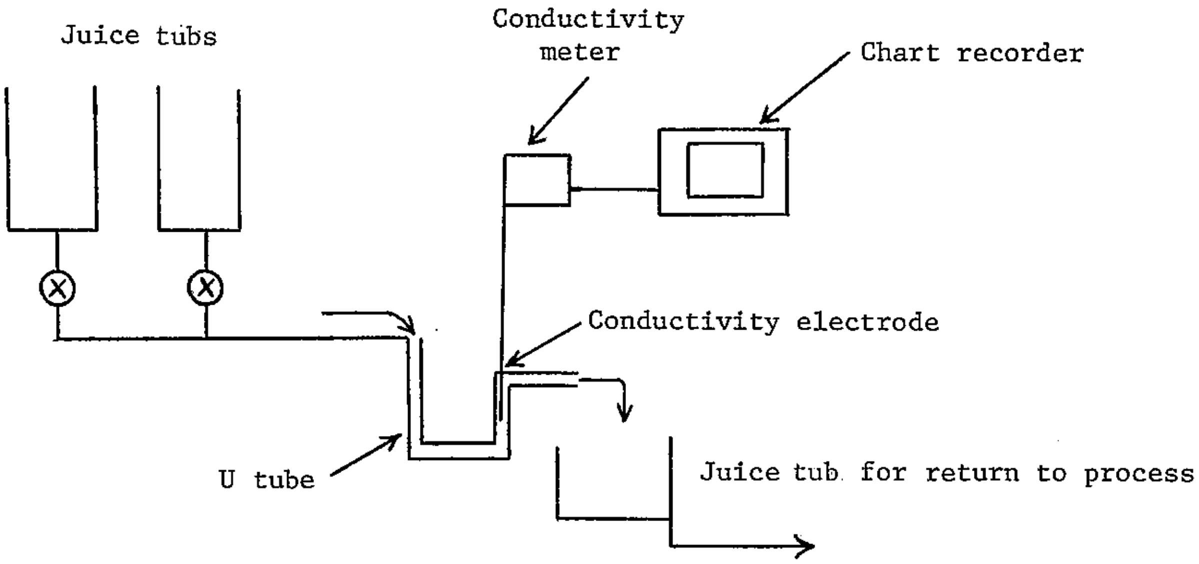

FIGURE 1 - Schematic arrangement of conductivity meter, electrode and chart recorder in the mill laboratory

ROCKY POINT ASH INVESTIGATION

Date GROWER KEY

Area location:

BLOCK VARIETY CLASS

CROP DATA

BURN DATE YIELD CONDITION E S L

Comments on harvester operation:

FIELD DATA

SOIL TYPE/S SURFACE CONDITION
WET MOIST DRY

Comments on field layout for drainage, salinity effects, previous history of problem

FERTILIZER:
STRAIGHTS PROD/ha N
P
K
MIXTURE: :
OVERALL N P K kg/ha

Ameliorants:

Soil sample No.

Juice Sample No.

FIGURE 2 - Field data sheet

2.4 Chemical analysis of juice samples

The 110 frozen juice samples were forwarded to the BSES laboratory in Bundaberg for determination of sulphated ash and ionic composition (Table II).

TABLE II

Assays performed on juice samples

Assay	Analytical method
Sulphated ash % w/w	Double ashing with H_2SO_4
Soluble Ca^{++} me/L	Atomic absorption spectrophotometry on diluted sample
Mg^{++} "	
Fe^{++} "	
Na^{+} "	Flame photometry on auto-analyzer on sample
K^{+} "	
Total juice phosphorus p.p.m.	Acid molybdate and spectrophotometry
Cl^{-} me/L	Potentiometric end point detection of $AgNO_3$ titration.

The relationship between sulphated ash and conductivity meter readings for the 110 juice samples was used to derive a calibration equation for inference of conductimetric ash values on all samples for which conductivity, Brix, pol and c.c.s. data were available.

2.5 Data management

All data acquired in the mill laboratory and from chemical analyses were stored in disc files for collation and analysis by computer programs for data management.

It was decided to break the project into two phases for purposes of interpretation and reporting:-

2.5.1 Phase I

A detailed investigation of juice composition and factors affecting ash levels in first expressed juice.

2.5.2 Phase II

A mill area survey of ash levels in first expressed juice.

3. RESULTS

3.1 Phase I

Detailed investigation of juice composition and factors affecting ash levels in first expressed juice

3.1.1 Extent of the data

Juice and soil samples for detailed analysis were collected throughout the study period. A total of 110 samples were collected from 56 farms in the mill area. The distribution of these farms is shown in Figure 3, with the exception of farms which supplied samples from the Windaroo and Coomera area, as these fall beyond the bounds of the map of the Parish of Albert.

The distribution of juice samples with respect to variety is shown in Table III.

TABLE III

Varietal composition (%) in 110 juice samples collected for detailed analysis from 1-17/10/79 and in cane crushed at Rocky Point mill during the 1979 season

Variety	Per cent each variety in 110 juice samples	Per cent each variety in 1979 cane supply
NCo310	57.3	66.6
Q90	20.9	21.1
Q86	5.5	4.6
H48-3116	5.5	3.8
Pindar	3.6	2.8
Expt, mixed and others	7.2	1.1

Figure 3 showed that sample farms were fairly well distributed throughout the mill area. It did appear however that the Norwell Road area was fairly heavily sampled, whereas the area to the east of New Norwell Road was poorly represented. The latter area was however well represented in the phase II survey.

Table III data indicated that the varietal origins of the 110 juice samples was a good representation of the varietal proportions in the cane supply during 1979.

3.1.2 Ash in first expressed juice

Data pertaining to ash % juice, ash % solids and ash % impurity in first expressed juice samples for detailed study are shown in Table IV.

TABLE IV

Ash data from 110 first expressed juice samples

	Mean	Std dev.	Range
Ash % juice	0.77	± 0.26	0.27 to 1.55
Ash % solids	3.4	± 1.1	1.10 to 6.70
Ash % impurity	30.3	± 7.6	11.8 to 50.5

Tables V(a), (b), (c) indicate the spread of ash data within classes for each of the three ash parameters.

TABLE V(a)

Distribution of ash % juice data between categories.
Ash is gravimetric ash % juice

Ash % juice	< 0.39	0.40-0.59	0.60-0.79	0.80-0.99	1.00-1.19	1.20-1.39	1.40-1.55
% of samples in each category	3.6	25.5	24.6	29.1	10.9	3.6	2.7

TABLE V(b)

Distribution of ash % solids data between categories

Ash % solids	< 1.99	2.00-2.99	3.00-3.99	4.00-4.99	5.00-5.99	> 6.00
% of samples in each category	9.1	27.3	32.7	21.8	7.3	1.8

TABLE V(c)

Distribution of ash % impurity data between categories

Ash % impurity	< 19.99	20-29.99	30-39.99	40-49.99	> 50
% of samples in each category	10.0	38.2	39.1	11.8	0.9

The 110 juice samples for detailed study were selected from conductivity readings on the monitor with the view to obtaining a reasonably even distribution of ash data within the range 0.40 to 1.20. This range was selected as a likely data span from the preliminary study in August 1979. Table V(a) data suggest that this objective was achieved.

3.1.2.1 Deviation of conductimetric ash

The industrial conductivity monitor was calibrated in terms of ash % juice from regression analysis of monitor readings and ash data for the 110 juice samples. Performance of the industrial conductivity monitor was checked for each of these samples against a standardized laboratory conductivity meter.

Calibration equation for industrial conductivity monitor

Ash % juice = 0.220 6 + 0.000 102 x Monitor conductivity (μS/cm)
r = 0.79
Std error of residuals = 0.16

Calibration equation for laboratory conductivity meter

Ash % juice = 0.127 + 0.000 115 x Lab. conductivity (μS/cm)
r = 0.92
Std error of residuals = 0.10

Relationship between industrial conductivity monitor and laboratory conductivity meter

Conductivity on monitor (μS/cm) = 768.1 + 0.831 x Lab. conductivity (μS/cm)
r = 0.85
Std error of residuals = 1019

These data showed that a significant and fair correlation existed between the industrial conductivity monitor reading and gravimetric ash in juice. A much better relationship existed between ash and conductivity readings from the laboratory meter.

The TPS conductivity process controller (Model 2802) used in this study performed satisfactorily, however the attached conductivity cell was far from ideal for the desired application. The aperture of the annular electrode was only 2.0 mm and was readily blocked by bagacillo in juice. It was therefore essential to flush the electrode with a jet of water at approximately two-hourly intervals.

Entrapment of fine air bubbles in the cell chamber may have also affected readings obtained from the monitor. It is thought that the tendency of the electrode to block, and the air bubble problem may have contributed to the poor sensitivity of the industrial conductivity monitor.

3.1.3 Ionic composition of first expressed juice

Data for average concentration of Ca^{++}, Mg^{++}, K^{+}, Na^{+}, Fe^{++}, Cl^{-} and phosphorus (P) in samples of first expressed juice are shown in Table VI, while the frequency distribution of the ionic concentrations is shown in Table VII.

TABLE VI

Summary of inorganic constituents analyzed in 110 samples of first expressed juice from Rocky Point Sugar Mill 1-17/10/79

Ion	Units	Mean	Median	Range
Ca^{++}	me/L	4.8	4.5	0.8 to 11.5
Mg^{++}	me/L	18.0	17.7	6.1 to 32.8
Na^{+}	me/L	4.7	3.7	0.4 to 21.1
K^{+}	me/L	64.6	58.9	7.7 to 169.0
Fe^{++}	me/L	1.5	1.3	0.4 to 3.3
Cl^{-}	me/L	42.0	37.3	14.7 to 107.8
P	p.p.m.	115.0	98.0	40.0 to 437.0

Results in Table VI indicate that potassium and magnesium were the dominant cations in juice, while chloride and phosphate radicles accounted for 45 and four per cent respectively of the anionic balance. In the absence of analytical data it is assumed that most of the remaining anions might be in the form of sulphate and aconitate radicles.

Surprisingly few data were available from the literature on inorganic composition of cane juice for comparison with results obtained at Rocky Point. Most of the literature searched originated in the period 1932-1952, prior to the widespread use of modern fertilizer practices and the introduction of interspecific hybrid cane varieties. De Stefano (1975) reported on a more recent study in Florida. Analytical techniques during the 1930's and the 1975 study differed markedly from current techniques. Therefore the comparisons with early data as in Tables XIII and IX should be interpreted with caution.

Levels of calcium and magnesium in Rocky Point juices were generally lower than reported values from Louisiana and Florida. This may be a reflection of a possible interaction with the extremely high level of potassium in surveyed juices at Rocky Point. From Honig's data (Table IX), calcium levels fell in the normal range but magnesium was high.

TABLE VII

Frequency distribution of juice samples with respect to Ca^{++}, Mg^{++}, Na^{+}, K^{+}, Fe^{++}, Cl^{-} and phosphorus levels in juice

Ca^{++} (me/L)	< 1.99	2.0-3.99	4.0-5.99	6.0-7.99	8.0-9.99	> 10.0
% samples in each class	11.8	30.9	24.5	20.1	9.1	3.6
Mg^{++} (me/L)	5.0-9.99	10.0-14.99	15.0-19.99	20.0-24.99	25.0-29.99	> 30.0
% samples in each class	4.5	24.6	41.8	17.3	8.2	3.6
Na^{+} (me/L)	< 0.99	1.0-2.99	3.0-5.99	6.0-7.99	8.0-9.99	> 10.0
% samples in each class	4.5	40.0	27.3	10.0	7.3	10.9
K^{+} (me/L)	< 29.99	30.0-59.99	60.0-89.99	90.0-119.99	120-149.99	> 150
% samples in each class	16.4	33.6	27.3	14.5	6.4	1.8
Fe^{++} (me/L)	< 0.99	1.0-1.49	1.5-1.99	2.0-2.49	2.5-2.99	> 3.0
% samples in each class	21.8	44.5	10.0	11.8	8.2	3.6
Cl^{-} (me/L)	< 29.9	30.0-44.9	45.0-59.9	60.0-74.9	75.0-89.9	> 90.0
% samples in each class	33.6	25.5	21.8	15.5	1.8	1.8
P (p.p.m.)	< 59.9	60.0-119.9	120-179.9	180-239.9	240.0-299.9	> 300
% samples in each class	6.4	60.1	24.5	3.6	2.7	2.7

TABLE VIII

Comparison of juice inorganics at Rocky Point with other reported data

Report	Ca^{++} me/L	Mg^{++} me/L	Na^{+} me/L	K^{+} me/L	Fe^{++} me/L	Cl^{-} me/L	$SO_4^{=}$ me/L	P p.p.m.
Fort & McKaig (1939)	9.6	21.1	2.9	56.1	-	10.4	20.8	314
McKaig & Hurst (1941)	7.0	26.1	-	38.9	-	7.3	14.1	223
Fort & Smith (1952)	8.5	16.6	-	-	-	7.3	5.2	115
De Stefano (1975) (1)	12.7	-	-	17.7	-	13.2	-	-
" " (2)	23.9	-	-	31.5	-	19.5	-	-
" " (3)	21.3	-	-	48.0	-	25.7	-	-
Irvine (1979)	-	-	-	41.0	-	-	-	-
Leverington et al (1965) (4)	-	-	-	73.6	-	-	-	154
" " " (5)	-	-	-	31.8	-	-	-	127
Kingston & Kirby (1979)	-	-	-	42.0	-	40.3	-	79
Rocky Point (this study)	4.8	18.0	4.7	64.6	1.5	42.0	-	115

(1) Sandy soil

(2) Muck soil

(3) Crusher juice

(4) High levels of soil potassium

(5) Low levels of soil potassium

TABLE IX

Levels of inorganic constituents in cane juice in Java from 1930-1940 from Honig (1953)

Ion, units		Range		
		Low	Normal	High
Ca^{++}	me/L	< 2.9	2.9 to 7.1	> 7.1
Mg^{++}	"	< 4.9	4.9 to 12.4	> 12.4
Na^{+}	"	< 9.7	9.7 to 19.4	> 19.4
K^{+}	"	< 17.0	17.0 to 31.8	> 31.8
Fe^{++}	"	< 1.5	1.5 to 2.5	> 2.5
Al^{+++}	p.p.m.	< 11	11 to 27	> 27
Cl^{-}	me/L	< 2.8	4.0 to 8.5	> 8.5
$SO_4^{=}$	me/L	< 2.5	2.5 to 4.2	> 4.2
P	p.p.m.	< 65	65 to 218	> 218
Si	p.p.m.	< 47	47 to 234	> 234

Juice sodium levels were low in comparison to the Java data of Honig, but were double the values for Louisiana; iron levels at Rocky Point were low to normal but chloride concentrations in both Qunaba and Rocky Point juices were approximately four times higher than values reported for Louisiana and 1.5 to three times the Florida values.

Fort and Smith (1952) indicated that chloride, sulphate, phosphate and aconitate ions accounted for 10, 19, 6 and 46 per cent of anions in clarified juice while 19 per cent were undetermined. Honig (1953) suggested that the actual concentration of chloride and sulphate ions does not change markedly from raw to clarified juice. When viewed together these statements raise queries about the anionic composition of Rocky Point juices where chlorides alone accounted for 45 per cent of anions.

Chloride analyses reported by Fort and McKaig (1939), McKaig and Hurst (1941) and presumably by Fort and Smith (1952) were based on a tedious technique which involved carbonate ashing of a raw juice sample with steps to retain chlorides. The authors claimed a good recovery of chloride when known standards were added to juice. De Stefano's results were based on mercuric nitrate titration of diluted juices with end points based on a colour change with diphenyl-carbazone indicator. The electrometric titration technique used on the Rocky Point juices should be a true reflection of juice chloride as there would have been no volatilization losses or masking of colour change end points. Major ionic interferences were not anticipated.

Levels of phosphorus in Rocky Point juices appeared normal in relation to most of the other reported data, but were considerably higher than the Qunaba results.

3.1.4 Soil analysis

Mean results of soil analyses performed on soil samples taken during the study are shown in Table X, along with data in Table XI to give an appreciation of the range and distribution of values encountered.

TABLE X

Summary of exchangeable + soluble ions and conductivity of 1:5 soil water extract data for Rocky Point soils

Assay	Depth cm	Mean	Median	Range
Ca me %	0-25	4.66	3.60	0.50 to 23.8
"	25-50	3.40	2.70	0.60 to 12.6
Mg me %	0-25	3.08	2.90	0.20 to 8.0
"	25-50	3.36	3.30	0.40 to 8.6
Na me %	0-25	1.08	0.80	0.10 to 4.25
"	25-50	1.81	1.39	0.10 to 5.65
K me %	0-25	0.16	0.14	0.04 to 0.47
"	25-50	0.13	0.10	0.04 to 0.39
Cl me %	0-25	0.52	0.38	0.03 to 3.25
"	25-50	0.50	0.30	0.02 to 3.51
EC mS/cm	0-25	0.16	0.11	0.021 to 1.03
"	25-50	0.23	0.18	0.029 to 1.05
Na % cations	0-25	13.3	11.6	1.7 to 44.9
"	25-50	20.7	20.2	1.9 to 55.8

3.1.4.1 Calcium

There were no soils which could be classed as deficient in calcium (< 0.5 me %) in the 0 to 25 cm zone, but 12 per cent of samples contained less than 1.5 me %. The latter soils are considered marginal for calcium and may respond to applications of lime. These soils were the sandy soils of the Woongoolba area and sandier phases of the humic gley soil type in the Norwell Road-Jacob's Well area and a podzolic soil south of the Pimpama River.

TABLE XI

Distribution of soil samples within categories of Ca^{++}, Mg^{++}, Na^{+}, K^{+}, EC and Na^{+} % soil cations in Rocky Point soils

Soil Ca^{++} me %	< 0.99	1.0 -1.99	2.0 -2.99	3.0 -3.99	4.0 -4.99	5.0 -5.99	> 6.0
% samples 0-25 cm	4.5	10.0	25.5	13.6	9.1	16.4	20.9
in each class 25-50 cm	8.2	20.9	26.4	18.2	10.9	3.6	11.8
Soil Mg^{++} me %	< 0.99	1.0 -1.99	2.0 -2.99	3.0 -3.99	4.0 -4.99	5.0 -5.99	> 6.0
% samples 0-25 cm	12.7	24.5	13.6	16.4	17.3	4.6	10.9
in each class 25-50 cm	8.2	26.4	11.8	15.4	20.0	4.6	13.6
Soil Na^{+} me %	< 0.19	0.20-0.39	0.40-0.59	0.60-0.79	0.80-0.99	1.0 -1.19	> 1.2
% samples 0-25 cm	7.3	11.8	16.4	12.7	11.8	6.4	33.6
in each class 25-50 cm	4.5	8.2	8.2	6.4	8.2	8.2	56.3
Soil K^{+} me %	< 0.119	0.12-0.179	0.18-0.239	0.24-0.299	0.30-0.359	0.36-0.439	> 0.44
% samples 0-25 cm	31.8	37.3	16.3	6.4	4.6	1.8	1.8
in each class 25-50 cm	54.6	23.6	10.9	3.6	6.4	0.9	0
Soil Cl^{-} me %	< 0.19	0.20-0.39	0.40-0.59	0.60-0.79	0.80-0.99	1.00-1.19	> 1.2
% samples 0-25 cm	7.3	47.2	18.2	13.6	1.8	5.5	6.4
in each class 25-50 cm	38.2	21.8	9.1	10.9	0.9	8.2	10.9
EC mS/cm	< 0.09	0.10-0.19	0.20-0.29	0.30-0.39	0.40-0.49	> 0.50	-
% samples 0-25 cm	41.7	30.9	14.6	4.6	3.6	4.6	-
in each class 25-50 cm	30.0	21.8	19.1	13.6	9.1	6.4	-
Na % cations	< 9.9	10-14.9	15-19.9	20-24.9	25-29.9	30-34.9	> 35
% samples 0-25 cm	42.7	25.5	11.8	7.3	2.7	7.3	2.7
in each class 25-50 cm	26.4	10.9	11.8	17.3	17.3	5.5	10.8

The very high levels of soil calcium,10 to 23.8 me % in the 0-25 cm zone were associated with alluvial soils near the Albert, Logan and Pimpama Rivers and fine textured humic gleys which adjoin the alluvials.

In most profiles the level of soluble + exchangeable calcium declined from 0-25 to 25-50 cm zones in the soil.

3.1.4.2 Magnesium

None of the surveyed soils were found to be deficient in magnesium, but sands in the Woongoolba area are marginal and may respond to magnesium. Unlike calcium, magnesium levels generally increased from the 0-25 to 25-50 cm zone. This may be a reflection of the contribution of salts of marine origin to profile salinity. The average ratios of Ca^{++}/ Mg^{++} ions in 0-25 and 25-50 cm zones were 2.1 and 1.7 respectively.

3.1.4.3 Sodium

A wide range of sodium values was encountered for both depths of soil sampling. From data in Table X it can be shown that mean sodium percentage of basic cations was 13.3 and 20.7 per cent for 0-25 and 25-50 cm zones respectively. Data from Table XI show for the above soil depths that sodium represented more than 15 per cent of basic cations in 31.8 and 62.7 per cent respectively of samples. The 15 per cent value has been arbitrarily set by the USDA Salinity Laboratory as the boundary between alkaline and non-alkaline soils. High levels of sodium in soil may have a debilitating effect by destroying soil structure and/or restricting the uptake of calcium, magnesium and potassium ions, Bower and Wadleigh (1949).

It should be remembered that soil sodium values quoted for Rocky Point are exchangeable + soluble ions. The moderate to high salinities encountered indicate that soluble sodium is probably a large proportion of the reported value. The above percentages would therefore present a slightly inflated picture of exchangeable sodium levels in the soil. Juice sodium values for Rocky Point suggest that sugar cane has been very successful in suppressing sodium uptake in the prevailing conditions.

3.1.4.4 Potassium

Soil potassium values ranged from 0.04 to 0.47 me %. In the 0-25 cm zone 31.8 per cent of samples showed low levels of exchangeable + soluble potassium, 53.6 per cent were in the medium range while 14.6 per cent contained high levels of potassium.

High levels of soil potassium were found in alluvial soils and the peaty gleys of the Norwell Road area. The latter soils also sustained moderate levels of salinity. Most of the soils in the mill area are derived from old flood plains and have been modified by recent alluvium or organic deposits in the swamps. Thus one would expect most of the soils to have satisfactory levels of potassium.

Low levels of soil potassium were found in podzolic soils south of the Pimpama River, in sandy soils in the Woongoolba-Jacob's Well area and in coarser phases of the humic gleys in Woongoolba and Norwell areas.

3.1.4.5 Phosphorus

No soil assays for phosphorus were conducted during this study. Data were available from eight BSES fertility monitoring sites on soils which were representative of district soils and from 60 soil samples analyzed by Austral-Pacific Fertilizers in 1970. These assays have indicated that acid clay soils in the Alberton area, the Stapylton and Pimpama podzolics and ground water podzols of the Jacob's Well area were all low in phosphorus. Humic and peaty gley soils generally showed moderate levels of available phosphorus (20 to 40 p.p.m.). Only alluvial soils showed high levels of available phosphorus.

The fertility monitoring site data have indicated high phosphorus fixation potentials in peaty gley and dark acid clay soils. Phosphorus fixation should not represent a problem on the humic gleys, as they are not as acidic and do not have the levels of iron and aluminium found in the former soils.

3.1.4.6 Electrical conductivity of 1:5 soil/water extract

As for sodium, a wide range of conductivity data, which represented soil salinity, was encountered throughout the survey. BSES soil salinity standards for the 1:5 extract are reproduced in Table XII. Comparison of these values with data in Table XI suggests that soil salinity in 19.2 and 32.7 per cent of samples in 0-25 and 25-50 cm zones respectively, might induce slight growth restrictions in sugar cane, while 8.2 and 15.5 per cent of samples from the above horizons could be associated with salinities which could induce moderate to severe growth restrictions to sugar cane.

The overall effects of salinity on growth in the Rocky Point area may have been minimized because of the relatively large areas of peaty and high organic matter humic gleys which have lower bulk density than mineral soils. Thus salinity determinations based on weight give the impression of higher salt contents than are encountered *in situ*.

3.1.4.7 Chloride

Soil chlorides in 0-25 and 25-50 cm were highly correlated with soil salinity as indicated in Table XIV.

TABLE XII

BSES soil salinity standards for sugar cane based on 1:5 soil water extracts (mS/cm)

Soil type	Degree of growth restriction in sugar cane			
	None	Slight	Moderate	Severe
Organic soil	< 0.32	0.32-0.65	0.65-0.97	> 0.97
Clay	< 0.28	0.28-0.55	0.55-0.83	> 0.83
Clay loam	< 0.21	0.21-0.42	0.42-0.62	> 0.62
Loam	< 0.19	0.19-0.39	0.39-0.58	> 0.58
Sandy loam	< 0.19	0.19-0.37	0.37-0.55	> 0.55
Sand	< 0.14	0.14-0.28	0.28-0.42	> 0.42
Conductivity of saturation extract (mS/cm)	0-2	2-4	4-6	> 6

3.1.4.8 Correlations between soil cations and anions

Correlation coefficients in Table XIII have been presented to support the inference that potassium levels in the 0-25 cm zone are largely related to soil genesis while levels in the 25-50 cm zone are influenced by soil genesis and soil salinity. This inference would appear correct if concentrations of sodium and chloride ions are taken as indices of the effect of salts of marine origin. The data in Table XIII show there were no significant statistical associations between potassium and sodium or chloride in the 0-25 cm zone yet correlations were positive and highly significant in the deeper zone.

Data in Table XIV show that on average EC of the 1:5 soil/water extract was significantly and positively correlated with the concentration of soluble + exchangeable sodium and chloride ions in the 0-25 cm zone. In the 25-50 cm zone all correlations were significant. The EC v. soil calcium association for the latter soil depth was negative whereas the association for the other ions was positive.

The negative associations between EC and soil calcium imply that soils with higher levels of soluble plus exchangeable calcium (i.e. finer textured soils) were less affected by salinity than were the coarser textured soils which were generally lower in calcium. Data in Table XV further support this observation.

TABLE XIII

Correlation coefficients between concentrations in me % of ions in Rocky Point soils

V1	V2	0-25 cm r	25-50 cm r
Ca^{++}	Mg^{++}	0.31*	0.31*
	Na^{+}	-0.07	-0.13
	K^{+}	0.18	0.03
	Cl^{-}	-0.14	-0.24*
Mg^{++}	Na^{+}	0.45*	0.61*
	K^{+}	0.48*	0.29*
	Cl^{-}	0.06	0.23*
Na^{+}	K^{+}	0.15	0.43*
	Cl^{-}	0.77*	0.79*
K^{+}	Cl^{-}	0.08	0.47*

* Significant ($p < 0.05$)

TABLE XIV

Correlation coefficients for associations between EC of 1:5 soil water extracts and soluble + exchangeable ions in 0-25 and 25-50 cm zones of Rocky Point soils

V1	V2	
	EC 1:5 extract 0-25 cm	EC 1:5 extract 25-50 cm
Soil Ca^{++} me %	-0.16	-0.19*
" Mg^{++} "	0.13	0.28*
" Na^{+} "	0.85*	0.81*
" K^{+} "	0.11	0.49*
" Cl^{-} "	0.89*	0.92*

* Significant ($p < 0.05$)

TABLE XV

Correlation coefficient for association between proportion of basic soil cations and EC of 1:5 soil water extracts

V1	V2	
	EC 1:5 extract 0-25 cm	EC 1:5 extract 25-50 cm
Soil Ca % cations	-0.49*	-0.53*
" Mg % "	0.13	0.12
" Na % "	0.75*	0.71*
" K % "	-0.09	0.01

* Significant ($p < 0.05$)

3.1.5 Fertilizer usage

Data on average rates of N, P and K fertilization and the frequency distribution of fertilizer rates among farms at Rocky Point are shown in Tables XVI and XVII respectively.

TABLE XVI

Summary of fertilizer application rates on surveyed farms at Rocky Point in 1979 (kg/ha of N, P or K)

Fertilizer	Average	Median	Range
Nitrogen (N)	179	177	63 to 340
Phosphorus (P)	32	32	0 to 62
Potassium (K)	62	65	0 to 129

TABLE XVII

Distribution of fertilizer application rates within usage classes

Nitrogen (kg N/ha)	< 99	100-149	150-199	200-249	250-299	> 300
% farms in each class	7.3	14.5	41.8	30.0	5.5	0.9
Phosphorus (kg P/ha)	0	1-19	20-39	40-59	60-62	
% farms in each class	5.5	7.3	55.5	25.5	6.2	
Potassium (kg K/ha)	0	15-49	50-99	100-129		
% farms in each class	9.1	26.4	52.7	11.8		

3.1.5.1 Nitrogen

Average nitrogen application rate on the surveyed farms was 179 kg N/ha, while on 72 per cent of farms the application rate fell between 150 and 249 kg N/ha. This range of application rates for most farms did not appear abnormal when consideration is given to district rainfall, drainage characteristics and proportions of 18 month or standover cane grown in the area.

The 7.3 per cent of sample blocks which received less than 100 kg N/ha were located on alluvial soils, or on humic gley soils where management objectives were achieved with 60 to 80 kg N/ha.

Only one farm was reported as using 340 kg N/ha from urea. This was the only fertilizer used on the farm where modest applications of phosphorus and potassium are probably also required.

There was no statistically significant relationship between cane or sugar yield and rate of nitrogen fertilizer.

3.1.5.2 Phosphorus

On average 32 kg P/ha was applied to blocks on surveyed farms when the range was from 0 to 62 kg P/ha. It would appear that adequate phosphorus was being applied to 81 per cent of the surveyed fields in 1979 (20 to 60 kg P/ha). New areas of peaty gley or acid clay soils should receive broadcast superphosphate at 1.25 t/ha, followed by 30 to 40 kg P/ha/year as row dressings for the first five to 10 years of cultivation. Once soil P levels have been established in excess of 20 p.p.m. it may be possible to reduce P application rates to maintenance dressings.

Liming should be a part of normal farm practice on the acidic phosphorus fixing soils in order to raise pH and minimize phosphorus fixation.

3.1.5.3 Potassium

Within the survey group 9.1 per cent of fields received no potassium fertilizer, 79.1 per cent received from 15 to 100 kg K/ha and a further 11.8 per cent received from 100 to 129 kg K/ha.

Of the 10 fields (9.1 per cent) which did not receive potash, three and four had high and medium levels respectively of soil potassium while a further three fields had low soil potassium levels. The latter fields would probably benefit from the use of potassium fertilizer.

Examination of the 11.8 per cent (13 fields) receiving from 100 to 129 kg K/ha revealed that five, six and two fields showed low, medium and high levels of soil potassium. Responses to more than 100 kg K/ha would therefore be unlikely on eight of these 13 fields (i.e. soil potassium levels 0.22 to 0.40 = high range).

An examination of all of the potassium fertilizer rate data and corresponding soil test values for soil potassium showed that there was no statistical association between the two parameters.

A low, but significant ($p < 0.05$) and negative correlation ($r = -0.24$) was noted between rate of potassium fertilizer and cane yield. Further examination of the available information revealed that similarly low but significant negative correlations existed between rate of potassium fertilizer and soil levels of calcium and magnesium ($r = -0.28$ and -0.20 respectively). Soil calcium levels were positively and significantly correlated with cane yield ($r = 0.20$) but no significant relationship existed between yield and soil magnesium.

Only very tentative interpretations of the implications of the above apparent associations are possible from the results to hand. It could be suggested that the fertilizer potassium rate/cane yield relationship is negative because higher rates of potash have been applied to soils with lower levels of calcium and/or magnesium, and fields with a Ca/Mg imbalance, even though only 12 per cent of soil samples showed less than 1.5 me % of calcium in the 0-25 cm zone. There is no suggestion that fertilizer potassium is directly contributing to the effect on yield: rather that lower levels of calcium and magnesium might be of greater importance because a significant and positive relationship existed between cane yield and soil potassium levels ($r = 0.24$).

The above aspect of plant nutrition should be corrected by using recommended liming practices for district soils.

There was no significant correlation between usage of potassium fertilizer and ash or potassium levels in first expressed juice.

3.1.6 Effects of soil chemistry on ash levels in first expressed juice

The effects of assayed soil parameters on ash levels in juice were examined with simple and multiple regression analyses. Results are summarized in Table XVIII.

3.1.6.1 Soil salinity

Soil salinity, as measured by EC of a 1:5 soil/water extract, was significantly and positively correlated with juice ash levels. Multiple regression analysis of EC on 0-25 and 25-50 cm horizons with ash per cent juice and ash per cent impurity revealed that salinity of the deeper horizon had almost twice as much influence on the relationship as did salinity in the 0-25 cm zone. This situation probably pertained because of higher subsoil salinities.

Because of the significant correlations between EC and concentrations of some soluble + exchangeable cations in soil it would not be statistically valid to include EC as an independent variable in multiple regression analyses with these soil parameters as other independent variables.

However, soil potassium and EC in the 0-25 cm zone were not significantly correlated and their joint use in multiple regression analysis was a significant improvement over the association between ash in juice and soil EC alone i.e. variation in EC alone accounted for 34.8 per cent of the variation in the ash/EC relationship, whereas inclusion of soil potassium explained a further 12.8 per cent of the variation. Soil salinity was 1.5 times as important as soil potassium in the association between salinity, soil potassium and ash in juice.

3.1.6.2 Soil cations and anions

Levels of exchangeable + soluble magnesium, sodium and potassium and soluble chloride in 0-25 and 0-50 cm zones were significantly and positively correlated with ash per cent and ash per cent impurity in juice. Concentration of exchangeable + soluble calcium had no significant association with ash levels in juice. Comparison of standard partial regression coefficients in the regression of ash and soil levels of calcium, magnesium, sodium and potassium showed that these parameters were ranked in the order sodium > potassium > magnesium > calcium in importance of effect upon the ash cation relationship.

The reason for the apparent lack of importance of soil calcium concentration in regressions between ash in juice and soil chemical parameters was not obvious. However, examination of regression analyses between ash in juice and proportions of basic soil cations revealed a significant and negative association between the calcium proportion of basic cations and ash in juice; magnesium and sodium proportions were significantly and positively correlated with ash, while there was no association between the proportion of potassium ions in soil and ash data.

TABLE XVIII

Results from regression of ash per cent juice, ash per cent impurity (in first expressed juice) on soil parameters

Soil parameter; depth	Ash % IXJ		Ash % impurity IXJ	
	r or R	b'	r or R	b'
EC mS/cm 0-25 cm	0.59	-	0.48	-
" 25-50 cm	0.61	-	0.53	-
" 0-25, 25-50 cm	0.62	0.24, 0.40	0.53	0.19, 0.36
Ca^{++} me % 0-25 cm	-0.02^{+}	-	-0.09^{+}	-
Mg^{++} " "	0.31	-	0.25	-
Na^{+} " "	0.58	-	0.48	-
K^{+} " "	0.42	-	0.36	-
Cl^{-} " "	0.46	-	0.42	-
Ca^{++}, Mg^{++}, Na^{+}, K^{+} "	0.68	-0.01, -0.14, 0.58, 0.40	0.57	-0.08, -0.10, 0.47, 0.35
EC, K^{+} "	0.69	0.55, 0.36		0.45, 0.31
Ca^{++} me % 0-50 cm	-0.05^{+}	-	-0.10^{+}	-
Mg^{++} " "	0.31	-	0.23	-
Na^{+} " "	0.57	-	0.48	-
K^{+} " "	0.54	-	0.47	-
Cl^{-} " "	0.53	-	0.41	-
Ca^{++}, Mg^{++}, Na^{+}, K^{+} "	0.68	-0.00, -0.16, 0.50, 0.41	0.58	-0.06, -0.14, 0.40, 0.37
Ca^{++} % basic cations 0-25 cm	-0.38	-	-0.40	-
Mg^{++} " " "	0.22	-	0.26	-
Na^{+} " " "	0.41	-	0.40	-
K^{+} " " "	0.02^{+}	-	0.06^{+}	-
Ca, Mg, Na, K % basic cations	0.44	-1.81, -1.13, -0.60, -0.12	0.44	-1.59, -0.94, -0.51, -0.08
Ca^{++} % basic cations 0.50 cm	-0.39	-	-0.37	-
Mg^{++} " " "	0.24	-	0.22	-
Na^{+} " " "	0.43	-	0.41	-
K^{+} " " "	0.11^{+}	-	0.14^{+}	-
Ca, Mg, Na, K % basic cations	0.47	0.39, 0.38, 0.62, 0.10	0.44	0.24, 0.27, 0.50, 0.11

r, R = simple and multiple correlation coefficients respectively

b' = standard partial regression coefficient

$+$ = not significant ($p < 0.05$)

All r and R not marked $^{+}$ are significant ($p < 0.05$)

As indicated previously this trend could also be explained by lower levels of soluble salts in soils where calcium ions are increasingly dominant resulting in a lower tendency by sugar cane to accumulate ions in an attempt to achieve osmotic balance.

The importance of soil sodium values in ash/soil cation associations further emphasizes the importance of soil salinity in affecting juice ash levels.

3.1.7 Effect of soil chemistry on inorganic juice constituents

3.1.7.1 Soil salinity

Regression coefficients between EC of 1:5 soil/water extracts and inorganic juice parameters are shown in Table XIX. This summary showed that there were no statistically significant associations between soil salinity and concentrations of calcium, magnesium and phosphorus in juice. Highly significant ($p < 0.01$) associations were revealed between soil salinity in the 0-50 cm depth interval and concentrations of sodium, potassium and chloride ions in first expressed juice. Multiple regression analyses between soil salinity in 0-25 and 25-50 cm zones and juice sodium and potassium revealed that salinity of the deeper zone was 4.1 times more important for sodium and 1.5 times more important for potassium than 0-25 cm salinity.

3.1.7.2 Soil cations and anions

Concentrations of calcium and phosphorus in juice were significantly and positively associated with levels of soluble + exchangeable calcium in 0-25 and 0-50 cm soil horizons. Soil calcium levels in the above soil depths were not significantly correlated with juice magnesium, sodium or potassium values. A negative association between soil calcium and juice chlorides achieved significance in the 0-50 cm depth.

Soil magnesium levels (0-25 and 0-50 cm) were positively and significantly correlated with concentrations of sodium, potassium and chloride in juice. Over the 0-50 cm depth interval the negative association between soil magnesium and juice calcium achieved significance.

Soil sodium levels were negatively and significantly correlated with juice calcium concentrations but positively and highly significantly correlated with juice sodium, potassium and chloride levels. Juice magnesium and phosphorus levels were not correlated with soil sodium values.

TABLE XIX

Effect of soil chemistry on inorganic juice constituents.
Values are correlation coefficients (r, R)

	Concentration me/L in first expressed juice					
	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	$PO_4^{=}$
EC 0-25 cm	-0.12	0.04	0.50*	0.51*	0.64*	0.02
EC 25-50 cm	-0.13	0.09	0.54*	0.52*	0.66*	-0.03
EC 0-25, 25-50 cm	-0.13	0.13	0.54*	0.53*	0.69*	0.10
EC 0-50 cm	-0.13	0.07	0.54*	0.53*	0.67*	0
Soil Ca me % 0-25 cm	0.46*	0.10	-0.05	-0.04	-0.17	0.48*
" Mg " "	-0.15	0.16	0.33*	0.28*	0.28*	0.15
" Na " "	-0.18*	0.05	0.53*	0.53*	0.64*	-0.05
" K " "	0	-0.12	0.17	0.39*	0.29*	0.28*
" Cl " "	-0.07	0.05	0.40*	0.36*	0.50*	-0.09
Soil Ca me % 0-50 cm	0.46*	0.08	-0.07	-0.06	-0.21*	0.54*
" Mg " "	-0.29*	0.13	0.29*	0.29*	0.28*	0.13
" Na " "	-0.21*	0.09	0.55*	0.52*	0.64*	-0.06
" K " "	-0.07	-0.22*	0.18*	0.49*	0.39*	0.25*
" Cl " "	-0.11	0.11	0.49*	0.41*	0.59*	0.04
Ca % soil cations 0-25 cm	0.50*	0.02	-0.29*	-0.36*	-0.46*	0.29*
Mg " " "	-0.48*	0.06	0.20*	0.22*	0.28*	-0.24*
Na " " "	-0.30*	-0.09	0.29*	0.38*	0.48*	-0.21*
K " " "	-0.07	-0.25*	-0.13	0	-0.02	-0.13
Ca % soil cations 0-50 cm	0.48*	0	-0.30*	-0.34*	-0.47*	0.30*
Mg " " "	-0.40*	0.10	0.19*	0.23*	0.31*	-0.20*
Na " " "	-0.33*	-0.03	0.38*	0.37*	0.53*	-0.23*
K " " "	-0.10	-0.29*	-0.14	0.09	0.06	-0.14

* r, R significant at ($p < 0.05$)

Levels of r or R for significance $p < 0.05$, df = 108, r = 0.18
$p < 0.01$, df = 108, r = 0.26

Soluble + exchangeable soil potassium values (0-25 and 0-50 cm) were positively and highly significantly correlated with concentrations of potassium, chloride and phosphorus in juice. In the 0-50 cm zone only, soil potassium and juice sodium were positively and significantly correlated; while increasing levels of soil potassium appeared to significantly restrict magnesium levels in juice. Inclusion of soil potassium with fertilizer potassium in multiple regression did not improve any of the correlations.

Soil chloride levels were positively and highly significantly associated with concentrations of sodium, potassium and chloride in juice.

3.1.7.3 Proportions of soil cations

The calcium proportion of basic soil cations was positively and highly significantly associated with juice calcium and phosphorus levels and negatively and highly significantly correlated with juice sodium, potassium and chloride concentrations. Concentration of magnesium in juice was not associated with the soil calcium balance.

The magnesium and sodium proportions of basic cations in soil were negatively and significantly associated with calcium and phosphorus in juice and positively and significantly correlated with juice sodium, potassium and chloride levels. Juice magnesium concentration was not associated with variation in the magnesium or sodium per cent soil cations.

The potassium proportion of basic soil cations was negatively and highly significantly correlated with juice magnesium concentration. Other quantified inorganic constituents of juice were not significantly associated with variations in the potassium percentage of soil cations.

3.1.7.4 Discussion for sections 3.1.6 and 3.1.7

Results presented in this section have shown that soil parameters have a strong and direct effect on the inorganic composition of cane juice. The correlations between soil salinity and soil sodium levels (0-25 cm) and between soil salinity and levels of magnesium, sodium, potassium and chloride in the 25-50 cm zone suggested that a substantial proportion of these ions were present in soluble forms in Rocky Point soils. It was hardly surprising therefore to find that strong correlations existed between soil salinity and concentration of sodium, potassium and chlorides in juice, and that soil and juice levels of these ions were also generally linked in strong associations.

The lack of association between concentration of magnesium in juice and me % of magnesium or the magnesium proportion of soil basic cations was surprising. All soil chemical parameters exhibited similar coefficients of variation, but the C.V. for juice magnesium was approximately half that of other studied inorganic juice constituents. It is therefore unlikely that data variability contributed to the absence of a significant association between juice magnesium concentration and levels of calcium, magnesium, sodium and chloride in soils. The apparent negative influence of me % soil potassium, in the 0-50 cm zone, and potassium per cent of basic cations in 0-25 and 0-50 cm zones on juice magnesium concentration may explain this observation.

Potassium antagonism of magnesium uptake has been well documented for a range of plant species in the literature and has been observed during the course of BSES research into calcium and magnesium nutrition of sugar cane in North Queensland. The antagonistic effect usually only applies when soil magnesium levels are approaching the deficient level. This situation did not apply in Rocky Point soils where the level of magnesium was generally more than adequate. However, the 68 per cent of surveyed fields which had medium to high levels of soil potassium clearly contributed to the very high juice potassium levels. Even though the negative association between juice potassium and magnesium concentrations failed to achieve significance it appears that potassium may have had an effect on juice magnesium levels.

The strong negative associations between the calcium proportion of basic cations and ash, sodium, potassium and chloride levels in juice should not be construed as a case for broad scale use of lime or gypsum in a programme to reduce ash levels.

3.1.8 Associations between the various inorganic constituents of juice

3.1.8.1 Ash and the ions

Simple and multiple correlation coefficients from regression analyses of ash per cent juice, ash per cent impurity on concentrations of calcium, magnesium, sodium, potassium, chlorides and phosphorus in juice are shown in Table XX.

Results in Table XX showed that calcium and magnesium concentrations in juice were negatively associated with ash per cent juice and ash per cent impurity. Only the magnesium/ash per cent juice correlation failed to achieve significance. Juice sodium, potassium and chloride were all positively and highly significantly associated with juice ash parameters. Potassium and chloride ions showed the strongest correlations. Positive associations between juice phosphorus and ash in juice just failed to achieve statistical significance.

TABLE XX

Results from regression analyses of ash in juice on ions in juice

Ions in juice	Ash % juice		Ash % impurity
	r or R	b'	r
Ca^{++} me/L	-0.23	-	-0.30
Mg^{++} "	-0.15^{+}	-	-0.23
Na^{+} "	0.46	-	0.38
K^{+} "	0.78	-	0.66
Cl^{-} "	0.82	-	0.69
$PO_4^{\equiv}$ "	0.18^{+}	-	0.13^{+}
Ca^{++}, Mg^{++}, Na^{+}, K^{+}	0.79	0.01, 0.11, 0.16, 0.69	0.70
" " " " , Cl^{-}	0.87	0.04, -0.16, 0.00, 0.31, 0.61	0.76
" " " " " , $PO_4^{=}$	0.88	-0.02, -0.15, -0.02, 0.26, 0.63, 0.15	0.77

$^{+}$ r not significant ($p < 0.05$): all other coefficients were significant.

3.1.8.2 Associations between ions in juice (Table XXI)

Calcium: Concentrations of calcium in juice were positively and significantly associated with magnesium and phosphorus levels, and negatively, but not significantly, with juice sodium.

Magnesium: Juice magnesium levels were positively and significantly related to concentrations of calcium and sodium in juice, but associations with potassium, chloride and phosphorus were not significant.

Sodium: Associations between juice sodium calcium and magnesium have been mentioned above. Juice sodium levels were positively and highly significantly correlated with concentrations of potassium and chloride in juice, but were not correlated with phosphorus levels in juice.

Potassium and chloride:

Associations between juice potassium, calcium, magnesium and sodium have been mentioned above. A highly significant and positive correlation existed between concentrations of potassium and chloride in juice.

Phosphorus: Juice phosphorus, expressed as phosphate for statistical analysis, was significantly associated only with juice calcium levels, and this was a positive association.

TABLE XXI

Correlation coefficients between concentrations of Ca^{++}, Mg^{++}, Na^{+}, Cl^{-} and $PO^{4=}$ ions in juice

Juice ions	Ca^{++} me/L	Mg^{++} me/L	Na^{+} me/L	K^{+} me/L	Cl^{-} me/L	$PO_4^{\equiv}$ me/L
Ca^{++} me/L	1.00	0.28*	-0.16	-0.23*	-0.25*	0.32*
Mg^{++} "	0.28*	1.00	0.20*	-0.10	0.06	0.02
Na^{+} "	-0.16	0.20*	1.00	0.46*	0.60*	0.03
K^{+} "	-0.23*	-0.10	0.46*	1.00	0.77*	0.12
Cl^{-} "	-0.25*	0.06	0.60*	0.77*	1.00	0.01
$PO_4^{\equiv}$ "	0.32*	0.02	0.03	0.12	0.01	1.00

* r significant ($p < 0.05$)

3.1.8.3 Discussion

Examination of relationships between inorganic ions and juice ash levels and ionic interrelationships have again implicated soil salinity as the major factor contributing to inorganic loadings in juice due to the dominance of chloride ions in the above associations.

3.1.9 Associations between inorganic juice constituents and sugar yield parameters for sugar cane

An investigation of possible associations between the inorganic composition of cane juice and cane yield, c.c.s., sugar yield, Brix and pol was conducted on available data through regression analysis. Correlation coefficients are shown in Table XXII.

TABLE XXII

Correlation coefficients between sugar yield parameters and inorganic juice constituents

Juice inorganics	Sugar yield parameters				
	t cane /ha	C.C.S.	t sugar /ha	Brix % IXJ	Pol % IXJ
Ca^{++} me/L	-0.02	-0.07	-0.03	-0.10	-0.09
Mg^{++} "	-0.28*	0.17	-0.23*	0.18*	0.17
Na^{+} "	-0.22*	0.04	-0.21*	0.26*	0.11
K^{+} "	0.01	-0.38*	-0.08	-0.06	-0.27*
Cl^{-} "	-0.18*	-0.32*	-0.25*	0.03	-0.19*
$PO_4^{\equiv}$ "	0.26*	-0.02	0.28*	0.13	0.06
Ash % juice	-0.06	-0.42*	-0.16	-0.04	-0.28*

* r significant ($p < 0.05$)

3.1.9.1 Cane yield

Cane yield was negatively and significantly associated with concentration of magnesium, sodium and chloride in juice, but positively and significantly associated with juice phosphorus. There was no apparent association between total juice cation levels, as measured by ash, and cane yield.

3.1.9.2 C.C.S.

C.C.S. was negatively and highly significantly correlated with juice potassium, chloride and ash per cent juice. Soil salinity was also shown to have had a significant and negative effect on c.c.s..

3.1.9.3 Sugar yield

The significant negative associations between cane yield and concentrations of magnesium, sodium and chloride in juice were carried through to sugar yields, as was the positive effect of juice phosphorus concentration. The negative effects of juice potassium and ash on c.c.s. did not achieve significance in effects on sugar yields.

3.1.9.4 Brix and pol

In order to examine further the apparent effect of specific ions on c.c.s., their effects on Brix and pol of first expressed juice were also examined. It was shown in Table XXII that juice calcium was unrelated to Brix or pol, and that magnesium and sodium in juice were significantly and positively associated with Brix only. Potassium and chloride in juice were not associated with variation in Brix, but were significantly and negatively associated with pol. Juice phosphorus was not associated with variations in Brix or pol. There was no statistically significant correlation between ash and Brix, but ash and pol were significantly and negatively correlated.

3.1.9.5 Discussion

The negative associations between cane yield and concentrations of magnesium, sodium and chloride in juice do not allow the yield decline to be directly attributed to the specific effects of these ions. Because of associations between inorganic juice constituents and salinity it is likely that the latter parameter was more important in yield decline than was juice composition.

Browne and Zerban (1955) have reviewed the effect that foreign, but optically active, substances have on the specific rotation of sugars. The effects may be either chemical in nature where the substances form sugar compounds which have lower specific rotation than pure sucrose solutions, or due to direct physical effects of the salt on the net optical rotation of the impure sucrose solution. These authors reported that chlorides, nitrates, sulphates, phosphates, acetates and citrates of the alkaline earths and many other salts all produce a decrease in the specific rotation of sucrose: the decrease being generally greater with increased amount and smaller molecular weight of the salt.

If all other variables are assumed constant, the range of potassium concentrations in Rocky Point juices was associated with a range of one unit of pol per cent juice. This depression in pol, whether associated with either potassium or chloride, appears to be larger than can be explained by chemical or physical effects of ions on polarization of sucrose. Alternatively, and more probably, it must be assumed that the range of soil salinities associated with the above juice compositions have adversely affected crop growth including synthesis and storage of sugars.

Other authors have reported effects of inorganic juice composition on sucrose concentration in juice. Stevenson et al (1970) showed that negative correlations existed between juice purity and potassium concentrations in juice from four varieties. The regression achieved significance only for the variety Trojan in plant cane. These authors did not report soil salinity or sulphated ash data. Prothero (1978), in Hawaii, has shown non-significant negative correlations between EC of juice and Brix, but a highly significant negative relationship between pol per cent cane and juice EC.

From these associations between soil salinity, ash and the yield parameters it would appear that reductions in soil salinity and ash through improved drainage should be attended by improved yield and c.c.s. in cane.

3.2 Phase II

Mill area survey of ash in first expressed juice

The mill area survey of ash in first expressed juice was based on 1 662 juice samples from 88 farms. For each juice sample seven parameters were recorded, making a total of 11 634 acquired data points. These data include the 110 samples from the 56 farms used in the phase I study.

3.2.1 Ash in first expressed juice

TABLE XXIII

Distribution of juices from the mill area survey with respect to ash categories in first expressed juice

Ash % juice	< 0.399	0.40-0.599	0.60-0.799	0.80-0.999	1.00-1.199	> 1.2
% samples in each class	0.1	28.5	51.0	15.0	4.5	0.9
Ash % impurity	< 19.99	20.0-29.99	30.0-39.99	40.0-49.99	50.0	-
% samples in each class	3.1	58.8	34.9	3.1	0.1	-

Conductimetric ash % juice data in the phase II study varied in the range 0.39 to 1.38 per cent. This range was slightly different to the range of 0.27 to 1.55 per cent quoted for the phase I data, because the latter values were gravimetric ash data, whereas the former were ash estimates derived from the calibrated industrial conductivity meter.

The ash distribution data in Table XXIII revealed that 71.4 per cent of samples contained more than 0.6 per cent ash in first expressed juice. This showed that the base ash loading in the cane supply was moderate to heavy, and that any measures taken to alleviate the situation must be considered for a large part of the mill area. Particular attention should be focussed on the area that supplied the 20 per cent of samples containing more than 0.8 per cent ash.

The average ash per cent impurity in first expressed juice for the 1 662 juice samples processed for c.c.s. analysis during the study period was 28.8 per cent. The corresponding weighted average ash per cent impurity in Brand 1 sugar was 51.3 per cent. Thus processing has resulted in an inflation of 1.8 fold in the ash per cent impurity entering the factory. Data reported by Kirby (1975) showed that an average inflation of 1.67 applied from first expressed juice to Brand 1 sugar from 1957-74 in another Queensland sugar mill which has produced high ash raw sugar. The corresponding average value in this period, for all mills in the State where IXJ ash is determined, was 1.48.

First expressed juice ash data were not available for the Rocky Point mill beyond the study period, but the inflation factor of 1.8 from first expressed juice to Brand 1 sugar during the study period could well average in the long term to an order of magnitude similar to the above example from Kirby (1975).

3.2.2 Effect of locality on ash in juice

The effect of locality on farm ash level was examined by plotting the average ash per farm during the study period on the Parish map (Figure 4). Examination of this "ash map" in relation to land use suitability classes for sugar cane (Figure 5), as prepared by the Department of Primary Industries, Holtz (1979), has shown that farms with average ash levels in excess of 0.7 per cent were associated with peaty or saline gley soils.

"Peaty gley soils occur in depressions and drainage lines often only one metre or less below the surrounding humic gleys. Prior to the Woongoolba Flood Mitigation Scheme these areas supported mainly tea-tree forests and were waterlogged for long periods each year.", Holtz (1979). Soil assay data from the phase I study showed that peaty gley soils contained moderate levels of salinity in the 0-50 cm zone.

Saline gley soils were generally unsuitable for cane production because of limitations from salinity and poor drainage.

Farms with average ash levels below 0.7 per cent were usually located on fine and medium textured humic gley soils which were probably more elevated than, and certainly exhibited better drainage characteristics and lower salinity levels in the 0-50 cm than did the peaty and/or saline gleys.

3.2.3 Variation in ash levels within farms

Considerable variation in ash levels was noted within individual assignments during the study period, (Table XXIV). Closer examination of these results revealed that variation between blocks could, in some instances, be attributed to location of blocks within an assignment in different sections of the district. Here previously mentioned soil factors influenced results.

Similar factors were thought to operate within farms where blocks were located within the one property description. This was particularly so on farms which lay across or adjoined drainage lines. Here drainage and/or salinity limitations were noted to be causing major restrictions to crop growth, either in sections of or whole fields.

TABLE XXIV

Variation in ash per cent juice within farms

Block No.	Variety	No. samples	Ash %	Std dev.	
Farm A - New Norwell Road					
18	NCo310	2	0.74	0.02	
21	Q90	8	0.57	0.05	
4B	NCo310	4	0.88	0.21	
Farm B - Norwell					
7B	Q86	3	0.76	0.04	
8	Q90	4	0.59	0.06	
9	NCo310	3	0.82	0.14	
20	NCo310	8	0.72	0.09	
25B	Q86	6	0.87	0.10	
33	Q90	4	0.55	0.08	
34	Pindar	4	0.47	0.08	
35	Q90	5	0.72	0.03	
Farm D					Location
1	Q90	11	0.72	0.06	Gilberton
4	H48-3116	9	0.65	0.08	Windaroo
8	NCo310	24	0.56	0.09	"
9	NCo310	7	0.63	0.04	"
12	NCo310	11	0.65	0.06	"
14	Q86	11	0.62	0.05	"
22	NCo310	5	0.49	0.06	"
33	NCo310	8	0.56	0.04	"
35	H48-3116	9	0.59	0.05	"
45	NCo310	10	0.59	0.08	"
5	NCo310, Q90	5	0.75	0.02	Norwell
51	H48-3116	9	0.95	0.15	"
52	Q90	6	0.77	0.10	"

3.2.4 Ash and c.c.s.

TABLE XXV

Correlation coefficients (r) between ash per cent juice and c.c.s., Brix and pol for varieties in the mill area study

Variety	No. samples	C.C.S.	Brix % juice	Pol % juice
All varieties	1 662	-0.36	-0.14	-0.29
NCo310	904	-0.26	-0.09	-0.20
Q90	397	-0.39	-0.12	-0.33
H48-3116	88	-0.50	-0.05+	-0.41
Q86	76	-0.61	-0.52	-0.60
Pindar	47	-0.78	-0.62	-0.75

\+ Not significant ($p < 0.05$): all other r's significant ($p < 0.05$)

Regression analysis was used to examine the mill area survey data for associations between ash and c.c.s., Brix and pol in juice from varieties where sample size was sufficiently large to make the analysis meaningful. Results shown in Table XXV indicate that the association between ash and c.c.s. was negative and highly significant. Brix and pol, with the exception of H48-3116 Brix, were also significantly associated with ash loadings in juice. It was of interest to note that variation in ash levels explained more of the variation in pol per cent juice than in Brix per cent juice.

As mentioned previously salts in juice, measured as ash, could be affecting pol values either through effects of ions on the net rotation of the clarified juice, or through reduced accumulation of sucrose in the field due to restrictions in vegetative growth and/or sugar synthesis caused by soil salinity. Because Brix was negatively associated with ash it would appear that the latter effect predominates as one would normally expect solution density to increase with higher salt loadings.

In order to examine further the negative associations between ash and sugar parameters in juice, varieties were included as dummy variables in multiple regression analyses of ash on c.c.s., Brix and pol. These analyses allowed varietal means for ash, c.c.s., Brix and pol to be compared using variance analysis. Results in Table XXVI showed that there were no significant differences between the average ashes for NCo310, Q90, H48-3116 and Pindar. Ash in Q86 was significantly higher than in all the preceding varieties.

TABLE XXVI

Varietal means for ash, c.c.s., Brix and pol in juices from mill area survey

Variety	Ash	C.C.S.	Brix % juice	Pol % juice
NCo310	0.70 a	13.95 a	21.33 a	19.04 a
Q90	0.69 a	14.31 b	21.16 b	18.96 a
H48-3116	0.67 a	13.62 c	20.18 c	18.08 b
Q86	0.76 b	13.29 d	20.19 c	17.79 b
Pindar	0.69 a	14.43 bf	21.27 ab	19.08 a

Means followed by the same letter are not significantly different ($p < 0.05$).

Most of the differences in c.c.s. between varieties were significant, with Q86 showing the poorest c.c.s.. Brix in H48-3116 and Q86 was significantly lower than that of the other three varieties. There were no significant differences between average pol values for NCo310, Q90 and Pindar. As for Brix, pols of H48-3116 and Q86 were significantly lower than those of the former three varieties.

Multiple regression analysis revealed that inclusion of varieties as dummy variables in c.c.s., Brix and pol relationships with ash contributed significantly to reductions in unexplained variation. It appeared however that ash was on average three times more important than individual varietal variables in explaining variation in c.c.s.. Ash and varieties only explained 19 per cent of the variation in c.c.s., therefore the relationship was not sufficiently precise to be used for predictive purposes. C.C.S. is affected by other factors such as rate of nitrogen usage in relation to harvest date in the subsequent season, crop yield, growing conditions during the peak growth months, crop class and whether the crop is lodged or erect. Most of the effects mentioned in the previous sentence are quite difficult to quantify. Hence the quantification of varietal and ash effects on c.c.s. at Rocky Point is therefore quite important.

Interaction terms between individual varieties and ash were not significant in their effect on the relationship between c.c.s. and ash in juice.

Data in this section showed that ash and varieties can affect c.c.s., but ash generally appears to be the more important variable.

3.2.5 Discussion

While variation exists within the mapping units shown in Figure 4, the mean ash values for farms, viewed in conjunction with major soil associations (Figure 5) has strongly linked the ash problem at Rocky Point with areas of peaty and saline gley soils. These soils have drainage and/or salinity limitations to growth of sugar cane. Cane yield data were not obtained for phase II study, but c.c.s. was clearly depressed in areas with higher ash levels in juice. Phase I data suggested that factors which caused variation in ash levels in juice explained more of the variation in c.c.s. than for cane yield.

Because of the high background ash resulting from the growing environment it is unlikely that changes in the varietal pattern will make a substantial contribution to lowering ash levels without attendant lowering of soil salinity.

4. CONCLUSIONS AND RECOMMENDATIONS

It was quite clear from phase I of this investigation that soil salinity played a major role in affecting the ash level and balance of ions in first expressed juice in the Rocky Point area. These results were reinforced by interpretation of the phase II data.

Thus it must be concluded that improvement in profile drainage characteristics and lowering of soil salinity levels could lead, in the long term, to reductions in ash loadings in juice at Rocky Point. The lower ash levels would assist the miller by alleviating processing difficulties, improving coefficients of work and reducing net titre penalties on raw sugar. Growers could expect to benefit from slight to marked improvements in cane yield and higher c.c.s..

Because of the large areas involved (1 550 ha of peaty gleys, Holtz (1979)), and the low lying nature of the land, marked improvements in drainage will be difficult and long term operations. Before major drainage works are undertaken to augment the existing "Flood Mitigation Scheme" several additional areas of research are indicated:-

1. A detailed topographic survey of the major part of the mill area within the Parish of Albert. This survey should include a study of mean water level heights in major drains in relation to a mean tidal datum.

2. A survey of the standing water-table heights and quality of water in the water-table throughout the mill area. This study of a likely benefited area could be extended through use of "Landsat" imagery to determine the proportion of the Rocky Point area that is being affected by poor drainage and/or salinity.

3. A pilot drainage scheme to gain a better understanding of the problems and benefits associated with lowering saline water-tables. This study should be extended to ensure that a permanent lowering of saline water-tables will not have adverse ecological effects on existing

supplies of fresh ground water and to gain some perspective of the economics of broad scale application of techniques to improve profile drainage.

4. A study of the change in balance of ions from first expressed juice to raw sugar in association with sugar refineries is indicated in order to determine which cations and anions are causing the greatest problem in raw sugars.

It is likely that similar soil salinity factors to those operating at Rocky Point are also contributing to ash problems in some other southern mill areas.

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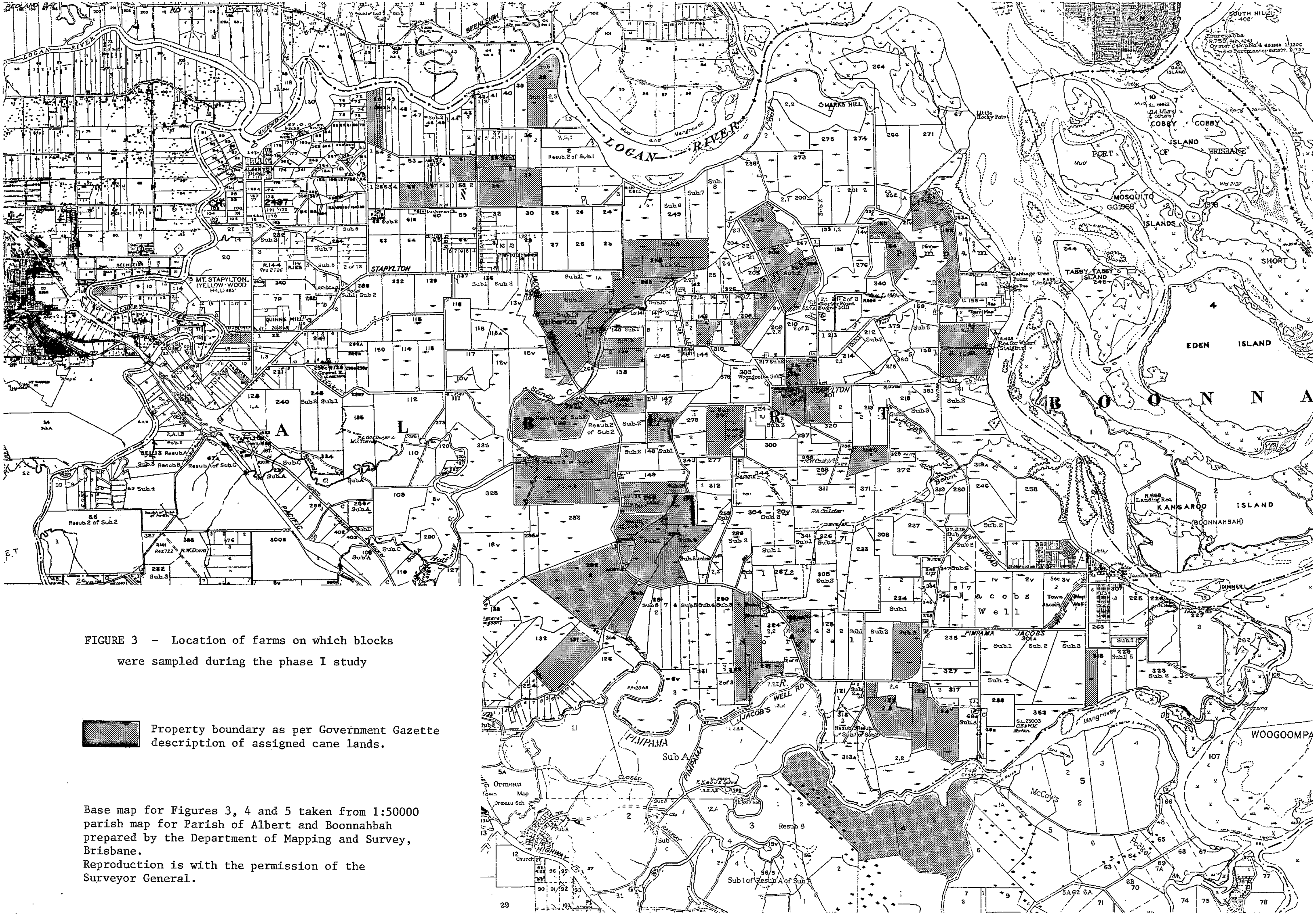

FIGURE 3 - Location of farms on which blocks were sampled during the phase I study

▨ Property boundary as per Government Gazette description of assigned cane lands.

Base map for Figures 3, 4 and 5 taken from 1:50000 parish map for Parish of Albert and Boonnahbah prepared by the Department of Mapping and Survey, Brisbane.
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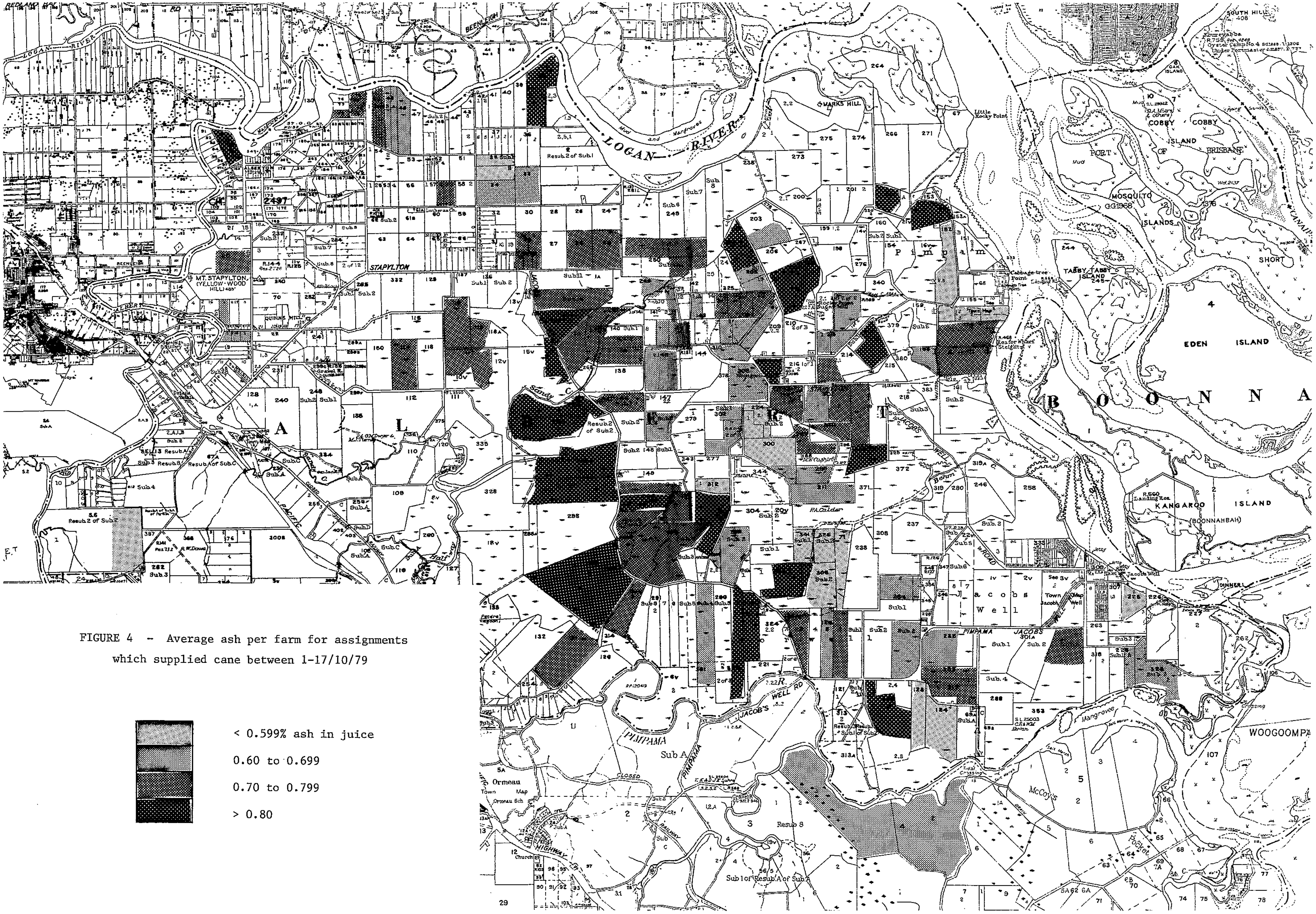

FIGURE 4 - Average ash per farm for assignments which supplied cane between 1-17/10/79

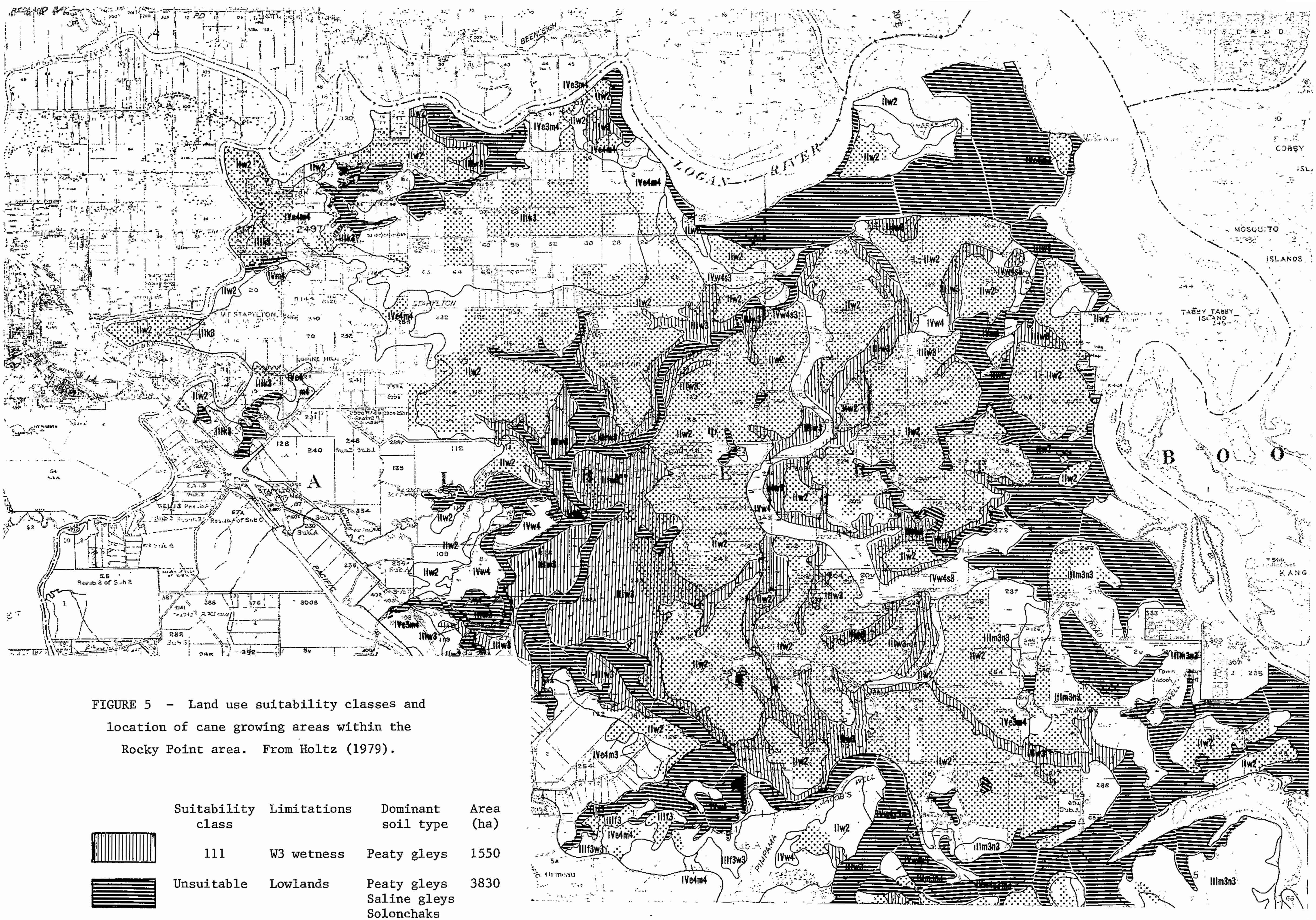

FIGURE 5 - Land use suitability classes and location of cane growing areas within the Rocky Point area. From Holtz (1979).

	Suitability class	Limitations	Dominant soil type	Area (ha)
▥	111	W3 wetness	Peaty gleys	1550
▤	Unsuitable	Lowlands	Peaty gleys Saline gleys Solonchaks	3830
░	Cane growing areas			

Adapted from Rocky Point Mill - Cane Growing Area, Land Suitability Map by G.K. Holz. and reproduced with the permission of the Queensland Department of Primary Industries.