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IRRIGATION QUALITY OF SOME STREAM WATERS IN THE LOCKYER VALLEY, SOUTH-EASTERN QUEENSLAND

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SUMMARY

Based on analytical results, samples of stream waters were classified into four levels of salinity from a consideration of electrical conductivity measurements, and four levels of sodium assessed on the relationship between conductivity and the sodium adsorption ratio.

At minimum stream flow, salinity levels are high in most water from Deep Gully, Sandy, Ma Ma and Flagstone Creeks and in Lockyer Creek between the junction of Tent Hill and Flagstone Creeks. In the above catchments, areas of saline soil could be anticipated as a result of irrigation over a long period.

A relationship between water quality and geological formations has been suggested.

I. INTRODUCTION

The Lockyer Valley is one of the oldest irrigation areas in Queensland. This natural catchment of 1,140 sq miles is open to the north and is bounded on the east by the Little Liverpool Range and on the south, the west and the north-west by the Great Dividing Range and spurs of the Great Dividing Range. The main drainage channel of the Lockyer Valley is Lockyer Creek, which rises in the foothills of the Great Dividing Range and meanders for a distance of approximately 70 miles in an easterly direction, joining the Brisbane River near Lowood.

The major tributaries of Lockyer Creek arise in the south and the west. These tributaries, as one moves from the eastern boundary to the western boundary of the valley, are Laidley Creek, Sandy Creek, Deep Gully, Tent Hill Creek, Ma Ma Creek, Flagstone Creek, Monkey Water Holes Creek, Rocky Creek, Murphy's Creek and Alice Creek. During dry periods some of these tributaries degenerate into a series of waterholes as one approaches the mouth, with no evidence of discharge by surface flow into Lockyer Creek. This is true of Sandy Creek, Ma Ma Creek and Rocky Creek. Subsurface discharge into Lockyer Creek by some of these streams probably occurs during such periods.

Irrigation commenced in the area in the 1930s and by 1935 fifty-four riparian licences had been issued. The demand for primary produce during the war years (1939-1945) was responsible for a rapid increase in irrigation installations and by 1947 over a thousand licenses had been issued to cover pumping from all sources.

To meet the growing demand for water the Irrigation and Water Supply Commission of Queensland, between the years 1941 and 1947, constructed four weirs at strategic points along Lockyer Creek, between Lowood and Gatton. These weirs (O'Reilly 0·9 miles, Brightview 22·64 miles, Wilson 38·09 miles and Jordan 40·52 miles from the mouth) have given a measure of control over the rate of discharge of water from Lockyer Creek. At the same time they have had a stabilizing effect on the levels of sub-artesian water, in some cases up to a distance of 40 chains from the creek (Bureau of Investigation 1949). This sub-artesian water is used extensively for irrigation and accounts for over 50% of all pumping licences issued.

By June 30, 1950, 470 riparian licences had been issued for the various streams in the Lockyer Valley considered in this paper. By the end of the next decade this number had increased to 560, representing an overall increase of 19% for these particular streams during the 10-year period.

The distribution of licences with reference to particular streams in 1950 and 1960, together with percentage increase in licences for individual streams during the decade, is set out in Table 1.

TABLE 1

DISTRIBUTION OF IRRIGATION LICENCES FOR THE YEARS 1950 AND 1960

Stream	Licences at June 30, 1950	Licences at June 30, 1960	Percentage Increase
Lockyer Creek	292	313	7·1
Laidley Creek	63	68	7·9
Tent Hill Creek	62	72	16·1
Ma Ma Creek	16	41	143·7
Sandy Creek	10	27	170·0
Flagstone Creek	17	20	17·6
Murphy's Creek	10	19	90·0
Total	470	560	..

Source: Annual Reports, Queensland Irrigation and Water Supply Commission.

While many water samples from the Lockyer Valley have been analysed by various authorities to assess irrigation quality, little of this information has been published. This paper gives some findings concerning the quality of stream waters in sections of the Lockyer Valley. Attention has been confined to Lockyer Creek west of Wilson Weir and to the southern and western tributaries of Lockyer Creek.

II. HYDROLOGY

Rainfall and stream discharge.—Reference to rainfall records covering the "normal period" (1911-1940) for the centres Lowood, Laidley, Gatton, Gatton College, Helidon and Hatton Vale indicates that normal average rainfall varies little from area to area within the Lockyer Valley. Of the centres named, Gatton has the highest average annual rainfall (28·93 in.) and Hatton Vale the lowest (27·72 in.). Approximately 70% of the total is received over the period November to April inclusive, with August the driest month.

Prior to 1947, gauging stations at Helidon and Tarampa measured stream discharge from the Lockyer Valley. The discharge measured at Helidon, although involving only one-tenth of the total area, accounted for 35% of the annual discharge from the whole catchment. Since the completion of the weirs on Lockyer Creek, Helidon gauging station has been the only one in the area measuring natural stream flow. It has been used in this paper as the datum against which general stream level at time of sampling is assessed.

Since rainfall records indicate little variation from area to area within the Valley, the general flow level of streams included in the gauging should also represent the general level of stream flow of streams not included in the gauging. Average monthly stream discharge as measured at Helidon is shown in Figure 1.

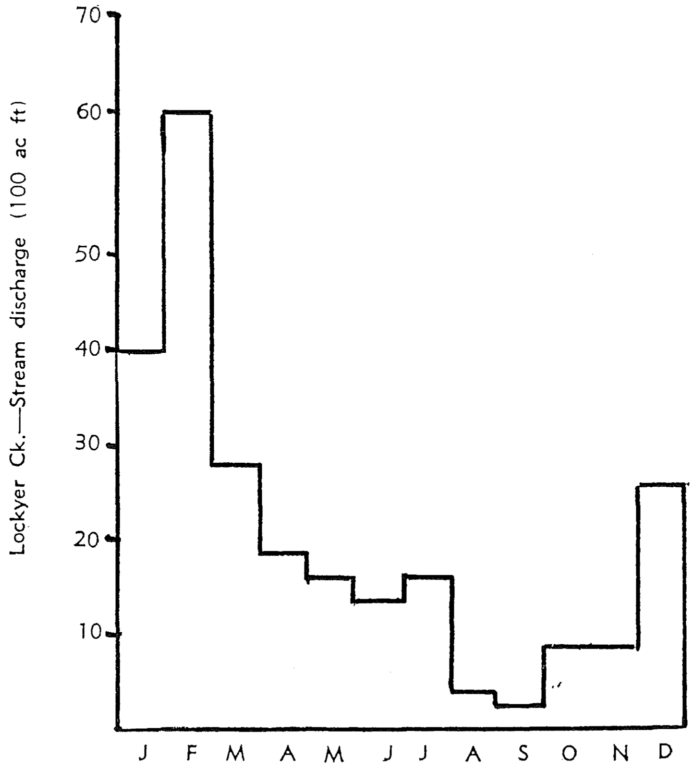


Fig. 1.—Average monthly stream discharge—Helidon Gauging Station, 1927-1955.

Monthly stream discharge as measured at this Station during the period of this investigation is shown in Figure 2, in which sampling dates for the various streams are also indicated.

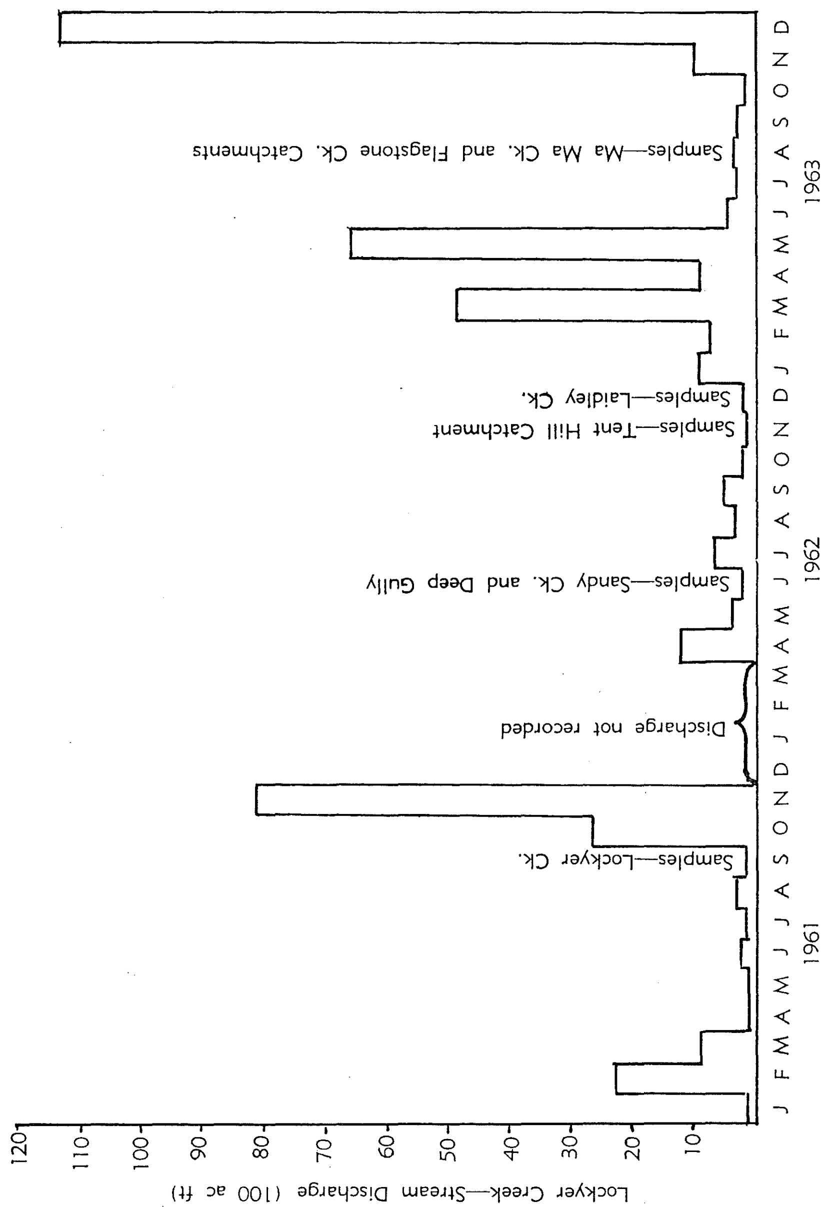
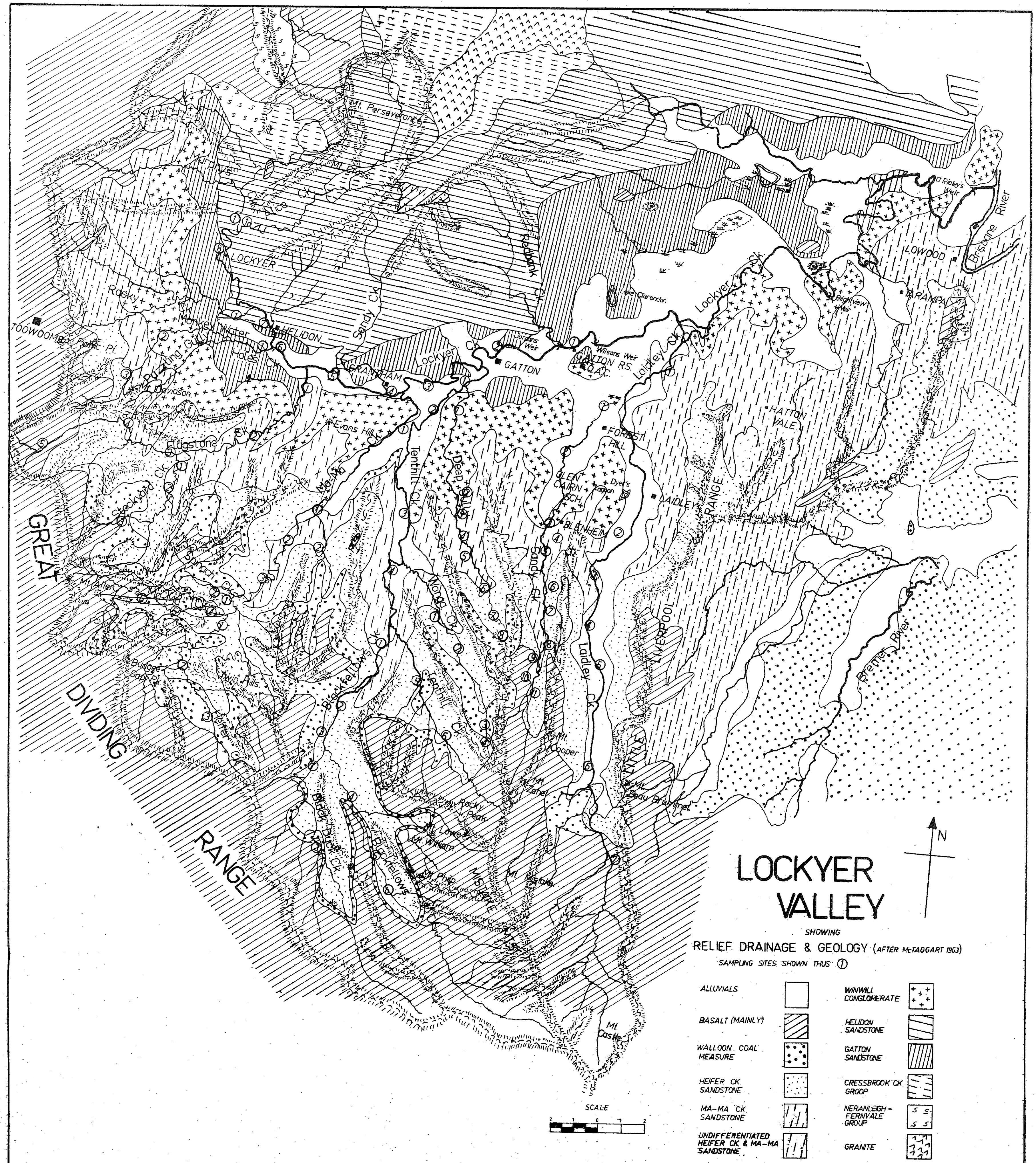


Fig. 2.—Monthly stream discharge—Helidon Gauging Station, 1961-1963.

Physiography and geology.—The basement rocks which floor the Lockyer Valley rise, sometimes sharply, above the alluvia to the south of Lockyer Creek, where they form the watersheds between the southern tributaries of the Lockyer.


LOCKYER VALLEY
SHOWING
RELIEF DRAINAGE & GEOLOGY (AFTER McTAGGART 1963)
SAMPLING SITES SHOWN THUS ①
ALLUVIALS
BASALT (MAINLY)
WALLOON COAL MEASURE
HEIFER CK. SANDSTONE
MA-MA CK. SANDSTONE
UNDIFFERENTIATED HEIFER CK & MA-MA SANDSTONE
WINWILL CONGLOMERATE
HELIDON SANDSTONE
GATTON SANDSTONE
CRESSBROOK CK. GROUP
NERANLEIGH-FERNVALE GROUP
GRANITE
SCALE
N
GREAT DIVIDING RANGE
TOOWOOMBA
HELIDON
GATTON
GRANTHAM
LOCKYER
FOREST HILL
LAIDLEY
LOWOOD
TARAMPA
HATTON VALE
LIVERPOOL RANGE
LAIDLEY RANGE
GLEN CAIRN SCH.
BLENHEIM
GATTON RS. Q.A.C.
Lockyer Ck
Laidley Ck
Tenthill Ck
Sandy Ck
Redbank Ck
Blackfellows Ck
Ma-Ma Ck
Flagstone Ck
Murphys Ck
Brisbane River
Bremer River
Mt. Perseverance
Evans Hill
Mt. Davidson
Mt. Cooper
Mt. Castle
Lake Clarendon
Wilsons Weir
Jordans Weir
O'Rieley's Weir

In many instances these ranges have been capped with basalt, which has weathered to form elevated plateaux. These plateaux and sides of such ridges have been cleared and grassed and are utilized for grazing and in many instances for dryland cropping.

Where the watersheds are of steep uncapped sandstone, little clearing has taken place and the infertile soils support the indigenous eucalypt forest vegetation.

Of the several geological surveys of the Lockyer Valley, the most recent is that of McTaggart (1963). McTaggart ascribes the sediments of the area to the mesozoic era. His delineations of the various geological "members" described have been superimposed onto a relief and drainage map of the Lockyer Valley for use in this paper.

III. METHODS

(a) Experimental

Sampling.—Sampling sites were selected along the Lockyer Creek west of Wilson Weir. These sampling positions are numbered on the map and were selected so that one sample was obtained from between each of the tributaries of Lockyer Creek. Sampling dates were designed to enable an assessment of water quality during a period of minimum stream flow.

Tributaries of Lockyer Creek were sampled as time permitted with the aim of ascertaining quality at or approaching minimum stream flow. In some cases samples were taken from bores either in the stream bed or in close proximity to the stream and occasionally from lagoons if it was considered such samples would give information concerning water quality in that particular area.

Sampling positions for particular catchments are indicated by numbers on the map. For each stream, sampling positions are numbered consecutively from mouth to source. In all cases the quality assessment of samples obtained from indicated positions can be ascertained by reference to the appropriate table, which also indicates whether the sample was obtained from a stream, bore or lagoon.

Analytical procedures.—Samples were filtered where necessary and the following analyses performed:—

(1) pH using a Jones Model C pH meter and a blue glass electrode.

(2) Electrical conductivity calculated from a measurement of resistance using a Philips Conductivity Measuring Bridge Model PR 9500. Conductivities are expressed in the units micro mhos/cm^3 at a standard temperature of 25°C.

(3) Calcium and magnesium by titration with E.D.T.A. as outlined by Cheng and Bray (1951).

(4) Carbonate, bicarbonate and chloride by methods outlined by the Association of Official Agricultural Chemists (1955).

(5) Sulphate by the method outlined by Richards (1954).

As the concentration of potassium is very low in most waters, this element was not determined. Sodium was calculated by difference.

Ionic concentrations are expressed in the unit milligram equivalents per litre.

(b) Criteria Used in Quality Assessment of Waters

In Australia, water analyses are normally performed by State authorities, and each State has developed its own method of expressing results and assessing quality for irrigation.

It would appear that any generally acceptable system of classifying a water from the point of view of irrigation quality should enable statements to be made concerning the long-term effects of this water on the levels of soil salinity and soil alkalinity. For this reason, the system of water classification evolved by the staff of the United States Salinity Laboratory has much to commend it. This system employs four salinity ratings, viz., low salinity (C1), medium salinity (C2), high salinity (C3) and very high salinity (C4), based on a consideration of measurements of electrical conductivity, combined with four alkalinity ratings, viz., low sodium (S1), medium sodium (S2), high sodium (S3) and very high sodium (S4).

The sodium ratings are based on a consideration of the sodium adsorption ratio (S.A.R.), which is determined from the formula

$$\frac{Na}{\sqrt{\frac{Ca^{++}+Mg^{++}}{2}}}$$

(concentrations are expressed in milliequivalents per litre) and its interaction with salinity levels. Details of classification of irrigation waters according to this scheme are fully set out by Richards (1954).

In 1958 the Department of Agriculture in New South Wales, as a result of an extensive study of information available from U.S.D.A. publications, decided to apply a system of "C" gradings to indicate the degree of salinity relative to the suitability of water for irrigation.

From field experience, and based on the analyses of thousands of samples, the New South Wales Department of Agriculture set the following upper limits of electrical conductivity for the various "C" gradings.

Grading	Electrical Conductivity (Ec) x 10^6 (25°C)	
	U.S.D.A.	N.S.W.D.A.
Low salinity water (C1)	250	900
Medium salinity water (C2) ..	750	1,500
High salinity water (C3) ..	2,250	2,500
Very high salinity water (C4) ..	2,250	2,500–5,000

This change in "C" gradings was thought advisable because of the few waters of U.S.D.A. C1 grading available outside the main irrigation areas, and also because of the fact that most farmers in New South Wales are not entirely dependent on irrigation but use it to supplement rainfall (T. H. Johns personal communication 1963).

As irrigation conditions in Queensland more nearly approach those of New South Wales than those of the U.S.A., the New South Wales modification of the U.S.D.A. classification has been used in this paper.

Comments relative to suggested conditions of utilization for irrigation of waters of various salinity and sodium gradings are given by Richards (1954).

IV. RESULTS

(a) Water Quality in Lockyer Creek

During periods of minimum stream flow, variations in quality occur from section to section of Lockyer Creek (Table 2). Between Wilson's Weir and Tent Hill Creek, quality remains very fair, with waters presenting a medium salinity hazard and a medium sodium hazard. West of Monkey Water Holes Creek, water quality is even better, showing a low to medium salinity hazard combined with a low sodium hazard (C2S1 and C1S1). However, in Lockyer Creek between the junctions of Tent Hill and Flagstone Creeks, water quality during periods of minimum stream flow shows considerable deterioration, particularly with respect to salinity levels. Water quality in this area combines a very high salinity hazard with a medium sodium hazard (C4S2). The possible reason for this will be referred to later.

(b) Water Quality in Tributaries of Lockyer Creek

Laidley Creek catchment.—Water from Laidley Creek is of good quality, being of low salinity and low sodium (C1S1) (Table 3). The only exception to this is sample 2, which was taken not from the creek but from a lagoon situated approximately ¼ mile west of Laidley Creek at the junction of Laidley West–Blenheim Road. This sample was quite unsuitable for irrigation (C4S4).

TABLE 2

CHEMICAL COMPOSITION—LOCKYER CREEK—MINIMUM STREAM FLOW

Location	Sampling Position	Sampling Date	pH	Conductivity Ec x 10^6 (25°C)	Ionic Composition (m-equiv./1)									Sol. Sodium Percentage	S.A.R.	Classification
					Ca^{++}	Mg^{++}	Na^{+}	Total	$CO_3^{=}$	HCO_3^{-}	$SO_4^{=}$	Cl^{-}	Res. Na_2CO_3			
Gatton Research Station ..	1	2.9.61	8·2	2,210	1·7	6·5	14·2	22·4	0·6	6·1	0·4	15·3	—	67·5	7·0	C3S2
Between Redbank and Tent Hill Creeks	2	2.9.61	8·4	1,790	1·3	4·9	11·3	17·5	0·4	4·5	0·2	12·4	—	68·0	6·4	C3S2
Between Tent Hill and Ma Ma Creeks	3	2.9.61	7·8	2,600	2·0	8·1	15·1	25·2	0·8	6·0	0·5	17·9	—	60·9	6·7	C4S2
Between Ma Ma and Sandy Creeks*	4	2.9.61	8·1	2,800	2·2	8·2	16·9	27·3	0·7	6·1	0·6	19·9	—	62·3	7·4	C4S2
Between Sandy and Flagstone Creeks*	5	2.9.61	7·9	2,800	2·6	6·2	19·1	27·9	1·1	6·1	0·6	20·1	—	68·5	9·1	C4S3
Between Flagstone and Puzzling Creeks	6	2.9.61	8·1	1,700	2·6	3·5	11·6	17·7	1·0	4·3	0·5	11·9	—	62·2	6·7	C3S2
Between Puzzling and Rocky Creeks	7	2.9.61	8·2	1,180	0·6	3·7	7·7	12·0	1·0	4·9	—	6·1	1·6	64·1	5·3	C2S1
Between Rocky and Murphy's Creeks	8	2.9.61	7·9	760	1·3	3·1	3·5	7·9	0·2	3·5	0·3	3·9	—	45·5	2·4	C1S1

* Maps of the Lockyer Valley show two Sandy Creeks. That referred to in this table to locate sampling positions along Lockyer Creek is a dry northern tributary of Lockyer Creek. The Sandy Creek referred to in Tables 1 and 3 is a southern tributary used for irrigation.

TABLE 3

CHEMICAL COMPOSITION—LAIDLEY CREEK, SANDY CREEK AND DEEP GULLY CATCHMENTS

Location	Sampling Position	Sampling Date	pH	Conductivity Ec x 10_6 (25°C)	Ionic Composition (m-equiv./1)									Sol. Sodium Percentage	S.A.R.	Classification
					Ca^{++}	Mg^{++}	Na^{+}	Total	$CO_3^{=}$	HCO_3^{-}	$SO_4^{=}$	Cl^{-}	Res. Na_2CO_3			
Laidley Creek	1	9.9.63	8·5	545	1·7	2·6	1·5	5·8	0·6	3·3	0·2	1·7	—	25·8	1·0	C1S1
	2*a*	7.12.62	7·3	14,800	12·2	30·3	105·6	148·1	—	1·1	4·2	142·8	—	71·3	22·9	C4S4
	3	7.12.62	8·5	666	2·4	2·8	2·2	7·4	—	5·2	0·2	2·0	—	29·7	1·4	C1S1
	4	7.12.62	8·6	606	1·7	2·2	3·8	7·7	—	5·7	0·3	1·7	1·8	49·3	2·7	C1S1
	5	7.12.62	8·7	555	2·2	2·0	1·8	6·0	—	4·4	0·2	1·4	0·2	30·0	1·2	C1S1
	6	7.12.62	8·7	476	1·7	1·1	2·9	5·7	—	4·2	0·3	1·2	1·4	49·8	2·4	C1S1
	7	7.12.62	7·8	417	1·5	2·0	1·3	4·8	—	3·7	0·2	0·9	0·2	27·0	1·0	C1S1
Sandy Creek	1	9.9.63	7·5	8,547	8·3	17·6	53·0	78·9	—	3·8	9·1	66·0	—	70·5	14·7	C4S4
	2	13.6.62	7·7	4,610	3·9	13·7	40·1	57·7	—	10·1	8·4	39·2	—	69·4	13·4	C4S4
	3	13.6.62	7·7	5,350	7·2	13·3	32·2	52·7	—	7·6	4·3	40·8	—	61·1	10·0	C4S3
	4*b*	13.6.62	7·7	5,230	16·6	20·8	19·6	56·0	—	8·1	4·8	44·1	—	35·0	4·5	C4S2
	5	13.6.62	8·0	2,890	6·1	8·7	13·6	28·4	0·2	5·7	1·8	20·7	—	47·8	5·0	C4S2
	6*b*	13.6.62	7·7	4,080	7·8	12·6	21·4	41·8	—	6·8	2·7	32·3	—	51·2	6·7	C4S2
	7	13.6.62	8·3	837	2·2	4·6	2·7	9·5	0·6	4·5	0·3	4·1	—	28·4	1·5	C1S1
	8	13.6.62	8·1	1,760	3·5	6·8	7·9	18·2	0·6	4·8	1·0	11·8	—	43·4	3·4	C3S1
	9*c*	13.6.62	7·5	10,410	20·0	42·8	47·9	110·7	—	9·6	5·9	95·2	—	43·2	8·5	C4S4
	10*c*	13.6.62	7·5	18,180	16·1	58·5	120·2	194·8	—	10·6	15·7	168·5	—	61·6	19·7	C4S4
	11	13.6.62	8·1	1,160	3·3	3·7	5·1	12·1	—	5·9	0·5	5·7	—	42·1	2·7	C2S1
Deep Gully	1	13.6.62	7·6	12,988	8·7	56·5	78·0	143·2	—	8·5	7·6	127·1	—	54·5	13·6	C4S4
	2*a*	13.6.62	7·8	17,850	26·4	50·5	122·4	199·3	—	4·9	14·6	179·8	—	61·4	19·6	C4S4
	3*a*	13.6.62	7·5	13,880	20·0	39·2	98·4	157·6	—	5·6	14·2	137·8	—	62·4	18·2	C4S4
	4	13.6.62	7·7	10,100	9·4	33·2	67·3	109·9	—	8·8	10·9	90·2	—	61·2	14·6	C4S4
	5*d*	13.6.62	7·9	8,196	2·4	13·9	68·1	84·4	1·6	15·7	4·9	62·2	—	80·6	23·4	C4S4
	6	13.6.62	7·7	11,490	14·0	44·7	63·7	122·4	—	8·9	10·5	103·0	—	52·0	11·8	C4S4
	7	13.6.62	7·7	10,740	12·2	47·6	55·8	115·6	—	7·3	8·6	99·7	—	48·2	10·1	C4S4
	8	13.6.62	7·8	7,870	7·8	35·6	40·7	84·1	—	10·1	6·2	67·8	—	48·4	8·6	C4S4

a Lagoon. *b* Bore. *c* Small western tributary. *d* Western tributary.

Sandy Creek catchment.—Sandy Creek water south of Blenheim reserve is of good quality, showing low to medium salinity levels coupled with a low level of sodium (samples 7 and 11) (Table 3). The two minor western tributaries of Sandy Creek (samples 9 and 10) discharge water of poor quality (C4S4) into the main stream. Deterioration in quality of water from Sandy Creek north of Blenheim reserve is marked and progresses from high salinity and low sodium above Blenheim reserve to very high salinity and very high sodium at and below Glencairn school (samples 1, 2, 3, 5 and 8). Two bores being used for irrigation in the Blenheim area (samples 4 and 6) showed water of poor quality, being of very high salinity and medium sodium (C4S2). The crops being irrigated were lucerne and beetroot, both salt-tolerant crops.

Deep Gully catchment.—Deep Gully is a minor southern tributary which joins Tent Hill Creek approximately a mile from the mouth of the latter. For most of the year Deep Gully is no more than a series of small waterholes over the lower two-thirds of its course. All samples obtained from the Deep Gully catchment, irrespective of source, were quite unsuitable for irrigation (C4S4) (Table 3).

Tent Hill Creek catchment.—Tent Hill Creek is one of the major southern tributaries of Lockyer Creek. Two main tributaries of Tent Hill Creek are Wonga and Blackfellow Creeks, the latter receiving the waters of Black Duck Creek before joining Tent Hill Creek.

Wonga Creek water is unsuitable for irrigation, being of very high salinity and high sodium (C4S3) (Table 4). An exception is the sample collected near the headwaters (sample 4).

Water from Tent Hill Creek and from the tributaries Blackfellow and Black Duck Creeks are of good quality, ranging from low salinity and low sodium to medium salinity and low sodium (C1S1 and C2S1). The headwaters of Tent Hill Creek and all water from Blackfellow Creek contain quantities of "residual sodium carbonate" ranging from a minimum of 0·3 to 1·7 m-equiv. /1.

Ma Ma Creek catchment.—Ma Ma Creek is a major southern tributary which joins Lockyer Creek opposite the township of Grantham. Near its source, Ma Ma Creek is joined by Heifer Creek, which gathers water from the south-eastern portion of Ma Ma Creek catchment, while Ma Ma Creek itself gathers water from the south-western portion of the catchment. Approximately half a mile below the junction of Heifer and Ma Ma Creeks, Spinach Creek joins Ma Ma Creek as a small western tributary of permanent flow, while approximately 4 miles below this junction an intermittently flowing tributary known as Dry Gully enters Ma Ma Creek from the south-east.

Above the junction of Ma Ma and Spinach Creeks, water of good quality is obtained both from Ma Ma Creek itself and from Heifer Creek (Table 5). These waters combine a medium salinity hazard with a low sodium hazard (C2S1). Below Spinach Creek the water of Ma Ma Creek is poor in quality, being associated with a very high salinity hazard but a low to medium sodium hazard.

TABLE 4

CHEMICAL COMPOSITION—TENT HILL CREEK CATCHMENT

Location	Sampling Position	Sampling Date	pH	Conductivity Ec x 10^6 (25°C)	Ionic Composition (m-equiv./1)									Sol. Sodium Percentage	S.A.R.	Classification
					Ca^{++}	Mg^{++}	Na^{+}	Total	$CO_3^{=}$	HCO_3^{-}	$SO_4^{=}$	Cl^{-}	Res. Na_2CO_3			
Wonga Creek	1	12.11.62	7·3	6,803	15·9	32·9	24·1	72·9	—	8·5	6·2	58·2	—	33·2	4·9	C4S3
	2	12.11.62	7·4	6,024	14·6	31·0	22·5	68·1	—	8·2	6·2	53·7	—	33·0	4·8	C4S3
	3	12.11.62	8·1	3,174	6·5	16·8	11·8	35·1	—	10·0	2·7	22·4	—	32·6	3·5	C4S1
	4	12.11.62	7·9	966	3·5	4·4	3·2	11·1	—	7·8	0·4	2·9	—	28·9	1·6	C2S1
Tent Hill Creek	1	2.9.61	8·3	950	1·3	5·7	2·9	9·9	0·4	3·4	0·2	5·9	—	29·6	1·1	C2S1
	2	12.11.62	7·8	1,110	3·5	5·0	3·1	11·6	—	5·0	0·7	5·9	—	26·8	1·5	C2S1
	3	12.11.62	7·8	900	2·6	3·7	2·9	9·2	0·2	3·8	0·7	4·5	—	31·4	1·6	C2S1
	4	12.11.62	8·4	724	2·4	2·2	3·0	7·6	—	5·0	0·3	2·3	0·4	39·4	2·3	C1S1
	5	12.11.62	8·3	680	2·2	2·2	3·0	7·4	0·6	4·1	0·3	2·4	0·3	40·6	2·4	C1S1
	6	12.11.62	8·3	289	0·6	0·4	2·4	3·4	0·6	1·8	0·1	0·9	1·4	70·7	2·9	C1S1
Blackfellow Creek	1	12.11.62	8·4	444	1·7	1·1	2·1	4·9	—	3·4	0·2	1·3	0·6	43·0	1·9	C1S1
	2	12.11.62	8·5	370	0·9	1·5	2·0	4·4	—	3·4	0·1	0·9	1·0	45·5	2·0	C1S1
	3	12.11.62	8·4	335	1·3	1·1	1·7	4·1	1·0	2·1	0·2	0·8	0·7	41·4	1·7	C1S1
	4	12.11.62	8·0	335	1·3	1·1	1·3	3·7	—	2·9	0·1	0·7	0·5	35·2	1·3	C1S1
	5	12.11.62	7·9	317	1·7	0·4	1·9	4·0	—	3·1	0·2	0·7	1·0	47·5	1·9	C1S1
	6	12.11.62	8·0	333	1·3	0·6	2·0	3·9	0·4	2·5	0·2	0·8	1·0	51·5	2·0	C1S1
Black Duck Creek	1	7.12.62	7·7	930	2·6	5·5	2·2	10·3	—	8·1	0·3	1·9	—	21·4	1·1	C2S1
	2	7.12.62	7·2	747	2·8	4·1	1·9	8·8	—	7·2	0·4	1·2	—	21·6	1·0	C1S1

TABLE 5

CHEMICAL COMPOSITION—MA MA CREEK CATCHMENT

Location	Sampling Position	Sampling Date	pH	Conductivity Ec x 10^6 (25°C)	Ionic Composition (m-equiv./1)									Sol. Sodium Percentage	S.A.R.	Classification
					Ca^{++}	Mg^{++}	Na^{+}	Total	$CO_3^{=}$	HCO_3^{-}	$SO_4^{=}$	Cl^{-}	Res. Na_2CO_4			
Heifer Creek	1	19.8.63	8·3	1,548	1·1	10·2	4·4	15·7	0·6	9·0	0·3	5·8	—	28·0	1·8	C2S1
	2	7.12.62	8·1	1,307	1·3	5·9	8·5	15·7	0·6	9·1	0·2	5·8	—	54·0	4·5	C2S1
	3	7.12.62	7·4	1,110	3·1	6·7	1·9	11·7	—	8·5	0·3	2·9	—	16·2	0·8	C2S1
Ma Ma Creek	1	2.9.61	7·8	3,060	4·8	16·6	10·1	31·5	0·7	7·1	1·3	22·4	—	28·2	3·2	C4S1
	2	13.8.63	8·2	3,472	3·7	17·0	14·4	35·1	0·8	7·7	2·0	24·6	—	41·0	4·5	C4S2
	3	29.11.62	7·3	2,770	4·8	14·6	8·7	28·1	—	7·4	1·2	19·5	—	30·9	2·8	C4S1
		13.8.63	8·3	2,105	3·7	10·2	6·9	20·8	0·8	7·0	0·9	12·1	—	33·1	2·6	C3S1
	4	29.11.62	8·0	1,709	3·1	11·2	3·5	17·8	0·6	7·1	0·4	9·7	—	19·6	1.3	C3S1
		13.8.63	8·3	1,695	3·1	8·5	5·9	17·5	0·6	7·5	0·7	8·7	—	33·7	2·5	C3S1
	5	19.8.63	7·6	1,042	3·1	5·7	3·5	12·3	—	7·4	0·1	4·8	—	28·4	1·7	C2S1
	6	19.8.63	7·7	1,240	3·1	6·7	3·4	13·2	—	8·5	0·1	4·6	—	25·6	1·5	C2S1
Spinach Creek	1	29.11.62	8·0	4,761	4·2	22·2	23·9	50·3	—	11·5	4·2	34·6	—	47·5	6.6	C4S3
		19.8.63	8·0	3,413	3·5	15·0	14·9	33·4	0·6	9·5	2·4	20·9	—	44·6	4·8	C4S2
	2	19.8.63	8·2	1,176	2·6	7·2	3·3	13·1	0·6	8·8	0·3	3·4	—	25·2	1·5	C2S1
Dry Gully	1	19.8.63	8·1	3,787	6·1	17·4	23·1	46·6	—	10·1	7·9	28·6	—	50·4	6·8	C4S2
	2*a*	29.11.62	7·9	7,437	6·7	29·0	49·3	85·0	1·2	14·2	9·6	60·0	—	58·0	11·7	C4S4

a Bore in creek bed.

TABLE 6

CHEMICAL COMPOSITION—FLAGSTONE CREEK, MONKEY WATER HOLES, ROCKY CREEK, MURPHY'S CREEK AND ALICE CREEK CATCHMENTS

Location	Sampling Position	Sampling Date	pH	Conductivity Ec x 10^6 (25°C)	Ionic Composition (m-equiv./1)									Sol. Sodium Percentage	S.A.R.	Classification
					Ca^{++}	Mg^{++}	Na^{+}	Total	$CO_3^{=}$	HCO_3^{-}	$SO_4^{=}$	Cl^{-}	Res. Na_2CO_3			
Flagstone Creek	1	2.9.61	7·5	2,130	3·6	12·1	8·2	23·9	0·5	8·0	0·5	14·9	—	34·3	2·9	C3S1
	2	13.8.63	7·2	3,021	5·5	14·6	11·5	31·6	—	14·9	0·5	16·2	—	36·4	3·6	C4S1
	3	13.8.63	8·1	1,162	2·4	6·1	3·7	12·2	—	6·3	0·2	5·7	—	30·3	1·9	C2S1
	4	13.8.63	7·7	1,091	3·3	5·4	2·8	11·5	—	7·2	0·2	4·1	—	24·3	1·3	C2S1
	5	13.8.63	8·1	1,158	2·6	8·1	2·9	13·6	0·6	6·0	0·1	6·9	—	21·3	1·2	C2S1
Stockyard Creek	1	13.8.63	8·0	2,330	4·6	11·5	6·8	22·9	—	8·4	0·5	14·0	—	29·6	2·4	C3S1
	2	13.8.63	7·7	1,610	3·3	9·8	3·4	16·5	—	7·9	0·5	8·1	—	20·6	1·3	C3S1
	3	13.8.63	7·5	1,344	3·5	8·1	4·6	16·2	—	10·1	0·4	5·7	—	28·4	1·8	C2S1
Monkey Water Holes Creek	1	2.9.61	7·7	7,350	12·2	34·9	27·1	74·2	0·4	3·9	2·9	67·0	—	36·5	6·3	C4S4
	2	13.8.63	8·0	3,157	5·9	16·5	11·5	33·9	0·6	7·5	2·1	23·7	—	33·9	3·3	C4S1
	3	13.8.63	8·1	1,066	2·4	7·2	2·4	12·0	0·4	8·0	0·1	3·5	—	20·0	1·1	C2S1
Puzzling Gully	1	13.8.63	7·3	11,363	10·5	23·1	81·6	115·2	—	5·4	6·2	103·6	—	70·8	19·9	C4S4
Rocky Creek	1	2.9.61	8·1	2,380	1·1	5·0	18·8	24·9	1·5	12·3	<0·1	11·1	7·7	75·5	11·1	C3S3
Murphy's Creek	1	2.9.61	7·8	1,020	2·3	4·2	3·6	10·1	0·2	4·0	<0·1	5·9	—	35·6	2·0	C2S1
Alice Creek	1	2.9.61	6·8	390	1·0	1·6	1·3	3·9	—	1·5	0·2	2·2	—	33·3	1·2	C1S1

The waters discharged into Ma Ma Creek by the tributaries Spinach Creek and Dry Gully are of poor quality, combining a very high salinity hazard with a medium to high sodium hazard.

Flagstone Creek catchment.—Flagstone Creek is the most westerly of the southern tributaries of Lockyer Creek used extensively for irrigation. The only significant tributary of Flagstone Creek is Stockyard Creek, which gathers water from the south-eastern sector of the Flagstone catchment and joins Flagstone Creek approximately 7 miles from the mouth of the latter.

Water from Flagstone Creek below the junction of Stockyard Creek is of poor quality for irrigation, combining a high to very high salinity hazard with a low sodium hazard (C3S1, C4S1) (Table 6). Above Stockyard Creek, water from Flagstone Creek is of good quality, being of medium salinity and low in sodium (C2S1). Stockyard Creek water is of poor quality over the lower two-thirds of the stream course, the water discharged into Flagstone Creek being high in salinity and low in sodium (C3S1).

Monkey Water Holes catchment.—Monkey Water Holes, a minor but permanent southern tributary which joins Lockyer Creek at Helidon, discharges water of very poor quality (Table 6). This water is very high in both salinity and sodium. Puzzling Gully, a small tributary of Monkey Water Holes, appears to be the chief source of "salts" associated with this catchment.

Rocky, Murphy's and Alice Creeks Catchment—Rocky Creek is a minor, intermittently flowing tributary of Lockyer Creek. Any water discharged by Rocky Creek into the Lockyer is of very poor quality, being associated with high levels of salinity and sodium (C3S3) (Table 6).

Murphy's Creek and Alice Creek are major tributaries which flow into the Lockyer from the ranges in the north-west of the Valley. Only one sample was obtained from the mouth of each of these streams. The water was of excellent irrigation quality, combining a low to medium salinity hazard with a low sodium hazard (C1S1 and C2S1).

(c) Relationship Between Water Quality and Geological Formations

In this attempt to relate water quality to geological formations, attention has been confined to the geological designations of McTaggart (1963). No single geological member appears to be the sole contributor to the salinity encountered in the various catchments. Highest levels of salinity are associated with Winwill Conglomerate and Ma Ma Creek Sandstone, and wherever either of these formations comprises a major portion of the catchment, water of poor quality can be anticipated. Since these two sediments occur in the northern half of the catchment of the southern tributaries of Lockyer Creek, water from these tributaries deteriorates in general as one proceeds from source to mouth. This fact is best illustrated by reference to analytical results of samples from Sandy Creek, Deep Gully, Ma Ma Creek and Flagstone Creek. The several "salt pans" which occur in the area covered in this paper are associated with one or other of these two geological formations.

While Winwill Conglomerate and Ma Ma Creek Sandstone are considered the major source of salinity, there is some evidence that both Heifer Creek Sandstone and the Walloon Coal Measure can contribute to the salinity of waters. This is indicated by reference to samples 2 and 3 from Wonga Creek (Table 4), sample 3 from Ma Ma Creek and sample 1 from Spinach Creek (Table 5).

Gatton Sandstone comprises only a small portion of the total area of sedimentary formations on the southern side of Lockyer Creek, and thus has no major influence on water quality in any of the streams sampled. However, limited unpublished analytical data from bores located in this sediment suggest that waters arising in this formation are characterized by high levels of sodium bicarbonate (free alkali).

V. DISCUSSION

While it is appreciated that quality of stream waters will vary from time to time throughout the year depending on rainfall, the aim of the authors was to sample during periods of minimum stream flow. If this aim was achieved the analytical figures presented in this paper should represent the poorest quality water in the various catchments being used by landholders. However, it is considered that the average quality of water utilized would not be much better than that at minimum stream flow, since the greatest demand for irrigation occurs during such periods.

Examination of the analytical data presented for the various streams suggests that with prolonged periods of irrigation saline soils could be expected to develop in a considerable portion of the catchments of Sandy Creek, Ma Ma Creek, Flagstone Creek and along Lockyer Creek between the junction of Tent Hill Creek and Flagstone Creek. The deterioration in quality of Lockyer Creek waters in this section would appear to be due to seepage from an area of Winwill Conglomerate which forms the southern boundary of the Lockyer between these two tributaries. No surface streams enter Lockyer Creek from the south in this section, except in times of flood. However, a "salt pan" exists in a broad shallow depression which runs from north of Evans Hill to join Lockyer Creek opposite Grantham township. Subsurface seepage from this drainage line is thought to be responsible for the increase in salinity of Lockyer Creek waters in this area.

Reference to Table 1 indicates that, over the decade 1950-1960, 90 extra licences were issued to cover pumping from streams in the Lockyer Valley. Forty-five of these licences were issued to landholders wishing to irrigate from

Sandy Creek, Ma Ma Creek and Flagstone Creek. While the authors have no knowledge of the precise location, or extra area irrigated, as a result of the issue of these licences, the analytical data presented for these streams suggest that the waters used to irrigate this extra area would be marginal as regards irrigation quality.

A reference has been made to an apparent relationship between water quality and geological formations. A fact which should not be overlooked in any endeavour to relate these two factors is the topography of the areas of the respective geological members. Generally, the topography of the areas embraced by Winwill Conglomerate and Ma Ma Creek Sandstone is of such a nature as to warrant the removal of natural tree vegetation to enable agricultural utilization of the slopes and plateaux. One specific instance is known in an area of Ma Ma Creek Sandstone, where a "salt pan" of approximately 20 acres has developed over a 20-year period following clearing of the natural arboreal vegetation in the headwaters of the catchment. In the section of the Lockyer Valley involved in this paper, areas of Heifer Creek Sandstone and Walloon Coal Measure are topographically unsuited to agricultural utilization and for the greater part retain their indigenous tree vegetation. Were such areas to be denuded of vegetative cover, their potential to contribute to the salinity of Lockyer Valley streams may be little different from that of Winwill Conglomerate and Ma Ma Creek Sandstone. Further detailed investigation is warranted to ascertain the veracity of this premise.

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