A.T. Laws.

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BYENUP, TOORDIT - GURRUP AND POORINGUP LAGOONS: WATER QUALITY CRITERIA IN RELATION TO PEAT MINING

by

M. W. Martin

Geological Survey of Western Australia

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1. INTRODUCTION

Byenup, Toordit-Gurrup and Poorginup Lagoons, located about 60 kilometres east of Manjimup (Fig. 1), are the subjects of applications for coal mining leases for the purpose of peat mining by Cladium Mining Pty Ltd.

The granting of these leases has been delayed for about five years to allow a programme of water sampling to be undertaken by the Department of Fisheries and Wildlife in order to establish base level salinities for the lagoons.

This report reviews the results recorded in an earlier report (Laws, 1979) in the light of additional data, and suggests water quality criteria for post-mining conditions based on the data collected over the five year monitoring period.

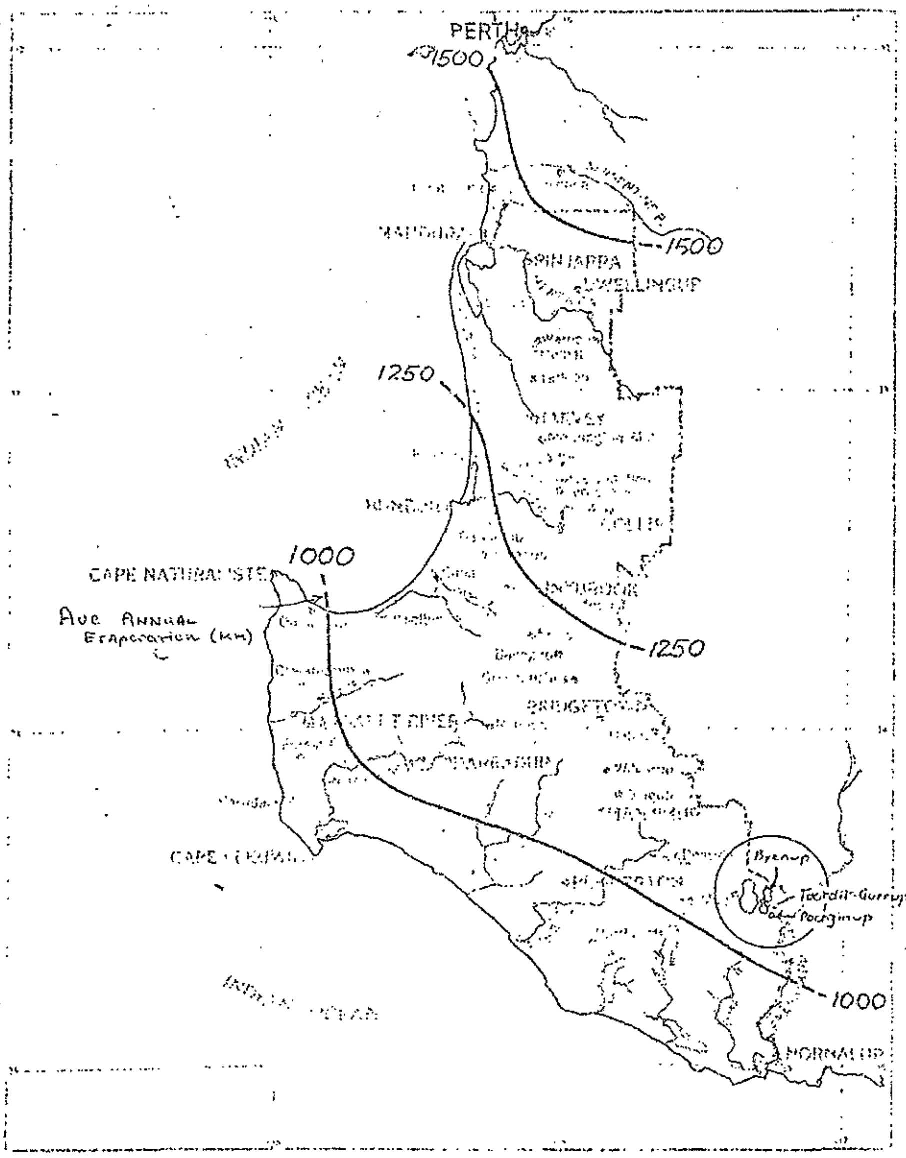
2. PREVIOUS WORK

Since April 1977, water samples have been collected at three monthly intervals and analysed for total dissolved solids (TDS) and pH by the Government Chemical Laboratories (GCL). This information to March 1979 has been detailed by Laws (1979) who also presents an overview of the lagoon hydrology.

From November 1978, Byenup, Toordit-Gurrup and Poorginup lagoons have been included in a regional monitoring of wetland areas conducted by the Department of Fisheries and Wildlife. Lagoon levels and *in situ* salinity measurements are made on a bi-monthly basis commencing in January each year. This results in three consecutive samples for the summer and winter periods.

Bathymetric surveys of Byenup and Toordit-Gurrup lagoons were completed in October 1979 by the Public Works Department, and capacity curves relating gauge board levels to volume were produced. Thick vegetation in Poorginup prevented completion of bathymetric surveying of the system.

fig. 1



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

	Initial	Date
Comp		
Drawn		
Chkd		
Apvd		

LOCATION

Map Index

To accompany Hydro Report 2433 by M. MARTIN.

Figure 1

81712/12/78 2.250 R72

A regional Engineering Geology and Hydrogeological study of the area was conducted in 1979/80 (Martin and Daetwyler, 1980) to investigate a proposed diversion of saline water from the Tone and Kent Rivers to the Frankland River, and includes a brief discussion of the hydrogeology of the Lake Muir system.

3. METHOD OF SAMPLING AND ANALYSIS

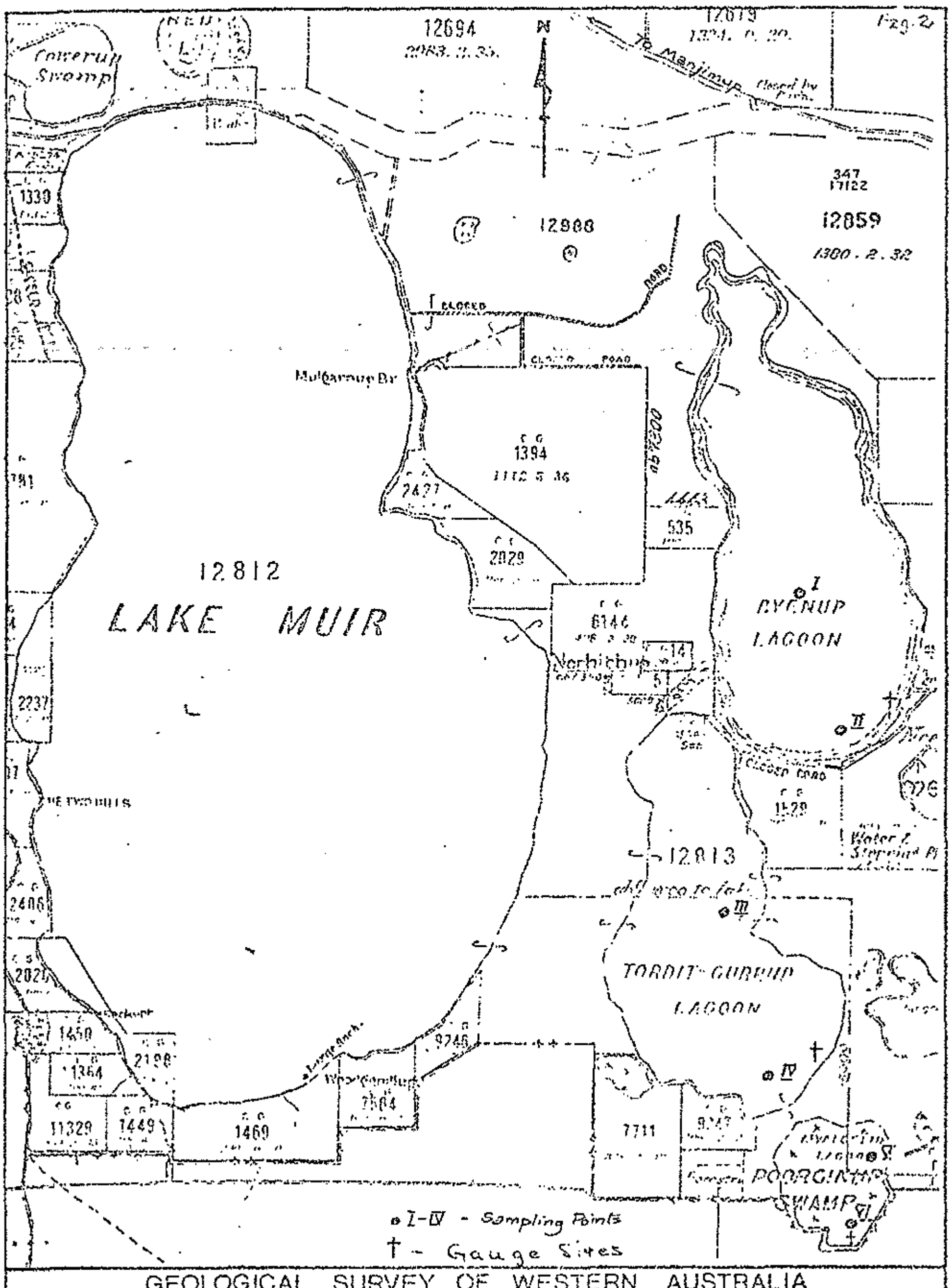
Initially, samples were collected from two sites at each lagoon (Fig. 2) with a surface and bottom sample at each location, and submitted to GCL for analysis. Total Dissolved Solids were measured by evaporation or empirically calculated from conductivity measurement.

From November 1978, salinities have been measured *in situ* with selected samples submitted to GCL for analysis as a calibration check. The calibration checks show a variation of about ±10% between *in situ* measurements and GCL measurements for the period to December 1980. This degree of variation is considered acceptable for base level salinity determinations. *In situ* measurements for 1981 are consistently greater than GCL analyses, and differences of up to 50% at the lower salinity range have been detected.

All pH measurements have been made by GCL. Because of only slight differences in pH between sites for each lagoon, later analyses have been limited to one sample from each lagoon.

4. ANALYTICAL RESULTS

The results of TDS and pH analyses are given in Table 1, and the method of TDS determination for each sample is indicated. Total dissolved solids, pH and reduced lagoon levels from all lagoons, and volumes and salt load for Byenup and Toordit-Gurrup lagoons are presented graphically in Figures 3, 4 and 5. It should be noted that plotted TDS values for Byenup and Toordit-



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

	Initial	Date
Comp	ATL	
Drawn	ATL	
Chkd		
Apvd		

Sampling Points

To accompany Hydro Report 2432 by M. MARTIN

Map Index

Figure 2

81712/12/78 2,250 1172

Gurrup are mean values for each lagoon because differences between sites are not significant. This is not the case for Poorginup Lagoon, and site salinities are indicated on Figure 3.

4.1 *Salinity*

There is a marked difference in salinity between the two sites at Poorginup Lagoon; most site V values fall within the range 600 mg/L to 900 mg/L whilst the majority of site VI values are in the range 300 mg/L to 600 mg/L. This suggests that site VI is located in an area where recharge is occurring. The difference in values also implies that mixing in the lagoon is very poor. As the predominant method of mixing in a shallow lagoon is by wind action, this result is not unexpected because of the thick vegetation cover and sheltered aspect of Poorginup Lagoon.

The seasonal response of salinity in this lagoon is not well defined, salinity tends to decrease over winter and increase during summer, however the pattern is broken when the lagoon is dry at the end of summer. Salinities at Poorginup appear to be fairly well buffered with no apparent trend over the period of record. The mechanism producing this long term buffering effect is not obvious from the available data, however it appears that there is a balance between salt input from run-off, rainfall and salt discharge from the lagoon by groundwater and surface outflow.

Salinities at Toordit-Gurrup Lagoon range from about 500 mg/L to 1500 mg/L TDS, and show a cyclic response with maximum values at the end of summer and minimum values at the end of winter. This cyclic pattern is also evident for Byenup Lagoon with salinities which range from about 2000 mg/L to 6000 mg/L TDS.

Salinities in both Byenup and Toordit-Gurrup lagoons appear to be rising over the period 1978 to 1982 however this is suggested as being a response to climatic variations rather than a long term trend. Evidence to support this can be obtained by considering the volumetric and salt load curves for these lagoons (Figs 3, 4).

TABLE 1: ANALYTICAL RESULTS

BYENUP LAGOON

DATE	I TDS	I pH	II TDS	II pH
April '77	<---- TDS:	5900[1]	pH: 8.4 ---->	
June '77	4400[1]	8.2	4200[1]	7.8
Sept '77	(T)1930[1] (B)2040[1]	7.9 7.7	(T)2260[1] (B)2360[1]	8.1 7.9
Dec '77	(T)2470[1] (B)2520[1]	7.9 7.8	(T)2570[1] (B)2520[1]	7.9 9.0
Mar '78	(T)3850[2] (B)3820[2]	8.2 8.0	(T)3830[2] (B)3840[2]	8.4 8.4
June '78	(T)3550[1] (B)3550[1]	8.1 7.8	(T)3780[1] (B)3780	8.2 8.2
Sept '78	(T)2340[1] (B)2440[1]		(B)2400[1]	
Nov '78	<--------- TDS:		2600[3] --------->	
Dec '78	(T)2850[3] (B)2850[3]		(T)2800[3] (B)2800[3]	
Jan 79	<-------TDS:		3300[3]--------->	
Mar '79	(T)4000[3]		(T)4000[4] (B)4000[3] 4040[2]	8.4
May '79	<--------- TDS:		4300[3] --------->	
June '79	(T)4050[3]		(T)4050[3] 4020[2]	8.4
July '79	<--------- TDS:		3700 --------->	
Sept '79	(T)2950[3] (B)2950[3]		(T)3300[3] (B)3300[3] (T)3510[1]	8.4
Nov '79	<--------- TDS:		3300[3] --------->	
Dec '79	(M)2800[3]		(M)3400[3] (M)3670[1]	8.3
Jan '80	<--------- TDS:		4200[2] --------->	
Mar '80	(M)8200[3]*		(M)8200[3]* (M)5230[2]	8.7

TOORDIT GURRUP

DATE	TDS	pH	TDS	pH
April '77	<---- (T) 1450[1] <---- (B) 1460[1]		8.3 ---> 8.3 --->	
June '77	1150[1]	7.3	1130[1]	8.1
Sept '77	(T) 970[1] (B) 960[1]	7.3 7.3	(T) 950[1] (B)1000[1]	7.9 7.5
Dec. '77	(T) 970[1] (B) 960[1]	7.3 7.8	(T) 960[1] (B) 960[1]	7.5 6.6
Mar '78	(T)1400[2] (B)1290[2]	7.7 8.2	(T)1400[1] (B)1290[2]	7.4 8.1
June '78	(T)1169[1] (B)1170[1]	7.5 7.5	(T)1170[1] (B)1180[1]	7.9 7.6
Sept '78	(T) 760[1] (B) 770[1]		(T) 700[1] (B) 710[1]	
Nov '78	<--------- TDS:		650[3] --------->	
Dec '78	(T) 700[3] (B) 800[3]		(T) 700[3] (B) 700[3]	
Jan '79	<--------- TDS:		750[3] --------->	
Mar '79	(T) 950[3]		(T) 900[3] (B) 900 870[2]	8.0
June '79	(T) 850[3]		(T) 850[3] 880[2]	8.2
July '79	<--------- TDS:		800[3] --------->	
Sept '79	(T) 800[3]		(T) 750[3] (B) 750[3] (T) 810[1]	8.1
Nov '79	<--------- TDS:		800[3] --------->	
Dec '79	(M)1400[3]		(M) 900[3] (M) 870[2]	7.9
Jan '80	<--------- TDS:		900[3] --------->	
Mar '80	(M)1250[3]		(M)1250[3] (M)1160[2]	8.5

POURGINUP

DATE	TDS	pH	TDS	pH
June '77	680[1]	6.1	580[1]	5.7
Sept '77	(T) 660[1] (B) 680[1]	6.3 6.1	(T) 300[1] (B) 310[1]	5.7 5.6
Dec '77	(T) 910[1] (B) 960[1]	6.3 6.6	(T) 430[1] (B) 440[1]	5.9 6.4
Mar '78	<-------------	DRY	------------>	
June '78	(T) 640[1]	6.2	(T) 760[1] (B) 820[1]	5.5 5.4
Sept '78	(T) 420[1]		(T) 410[1]	
Nov '78	<---------	TDS:	350[3] --------->	
Dec '78	(T) 750[3]		(T) 350[3]	
Jan '79	<---------	TDS:	500[3] --------->	
Mar '79	<-------------	DRY	------------>	
May '79	<-------------	DRY	------------>	
June '79	DRY		(T) 700[3] 720[2]	5.8
July '79	<---------	TDS:	600[3] --------->	
Sept '79	(T) 850[3]		(T) 400[3] (T) 460[1]	5.7
Nov '79	<---------	TDS:	300[3] --------->	
Dec '79	(M) 900[3]		(M) 400[3] (M) 470[1]	6.0
Jan '80	<---------	TDS:	500[3] --------->	
Mar '80	<-------------	DRY	------------>	
June '80	<-------------	DRY	------------>	
July '80	<----------	TDS:	550 --------->	
Sept '80	740[2]	5.6	510[2]	5.2

BYENUP LAGOON

DATE	TDS	pH	TDS	pH
May '80	<-- TDS:	5030[2]	pH:	8.5 -->
June '80	4900[2]	8.4	4890[2]	8.7
July '80	<---------- TDS: 4600[3] ---------->			
Sept '80	3870[2]	7.8	4060[2]	8.1
Nov '80	<---------- TDS: 4300[2] ---------->			
Dec '80	4220[2]	8.6	4280[2]	9.0
Jan '81	<---------- TDS: 5900[3] ---------->			
Mar '81	(T)7000[3]		6640[2] (T)7000[3]	
May '81	<---------- TDS: 7000[3] ---------->			
June '81	(T)6200[3]		(T)6200[3] 5850[2]	8.7
July '81	<---------- TDS: 5700[3] ---------->			
Sept 81	(T)2400[3]		(T)2500[3] 2320[2]	8.0
Nov '81	<---------- TDS: 2800[3] ---------->			
Dec '81	(T)2900[3] 2930[2]	7.7	(T)2800[3] 2910[2]	8.2
Jan '82	<---------- TDS: 3250[3] ---------->			
Mar '82	3870[2]	8.6	3860[2]	8.7
May '82	<-- TDS:	4390[3]	pH:	9.0[3] -->
June '82	3800[3] 3790[2]	8.8	3800[3]	

TOORDIT GURRUP

DATE	TDS	pH	TDS	pH
May '80	<-- TDS:	1150[2]	pH:	8.2 -->
June '80	1190[2]	7.6	1120[2]	8.2
July '80	<---------- TDS: 1050 ---------->			
Sept '80	980[2]	7.6	1000[2]	7.7
Nov '80	<---------- TDS: 1100[3] ---------->			
Dec '80	1110[2]	8.0	1060[2]	8.5
Jan '81	<---------- TDS: 2150[3]* ---------->			
Mar '81	(T)1750[3]		1470[2] (T)1700[3]	
May '81	<---------- TDS: 1750[3] ---------->			
June '81	(T)1600[3]		(T)1600[3] 1350[2]	8.2
July '81	<---------- TDS: 1500[3] ---------->			
Sept '81	(T)1100[3]*		(T)1100[3]* 870[2]	7.9
Nov '81	<---------- TDS: 1200[3] ---------->			
Dec '81	(T)1200[3]* 933[2]	8.0	(T)1200[3]* 943[2]	7.8
Jan '82	<---------- TDS: 1350[3] ---------->			
Mar '82	(T)1220[2]	7.9	(T)1150[2]	8.4
	<-- TDS:	1450[3]	pH:	8.7[3] -->
May '82	<-- TDS:	1600[3]	pH:	8.5[3] -->
June '82	(T)1240[3]		(T)1300[3] 1140[2]	8.3

POORGINUP

DATE	TDS	pH	TDS	pH
Dec '80	400[2]	6.1	400[2]	6.1
Jan '81	<---------- TDS: 1600* ---------->			
Mar '81	<-------------- DRY -------------->			
May '81	<-------------- DRY -------------->			
June '81	(T)1000[3]*		(T)1100[3]* 780	5.2
July '81	<---------- TDS: 950[3]* ---------->			
Sept '81	(T) 600[3]*		(T) 400[3]* 240[2]	6.0
Nov '81	<---------- TDS: 600[3] ---------->			
Dec '81	(T) 700[3]* 432[2]	6.3	(T) 700[3]* 477[2]	6.4
Jan '82	<---------- TDS: 800[3] ---------->			
Mar '82	<-- TDS: 950[3] 1070[2]	5.8	pH: 6.2[3] --> 680[2]	5.7
May '82	<-- TDS:	1000[3]	pH:	5.0 -->
June '82	(T) 750[3]		(T) 750[3] 570[2]	6.1

[1]*Govt Chem. Lab, evaporation.* [2]*Govt Chem. Lab, from conductivity.* [3]*In situ analysis.* [4]*Possible error.*

The seasonal relationship between salinity, lagoon volume and salt storage is most apparent for Byenup Lagoon (Fig. 4) which has a repeated cycle of increasing volume and salt storage with decreasing salinity over winter and increasing salinity and decreasing salt storage and volume over summer. This represents an open system where salts are flushed from the lagoons each year, and appears to be the mechanism controlling salinity levels. For the period 1978 to 1982, the long term trend is for decreasing volume, decreasing salt load and increasing salinity which is analogous with the summer seasonal cycle. It appears that over this period there has been insufficient rainfall to promote complete flushing of salts concentrated by evaporation, but a "winter cycle" should be observed over a long term climatic period which is predominated by above average rainfall.

4.2 *pH*

The pH values for these lagoons fall within a distinct range which is characteristic for each lagoon. At Poorginup, the pH falls within the range 5.0 to 6.5, Toordit-Gurrup 7.0 to 8.5 and Byenup 7.5 to 9.0 pH units. This narrow range of pH for each lagoon indicates that the system is fairly well buffered. The buffering effect is probably caused by biotic activity which removes carbon dioxide from solution with a subsequent increase in pH.

5. DISCUSSION

The additional monitoring of these lagoons confirms the conclusion of Laws (1979) that each lagoon must be considered separately. Also, the systematic increase in salinity and pH between lagoons suggests that there is a cascade effect from Poorginup through Toordit-Gurrup to Byenup Lagoon then out of the system, and implies that the system is interdependent and any change in one lagoon will be attentuated in the next in line lagoon and thus through the system.

This cascade effect indicates that mining should be conducted progressively from one lagoon in the system to the next, but presents a dilemma as to the sequence of mining most desirable in terms of environmental impact and eventual rehabilitation.

The mining sequence Poorginup; Toordit-Gurrup then Byenup has the advantage that initial environmental disturbance will be limited to a fairly small fresh water body which might be simply rehabilitated, but has the disadvantage that drainage of the lagoon for mining purposes will influence Toodit-Gurrup and Byenup base level salinities and pH. Also, if rehabilitation is not completely successful, the effects will be transmitted down the system and may result in a viable lagoon becoming too saline to support wildlife.

Mining carried out in the sequence Byenup, Toordit-Gurrup, Poorginup lagoon has the advantage that any deleterious effect at Byenup is unlikely to effect Toordit-Gurrup or Poorginup lagoons. Also, water from the two fresher lagoons can be used to fill Byenup Lagoon if mining continues. This sequence of mining will allow continued monitoring of base level salinities in the undisturbed lagoons. The disadvantage with this mining sequence appears to be an environmental one as Byenup Lagoon represents about half the total area of the lagoon system, and will be of greatly reduced value with respect to wildlife during mining. As this lagoon may eventually be mined regardless of the sequence of operations, this objection does not appear to present a problem.

On the basis of the available data, the preferred sequence of mining is Byenup Lagoon/Toordit-Gurrup Lagoon/Poorginup Lagoon.

The natural flushing of the lagoons appears to be critical to their survival as wildlife reserves. Any drainage diversion structues must be constructed with control facilities to allow release of water from the lagoons at optimum times. This will facilitate post-mining management of the system if it is found that the natural salt balance is disturbed and salinity increases occur.

6. WATER QUALITY CRITERIA

The format used by Laws (1979) of setting water quality criteria for each lagoon has been adapted here, and relevant values are displayed in Table 2. Maximum salinities have been set at two standard deviations of the mean quarterly lagoon salinity, and a range of pH values for each lagoon is recommended. The values set by Laws (1979) are also shown in Table 2.

TABLE 2: PROPOSED WATER QUALITY CRITERIA

AVERAGE LAGOON SALINITIES (Mg/L) WITH 50% INCREASE AND ABSOLUTE VALUES (LAWS 1979)

Site	Absolute values	MARCH		JUNE		SEPTEMBER		DECEMBER	
		Average	Plus 50%	Average	Plus 50%	Average	Plus 50%	Average	Plus 50%
I (B)	6000	4493	6000*	3833	5750	2103	3195	2650	3975
II (B)	6000	4403	6000*	3920	5880	2365	3548	2686	4629
III (TG)	1800	1330	1800*	1163	1745	865	1298	814	1221
IV (TG)	1800	1262	1800*	1155	1733	840	1260	900	1350
V (P)	1500	900	1350	660	990	587	881	923	1385
VI (P)	1500	900	1350	720	1080	340	510	443	665

Based on revised data to June 1982

		Plus 2S+		Plus 2S		Plus 2S		Plus 2S
Byenup Lagoon	4616	7175	4400	6190	2760	4040	3017	4123
Toordit-Gurrup Lagoon	1250	1790	1182	1606	852	1078	931	1291
Poorinqup Lagoon	usually	1200	704	865	500	862	563	1017

+S = standard deviation

AVERAGE LAKE pH WITH ALLOWED LIMIT (LAWS, 1979)

	MARCH		JUNE		SEPTEMBER		DECEMBER	
	Average	With Limit	Average	With Limit	Average	With Limit	Average	With Limit
I (B)	8.2	7.2-9.0	8.0	7.0-9.0	7.8	6.8-8.8	7.85	6.8-8.8
II (B)	8.4	7.4-9.0	8.1	7.1-9.0	8.0	7.0-9.0	8.5	7.5-9.0
III (TG)	8.1	7.1-9.0	7.4	6.4-8.4	7.3	6.3-8.3	7.65	6.5-8.5
IV (TG)	8.0	7.0-9.0	7.9	6.9-8.9	7.7	6.7-8.7	7.05	6.1-8.1
V (P)	5.5	5.0-6.5	6.15	5.1-7.1	6.2	5.2-7.2	6.45	5.4-7.4
VI (P)	5.5	5.0-6.5	5.5	5.0-6.5	5.65	5.0-6.6	6.15	5.1-7.1

Proposed pH range

Byenup Lagoon	5.0-9.0
Toordit-Gurrup Lagoon	5.0-8.5
Poorginup Lagoon	5.0-6.5

As can be seen from Table 2, only one salinity maximum is set for each lagoon in contrast to the recommendations of Laws where values for each site are tabled. This is because post mining lagoon conditions are likely to induce better mixing even in Poorginup Lagoon and hence a single value for maximum salinity is appropriate.

The allowable values of pH have been set as a range for each lagoon. However, as water from one lagoon will be used to supplement a mined lagoon, the pH in the mined lagoon should not fall below the lowest value of the supplementing water, and results in a sliding scale for post-mining conditions.

It is also recommended that the responsibility of reading gauge board levels, collecting water samples and their submission to the Government Chemical Laboratories for analysis should rest with the mining company. This should commence from the date of granting of any lease, but for the sake of uniformity and consistency it is recommended that the first year of sampling by the company be in conjunction with, or supervised by the Department of Fisheries and Wildelife. Samples should be collected at three monthly intervals commencing in March each year, and stored in sealed 1 litre plastic containers. Samples should be collected from sites I, III and V or from the diversion structure used to drain a lagoon during mining. As part of the lease requirements, the company should also be required to re-establish any disturbed gauge boards and re-survey the lagoon bed to facilitate the construction of new storage curves and thus allow calculations of salt storage variation subsequent to mining.

To ensure that mining is conducted in the desired order, leases should be granted for each lagoon rather than a blanket tenement covering all lagoons. This will ensure that mining will not commence on a new lagoon until satisfactory rehabilitation at a mined lagoon is reasonably assured.

8. CONCLUSIONS AND RECOMMENDATIONS

(1) The Poorginup, Toordit-Gurrup, Byenup lagoon system represents an open system which undergoes seasonal flushing.

(2) Flushing of water from the system is critical to maintaining salinity and pH levels in each lagoon.

(3) The preferred order of mining for this system is Byenup, Toordit-Gurrup, Poorginup, with granting of separate leases for each lagoon subject to satisfactory rehabilitation of a mined lagoon.

(4) Water quality criteria should be set as detailed in Table 2 of this report.

(5) The company or its consultants should be responsible for gauge board reading and water sample collection and their submission to Government Chemical Laboratories for analysis. However, for the sake of uniformity and consistency it is recommended that the first year of sampling be in conjunction with or supervised by the Department of Fisheries and Wildlife.

(6) Rehabilitation works must include provisions for the controlled flushing of a mined lagoon through appropriately designed drainage works.

(7) At the completion of mining of each lagoon, the company should be required to survey the lake bed and re-establish gauge boards. Analysis results should be reviewed after a three year period and thereafter annually by a hydrogeological consultant.

(8) The allowable lagoon salinities may be adjusted if this is warranted in the light of three or more years of monitoring.

M W MARTIN
GEOLOGIST