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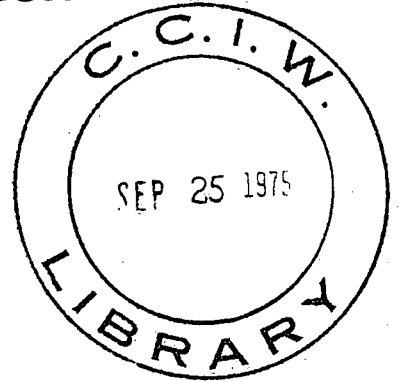


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A CHEMICAL-BIOCHEMICAL EXAMINATION OF THE

RED ROCK - NIPIGON BAY AREA

(Preliminary report of a part of ULRG  
Item V - Project D-12)

by B. Brownlee and W.M.J. Strachan

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Process Research Division  
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September, 1975.

## A CHEMICAL-BIOCHEMICAL EXAMINATION OF THE RED ROCK - NIPIGON BAY AREA

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### INTRODUCTION

The extent of the area of impact of a point source industrial discharge will vary depending upon many factors, not the least of which is the nature of the parameter being employed to define such areas. In the case of a complex effluent, such as would be expected from a Kraft Pulp Mill, there will be some organic compounds which will persist well beyond the "plume", as defined by visual means, and some of these may have an effect on one or another form of biota. Such effects may come about through accumulation, or by direct action, resulting in acute or chronic toxicity or tainting in the case of fish.

Exclusive of physical factors, it was anticipated that some indication of the above impact areas might be obtained through a programme designed to monitor a number of chemical and biochemical parameters. This would greatly assist in the selection of sampling sites for more intensive organic examination and could be correlated with changes in the concentrations of individual organic compounds. The following geographical sequence of events was predicted:

1) In the immediate area of the outfall, biological indices should be minimal, due to the toxicity of the relatively undiluted effluent. At the same time, both the dissolved and the particulate organic content of the waters should be high arising from the Kraft Mill processes and the nutrient chemicals (nitrogen, phosphorous and carbon) have been observed to be elevated in the effluent (Lao et al., 1975a);

2) Somewhat beyond the above area, microbial activity would be the first biological indicator expected to increase but this might occur within a very short distance of the outfall. There should also be a decrease in the concentration of dissolved and particulate organics -- the former by degradation, dilution and, to a lesser extent, adsorption; the latter by precipitation and degradation. These and other transitions need not (probably would not) coincide for all parameters;

3) Considerably beyond the outfall and the area of initial microbial activity, algal growth should increase and would probably coincide with a decrease in microbial activity (from a dilution of nutrients) and there would be, as well, a drop in dissolved organics, through adsorption;

4) Finally, there would be the peripheral area where the waters assumed the characteristics of background waters.

The real situation is undoubtedly more complicated than this simplified approach, particularly as a result of the variability of winds and currents. These factors would require that the above areas

be related to the direction of the water movement as distinct from random linear distance from the outfall. It was anticipated, however, that such effects could be time-averaged since the area of examination was proposed as being well beyond the visual "plume" and consequently, not subject to the momentary vagaries of outfall ~~of outfall~~ composition and weather. For this reason, surface effects in the immediate region of the mill outfall were not followed in this study and sampling was largely restricted to subsurface sites outside the plume.

#### Sampling

Two separate days, one week apart, were employed for the sampling programme. A single day was assumed to be a "point-in-time" and to reflect the effluent behaviour in the bay area. During the sampling period, the five metre current data (July data, Polak, 1975) indicated an average current of 0.7 km/day, <sup>in a mean northerly direction</sup> ~~largely towards the north~~, near the outfall. Since most sample points were separated by a minimum of this 24-hour movement, the presumption of a "momentary" pattern seems reasonable.

Because of restrictions on establishing the position while sampling, a total of sixteen sites, located as indicated in the map (Figure 1), was the limit of the number which could be sampled in a working day. All positions were located by means of radar from a

central anchorage (C.S.S. PORTE DAULPHINE) or from a smaller radar set aboard the work vessel (C.S.L. AQUA) employed in this study. In addition, the map indicates the mean wind direction and speed during the sampling as well as the behaviour of the plume (Fox, 1975) on the preceeding day, as determined by dye studies.

All water quality samples were obtained with a Van Dorn bottle from five metres. The bottle was triggered as it arrived at this depth so as to lessen avoidance on the part of any biological species. The samples were stored in rinsed, one-gallon, brown, glass bottles and processed within a few hours for the indicated parameters.

The microbiological samples were obtained, employing sterilized, evacuated sampling bulbs according to methods routinely followed by C.C.I.W. microbiologists (Rao et al., 1975a). Sampling was limited to one metre except at the outermost stations where a ten-metre sample was also obtained. In other studies of this area, the microbiology did not prove to be different at these depths and it was considered that the water column was microbiologically homogeneous--at least for 1-10 metres.

#### Analyses

Three general groupings of parameters were examined: dissolved and particulate materials, and biological indices. Where indicated, dissolved was distinguished from particulate by use of either an  $0.46$   $\mu$   $0.54$   $\mu$

membrane filter (for nutrients and A.T.P.) or with a GF/C or Nucleopore glass fibre filter (for particulate carbon and nitrogen and for chlorophyll). The procedures employed for the analyses are largely those of the Water Quality Branch at C.C.I.W. (1974), the bare essentials of which are indicated here. Where the methods are not those of W.Q.B., they are given in more detail.

A. Biological Indices:

- 1) Chlorophyll (CHLO): Preparation of samples was as for PC except that 42.5 mm GF/C filters were used. These were folded in half and stored frozen before analyzing according to standard W.Q.B. procedures;
- 2) Adenosine triphosphate (ATP): Samples were prepared in duplicate by filtration of 250 ml through 47 mm 0.45  $\mu$  membrane filters and extraction of ATP from collected material by the method of Holm-Hansen and Booth (1966). The extracts were stored frozen and analyzed by the luminescence bioassay utilizing DuPont luciferin-luciferase and an ATP photometer in the peak area mode;
- 3) Heterotrophs (HETS), fecal streptococci, fecal coliform and total coliform: All were analyzed according to standard procedures and are part of the ~~report of~~ <sup>study by</sup> Rao et al. (1975<sup>b</sup>). ~~reported~~ <sup>recorded</sup> Only HETS is ~~reported~~ here since the numbers of the other microbial parameters were small and showed minimal pattern behaviour.

B. Dissolved Materials:

- 1) Soluble reactive phosphorous (SR-P): Filtered samples were reacted to form a phosphomolybdate complex which was reduced with stannous chloride to molybdenum blue and measured photometrically.
- 2) Total filtered phosphorous (TF-P): Filtered samples were digested with sulphuric acid and persulphate and treated as for SR-P.
- 3) Nitrate plus nitrite ( $\text{NO}_3$ ): Filtered samples were reduced to nitrite with Cd and determined colourimetrically after ~~reduction~~ <sup>reaction</sup> with sulphanilamide and naphthylethylenediamine.
- 4) Total filtered nitrogen (TF-N): Filtered samples were subjected to ultraviolet digestion in acidic and alkaline media before analysis as for  $\text{NO}_3$ .
- 5) Dissolved organic carbon (DOC): Acidified filtered samples were oxidized with persulphate after gas stripping of  $\text{CO}_2$ . The oxidized samples were determined as  $\text{CO}_2$  in an I.R. Analyzer.
- 6) Total dissolved carbon (TC): The procedure for DOC is employed without the acidified gas stripping step.

C. Particulate Material:

- 1) Particulate carbon (PC): The sample was filtered through a 47 mm Nucleopore glass fibre filter and rinsed with a few



ml of distilled water. The filters were stored frozen until analysis on a C-H-N Analyzer;

- 2) Particulate organic carbon (POC): Samples were collected on GF/C, filtered and rinsed with acidified water. The filters were stored frozen and subsequently analyzed on a C-H-N Analyser;
- 3) Particulate nitrogen (PN-1): As for PC; (PN-2): As for POC;
- 4) Total phosphorous (T-P): An unfiltered sample is treated as for TF-P;
- 5) Particulate phosphorous (P-P): This parameter is derived as the difference between T-P and TF-P;
- 6) Seston (SEST): Particulate material was collected on a pre-weighed, combusted (450°C) Nucleopore glass fibre filter, dried overnight at 110°C and weighed;
- 7) Inorganic Seston (ISES): The filters from SEST were combusted for six hours at 450°C and reweighed;
- 8) Organic Seston (OSES): This parameter is defined as SEST - ISES.

### Results

The values for the preceding parameters are presented in Tables IA,B,C and IIA,B,C, corresponding to the three categories A (biological), B(dissolved) and C (particulate). The area was examined

on each of two days (July 25 and August 1, 1975). While distances are given, in the A tables, these do not reflect the water movement since it was subsequently shown (Polak, 1975) that for the bulk of the time during these studies, the flow in the east channel (measured near station 8) was towards the mill as compared to the expected direction (away from the mill). Near the outfall itself (near stations 1 and 15) the resultant flow was towards the north, albeit slowly (0.3 km/day). These particular observations largely negated the anticipated usefulness of this approach since distance became a parameter which was of little practical value. It was still expected, however, that some of the measured parameters would show inter-relationships which could be useful in interpreting behaviour of either other parameters or the behavior of specific organic concentrations. It might also indicate which, if any of the parameters, if preceded by current studies, would be useful in defining impact areas at other point source sites.

The following, then, are the comments on co-relations, among the parameters, the correlation coefficients of which are summarized in Table III.

(A) Biological Parameters

A.T.P. has poor correlations with all other parameters excepting those with particulate nitrogen and chlorophyll. Since chlorophyll also correlates with the nitrogen forms and the correlations are only moderately good, no particular advantage is gained by following this parameter. A very poor extrapolation to zero chlorophyll a levels

results in a baseline level of 0.1  $\mu\text{g/l}$  A.T.P. which might be ascribed to bacterial levels.

Chlorophyll-a correlates well with particulate nitrogen, particulate organic carbon and organic seston. It is reasonable to expect that the organic seston in this area is largely comprised of plant derived material and that therefore there might be a correlation with chlorophyll. The other noted parameters (PN-1 and POC) also correlate with the organic seston and are discussed under particulate parameters. An extrapolation of organic seston to zero chlorophyll-a concentrations reveals an intercept of some 0.4 mg/l of non-phytoplanktonic organic seston, presumably evenly distributed within the sample area. This observation is also supported by the extrapolation of POC to zero chlorophyll levels to an approximate 0.2 mg/l organic carbon. At a 1:2 ratio, this is a reasonable figure for natural organic compounds, given the precision of the extrapolations.

Heterotrophs also correlate well with all the seston and particulate forms of carbon and nitrogen. In addition, it correlates moderately with dissolved total and organic carbon and with dissolved nitrate. These relationships are, as might be expected, from organisms drawing on both particulate and dissolved material.

#### (B) Dissolved Parameters

There are few correlations among these parameters that are unexpected. Only total filtered and organic phosphorus correlate for the phosphorous pool. Their high correlation is readily explained by

noting the large percentage (76%) which the latter forms of the former.

Nitrate-nitrogen correlates moderately with particulate carbon and nitrogen forms and an examination of the plot between organic seston and this parameter (N03) indicates a bay-wide organic seston level of 0.5 mg/l in good agreement with that obtained from the chlorophyll relationship.

There is also a good correlation between dissolved organic carbon and total carbon, the former representing approximately one-third of the latter. Since both are at relatively constant levels throughout the bay, no particular significance is attached to this observation.

#### (C) Particulate Parameters

Particulate phosphorous shows no correlations of any note except with total phosphorous. No explanation is offered.

The particulate carbon forms (total and organic) and nitrogen are all well correlated with each other and also with the seston forms. The correlations are particularly good <sup>between</sup> ~~with~~ the organic seston and the elemental forms, a not unexpected observation.

It is interesting to examine the fraction that the non-organic seston forms of the total seston - a remarkably constant 60-70 percent for all July 25 samples and 70-80 percent for August 1 samples - indicating the common nature of seston throughout the bay. This holds for samples obtained from the Nipigon River as well as from near the mill outfall. At both sites, the analyses indicate slightly elevated levels

of seston and consequently, it appears that most of the seston in the bay originates from these two sources (as distinct from the lower carbon content sediments) and that it is of a similar nature.

### Conclusions

The use of chemical-biochemical parameters to define an impact area for a kraft mill effluent plume is not recommended except, perhaps, for the very immediate outfall area. In the case of the Red Rock mill, the dilution (mill outflow:river flow) factor is some 3-400 ( ) and this is probably the deciding influence on parameter behaviour. In situations involving less dilution, such pattern parameter studies may well be of value. If it is attempted elsewhere, however, it is strongly recommended that current studies be undertaken before any water quality analyses and that sampling be concentrated in the direction(s) so indicated.

Particulate matter in the bay is of a uniform composition and averages some 2-3 mg/l of which approximately one-third is organic. Of this organic seston, 0.4-0.5 mg/l (i.e.- half) is of a non-phytoplankton origin.

## References

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- Water Quality Branch (1974) - Analytical Methods Manual, Inland Waters Directorate, Ottawa.

Table IA: Biological Parameters for July 25, 1975 at Five Metres.

Station No.	Outfall Distance (km)	Chlorophyll-a ( $\mu\text{g/l}$ )	A.T.P. <sup>(1)</sup> ( $\mu\text{g/l}$ )	Heterotrophs <sup>(2)</sup> (MF/100 ml $\times 10^{-3}$ )
18	8.8	1.4	0.2	0.3
14	3.0	4.3	0.3	1.6
1	0.7	3.0	0.6	27.
15	1.0	3.0	0.3	55.
4	1.6	2.6	0.5	1.3
16	1.7	2.8	0.3	4.8
5	1.8	2.6	0.3	37.
3	2.2	2.5	0.5	1.2
7	2.5	2.4	0.4	1.3
17	3.1	2.1	0.4	5.6
6	3.0	2.1	0.5	26.
8	5.7	3.7	0.6	0.6
9	4.7	2.9	0.7	0.8
10	3.9	2.1	0.2	14.
12	3.6	1.9	0.2	4.7
19	6.8	2.0	0.3	4.6

(1) these averages of duplicate analyses showed an average deviation, from data on both days, of 0.07  $\mu\text{g/l}$ .

(2) values are largely for 1 metre from the work of Rao et al (1975).

Table IB: Dissolved Parameters <sup>(1)</sup> for July 25, 1975 at Five Metres

Station No.	Carbon			Nitrogen			Phosphorous		
	TDC	DOC	DIC	TF-N	NO <sub>3</sub>	DON	TF-P	SR-P	OR-P
18	23.0	6.0	17.0	.245	.035	.210	.0034	.0000	.0034
14	19.5	5.0	14.5	.460	.070	.390	.0077	.0070	.0007
1	21.0	7.0	14.0	.180	.055	.125	.0010	.0000	.0010
15	21.0	9.0	12.0	.330	.050	.280	.0024	.0011	.0013
4	19.5	7.5	12.0	.255	.070	.185	.0055	—	—
16	20.0	7.5	12.5	.220	.060	.160	.0040	—	—
5	21.5	9.0	12.5	.190	.055	.135	.0027	.0003	.0024
3	19.5	5.5	14.0	.260	.060	.200	.0041	.0005	.0036
7	19.5	5.0	14.5	.280	.080	.200	.0027	.0007	.0020
17	20.0	7.5	12.5	.215	.060	.155	.0057	—	—
6	20.5	7.5	13.0	.195	.060	.135	.0032	.0000	.0032
8	17.5	7.0	10.5	.215	.095	.120	.0048	.0044	.0004
9	23.0	9.0	14.0	—	.080	—	.0032	.0000	.0032
10	20.5	8.0	12.5	.250	.060	.190	.0026	.0000	.0026
12	20.5	8.0	12.5	.205	.050	.155	.0025	.0000	.0025
19	20.5	8.0	12.5	.260	.045	.215	.0033	.0013	.0020

(1) All values shown are mg/l of the appropriate element. For translation of the parameters, see Analyses.



Table IC: Particulate Parameters<sup>(1)</sup> for July 25, 1975 at Five Metres

No.	Seston			Carbon		Nitrogen		Phosphorous	
	SEST	ISES	OSES	PC	POC	PN-1	PN-2	T-P	P-P
18	3.07	2.11	0.96	—	.284	—	.028	.0062	.0028
14	2.83	1.75	1.08	.52	.406	.075	.046	.0064	—
1	3.46	2.27	1.19	.66	.451	.062	.046	.0066	.0056
15	3.05	2.04	1.01	.56	.463	.069	.048	.0030	.0006
4	2.39	1.56	0.83	.43	.375	.067	.040	.0055	.0000
16	2.38	1.49	0.89	.41	.349	.058	.040	.0049	.0009
5	6.69	5.50	1.19	.64	.484	.058	.047	.0092	.0065
3	2.63	1.78	0.85	.44	.365	.061	.040	.0055	.0014
7	2.73	1.75	0.98	.41	.456	.050	.053	.0056	.0029
17	2.49	1.67	0.82	.41	.328	.056	.034	.0091	.0034
6	2.66	1.82	0.84	.46	.425	.054	.050	.0076	.0044
8	2.57	1.53	1.04	.39	.499	.053	.068	.0065	.0017
9	2.89	1.98	0.91	.45	.396	.063	.052	.0064	.0032
10	2.98	2.08	0.90	.43	.361	.057	.036	.0075	.0049
12	13.34	12.15	1.19	.60	.357	.048	.039	.0120	.0095
19	3.14	2.38	0.76	.35	.270	.049	.029	.0061	.0028

(1) All values are mg/l (of element if indicated). For translation of the parameters, see Analyses.

Table IIA: Biological Parameters for Aug. 1, 1975 for Five Metres

Station No.	Outfall Distance (km)	Chlorophyll-a ( $\mu\text{g/l}$ )	A.T.P. <sup>(1)</sup> ( $\mu\text{g/l}$ )	Heterotrophs <sup>(2)</sup> (MF/100 ml $\times 10^{-3}$ )
18	8.8	1.4	0.1	0.3
14	3.0	1.2	0.3	0.5
1	0.7	1.4	0.2	1.1
15	1.0	1.1	0.2	42.1
4	1.6	1.0	0.2	0.7
16	1.7	1.2	0.2	0.5
5	1.8	1.0	0.2	9.0
3	2.2	0.7	0.2	2.2
7	2.5	0.9	0.2	5.1
17	3.1	0.9	0.2	0.3
6	3.0	1.3	0.3	8.4
8	5.7	0.6	0.2	0.6
9	4.7	1.5	0.2	1.5
10	3.9	1.2	0.7	4.0
12	3.6	1.6	0.3	28.
19	6.8	1.5	0.2	4.7

(1) these averages of duplicate analyses showed an average deviation, from data on both days, of 0.07  $\mu\text{g/l}$ .

(2) values are largely for 1 metre from the work of Rao et al (1975)

Table ~~JIB~~ <sup>Dissolved</sup> ~~Particulate~~ Parameters <sup>(1)</sup> for Aug. 1, 1975 at Five Metres

Station No.	Carbon			Nitrogen			Phosphorous		
	TDC	DOC	DIC	TF-N	NO <sub>3</sub>	DON	TF-P	SR-P	OR-P
18	24.5	9.0	15.5	.245	.035	.210	.0024	.0000	.0024
14	21.5	7.5	14.0	.225	.095	.130	.0083	.0000	.0083
1	23.5	9.0	14.5	.200	.060	.140	.0130	.0015	.0115
15	27.0	12.5	14.5	.180	.050	.130	.0032	.0011	.0021
4	21.5	8.5	13.0	.250	.090	.160	.0048	.0009	.0039
16	22.0	9.0	13.0	.245	.075	.170	.0027	.0010	.0017
5	21.5	8.5	13.0	.260	.080	.180	.0017	.0002	.0015
3	20.0	7.0	13.0	.250	.135	.215	.0044	.0006	.0038
7	18.0	7.5	10.5	.250	.150	.100	.0042	.0010	.0032
17	20.5	5.5	15.0	.250	.125	.125	.0015	.0005	.0010
6	23.0	9.0	14.0	.215	.060	.155	.0010	.0000	.0010
8	15.5	6.0	9.5	.315	.100	.215	.0020	.0018	.0002
9	18.0	8.0	10.0	.255	.110	.145	.0027	.0013	.0014
10	20.5	10.0	10.5	.265	.060	.205	.0070	.0008	.0062
12	21.5	10.0	11.5	.200	.065	.135	.0031	.0007	.0024
19	20.5	9.0	11.5	.250	.080	.170	.0022	.0005	.0017

(1) All values shown are mg/l of the appropriate element. For translation of the parameters, see Analyses.

Table IIC: Particulate Parameters<sup>(1)</sup> for Aug. 1, 1975 at Five Metres

Station No.	Seston			Carbon		Nitrogen		Phosphorous	
	SEST	ISES	OSES	PC	POC	PN-1	PN-2	T-P	P-P
18	3.23	2.54	0.69	.37	.261	.036	.030	.0065	.0041
14	2.69	2.02	0.67	.30	.266	.030	.030	.0100	.0017
1	2.84	2.13	0.71	.35	.222	.032	.025	.0160	.0030
15	3.48	2.05	1.43	.81	.514	.050	.039	.0160	.0128
4	2.39	1.69	0.70	.32	.257	.033	.032	.0140	.0092
16	2.59	1.92	0.67	.29	.252	.028	.027	.0064	.0037
5	2.62	1.99	0.63	.28	.247	.033	.022	.0064	.0047
3	1.83	1.25	0.58	.25	.158	.029	.014	.0150	.0106
7	1.80	1.26	0.54	.25	.210	.028	.020	.0045	.0003
17	1.74	1.22	0.52	.22	.242	.024	.020	.0036	.0021
6	2.65	1.94	0.71	.36	.266	.036	.026	.0065	.0055
8	1.29	0.78	0.51	.20	.170	.022	.016	.0040	.0020
9	2.18	1.63	0.55	.28	.213	.026	.017	.0350	.0323
10	3.12	2.37	0.75	.40	.288	.044	.027	.0110	.0040
12	2.67	1.92	.075	.34	.286	.037	.024	.0120	.0089
19	2.82	2.15	0.67	.28	.235	.032	.025	.0076	.0054

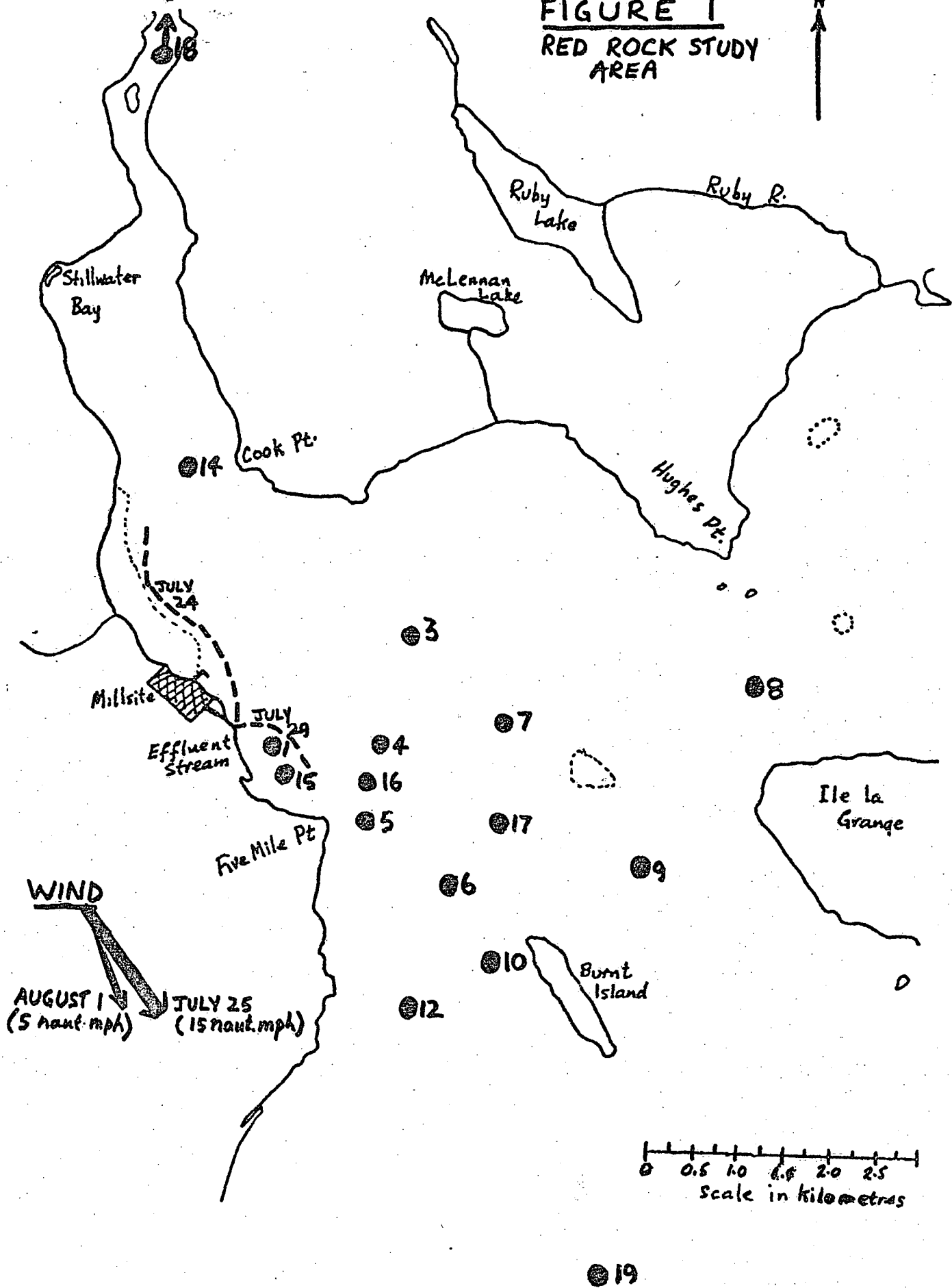
(1) ~~See Table IC~~ All values shown are mg/l of the appropriate element. For translation of the parameters, see Analyses.

	TDC	DOC	DIC	TF-N	NO3	DON	TF-P	SR-P	OR-P	SEST	ISES	
TDC	1.000	0.724	0.653	-0.560	-0.534	-0.145	0.235	-0.343	0.362	0.425	0.356	
DOC		1.000	-0.050	-0.485	-0.488	-0.160	0.184	-0.097	0.222	0.416	0.371	
DIC			1.000	-0.279	-0.237	-0.034	0.139	-0.391	0.281	0.159	0.108	
TF-N				1.000	0.150	0.763	-0.327	-0.082	-0.304	-0.456	-0.422	
NO3					1.000	-0.332	-0.156	0.075	-0.185	-0.602	-0.538	
DON						1.000	-0.148	-0.184	-0.085	-0.087	-0.092	
TF-P							1.000	0.228	0.938	0.022	0.029	
SR-P								1.000	-0.124	-0.191	-0.264	
OR-P									1.000	0.090	0.124	
SEST										1.000	0.951	
ISES											1.000	
OCES												
PC												
POC												
PN-1												
PN-2												
T-P												
P-P												
HETS												
CHLO												
ATP												

	OCES	PC	POC	PN-1	PN-2	T-P	P-P	HETS	CHLO	ATP
TDC	0.524	0.615	0.309	0.212	0.066	0.147	0.066	0.484	-0.118	-0.153
DOC	0.426	0.540	0.197	0.123	-0.040	0.321	0.263	0.578	-0.131	-0.079
DIC	0.230	0.298	0.231	0.172	0.139	-0.140	-0.193	0.066	-0.027	-0.149
TF-N	-0.403	-0.373	-0.238	0.004	-0.124	-0.329	-0.221	-0.127	-0.022	0.065
NO3	-0.614	-0.641	-0.524	-0.655	-0.420	0.086	0.144	-0.488	-0.428	-0.356
DON	-0.032	0.015	-0.007	0.349	0.029	-0.255	-0.209	0.159	0.136	0.242
TF-P	-0.014	0.016	-0.124	-0.022	-0.009	0.243	-0.108	-0.220	-0.021	0.246
SR-P	0.165	-0.015	0.256	0.110	0.473	0.007	-0.074	-0.164	0.453	0.304
OR-P	-0.073	0.022	-0.218	-0.062	-0.178	0.244	-0.084	-0.166	-0.184	0.142
SEST	0.677	0.703	0.601	0.590	0.461	0.004	-0.003	0.556	0.447	0.217
ISES	0.524	0.565	0.453	0.478	0.332	0.019	0.010	0.469	0.367	0.167
OCES	1.000	0.954	0.935	0.786	0.772	-0.055	-0.052	0.671	0.578	0.325
PC		1.000	0.845	0.758	0.602	0.043	0.038	0.766	0.437	0.241
POC			1.000	0.848	0.910	-0.187	-0.148	0.603	0.757	0.444
PN-1				1.000	0.803	-0.266	-0.264	0.592	0.815	0.590
PN-2					1.000	-0.282	-0.286	0.327	0.892	0.559
T-P						1.000	0.938	-0.057	-0.204	-0.207
P-P							1.000	0.020	-0.201	-0.300
HETS								1.000	0.309	-0.057
CHLO									1.000	0.566
ATP										1.000

Table III: CHEMICAL-BIOCHEMICAL  
PARAMETER CORRELATIONS

FIGURE 1  
RED ROCK STUDY  
AREA



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