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LOWESWATER SURVEY

JULY 1993

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LOWESWATER SURVEY
JULY 1993

EXECUTIVE SUMMARY

The objective of the Loweswater 1993 surveys was to collect data which would reflect the current state of the lake, and assess the deoxygenation levels in the lake.

The lake was surveyed in July (28^{th} and 29^{th}), Figure 1. The evening before each boat survey dissolved oxygen (DO) meters were deployed at suitable positions near the inlet and in the outlet of the lake. The next day(s) the boat was anchored at each sampling site and its position determined using a theodolite from the shore. Water samples and profiling measurements were taken at each location.

DO meter results (Figure 2) showed that the water near the inlet was more oxygenated than in the outlet.

Figure 3 summarises the profiler results at all sampled stations. The results indicate that the water column was stratified in July.

Figures 5, 6 and 7 plot all water sample data. At sites 7, 8, and 9 the alkalinity, ammonia and silicate levels were generally higher in bottom samples. Nitrate and chloride results indicated no distinct patterns. The high levels of nitrates compared to ammonia and nitrite indicate that the process of oxidation ($NH_3 \rightarrow NO_2 \rightarrow NO_3$) is well advanced. Chlorophyll and phaeophytin levels were low at all sites.

The overall total phosphorus levels indicate that Loweswater can be defined as meso-eutrophic, based on the Organisation for Economic Co-operation and Development categories[5].

Phytoplankton productivity on this survey was relatively low, Figure 8. The trophic status of the lake as indicated by the chlorophyll could be described as either oligotrophic or mesotrophic, depending on authors.

Most stations contained similar total metal levels. Stations 4 and 8 bottom samples showed increased levels of all analysed total metals.

Depending on the chemical parameter selected, the trophic status of Loweswater could be classified as oligotrophic or mesotrophic or meso-eutrophic. The 1993 survey was too limited to provide a good indication of Loweswater water quality. Further surveys reflecting summer conditions are needed.

LOWESWATER SURVEY

JULY 1993

1.0 INTRODUCTION

Loweswater is one of the smaller Cumbrian lakes, see Figure 1, lying in the extreme north of the Lake District (national grid reference NY 127 215). The main tributaries of the lake consist of four relatively small streams: Dub Beck (NY 117 224), Black Beck (NY 118 219), Holme Beck (NY 122 217), and Crabtree Beck (NY 130 216). The outlet of the lake is Dub Beck (NY 135 219) which feeds into Crummock Water (from which water for public water supply is extracted). Some of Loweswater's physical characteristics[1] include:

Length	:	1.8	km
Max width	:	0.6	km
Area	:	0.6	km^2
Depth mean	:	8.4	m
Depth max	:	16.0	m

Although little data is available, previous reports[1,2] indicate that progressive deoxygenation in the summer time occurs in Loweswater. This phenomenum is not well understood as the lake does not have any known treated sewage inputs and farming is not intensive.

The objective of the Loweswater 1993 survey was:

- to collect data which will reflect the current state of the lake, and assess the level of water deoxygenation in the lake.

2.0 METHODOLOGY

Loweswater was surveyed in July (28^{th} and 29^{th}). Ten sites were selected in order to provide overall coverage of the lake, based on the previous survey work[3].

Figure 1 represents Loweswater, and shows the position of the pHox dissolved oxygen (DO) meters used during the survey. The evening before the boat survey, the DO meters were deployed at suitable positions near the inlet and in the outlet of the lake. The next day the boat was anchored at each sampling site and its position determined using a theodolite from the shore. Water samples and profiling measurements were taken at each location.

Calibrations of the DO meters and Windermere profilers were carried out before and after the survey. This procedure was essential to ensure that the instrument readings were accurate, taking into account any possible deviations from the initial 100 % oxygen levels.

2.1 DISSOLVED OXYGEN METERS

Once the DO meters were deployed, logging was initiated at 15 minute intervals for the duration of survey. The instrument measured both temperature and dissolved oxygen (in mg/l and % saturation).

At the end of the survey, the DO meters were retrieved, and results downloaded onto a Psion portable computer/organiser and transferred to an IBM computer in the office using the GP2 software.

2.2 PROFILER MEASUREMENTS

The Windermere profiler was used to measure depth, temperature, dissolved oxygen (% saturation), pH, surface light, light-at-depth, and conductivity,. Readings were generally taken at metre intervals from the surface down to the lake bed. Extra readings were also taken when rapid changes were noted, *eg*. near the surface, or in areas of sudden oxygen or temperature decreases.

The results could be read off the portable Husky computer and data stored *in situ*. Data were then transferred to an IBM compatible PC in the office.

2.3 WATER SAMPLES

Surface samples were taken about 20 cm below the surface, and bottom samples taken using a dual line Casella.

Surface samples were used to determine alkalinity, chloride, filtered nutrients (ammonia, nitrate, nitrite, phosphate and silicate), chlorophyll, and phaeophytin concentrations. Bottom samples were analysed for alkalinity, chloride, filtered nutrients and total phosphorus contents.

Algal samples were collected from the water column using the "IFE tube method" to ensure representation of the algal species throughout the top water depths. A 5 m tubing (30 mm ID), with a weight and a string attached to one end, is lowered into the water so that it forms a U-shape. One end is then sealed, the captured volume raised, and the contents transferred to a 1 litre plastic bottle. Lugol's Iodine is then added as a fixing agent for subsequent enumeration of the phytoplankton.

All samples were stored in a cool box on the boat. The 1 litre bottles for chlorophyll and phaeophytin determinations were taken to the shore for filtering.

3.0 RESULTS

Appendix 1 lists all boat sampling locations for July 1993, based on theodolite readings. Raw data for the Windermere profiler, water samples and DO meters can be found in Appendix 2.

3.1 DISSOLVED OXYGEN METERS

Figure 2 illustrates all inlet and outlet DO meter results. The overall levels of dissolved oxygen show that the water near the inlet is more oxygenated than that at the outlet. Table 1 shows that the dissolved oxygen levels near the inlet ranged between 102 and 115 %, and at the outlet between 71 and 110 %.

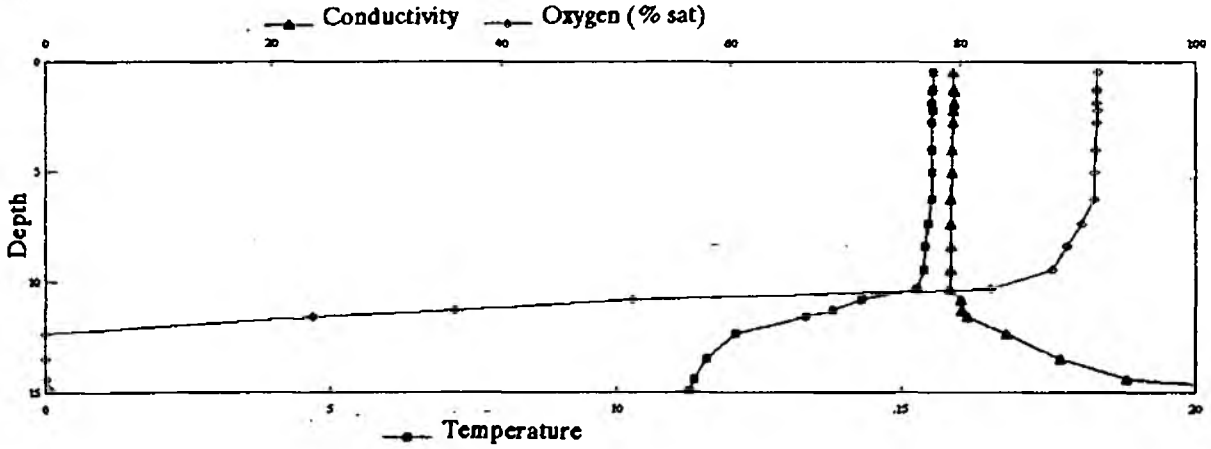
3.2 WINDERMERE PROFILER

Figure 3 summarises the profiling results for each sampling site. Problems with the surface light meter connection and the pH sensor produced erroneous readings, so those results had to be discarded.

Stratification in the water column was observed at stations 3, 4, 7, 8, and 9 with a definite thermocline present (temperature changes which exceed the rate of 1 °C per metre depth[4]). Great variations in values were noted :

	Mean	StdDev	Minimum	Maximum
DO (% sat)	81.14	27.13	0	102.54
Temp. (°C)	14.98	1.11	11.27	15.64
Cond. (µS/cm)	74.96	20.78	0.21	106.02

Increases with depth in conductivity coincided with sharp decreases in oxygen saturation and temperature Such changes were observed at stations located in the deeper parts of the lake. Site 7 displays a good example of water stratification.



In the I.F.E. Lakes Tour[2], August profiles also indicated water deoxxygenation. However, anoxia of the hypolimnion was absent in April and in October.

Figure 4 illustrates oxygen saturation contours of the lake for the survey, based on the profiling data. The contours indicate deoxygenation with increasing depth.

3.3 WATER SAMPLES

Figures 5 to 7 plot all water sample data for the July survey and Table 2 summarises results. In general, nutrient results were within the same ranges as in publications[2,3,9].

CHLORIDE AND ALKALINITY - Figure 5. Chloride levels were overall below 15 mg/l in both surface and bottom samples.

Alkalinity results indicate that in general, levels averaged below 15 mg/l $CaCO_3$, although higher values were recorded in some bottom samples, with values reaching 28 mg/l $CaCO_3$ (station 7).

TOTAL PHOSPHORUS - Figure 6. Total phosphorus was only determined on bottom samples. Levels averaged 64 $\pm$ 59 μg/l, and reached 210 μg/l at station 8. The overall total phosphorus levels indicate that Loweswater can be defined as eutrophic, based on the Organisation for Economic Co-operation and Development categories[5] and other authors[4].

OTHER NUTRIENTS - Figure 5. Ammonia levels were generally less than 0.05 mg/l with the exception of higher levels in bottom samples, reaching 0.16 and 0.20 mg/l at sites 7 and 8.

Nitrate levels were generally around 0.3 mg/l with slightly higher levels recorded at site 1 (bottom 0.5 mg/l) and site 7 (surface 0.4 mg/l).

Based on the levels of inorganic nitrogen, Loweswater can be classed as meso-eutrophic, *i.e.* concentrations between 0.30 and 0.65 mg/l[6,7].

Silicate results show that levels were generally close to 0.2 mg/l, although some bottom samples results were higher than at the surface (*eg.* 1.8 mg/l at sites 7 and 8).

Nitrite and soluble phosphate levels at all sites were found to be less than their detection limits, 0.02 and 0.01 mg/l respectively. As lake classification may in the future take into account phosphate concentrations[9], a better laboratory technique should be used in future to determine the exact levels of phosphate present in the lake.

CHLOROPHYLL AND PHAEOPHYTIN - Figure 5. Chlorophyll and phaeophytin were measured on all surface samples. Chlorophyll levels were low at all sites, less than 4 µg/l, as were phaeophytin levels less than 3 µg/l. Status of Loweswater based on chlorophyll values is discussed in Section 3.4: phytoplankton productivity.

TOTAL METALS - Figure 7. Surface and bottom water samples were analysed for total metals: cadmium, copper, nickel, chromium, lead, zinc and arsenic.

Most stations contained similar total metal levels. However stations 4 and 8 bottom samples showed increased levels of all analysed total metals.

It can be noted that all analysed total metals fell below their respective environmental quality standards (EQSs) levels for Protection of sensitive aquatic life (see Appendix 3). **Remember that compliance with EQSs is based on annual averages for dissolved metals and therefore caution should be applied when interpreting results.**

Further investigations should be pursued in order to comment on the possible reasons for the differences in metal levels at specific stations.

3.4 ALGAL SAMPLES

The algae results are presented in Table 3.

PHYTOPLANKTON COMPOSITION

Each water sample was concentrated by passive sedimentation 20 ml. Sub-samples were then taken and counted using a Leitz Dialux 20 compound microscope. A x25 objective was used in combination with a Lund chamber[8] and the densities expressed in cells/ml. Where possible algal cells were counted individually, but certain genera were counted as filaments or colonies.

Cell concentrations (cells/ml) were calculated using the following formula:

$$\text{Cell conc.} = \frac{\text{N}^{\text{O}} \text{ of algae counted x Factor for chamber}}{\text{N}^{\text{O}} \text{ of fields x sample concentration}}$$

Fifteen algal taxa were recorded. The most dominant group was the diatoms (Bacillariophyceae) which included moderate densities of *Tabellaria flocculosa* and low densities of *Aulacoseira spp*, *Fragilaria crotonensis* and centric diatoms (indet).

Tabelleria flocculosa achieved the greatest abundance with a density of 1201.4 cells/ml at

station 10. Other genera were represented less frequently and at lower densities, the least being *Aulacoseira spp* at 12.8 cells/ml at station 7. *Tabellaria flocculosa* was found consistently at all stations, the lowest density of 313.42 cells/ml at station 9.

The next most abundant group, the blue-green algae (Cyanophyceae), was present at relatively low densities, the greatest represented by *Anabaena spp* at station 10 with 202.4 cells/ml. These algae were also recorded at stations 3, 7, 8 and 9.

Oscillatoria spp were recorded at a maximum density of 35.17 cells/ml, and were found at all sample stations. The remaining blue-greens, *Aphanizomenon flos aquae*, Microcystic *spp* and *Chroococcus spp* were found infrequently and in low abundance.

The green and yellow flagellates (Cryptophyceae), including *Mallomonas spp* and *Cryptomonas spp*, were present at relatively low densities with a range of 6.3 to 108.82 cells/ml.

The Dinoflagellates were represented by *Ceratium hirundinella*, at cell densities of 6.5 to 27.2 cells per ml, and to a lesser extent by *Dinobryon spp* with cell densities of 3.26 to 6.4 cells/ml. The Desmids, (Desmidiaceae) were represented by two genera, *Spondylosium sp* and *Starastrum spp*, both present at low densities, below 14 cells/ml.

PHYTOPLANKTON PRODUCTIVITY

Mean chlorophyll values were reported as: 2.55 µg/l (July 1993); 1.67 µg/l (September 1992) [3]; ranging between 5.52 and 9.84 µg/l (1991)[2]; between 0.40 and 3.61 µg/l (Summer 1991)[3].

Based on available chlorophyll data, Loweswater can be classed as ultra-oligotrophic[6] (*i.e.* less than

5 µg/l), oligotrophic[9] (*i.e.* 0.3 to 2.5 µg/l), or mesotrophic[6,9] *i.e.* 1 to 15 µg/l). More data should be collected in order to make better use of classification tables.

COMPARISON WITH PREVIOUS SURVEYS

Phytoplankton compositions were similar between July 1993 and September 1992[10], but densities were different, see Figure 8. Substantial increase (up to 600 fold) of the diatom *Tabellaria flocculosa* was noted in July 1993. These results indicate that Loweswater has a relatively low productivity. Careful interpretation must be given as samplings were carried out at different months.

Note that there was only one positive result, in October 1993, from the N.R.A. blue-green reactive monitoring on Loweswater. The sample was dominated by *Oscillatoria spp* with considerable numbers of *Anabaena spp* and *Coelosphaerium spp*.

4.0 RECOMMENDATIONS

In future surveys, it is suggested that:

- inlet meters are positioned in the river in order to measure the quality of the inflowing water,

- better laboratory technique is used to determine the exact concentrations of phosphate present in the lake.

- More chlorophyll data should be collected in order to better classify Loweswater's status (*i.e.* oligotrophic *versus* mesotrophic).

- further investigations on nutrients, total and dissolved metal levels should be pursued in order to better understand their distributions throughout the lake.

Following the 1993 Loweswater survey, it is recommended that further work be carried to include seasonal water quality changes in order to provide a better insight into the degree and the duration of stratification occurring in the lake. More work on nutrient, dissolved metals, and phytoplankton spatial and temporal distributions are also needed.

5.0 ACKNOWLEDGMENTS

The Loweswater 1993 survey required the help and input of various NRA staff from Sections across the North West. The authors wish to thank the Water Quality Planning RFH Section for their continuous assistance (past, present and future), Pollution Control and Fisheries covering Loweswater area, and both Carlisle and Warrington Laboratories for their support. Personal thanks to Sheila Sowerby and Briony Arstall for their good advice, and to David Scott for his contribution on all phytoplankton identification and interpretation.

We also acknowledge our thanks to the National Trust as owner of the lake for their permission to use a powered boat on Loweswater.

6.0 SELECTED REFERENCES

1. George D.G.: A general assessment of long-term change in the larger lakes of the English Lake District. Institute of Freshwater Ecology, 1992.

2. Hall G.H., Allen P.V., Corry J.E., Cranwell P.A., Haworth E.Y., Hewitt D.P. and Jaworski G.H.M.: The Lakes Tour 1991: a survey of the Cumbrian lakes. Institute of Freshwater Ecology, 1992.

3. N.R.A. North West: Loweswater Survey September 1992 Water Quality Planning Section, October 1993.

4. Hellawell J.M.: Biological indicators of freshwater pollution and environmental management. Elsevier Applied Science, London and New York, 1989.

5. Lester J.N., and Kirk P.W.W. eds.: Management strategies for phosphorus in the environment. Vollenweirder R.A. Pro. Int. Conf. Lisbon, July 1985. Selfer, London, 1985.

6. Harper D.: Eutrophication of freshwaters: principles, problems and restoration. Chapman and Hall eds., London, 1992.

7. Irving R: Too much of a good thing: nutrient enrichment in the UK's inland and coastal waters. WWF(UK), October 1993.

8. Lund J.W.G.: Standard Method. Institute of Freshwater Ecology, 1959.

9. Lambert J.E. Cyanobacteria (blue-green algae) in Loweswater: A literature review and report on original work. MSc University of London, 1991.

10. Scott D., and Roun K.J.: A report on the identification and enumeration of phytoplankton from Loweswater Lake, sampled 17/09/92. NRA Technical Memorandum NB208(2/93).

TABLE 1: DO meters - summary results for Loweswater 1993 survey.

INLET

	Dissolved oxygen (% sat)				Temperature (°C)			
	Mean	S.D.	Min	Max	Mean	S.D.	Min	Max
July	109.80	13.71	102	115	16.05	0.75	15	17.3

OUTLET

	Dissolved oxygen (% sat)				Temperature (°C)			
	Mean	S.D.	Min	Max	Mean	S.D.	Min	Max
July	89.91	11.43	71	110	15.73	0.72	14.8	17.8

NOTE: S.D. Standard Deviation
Min Minimum
Max Maximum

TABLE 2: Surface and bottom water samples - summary results for Loweswater 1993 survey.

	DEPTH	SITES	MEAN	S.D.	MAX	MIN
Alkalinity	Surface	10	13	1	14	12
mg/l $CaCO_3$	Bottom	10	17	6	28	11
Chloride	Surface	10	12	1	14	12
mg/l	Bottom	10	12	1	14	11
Ammonia	Surface	10	0.027	-	-	-
mg/l - N	Bottom	10	0.066	0.063	0.200	0.027
Nitrate	Surface	10	0.3	0.0	0.4	0.3
mg/l - N	Bottom	10	0.3	0.1	0.5	0.2
Nitrite	Surface	10	0.013	-	-	-
mg/l - N	Bottom	10	0.013	-	-	-
Silicate	Surface	10	0.2	0.1	0.2	0.1
mg/l - SiO_2	Bottom	10	0.7	0.7	1.8	0.1
Phosphate	Surface	10	0.07	-	-	-
mg/l - P	Bottom	10	0.07	-	-	-
Total P	Surface	0	-	-	-	-
mg/l - P	Bottom	10	0.06	0.06	0.21	0.02
Chlorophyll	Surface	10	2.55	0.71	3.60	1.52
µg/l	Bottom	0	-	-	-	-
Phaeophytin	Surface	10	1.95	0.38	2.60	1.40
µg/l	Bottom	0	-	-	-	-
Total lead	Surface	10	0.38	0.27	0.86	0.14
µg/l	Bottom	10	2.19	3.73	12.40	0.16
Total cadmium	Surface	10	0.071	0.047	0.860	0.140
µg/l	Bottom	10	0.126	0.114	0.340	0.030
Total copper	Surface	10	0.54	0.17	0.92	0.39
µg/l	Bottom	10	0.85	0.07	2.70	0.34
Total zinc	Surface	10	3.56	2.95	11.00	1.22
µg/l	Bottom	10	6.48	8.12	28.50	1.44
Total chromium	Surface	10	0.27	0.09	0.47	0.18
µg/l	Bottom	10	0.32	0.15	0.65	0.18
Total nickel	Surface	10	0.47	0.09	0.67	0.38
µg/l	Bottom	10	0.79	0.57	2.30	0.36
Total arsenic	Surface	10	0.41	0.06	0.52	0.29
µg/l	Bottom	10	2.79	4.00	12.00	0.30

NOTE: S.D. Standard Deviation
MAX Maximum
MIN Minimum
\- Not sampled

TABLE 3:

	LOWESWATER JULY 1993 SURVEY									
TAXA	1	2	3	4	5	6	7	8	9	10
DIATOMS										
ARLACOSEIRA spp							12.60			
CENTRIC DIATOMS (INDET)	6.40					19.50		21.13	9.79	6.52
FRAGILLARIA CROTONENSIS				13.05						
TABELLARIA FLOCCULOSA	531.30	878.58	866.56	1,155.70	741.71	1,149.20	992.24	438.40	313.42	1,201.40
BLUE GREENS										
ANABAENA sp			6.80				44.80	115.20	13.05	202.40
APHANIZOMENON FLOS AQUAE									9.79	
CHROOCOCCUS sp			136.03		6.30			26.41		
MICORCYSTIC spp						6.52				
OSCILLATORIA spp	19.20	32.00	20.40	6.50	25.35	39.17	25.60	5.20	6.52	13.05
DESMIDS										
SPONDYLOSIUM sp					6.30					
STAURASTRUM spp		6.40		13.05						
DINOFLAGELLATES										
CERATIUM HIRUNDINELLA	19.20		27.20	26.11	31.69			10.56	16.32	6.50
DINOBRYON SPP							6.40		3.26	
FLAGELLATES										
CRYPTOMONAS spp & MALLOMONAS sp		25.60	108.82	19.56	6.33	6.52	38.40	26.41	39.17	52.23

UNITS: Cells or filaments / ml

LIST OF FIGURES

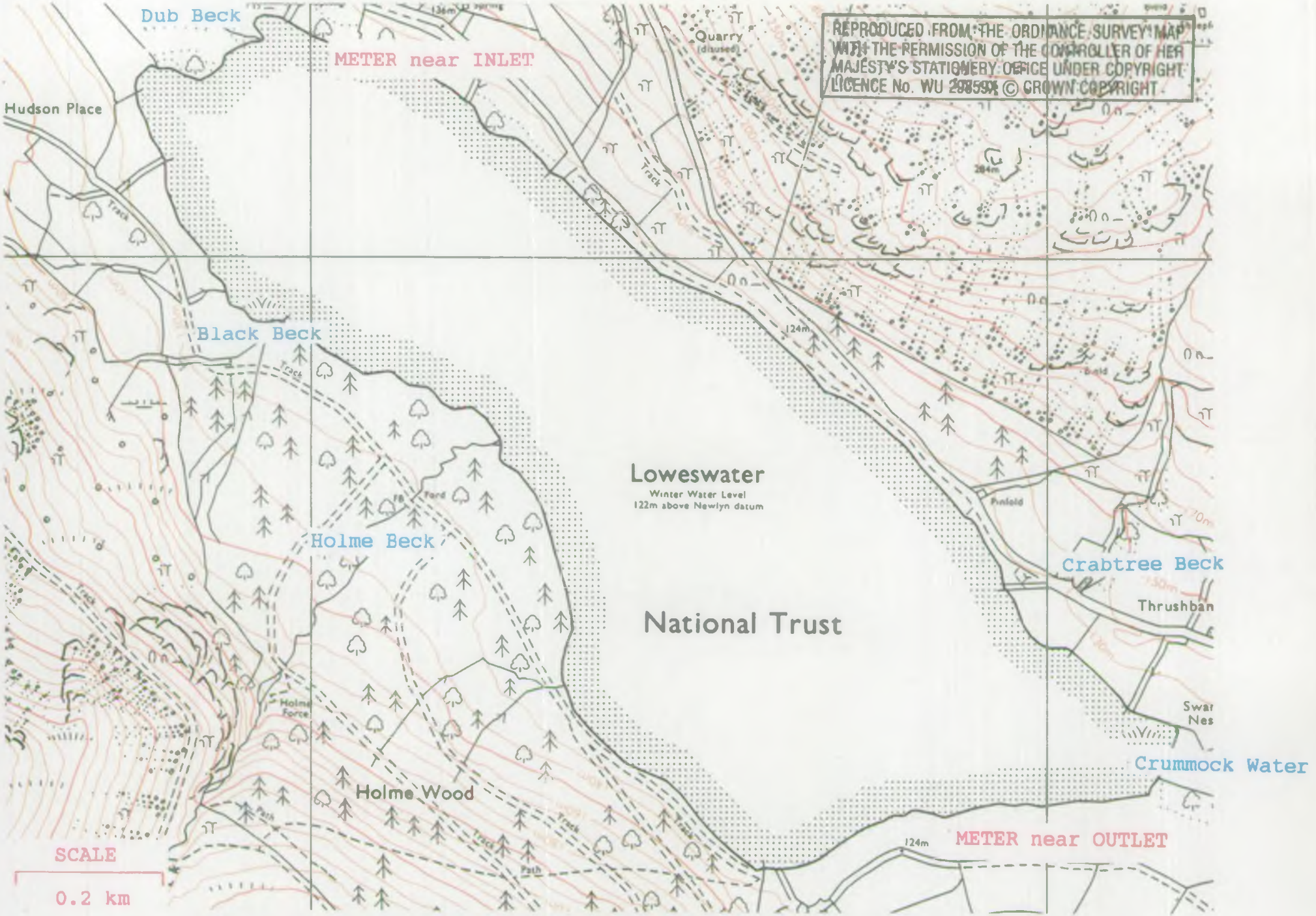


Figure 1: Loweswater, showing the position of the 'inlet' and 'outlet' dissolved oxygen meters used in the 1993 survey

Loweswater survey

28 to 29 July 1993

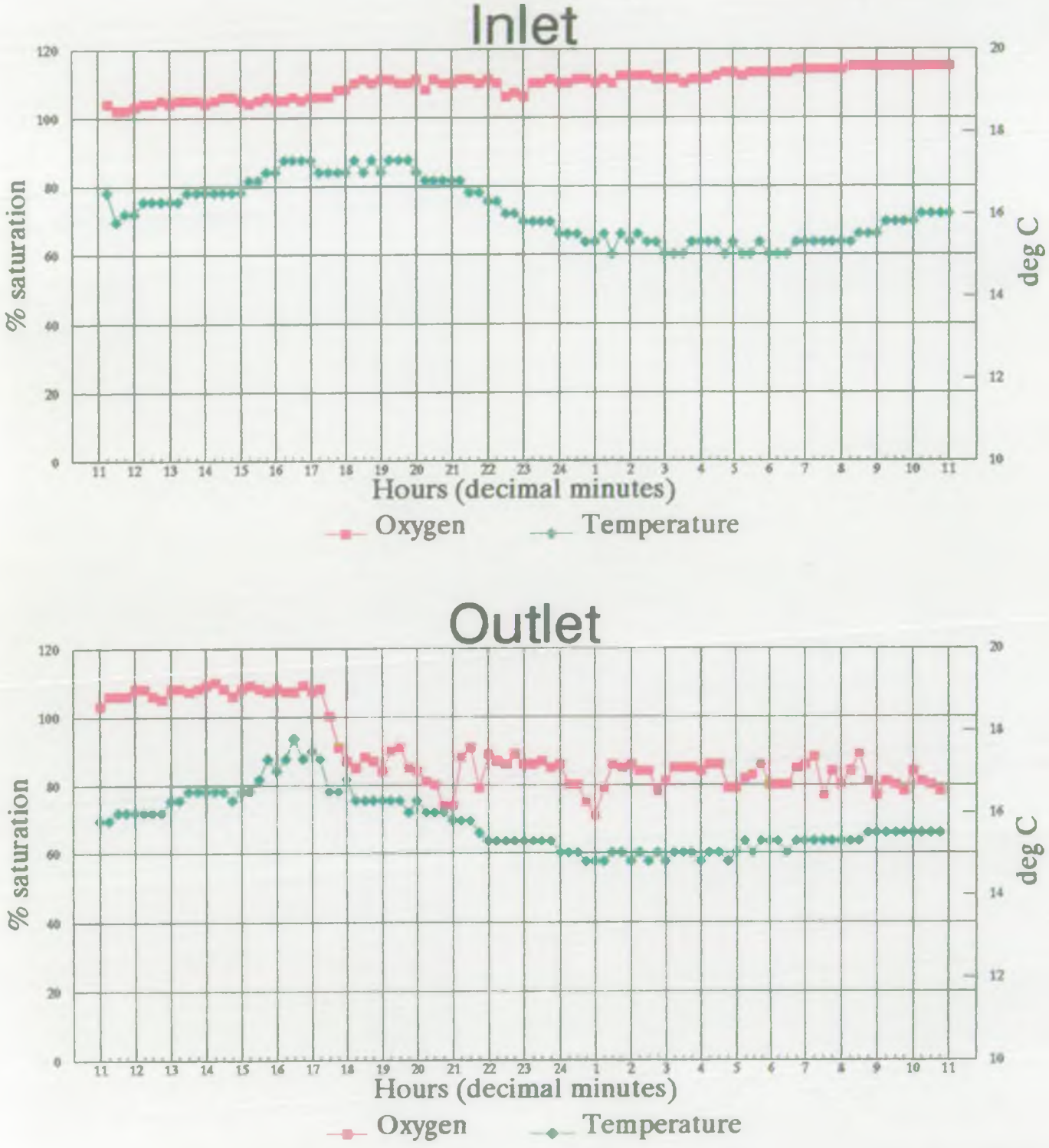


Figure 2: Dissolved Oxygen and temperature results from both 'inlet' and 'outlet' DO meters used during the July 1993 survey

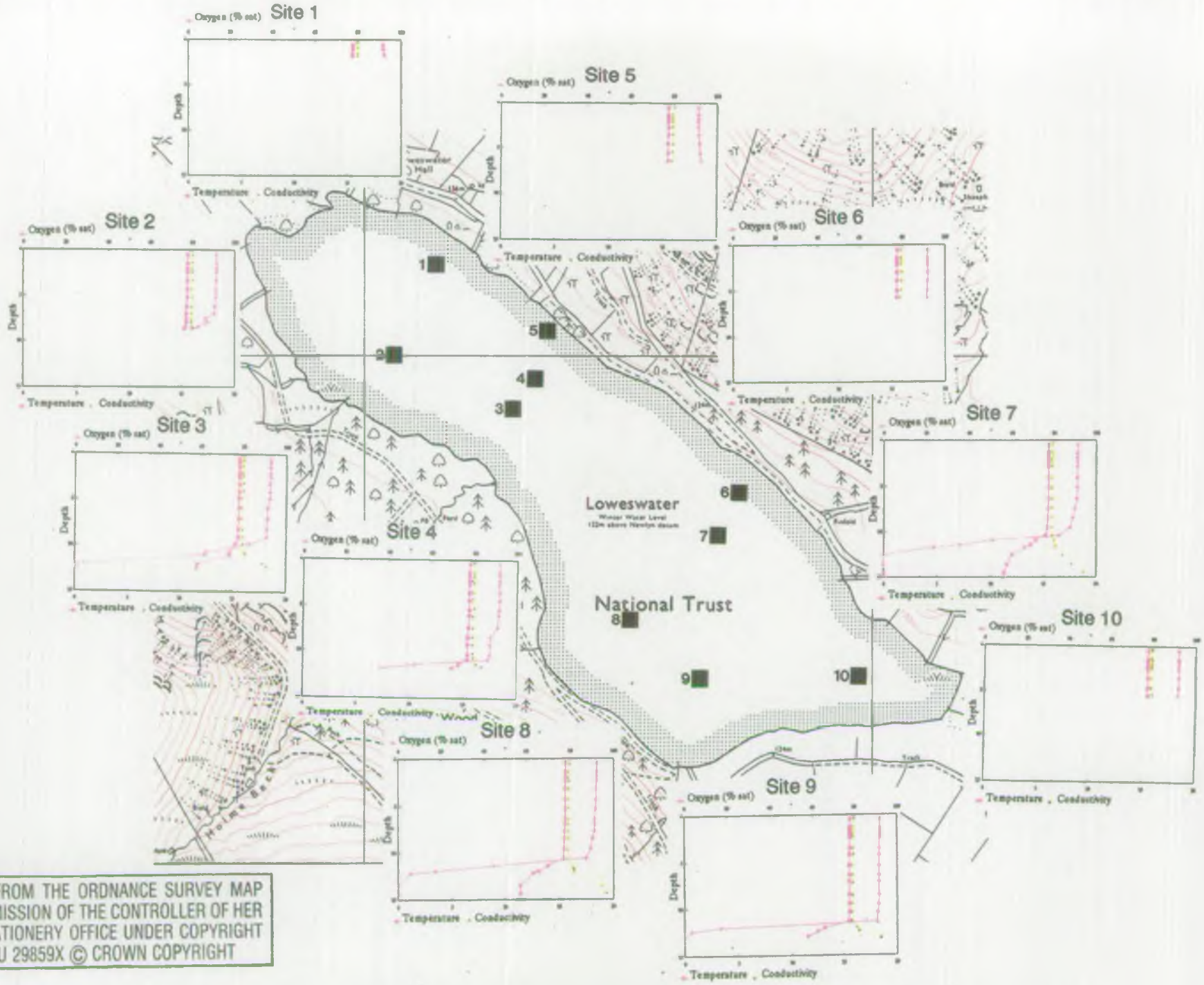


Figure 3: Windermere Profiler Results July 1993 sites 1 - 10

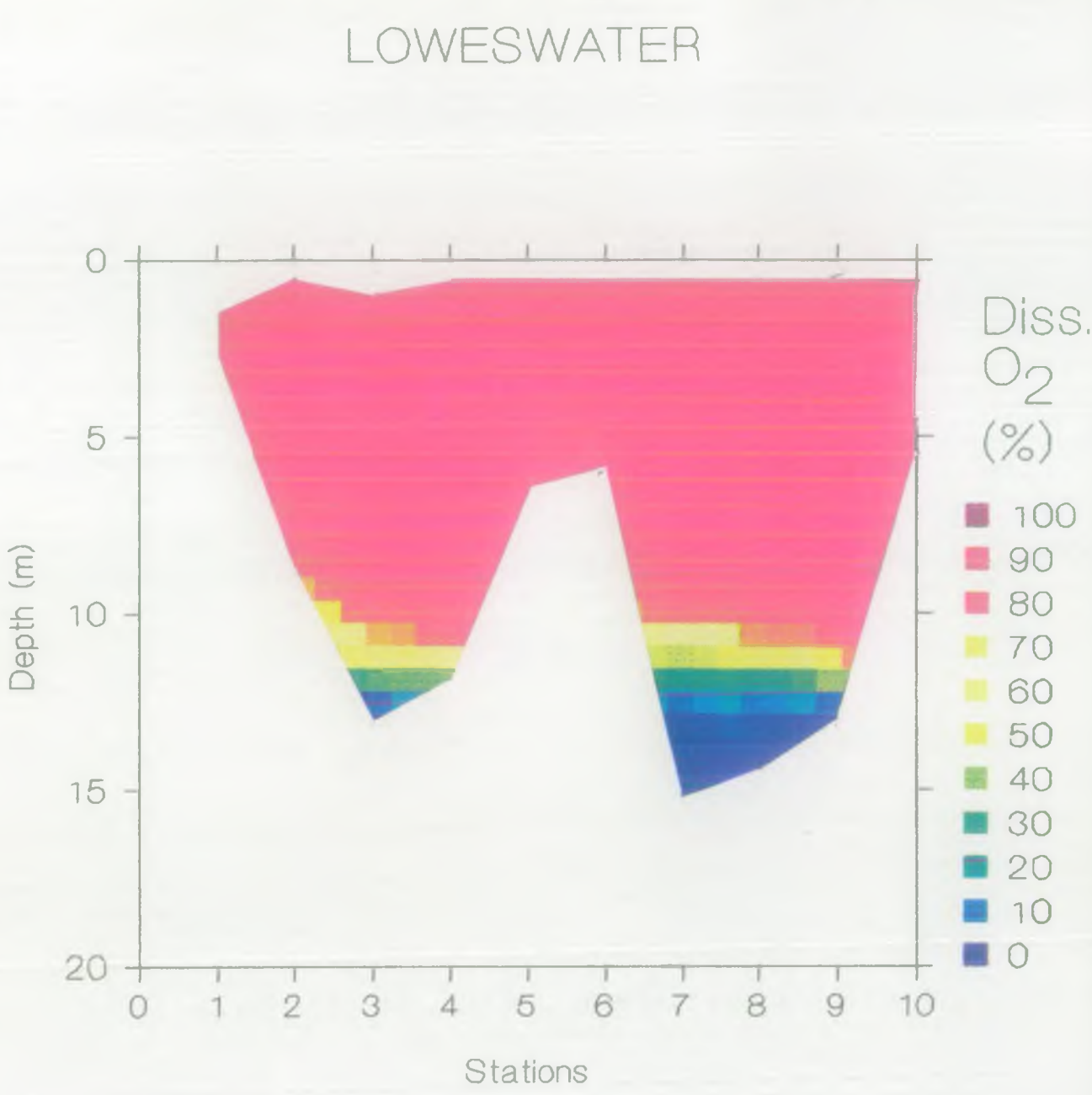


Figure 4: Dissolved oxygen (% sat.) contour of Loweswater in July, based on the profiler data.

LOWESWATER

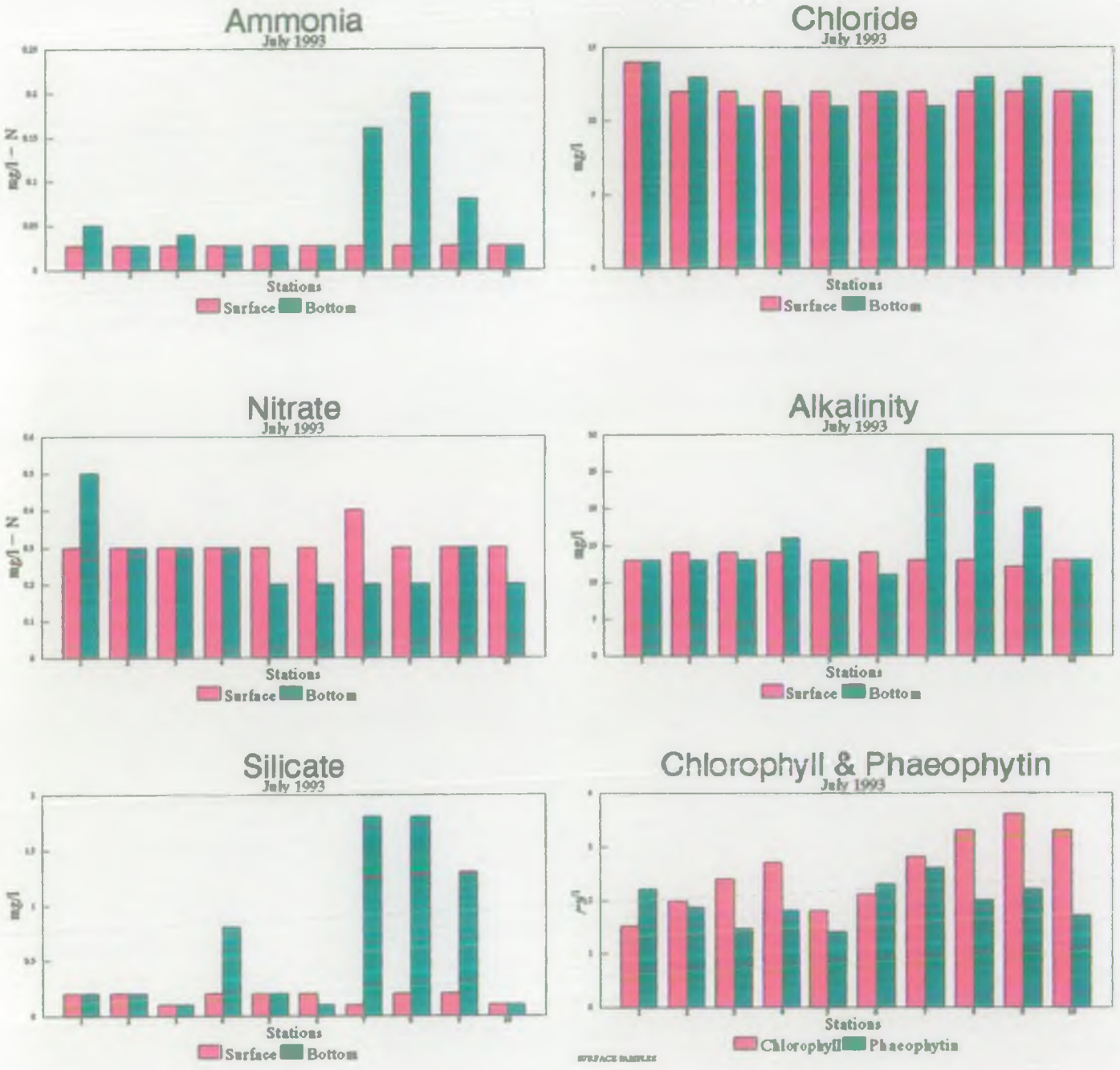
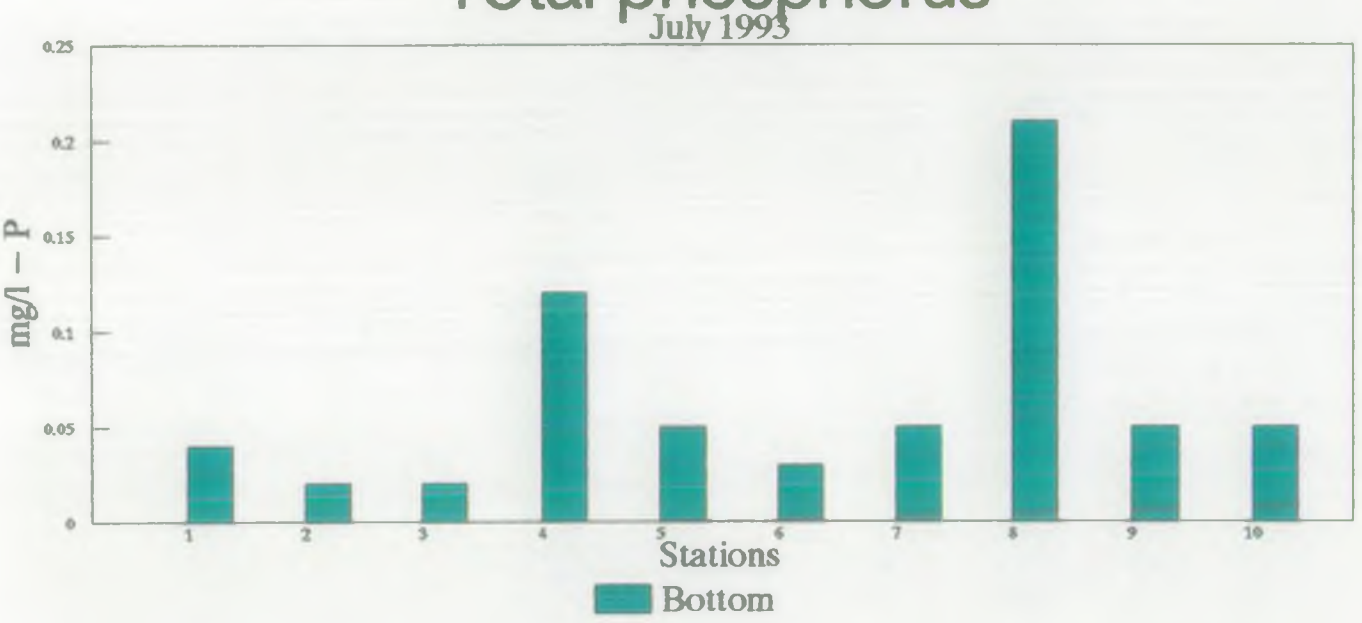


Figure 5: Surface and bottom water samples for July survey: ammonia, chloride, nitrate, alkalinity, silicate, chlorophyll & Phaeophytin results.

LOWESWATER



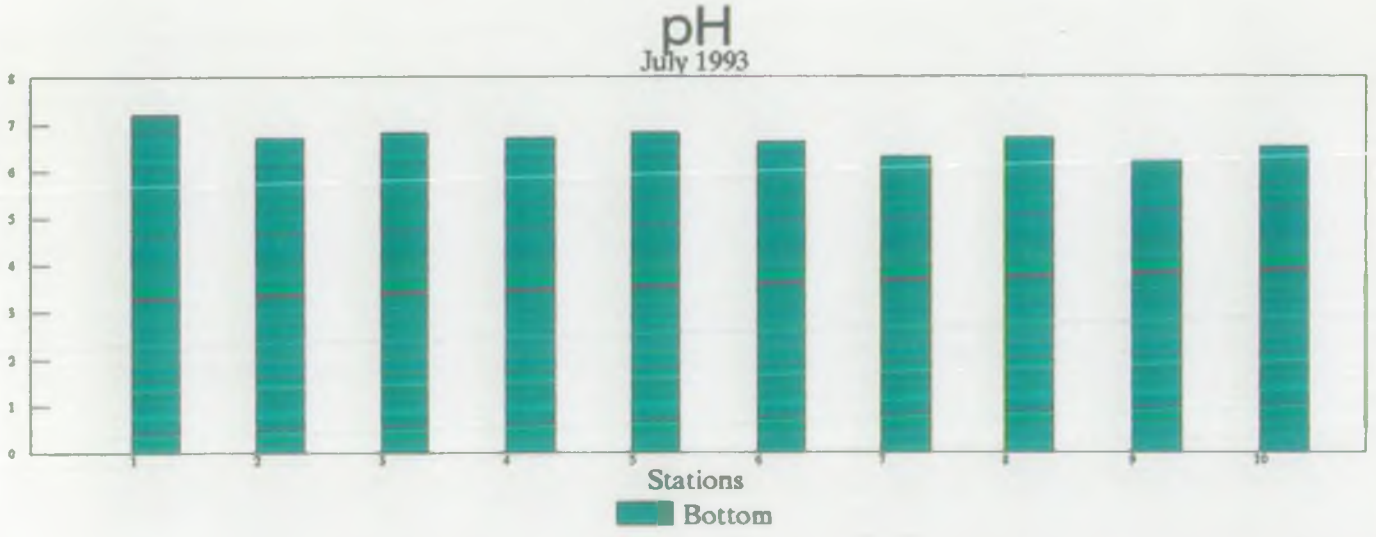


Figure 6: Bottom samples for July survey: total phosphorus and pH results.

LOWESWATER

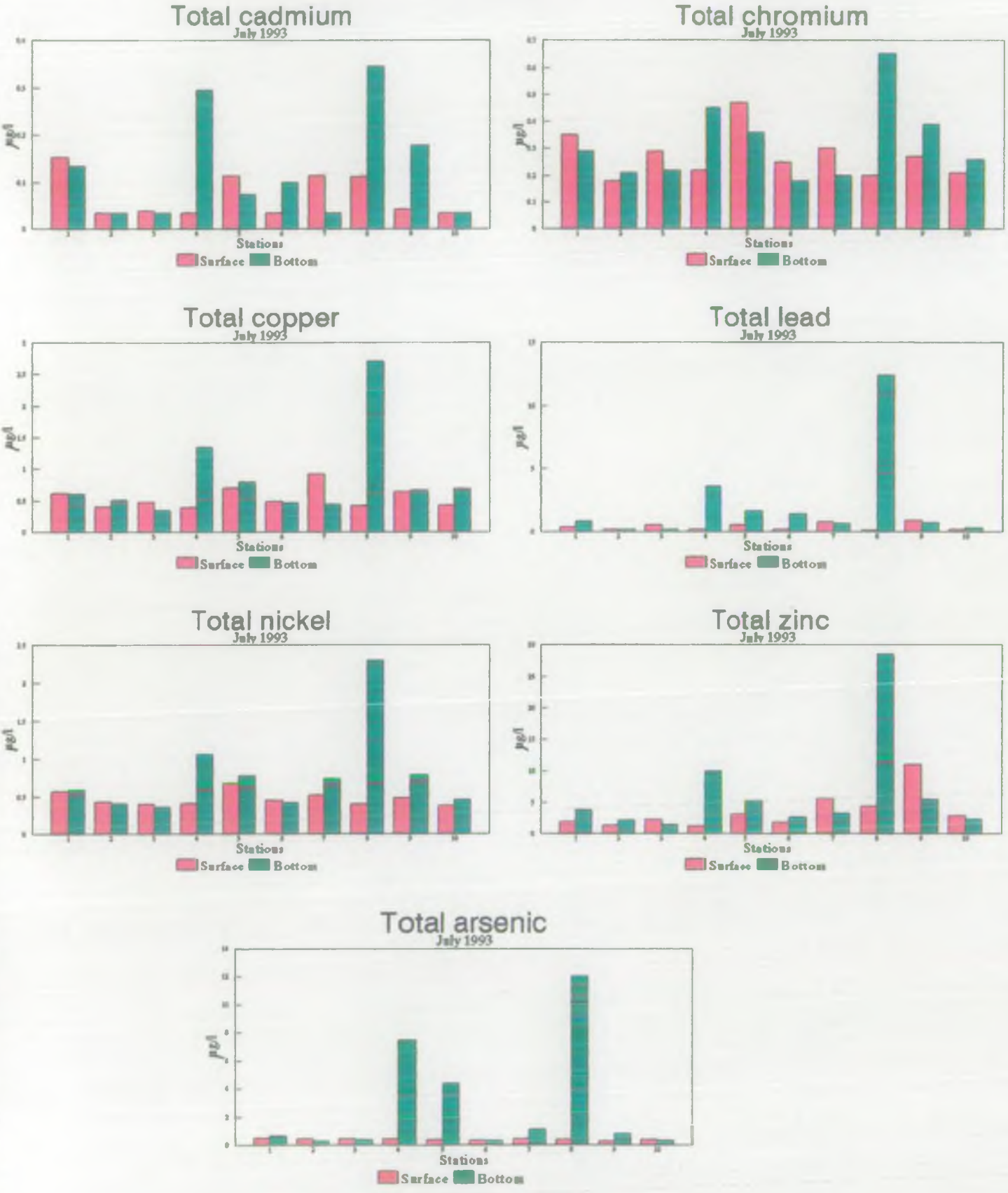


Figure 7: Surface and bottom water samples total metals results - cadmium, chromium, copper, lead, nickel zinc, arsenic.

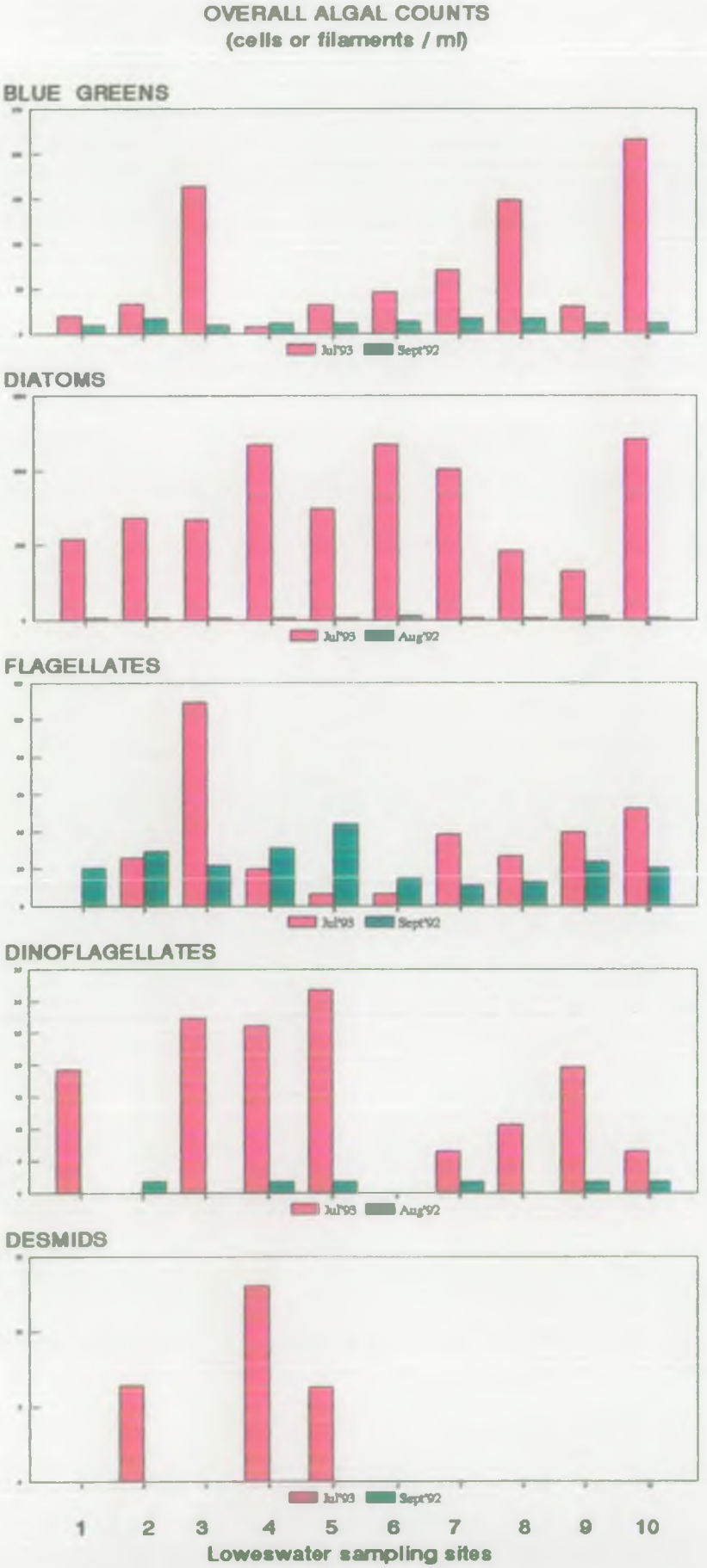


Figure 8: Comparison of algal counts between two surveys.

APPENDIX 1

LOCATION OF SAMPLING SITES

LOWESWATER JULY 1993 SURVEY

SITE	N.G.R.(*)
1	NY 1288 2138
2	NY 1254 2142
3	NY 1266 2164
4	NY 1269 2172
5	NY 1242 2189
6	NY 1228 2198
7	NY 1216 2190
8	NY 1222 2198
9	NY 1230 2208
10	NY 1209 2208

Meter near outlet	NY 1295 2125
Meter near inlet	NY 1190 2228

(*) National Grid Reference numbers based on theodolite readings

APPENDIX 2

RAW DATA - JULY 1993

SUMMARY

DATA UNITS

DISSOLVED OXYGEN METERS

WINDERMERE PROFILER

SURFACE AND BOTTOM WATER SAMPLES

.../...

DATA UNITS:

PARAMETER	UNITS	LABEL IN TABLES
'blank'		missing data
Depth	m	or S = Surface B = Bottom
Temperature	°C	Temp
Conductivity	µS/cm (25°C)	Cond
Alkalinity	mg/l	Alkalin.
Chloride	mg/l	
Dissolved oxygen	% sat.	DO or %SAT
Ammonia	mg/l-N	NH_3
Nitrate	mg/l-N	NO_3
Nitrite	mg/l-N	NO_2
Silicate	mg/l-SiO_2	SiO_2
Orthophosphate	mg/l-P	PO_4
Total phosphorus	mg/l-P	Total-P
Chlorophyll	µg/l	
Phaeophytin	µg/l	Phaeo.
Total metals	µg/l	Pb, Cd, Cu, Zn, Cr, Ni, As

.../...

LOWESWATER SURVEY JULY 1993 – DO METER RESULTS

OUTLET

Time	%SAT	Temperature
11	103	15.8
11.25	106	15.8
11.5	106	16
11.75	106	16
12	108	16
12.25	108	16
12.5	106	16
12.75	105	16
13	108	16.3
13.25	108	16.3
13.5	107	16.5
13.75	108	16.5
14	109	16.5
14.25	110	16.5
14.5	108	16.5
14.75	108	16.3
15	108	16.5
15.25	109	16.5
15.5	108	16.8
15.75	107	17.3
16	108	17
16.25	107	17.3
16.5	107	17.8
16.75	109	17.3
17	107	17.5
17.25	108	17.3
17.5	100	16.5
17.75	91	16.5
18	87	16.8
18.25	85	16.3
18.5	88	16.3
18.75	87	16.3
19	84	16.3
19.25	90	16.3
19.5	91	16.3
19.75	85	16
20	84	16.3
20.25	81	16
20.5	80	16
20.75	74	16
21	74	15.8
21.25	88	15.8
21.5	91	15.8
21.75	79	15.5
22	89	15.3
22.25	87	15.3
22.5	86	15.3
22.75	89	15.3
23	86	15.3
23.25	86	15.3
23.5	87	15.3
23.75	85	15.3
24	86	15
0.25	80	15
0.5	80	15
0.75	75	14.8
1	71	14.8
1.25	79	14.8
1.5	86	15
1.75	85	15
2	86	14.8
2.25	84	15
2.5	84	14.8
2.75	78	15
3	81	14.8
3.25	85	15
3.5	85	15
3.75	85	15
4	84	14.8
4.25	86	15
4.5	86	15
4.75	79	14.8
5	79	15
5.25	82	15.3
5.5	83	15
5.75	86	15.3
6	80	15.3
6.25	80	15.3
6.5	80	15
6.75	85	15.3
7	86	15.3
7.25	88	15.3
7.5	77	15.3
7.75	84	15.3
8	80	15.3
8.25	84	15.3
8.5	89	15.3
8.75	81	15.5
9	77	15.5
9.25	81	15.5
9.5	80	15.5
9.75	78	15.5
10	84	15.5
10.25	81	15.5
10.5	80	15.5
10.75	78	15.5
11		

INLET

Time	%SAT	Temperature
11		
11.25	104	16.5
11.5	102	15.8
11.75	102	16
12	103	16
12.25	104	16.3
12.5	104	16.3
12.75	105	16.3
13	104	16.3
13.25	105	16.3
13.5	105	16.5
13.75	105	16.5
14	104	16.5
14.25	105	16.5
14.5	106	16.5
14.75	106	16.5
15	105	16.5
15.25	104	16.8
15.5	105	16.8
15.75	106	17
16	105	17
16.25	105	17.3
16.5	106	17.3
16.75	105	17.3
17	106	17.3
17.25	106	17
17.5	106	17
17.75	106	17
18	106	17
18.25	110	17.3
18.5	111	17
18.75	110	17.3
19	111	17
19.25	111	17.3
19.5	110	17.3
19.75	110	17.3
20	111	17
20.25	108	16.8
20.5	111	16.8
20.75	110	16.8
21	110	16.8
21.25	111	16.8
21.5	111	16.5
21.75	110	16.5
22	111	16.3
22.25	110	16.3
22.5	106	16
22.75	107	16
23	106	15.8
23.25	110	15.8
23.5	110	15.8
23.75	111	15.8
24	110	15.5
0.25	110	15.5
0.5	111	15.5
0.75	111	15.3
1	110	15.3
1.25	111	15.5
1.5	110	15
1.75	112	15.5
2	112	15.3
2.25	112	15.5
2.5	112	15.3
2.75	111	15.3
3	111	15
3.25	111	15
3.5	110	15
3.75	111	15.3
4	111	15.3
4.25	111	15.3
4.5	112	15.3
4.75	113	15
5	113	15.3
5.25	112	15
5.5	113	15
5.75	113	15.3
6	113	15
6.25	113	15
6.5	113	15
6.75	114	15.3
7	114	15.3
7.25	114	15.3
7.5	114	15.3
7.75	114	15.3
8	114	15.3
8.25	115	15.3
8.5	115	15.5
8.75	115	15.5
9	115	15.5
9.25	115	15.8
9.5	115	15.8
9.75	115	15.8
10	115	15.8
10.25	115	16
10.5	115	16
10.75	115	16
11	115	16

LOWESWATER 28 July 1993 – WINDERMERE PROFILER RESULTS

Site	Time	Temp	Depth	DO	Cond
1	12.13	15.47	0.5	91.33	79.92
1	12.13	15.47	0.58	91.46	79.93
1	12.13	15.47	0.98	91.51	79.93
1	12.13	15.47	0.99	91.61	79.93
1	12.13	15.46	1.51	91.75	79.94
1	12.13	15.45	1.78	92.16	79.96
2	12.22	15.46	0.5	91.11	79.57
2	12.22	15.46	1.47	91.16	79.57
2	12.22	15.45	2.04	91.14	79.5
2	12.22	15.46	2.39	91.06	79.57
2	12.22	15.43	3.33	90.86	79.39
2	12.22	15.41	4.32	90.76	79.59
2	12.22	15.41	5.18	90.66	79.51
2	12.22	15.37	6.15	90.14	79.59
2	12.22	15.36	6.94	89.98	79.6
2	12.22	15.35	7.47	85.76	79.55
2	12.22	15.36	7.87	86.71	79.54
2	12.22	15.27	8.41	82.23	79.55
2	12.22	15.16	8.63	79.04	79.6
3	12.37	15.52	0.5	92.2	79.53
3	12.37	15.51	0.83	92.24	79.62
3	12.37	15.51	1.38	92.19	79.54
3	12.37	15.51	2.03	92.34	79.54
3	12.37	15.51	2.47	92.29	79.54
3	12.37	15.51	3.25	92.13	79.48
3	12.37	15.51	4.1	92.18	79.48
3	12.37	15.5	4.8	92.16	79.42
3	12.37	15.47	5.84	91.03	79.39
3	12.37	15.47	7.01	90.92	79.41
3	12.37	15.46	8.16	90.57	79.34
3	12.37	15.45	9.06	90.44	79.29
3	12.37	15.16	9.77	81.87	79.83
3	12.37	14.58	10.7	62.17	80
3	12.37	14.6	11.04	61.28	79.96
3	12.37	11.57	12.03	0.17	89.48
3	12.37	11.49	12.48	0.39	92.11
4	12.54	15.5	0.5	91.38	79.64
4	12.54	15.49	1.42	91.51	79.58
4	12.54	15.49	1.71	91.51	79.58
4	12.54	15.49	2.24	91.5	79.52
4	12.54	15.49	2.65	91.4	79.52
4	12.54	15.49	3.55	91.5	79.52
4	12.54	15.49	4.37	91.5	79.44
4	12.54	15.47	5.37	91.28	79.39
4	12.54	15.47	6.01	91.07	79.41
4	12.54	15.44	7.38	90.63	79.3
4	12.54	15.35	8.46	87.34	79.4
4	12.54	15.34	9.23	87.22	79.34
4	12.54	15.35	10.4	87.24	79.25
4	12.54	15.32	10.91	86.03	79.24
4	12.54	14.48	11.44	52.03	80.25
4	12.54	13.89	11.8	36.32	83.15
5	13.12	15.5	0.5	91.23	79.87
5	13.12	15.51	1.28	91.2	79.78
5	13.12	15.5	1.71	91.18	79.79
5	13.12	15.5	2.07	91.28	79.79
5	13.12	15.5	2.7	91.33	79.72
5	13.12	15.48	3.53	91.54	79.75
5	13.12	15.47	4.48	91.76	79.63
5	13.12	15.45	5.51	92.13	79.5
5	13.12	15.45	6.33	92.57	79.58

.../...

Site	Time	Temp	Depth	DO	Cond
6	13.44	15.57	0.5	92.04	79.74
6	13.44	15.55	1.36	91.91	79.71
6	13.44	15.55	1.71	92.01	79.71
6	13.44	15.54	2.11	92.04	79.57
6	13.44	15.55	2.89	92.12	79.62
6	13.44	15.54	2.98	92.09	79.64
6	13.44	15.55	3.85	92.05	79.56
6	13.44	15.55	3.88	91.86	79.63
6	13.44	15.53	4.95	91.78	79.58
6	13.44	15.53	5.76	91.44	79.43
7	14.16	15.54	0.5	91.75	79.42
7	14.16	15.54	1.29	91.7	79.49
7	14.16	15.53	1.4	91.69	79.51
7	14.16	15.53	1.89	91.69	79.51
7	14.16	15.54	2.27	91.75	79.42
7	14.16	15.53	2.79	91.69	79.43
7	14.16	15.53	4.06	91.58	79.37
7	14.16	15.53	5.08	91.48	79.37
7	14.16	15.52	6.29	91.47	79.31
7	14.16	15.47	7.42	90.48	79.26
7	14.16	15.41	8.43	89.24	79.28
7	14.16	15.39	9.47	87.96	79.25
7	14.16	15.26	10.38	82.65	79.11
7	14.16	14.33	10.86	51.44	80.09
7	14.16	13.84	11.35	35.92	80.22
7	14.16	13.31	11.62	23.57	80.66
7	14.16	12.1	12.42	0	84.02
7	14.16	11.6	13.54	0	88.59
7	14.16	11.37	14.45	0.11	94.25
7	14.16	11.27	14.97	0.56	106.02
8	14.25	15.58	0.5	92.31	79.42
8	14.25	15.57	1.43	92.24	79.37
8	14.25	15.56	1.88	92.13	79.38
8	14.25	15.55	2.33	92.12	79.4
8	14.25	15.53	3.17	91.78	79.36
8	14.25	15.53	4.41	91.88	79.28
8	14.25	15.53	5.33	91.74	79.28
8	14.25	15.51	6.43	91.05	79.11
8	14.25	15.5	6.93	91.13	79.19
8	14.25	15.51	7.71	91.06	79.02
8	14.25	15.46	8.48	90.27	79.12
8	14.25	15.42	9.59	89.31	79.12
8	14.25	15.34	10.61	87.26	79.12
8	14.25	13.95	11.43	44.03	81.16
8	14.25	13.07	12.01	17.34	81.99
8	14.25	12.62	12.22	5.43	81.65
8	14.25	11.4	13.47	0	94.77
8	14.25	11.46	14.37	0.56	96.61
9	14.44	15.59	0.5	92.08	79.41
9	14.44	15.57	1.42	91.99	79.37
9	14.44	15.57	1.81	91.99	79.37
9	14.44	15.56	2.15	91.98	79.31
9	14.44	15.55	2.47	91.82	79.32
9	14.44	15.55	3.55	91.71	79.26
9	14.44	15.53	4.29	91.59	79.13
9	14.44	15.53	5.42	91.59	79.13
9	14.44	15.53	6.48	91.54	79.13
9	14.44	15.53	7.16	91.49	78.98
9	14.44	15.53	8.51	91.54	78.98
9	14.44	15.53	9.48	91.28	79
9	14.44	15.51	10.4	90.9	78.88
9	14.44	15.49	11.36	90.42	78.85
9	14.44	13.17	11.99	16.7	81.56
9	14.44	12.53	12.38	3.18	82.06
9	14.44	11.55	12.92	0	93.45
10	15.17	15.64	0.5	92.62	79.46
10	15.17	15.61	1.44	92.62	79.43
10	15.17	15.61	1.64	92.57	79.43
10	15.17	15.61	2.1	92.62	79.43
10	15.17	15.61	2.5	92.65	79.37
10	15.17	15.61	3.48	92.55	79.3
10	15.17	15.61	4.58	92.6	79.37
10	15.17	15.6	5.38	92.15	79.61

LOWESWATER SURVEY: SURFACE AND BOTTOM SAMPLES

JULY 1993

SURFACE

Station	Depth	SiO2	Alkalin.	Chloride	NH3	NO2	NO3	PO4	Chlorophyll	Phaeophytin
1	S	0.2	13	14	0.027	0.013	0.3	0.007	1.52	2.2
2	S	0.2	14	12	0.027	0.013	0.3	0.007	1.98	1.87
3	S	0.1	14	12	0.027	0.013	0.3	0.007	2.39	1.47
4	S	0.2	14	12	0.027	0.013	0.3	0.007	2.69	1.8
5	S	0.2	13	12	0.027	0.013	0.3	0.007	1.8	1.4
6	S	0.2	14	12	0.027	0.013	0.3	0.007	2.1	2.3
7	S	0.1	13	12	0.027	0.013	0.4	0.007	2.8	2.6
8	S	0.2	13	12	0.027	0.013	0.3	0.007	3.3	2
9	S	0.2	12	12	0.027	0.013	0.3	0.007	3.6	2.2
10	S	0.1	13	12	0.027	0.013	0.3	0.007	3.3	1.7

JULY 1993

BOTTOM

Station	Depth	SiO2	Alkalin.	Chloride	NH3	NO2	NO3	PO4	Tot-P	pH
1	B	0.2	13	14	0.05	0.013	0.5	0.007	0.04	7.2
2	B	0.2	13	13	0.027	0.013	0.3	0.007	0.02	6.7
3	B	0.1	13	11	0.04	0.013	0.3	0.007	0.02	6.8
4	B	0.8	16	11	0.027	0.013	0.3	0.007	0.12	6.7
5	B	0.2	13	11	0.027	0.013	0.2	0.007	0.05	6.8
6	B	0.1	11	12	0.027	0.013	0.2	0.007	0.03	6.6
7	B	1.8	28	11	0.16	0.013	0.2	0.007	0.05	6.3
8	B	1.8	26	13	0.2	0.013	0.2	0.007	0.21	6.7
9	B	1.3	20	13	0.08	0.013	0.3	0.007	0.05	6.2
10	B	0.1	13	12	0.027	0.013	0.2	0.007	0.05	6.5

LOWESWATER SURVEY – SURFACE AND BOTTOM SAMPLES

JULY 1993

SURFACE

Station	Depth	Pb	Cd	Cu	Zn	Cr	Ni	As
1	S	0.33	0.154	0.61	1.92	0.35	0.57	0.52
2	S	0.18	0.033	0.4	1.36	0.18	0.43	0.43
3	S	0.52	0.038	0.47	2.3	0.29	0.4	0.43
4	S	0.15	0.033	0.39	1.22	0.22	0.41	0.47
5	S	0.53	0.114	0.7	3.15	0.47	0.67	0.38
6	S	0.18	0.033	0.48	1.8	0.25	0.45	0.36
7	S	0.75	0.114	0.92	5.6	0.3	0.52	0.43
8	S	0.14	0.112	0.41	4.4	0.2	0.4	0.42
9	S	0.86	0.042	0.64	11	0.27	0.48	0.29
10	S	0.16	0.033	0.42	2.9	0.21	0.38	0.4

BOTTOM

Station	Depth	Pb	Cd	Cu	Zn	Cr	Ni	As
1	B	0.85	0.134	0.6	3.8	0.29	0.58	0.68
2	B	0.16	0.033	0.51	2.15	0.21	0.41	0.3
3	B	0.17	0.033	0.34	1.44	0.22	0.36	0.39
4	B	3.6	0.295	1.34	10	0.45	1.06	7.5
5	B	1.66	0.073	0.79	5.3	0.36	0.77	4.4
6	B	1.42	0.099	0.46	2.6	0.18	0.42	0.32
7	B	0.64	0.033	0.44	3.25	0.2	0.73	1.16
8	B	12.4	0.345	2.7	28.5	0.65	2.3	12
9	B	0.73	0.178	0.66	5.5	0.39	0.78	0.8
10	B	0.27	0.033	0.68	2.3	0.26	0.46	0.35

APPENDIX 3

ENVIRONMENTAL QUALITY STANDARDS

FOR METALS IN INLAND SURFACE WATERS

(Information Dated September 1993)

QUALITY STANDARDS

Protection of sensitive aquatic life
(µg/l, annual mean, dissolved)

Hard.(mg/l CaCO3)	0-50	50-100	100-150	150-200	200-250	250+
Lead	4	10	10	20	20	20
Chromium	5	10	20	20	50	50
Zinc (total)	8	50	75	75	75	125
95 % of samples	(30)	(200)	(300)	(300)	(300)	(500)
Copper	1	6	10	10	10	28
95 % of samples	(5)	(22)	(40)	(40)	(40)	(112)
Nickel	50	100	100	150	200	200
Arsenic	50	50	50	50	50	50

Protection of other aquatic life
(µg/l, annual mean, dissolved)

Hard.(mg/l CaCO3)	0-50	50-100	100-150	150-200	200-250	250+
Lead	50	125	125	250	250	250
Chromium	150	175	200	200	250	250
Zinc (total)	75	175	250	250	250	500
95 % of samples	(300)	(700)	(1000)	(1000)	(1000)	(2000)
Copper	1	6	10	10	10	28
95 % of samples	(5)	(22)	(40)	(40)	(40)	(112)
Nickel	50	100	100	150	200	200
Arsenic	50	50	50	50	50	50

Protection of all aquatic life

pH (95%)	6 - 9

QUALITY STANDARDS - endorsed
annual mean

Cadmium	5.0 µg/l	total

NW:WAR:RFH
:WQ:MSP-94
-002

c. 1 aa