ENGINEERING
AND
ENVIRONMENT LIMITED

ALGAL GROWTH IN THE IMPOUNDED WATERS OF A PROPOSED BARRAGE AT CARDIFF BAY - PREDICTION USING 1989 DATA

CLIENT: NATIONAL RIVERS AUTHORITY, WELSH REGION
PLAS-YR-AFON
ST. MELLONS BUSINESS PARK
CARDIFF
CF3 OLT

CONTRACT REF: XS734

B D SCANNELL
SCIENTIFIC PROJECT MANAGER
ENGINEERING & ENVIRONMENT LTD
TREMAINS HOUSE
TREMAINS COURT
BRIDGEND, MID GLAMORGAN
CF31 2AR

CONTENTS

1.0 INTRODUCTION

A model was developed during late 1987 by Welsh Water and the Freshwater Biological Association jointly, to predict the algal dynamics in the waters impounded by a proposed barrage at Cardiff Bay. It was run for the period January 1976 to August 1987 and the results are reported in ref.1.

The work reported here employed the same model and used data for the period January to October 1989 inclusive.

2. DATA

2.1 Model Input Data Requirements

The model requires the following daily input data:

(i) Daily mean flow (m^3/s); Taff and Ely
(ii) Mean PO4.P concentration (mg/m^3); Taff and Ely
(iii) Mean TON.N concentration (mg/m^3); Taff and Ely
(iv) Mean water temperature (^oC); Taff and Ely
(v) Cloud Cover (Octals)

In addition there is a default set of data and paramaters which configure the model execution, these are detailed in appendix 1.

Daily mean flow for both rivers is available for the Taff at Pontypridd and the Ely at St. Fagans.

Mean nutrient concentration data is not routinely available. Instead, instantaneous flow and nutrient concentration data is used to compute an instantaneous load, which is assumed to be constant during the day and a daily load is calculated. The daily load is then used with the daily mean flow to calculate the daily mean concentration. In effect:

$$C_{Mean} = C_{Inst} * (Q_{(Inst)}/Q_{(Mean)})$$

Where;
C_{Mean} = Daily mean concentration (mg/m^3)
C_{Inst} = Observed instantaneous concentration (mg/m^3)
Q_{Mean} = Daily mean flow (m^3/s)
Q_{Inst} = Instantaneous flow concurrent with concentration measurement (m^3/s)

Since daily monitoring is not undertaken, it is necessary to interpolate the data for the days when no observations were made. This is done by linearly interpolating the calculated daily loads between successive observations and then using the daily mean flow to calculate the equivalent daily mean concentration. Clearly, the appropriateness of this is dependant upon the number of data values available, their temporal spacing and the incidence of extreme values within the data set.

In the same way, river water temperature is not monitored on a daily basis and a similar process of interpolation between observations is necessary for this data.

Data on reduction of incident radiation during the period of growth due to cloud cover is also required on a daily basis.

2.2 Supplied Inputs Data

2.2.1 NRA Monitoring Data

The temperature and nutrient loading data originally supplied consisted of a limited number of samples collected as part of the NRA routine monitoring programme (Table 1). The daily loads and mean concentrations were calculated as outlined above and interpolated for the missing values. Figures 1a, 1b, 2a and 2b show the interpolated phosphate (PO_4.P) and nitrogen (TON.N) daily loads (kg/day) and the instantaneous flows used in their calculation for both the Taff and the Ely.

2.2.2 Historical Monitoring Data 1976 to 1987

The paucity of data (especially for the Ely) lead to an examination of the 1976 to 1987 data in an attempt to identify any significant characteristics which could be used to generate an artificial input data set. The results of this examination are shown in figures 3a to c and 4a to c as described below:

Figures 3a and 4a show the distribution of observed PO_4.P loads for the Taff and Ely respectively.

Figures 3b and 4b show the distribution of log (PO_4.P load) for the Taff and Ely respectively.

Figures 3c and 4c show the variation of TON.N loads with river flow for the Taff and Ely respectively.

The tentative suggestion is that in both rivers, the PO_4.P load has an approximately log-normal distribution which is unrelated to river flow. Also the regression results suggest that there is some correlation between river flow and TON.N load.

This data uses all observations from the complete period 1976 to 1987, during which time it is known that significant changes to the loading will have occurred due, for example, to re-sewering work. A more detailed analysis of the data on a year-by-year basis may provide more information though the problem of lower data density would then appear, especially for the later years.

2.2.3 1989 Monitoring Data - Wimpey Laboratories

The data collected over the period February to September 1989 by Wimpey Laboratories Ltd under contract to Wallace Evans & Partners was made also available, ref. 2. This contained data from routine monitoring of both the Taff and the Ely, including the essential parameters of TON, PO_4, instantaneous flow and temperature.

2.3 Input Data Files

The data collected by Wimpey Laboratories was integrated with that provided by the NRA monitoring programme to produce the most complete set achievable, see Table 2.

Daily loads calculated from instantaneous flow and concentration data on the days of observations were used as the basis for a linear interpolation to produce an input file containing daily mean flow, mean PO_4.P concentration, mean TON.N concentration and water temperature for both input rivers, see Table 3. Figures 7a, b, c and d illustrate this data set.

Data on hourly cloud cover was obtained from the Meteorological Office, Bracknell for Rhoose Airport over the period of the simulation. An average cloud cover for the period 0600 to 1900 hrs each day was used as representative of the incident radiation "lost", Figure 7e.

3 MODEL RESULTS

3.1 Run 1 - Baseline Run

The model was run using the integrated data set described above, adopting all of the default conditions and parameters described in appendix 1 and starting from scratch on 1/1/89. Figures 8a through 8e illustrate the results from this run:

Figure 8a shows all species

8b shows only the four species of specific interest

8c shows detail of the prediction for Microcystis and Anabaena, the two species capable of surface accumulation

8d shows the residual nutrient concentration within the lake

8e shows the combined river inflow and the equivalent retention period.

3.2 Run 2 - Unlimited Nutrient

The results from Run 1 suggested that phosphorus availability could have become a limiting factor, therefore a second run was carried out which allows algae to grow at their light, flushing and grazing limited rates without consuming nutrients ie. simulating on unlimited nutrient resource. This run is necessary since no consideration is given in the model to nutrients released from the sediment.

Figures 9a through to 9d show the results of this second run:

Figure 9a shows all species

Figure 9b shows the four most significant species

Figure 9c shows details of the species capable of producing surface accumulations

Figure 9d shows the nutrient concentration within the bay.

4 SUMMARY

The FBA/WW model has been run for the observed data on input river flow, nutrient loading and temperature collected for routine monitoring by NRA Welsh region and by Wimpey Laboratories under contract to Cardiff Bay Development Corporation's Consulting Engineers, Wallace Evans & Partners.

Two simulations have been carried out. Run 1 being a baseline prediction incorporating the full default conditions. Run 2 simulates the case of unlimited nutrient availability.

REFERENCES

1 Welsh Water Authority, Tidal Waters Unit Report. Reference TW/88/3 1988

2 Wimpey Laboratories Ltd "Cardiff Bay Barrage River Water Quality Monitoring" provision data report to Wallace Evans & Partners.

Table 1A
Taff Loading Data 1989
NRA Supplied Data

DD	MM	Inst Q m3/s	PO4.P mg/l	TON.N mg/l	Temp C	Mean Q m3/s	PO4.P kg/d	TON.N kg/d	Av PO4.P mg/m3	Av TON.N mg/m3
23	1				5	28.78				
1	3				5	31.44				
3	5				14	7.115				
5	6	4.162	.35	1.5	14	4.652	126	539	313.1	1342.0
7	7	9.001	.16	2.64	18	11.63	124	2053	123.8	2043.2
7	8	2.77	.56	1.19	21	2.772	134	285	559.6	1189.1
4	9	.528		2.13	15.5	2.597		97		433.1
5	1	8.372	.32	1.89		34.98	231	1367	76.6	452.3
26	1	15.483	.16	1.38		14.53	214	1846	170.5	1470.5
1	2	11.657	.23	1.56		11.22	232	1571	239.0	1620.8
6	2	12.545	.19	1.33		12.12	206	1442	196.7	1376.6
8	2	10.337	.23	1.58		10.19	205	1411	233.3	1602.8
13	2	39.436	.22	1.27		24.98	750	4327	347.3	2005.0
16	2	17.398	.13	.96		16.37	195	1443	138.2	1020.3
27	2	45.534	.06	1.08		43.72	236	4249	62.5	1124.8
6	3	20.802	.09	1.27		27.1	162	2283	69.1	974.9
9	3	158.681	.11	.59		110.5	1508	8089	158.0	847.3
15	3	73.803	.07	.75		53.04	446	4782	97.4	1043.6
21	3	32.571	.09	.91		32.64	253	2561	89.8	908.1

Table 1B
Ely Loading Data 1989
NRA Supplied Data

DD	MM	Inst Q m3/s	PO4.P mg/l	TON.N mg/l	Temp C	Mean Q m3/s	PO4.P kg/d	TON.N kg/d	Av PO4.P mg/m3	Av TON.N mg/m3
8	2				7	1.97				
5	5				16	1.43				
15	6	.661	1.3	1.75	21	.65	74	100	1326.1	1785.1
13	7	.901	1.2	3.05	21	.90	93	237	1208.0	3070.4
15	9	1.835	.64	4.07		1.95	101	645	603.8	3839.8

Table 2A
TAFF RIVER LOADING DATA 1989
Combined NRA Wimpey Laboratory Data

DD	MM	Inst Q m3/s	PO4.P mg/l	TON.N mg/l	Temp C	Chl_a ug/l	Mean Q m3/s	PO4.P Kg/d	TON.N Kg/d	Av PO4.P mg/m3	Av TON.N mg/m3
5	1	8.372	.32	1.89			34.98	231	1367	76.6	452.3
26	1	15.483	.16	1.38			14.53	214	1846	170.5	1470.5
1	2	11.657	.23	1.56			11.22	232	1571	239.0	1620.8
6	2	12.72	.205	1.1	10		12.12	225	1209	215.1	1154.5
8	2	10.337	.23	1.56			10.19	205	1411	233.3	1602.8
10	2	10.45	.215	1.55	9.95	1	9.982	194	1399	225.1	1622.7
12	2	13.2	.16	.9	8.45		12.75	205	1026	186.4	931.8
13	2	39.436	.22	1.27			24.98	750	4327	347.3	2005.0
15	2	18.78	.185	1	8.95	2.65	25.17	300	1623	138.0	746.1
16	2	17.398	.13	.96			16.37	195	1443	138.2	1020.3
18	2	285.82	.02	.55	10.4		232.3	494	13582	24.6	676.7
20	2	57.25	.04	.42	8.3	1.65	41.59	198	2077	55.1	578.1
22	2	49.18	.21	.75	7.6		36.96	892	3187	279.4	998.0
27	2	45.534	.06	1.08			43.72	236	4249	62.5	1124.8
28	2	31.17	.07	1.41	6.8	1.25	31.17	189	3797	70.0	1410.0
2	3	106.88	.08	.575	6.45		71.42	739	5310	119.7	860.5
5	3	25.91	.13	.985	9	.5	23.97	291	2205	140.5	1064.7
6	3	20.802	.09	1.27			27.1	162	2283	69.1	974.9
8	3	19.78	.2	1.045	7.1		61.75	342	1786	64.1	334.7
9	3	105.27	.08	1.205	8.4	1	110.5	728	10960	76.2	1148.0
12	3	29.66	.17	.865	7.8		36.01	436	2217	140.0	712.5
15	3	61.7	.1	.525	8.5	.7	53.04	533	2799	116.3	610.7
18	3	22.9	.13	1.125	6.4		39.19	257	2226	76.0	657.4
21	3	31.09	.12	1.12	7.3	.3	32.64	322	3009	114.3	1066.8
24	3	135.37	.04	.46	8.6		95.25	468	5380	56.8	653.8
27	3	22.81	.13	1.15	9.8	.3	22.36	256	2266	132.6	1173.1
30	3	16.22	.205	1.26	9.7		15.61	287	1766	213.0	1309.2
2	4	26.04	.2	1.105	9.8	.4	20.33	450	2486	256.2	1415.4
5	4	12.93	.2	.97	6.6		15.46	223	1084	167.3	811.3
8	4	15.19	.265	.73	7.6	.65	14.7	348	958	273.8	754.3
11	4	30.66	.17	.915	8.9		34.18	450	2424	152.5	820.8
14	4	14.81	.255	1.87	9.7	4.4	14.5	326	2393	260.5	1910.0
17	4	13.02	.245	1.11	9.7		12.85	276	1249	248.2	1124.7
20	4	10.57	.275	1.125	9.7	2.75	10.35	251	1027	280.8	1148.9
21	4	9.95	.22	1.105	9.7		9.804	189	950	223.3	1121.5
27	4	9.47	.65	1.31	9.3	8.05	9.004	532	1072	683.6	1377.8
3	5	7.04	.355	2.005	14.6	20.5	7.115	216	1220	351.3	1983.9
9	5	5.94	.33	2.17	13.9	12.45	5.874	169	1114	333.7	2194.4
15	5	5.86	.325	1.655	14.4		5.391	165	838	353.3	1799.0
21	5	4.83	.4	1.65	18.6	19	4.924	167	689	392.4	1618.5
27	5	4.12	.44	2.4	16.5		4.169	157	854	434.8	2371.8
30	5	4.07	.345	1.13	17.9	9.8	4.017	121	397	349.6	1144.9
2	6	4.25			14.8		4.435				
5	6	3.95	.4	2.1	14.1	10.35	4.134	137	717	382.2	2006.5
8	6	4.93	.63	1.96	13.6		5.28	268	835	588.2	1830.1
11	6	4.89	1.025	8.07	14.1	3.5	4.135	433	3410	1212.2	9543.5
14	6	3.76	.63	2.6	20.3		3.73	205	845	635.1	2620.9
17	6	3.57	.76	3.26	21.4	2.9	3.582	234	1006	757.5	3249.1
20	6	3.42	.57	2.095	23		3.363	168	619	579.7	2130.5
23	6	3.18	.48	2.335	22.4	2.65	3.192	132	642	478.2	2326.2
26	6	3.5	1.63	7.17	19.1		4.868	493	2168	1171.9	5155.1
29	6	7.12	.535	2.405	17.1	9.95	5.308	329	1479	717.6	3226.0
2	7	3.049	.505	3.35	16.2		4.211	133	883	365.6	2425.6
5	7	3.508	.69	2.81	23	1.15	3.595	209	852	673.3	2742.0
7	7	9.001	.16	2.64			11.63	124	2053	123.8	2043.2

Table 24
TAFF RIVER LOADING DATA 1989
Combined NRA Wimpey Laboratory Data

DD MM	inst Q m3/s	PO4.P mg/l	TON.N mg/l	Temp C	Chl_a ug/l	Mean Q m3/s	PO4.P Kg/d	TON.N Kg/d	Av PO4.P mg/m3	Av TON.N mg/m3
10 7	4.856	.24	2.32	20.3		4.632	101	973	251.6	2432.2
13 7	3.783	.555	2.39	21.6	.55	3.767	181	781	557.4	2400.2
16 7	3.612	.475	2.185	24		3.434	148	682	499.6	2298.3
19 7	3.304	.635	2.325	24.1	11.45	3.237	181	664	648.1	2373.1
22 7	3.088	.615	2.5	23.9		3.011	164	667	630.7	2563.9
25 7	3.03	.595	1.855	24.8	34.5	2.955	156	486	610.1	1902.1
28 7	2.85	.315	2.355	20.7		2.84	78	586	319.4	2388.2
31 7	3.385	.16	2.07	17	17	3.26	47	605	166.1	2149.4
3 8	2.973	.295	1.91	18.9		2.966	76	491	295.7	1914.5
6 8	2.77	.415	2.02	19	8.7	2.861	99	483	401.8	1955.7
7 8	2.77	.56	1.91			2.772	134	457	559.6	1908.6
9 8	2.825	.39	1.83	19.7		4.231	95	447	260.4	1221.9
12 8	3.244	.285	1.77	20.5	6.25	3.107	80	496	297.6	1848.0
15 8	5.917	.23	1.915	19		4.882	118	979	278.8	2321.0
18 8	3.304	.2	1.395	17	6.4	3.257	57	398	202.9	1415.1
21 8	3.55	.43	2.2	18.8		3.285	132	675	464.7	2377.5
24 8	2.752	.3	2.53	17.6	1.25	2.823	71	602	292.5	2466.4
27 8	2.558	.61	2.76	17.8		2.659	135	610	586.8	2655.2
30 8	2.734	.545	2.59	17.3	7.85	3.252	129	612	458.2	2177.4
2 9	2.438	.55	3.3	15.7		2.578	116	695	520.1	3120.8
4 9	.528		2.13			2.597		97		433.1
5 9	2.716	.73	2.95	17.5	.9	2.591	171	692	765.2	3092.3
8 9	2.371	.675	2.15	16.5		2.447	138	440	654.0	2083.2
14 9	2.506	.705	2.4	14.6	14.5	6.87	153	520	257.2	875.5
17 9	24.054	.04	.72	14.4		14.67	83	1496	65.6	1180.6
19 9	8.965	.315	1.55	14.7	7	7.557	244	1201	373.7	1838.8
25 9	4.026	.415	1.8	16.5		3.894	144	626	429.1	1861.0

Table 2b
ELY RIVER LOADING DATA 1989
Combined NRA Wimpey Laboratory Data

DD	MM	INST Q m3/s	PO4.P mg/l	TON.N mg/l	Temp C	Chl - a ug/l	Mean Q m3/s	PO4.P kg/d	TON.N kg/d	Av PO4.P mg/m3	Av TON.N mg/m3
6	2	2.31	.46	3.54	10	2.1	2.25	91.8	706.5	472	3634
10	2	1.89	.56	3.68	9.45	1.45	1.858	91.4	600.9	570	3743
12	2	2.7	.5	2.55	8.25		2.508	116.6	594.9	538	2745
15	2	3.32	.33	2.7	8.7	2.4	4.244	94.7	774.5	258	2112
18	2	40.73	.07	1.15	10.1		33.9	246.3	4046.9	84	1382
20	2	11.13	.09	2.13	8.15	2.05	9.002	86.5	2048.3	111	2634
22	2	9.61	.32	2.28	7.9	2.45	8.005	265.7	1893.1	384	2737
28	2	8.05	.1	2.26	6.4	.8	7.813	69.6	1571.9	103	2329
2	3	16.66	.18	2.705	8.25		16.4	259.1	3893.6	183	2748
5	3	6.71	.24	3.055	9.2	.35	6.203	139.1	1771.1	260	3305
8	3	5.38	.28	3.14	7.1		14.61	130.2	1459.6	103	1156
9	3	28.46	.04	.31	8.6	.25	20.96	98.4	762.3	54	421
12	3	7.06	.2	2.76	7.6		8.028	122.0	1683.6	176	2427
15	3	12.73	.11	2.315	9.1	1.5	12.21	121.0	2546.2	115	2414
18	3	6.48	.19	2.94	6.5		11.74	106.4	1646.0	105	1623
21	3	9.44	.15	2.39	7.7	1.35	9.263	122.3	1949.3	153	2436
24	3	43.73	.085	1.16	9.1		23.59	321.2	4382.8	158	2150
27	3	6.59	.215	2.805	10.1	1.65	6.228	122.4	1597.1	227	2968
30	3	4.41	.31	3.01	9.8		4.269	118.1	1146.9	320	3109
2	4	7.53	.315	2.55	9.6	6.3	5.413	204.9	1659.0	438	3547
5	4	3.13	.32	2.865	6.8		3.782	86.5	774.8	265	2371
8	4	3.32	.265	.615	7.8	1.45	3.205	76.0	176.4	275	637
11	4	9.95	.255	2.24	9.5		6.934	219.2	1925.7	366	3214
14	4	3.21	.27	2.835	9.9	4.8	3.096	74.9	786.3	280	2939
17	4	3.47	.335	2.625	9.3		3.4	100.4	787.0	342	2679
20	4	2.65	.39	2.975	9.5	4.75	2.564	89.3	681.2	403	3075
21	4	2.41	.405	2.815	9.6		2.407	84.3	586.2	406	2819
27	4	2.55	.75	3.66	8.2	5.95	2.222	165.2	806.4	861	4200
3	5	1.81	.495	4.81	13	8.8	1.735	77.4	752.2	516	5018
9	5	1.17	.96	7.225	14.6	10.5	1.226	97.0	730.4	916	6895
15	5	1.25	.875	5.12	15		1.147	94.5	553.0	954	5580
21	5	.93	1.265	5.345	19.3	8.9	.938	101.6	429.5	1254	5299
27	5	.77	1.485	6.405	15.8		.767	98.8	426.1	1491	6430
30	5	.73	.975	4.215	16.2	6.45	.746	61.5	265.8	954	4125
2	6	1.71	.96	6.52	13.1		.895	141.8	963.3	1834	12457
5	6	.79	.97	5.46	14	1	.804	66.2	372.7	953	5365
9	6	.73	1.625	7.075	13.4		.887	102.5	446.2	1337	5823
11	6	.76	1.07	8.08	14.2	2.8	.767	70.3	530.6	1060	8006
14	6	.68	1.39	6.54	19.4		.693	81.7	384.2	1364	6417
15	6	.661	1.3	1.75			.648	74.2	99.9	1326	1785
17	6	.62	.275	2.84	19.6	4	.592	14.7	152.1	288	2974
20	6	.52			23		.556				
23	6	.51	1.62	4.57	20.6	15.5	.526	71.4	201.4	1571	4431
26	6	.65	.575	2.225	18.5		.934	32.3	125.0	400	1548
29	6	1.74	.965	4.115	17.2	61.5	1.563	145.1	618.6	1074	4581
2	7	.545	.475	3.33	16		.928	22.4	156.8	279	1956
5	7	.594	1.125	3.915	20	1.7	.63	57.7	200.9	1061	3691
10	7	1.421	.345	4.35	18.3		1.363	42.4	534.1	360	4535
13	7	.909	1.2	7.26	19.4	1.1	.895	94.2	570.2	1219	7374
16	7	.701	1.015	6.74	21.1		.708	61.5	408.2	1005	6673
19	7	.669	1.39	6.285	22.5	6.1	.676	80.3	363.3	1376	6220
22	7	.58	1.27	4.475	24		.578	63.6	224.3	1274	4490
25	7	.511	1.145	3.69	23.3	10.35	.536	50.6	162.9	1092	3518
28	7	.511	1.285	3.92	20		.521	56.7	173.1	1260	3845
31	7	.639	.975	4.715	16.5	21	.632	53.8	260.3	986	4767

Table 2b

ELY RIVER LOADING DATA 1989

Combined NRA Wimpey Laboratory Data

DD	MM	INST Q m3/s	PO4.P mg/l	TON.N mg/l	Temp C	Chl - a ug/l	Mean Q m3/s	PO4.P kg/d	TON.N kg/d	Av PO4.P mg/m3	Av TON.N mg/m3
3	8	.531	1.365	6.49	18.8		.531	62.6	297.8	1365	6490
6	8	.472	1.09	5.655	19.5	23	.472	44.5	230.6	1090	5655
9	8	.453	1.305	5.035	20.3		.847	51.1	197.1	698	2693
12	8	.601	.78	4.915	19.5	15	.567	40.5	255.2	799	5032
15	8	.998	1.175	5.53	18.7		.906	101.3	476.8	1294	6092
18	8	1.397	.24	3.455	15.7	15.5	1.119	29.0	417.0	300	4313
21	8	.9	.61	5.585	19.3		.76	47.4	434.3	722	6614
24	8	.601	.845	5.375	17.8	1.7	.601	43.9	279.1	845	5375
27	8	.587	1.285	5.115	16.5		.559	65.2	259.4	1349	5371
30	8	.609	1.295	7.575	17.1	3.35	.714	68.1	398.6	1105	6461
2	9	.531	1.51	6.05	16.9		.521	69.3	277.6	1539	6166
5	9	.517	1.59	5.5	15.4		.513	71.0	245.7	1602	5543
8	9	.478	1.83	6.1	16.9		.474	75.6	251.9	1845	6151
14	9	.538	2.2	4	15.1	2.35	2.319	102.3	185.9	510	928
15	9	1.835	.64	4.07			1.945	101.5	645.3	604	3840
17	9	18.612	.535	1.9	15.6		6.927	860.3	3055.3	1437	5105
19	9	2.634	.38	3.65	15.5	1.95	1.987	86.5	830.7	504	4839
25	9	.863	.775	4.8	16.9		.878	57.8	357.9	762	4718

Table 3
Interpolated Input Data For FBA/WW Algal Model
Combined NRA/Wimpey Laboratory Data

	<-----TAFF			----->	<-----ELY			----->
JD	Mean Q m3/s	Av PO4.O mg/m3	Av TON.N mg/m3	Temp C	Mean Q m3/s	Av PO4.P mg/m3	Av TON.N mg/m3	Temp C
1	7.559	354.4	2094.0	5.00	1.845	575.9	4432.2	5.00
2	7.381	363.0	2144.3	5.14	1.793	592.6	4560.7	5.14
3	7.474	358.4	2117.4	5.28	1.722	617.1	4748.8	5.28
4	9.350	286.5	1692.4	5.42	1.972	538.8	4146.8	5.42
5	34.980	76.6	452.3	5.56	10.889	97.6	751.0	5.56
6	18.960	140.8	848.5	5.69	4.789	221.9	1707.5	5.69
7	13.340	199.4	1225.7	5.83	3.206	331.4	2550.7	5.83
8	11.810	224.4	1406.9	5.97	2.963	358.6	2759.8	5.97
9	13.380	197.4	1261.5	6.11	3.055	347.8	2676.7	6.11
10	11.600	226.8	1477.8	6.25	2.873	369.9	2846.3	6.25
11	12.750	205.6	1365.2	6.39	3.436	309.3	2379.9	6.39
12	19.600	133.3	901.6	6.53	5.841	181.9	1400.0	6.53
13	41.400	62.9	433.2	6.67	5.888	180.5	1388.8	6.67
14	31.180	83.1	583.7	6.81	6.737	157.7	1213.8	6.81
15	18.720	138.0	986.3	6.95	4.526	234.8	1806.8	6.95
16	18.110	142.1	1034.1	7.09	4.389	242.1	1863.2	7.09
17	20.060	127.8	946.7	7.23	4.652	228.4	1757.8	7.23
18	14.610	174.8	1317.9	7.37	3.532	300.8	2315.2	7.37
19	12.970	196.2	1504.9	7.51	3.230	329.0	2531.7	7.51
20	15.600	162.5	1268.1	7.65	4.434	239.6	1844.2	7.65
21	18.430	137.0	1087.7	7.79	6.504	163.4	1257.3	7.79
22	13.680	183.9	1484.7	7.93	3.890	273.2	2102.2	7.93
23	28.780	87.1	714.9	8.07	4.588	231.6	1782.3	8.07
24	19.900	125.5	1047.2	8.20	3.859	275.4	2119.0	8.20
25	15.430	161.2	1367.6	8.34	3.350	317.2	2441.0	8.34
26	14.530	170.5	1470.5	8.48	3.232	328.8	2530.1	8.48
27	15.420	162.9	1351.2	8.62	2.953	359.8	2769.2	8.62
28	21.960	115.9	924.7	8.76	5.326	199.5	1535.4	8.76
29	14.510	177.8	1362.9	8.90	3.240	328.0	2523.9	8.90
30	12.840	203.5	1498.9	9.04	2.955	359.6	2767.3	9.04
31	11.880	222.8	1575.4	9.17	2.763	384.6	2959.6	9.17
32	11.220	239.0	1620.8	9.31	2.582	411.5	3167.1	9.31
33	10.620	251.1	1633.4	9.45	2.430	437.3	3365.2	9.45
34	10.120	262.0	1631.2	9.59	2.328	456.4	3512.6	9.59
35	20.590	128.1	761.0	9.72	2.879	369.1	2840.4	9.72
36	16.260	161.3	912.1	9.86	2.667	398.4	3066.1	9.86
37	12.120	215.1	1154.5	10.00	2.250	472.3	3634.4	10.00
38	10.810	230.6	1402.6	9.99	2.063	514.6	3815.7	9.86
39	10.190	233.3	1602.8	9.98	1.972	537.8	3836.9	9.73
40	10.410	222.1	1562.4	9.96	1.917	552.7	3787.6	9.59
41	9.982	225.1	1622.7	9.95	1.858	569.6	3743.4	9.45
42	14.510	159.3	967.5	9.20	2.506	480.5	2761.4	8.85
43	12.750	186.4	931.8	8.45	2.508	538.3	2745.2	8.25
44	24.980	347.3	2005.0	8.62	5.703	221.8	1328.8	8.40
45	14.920	407.2	2307.8	8.78	2.908	405.9	2844.2	8.55
46	25.170	138.0	746.1	8.95	4.244	258.2	2112.2	8.70
47	16.370	138.2	1020.3	9.43	3.139	535.4	6877.7	9.17
48	84.090	47.4	1034.0	9.92	14.400	157.4	2376.0	9.63
49	232.300	24.6	676.7	10.40	33.900	84.1	1381.7	10.10
50	90.030	44.5	1006.6	9.35	13.050	147.6	2702.9	9.13
51	41.590	55.1	578.1	8.30	9.002	111.3	2633.5	8.15
52	38.210	165.1	797.3	7.95	6.984	291.9	3265.9	8.03
53	36.960	279.4	998.0	7.60	8.005	384.2	2737.1	7.90
54	58.390	150.9	673.8	7.47	12.690	212.5	1677.8	7.65
55	162.600	44.8	257.1	7.33	27.480	84.4	752.2	7.40
56	62.110	92.9	712.6	7.20	17.500	110.9	1145.8	7.15

Table 3
Interpolated Input Data For FBA/WW Algal Model
Combined NRA/Wimpey Laboratory Data

	<---TAFF			--->	<---ELY			--->
JD	Mean Q m3/s	Av PO4.O mg/m3	Av TON.N mg/m3	Temp C	Mean Q m3/s	Av PO4.P mg/m3	Av TON.N mg/m3	Temp C
57	58.400	72.8	800.0	7.07	16.240	96.2	1196.6	6.90
58	43.720	62.5	1124.8	6.93	9.789	120.9	1921.8	6.65
59	31.170	70.0	1410.0	6.80	7.813	103.0	2328.6	6.40
60	31.440	170.7	1676.3	6.63	6.222	305.7	5083.4	7.33
61	71.420	119.7	860.5	6.45	16.400	182.9	2747.9	8.25
62	33.230	205.3	1488.9	7.30	8.337	304.2	4423.2	8.57
63	29.460	173.0	1272.9	8.15	7.843	264.3	3657.8	8.88
64	23.970	140.5	1064.7	9.00	6.203	259.6	3304.7	9.20
65	27.100	69.1	974.9	8.37	8.487	185.7	2273.7	8.50
66	20.590	141.5	1143.5	7.73	6.028	255.7	3001.8	7.80
67	61.750	64.1	334.7	7.10	14.610	103.1	1156.3	7.10
68	110.500	76.2	1148.0	8.40	20.960	54.3	420.9	8.60
69	54.190	134.6	1718.4	8.20	10.030	122.6	1234.0	8.27
70	30.110	204.9	1972.3	8.00	7.459	177.1	2135.8	7.93
71	36.010	140.0	712.5	7.80	8.028	175.9	2427.2	7.60
72	27.700	195.6	1007.3	8.03	5.930	237.5	3847.2	8.10
73	129.000	44.9	233.7	8.27	32.030	43.8	816.2	8.60
74	53.040	116.3	610.7	8.50	12.210	114.7	2413.6	9.10
75	36.030	141.7	837.7	7.80	11.630	115.6	2235.3	8.23
76	25.480	158.6	1097.8	7.10	7.512	171.4	2998.4	7.37
77	39.190	76.0	657.4	6.40	11.740	104.9	1622.8	6.50
78	56.100	57.5	513.0	6.70	13.790	93.7	1466.4	6.90
79	41.640	83.6	763.7	7.00	12.250	110.6	1746.2	7.30
80	32.640	114.3	1066.8	7.30	9.263	152.9	2435.7	7.70
81	30.560	140.4	1438.8	7.73	7.679	284.3	4160.7	8.17
82	68.350	71.0	777.2	8.17	13.170	224.0	3138.8	8.63
83	95.250	56.8	653.8	8.60	23.590	157.6	2150.4	9.10
84	35.480	129.6	1416.5	9.00	9.341	315.8	4280.0	9.43
85	26.220	144.2	1458.6	9.40	7.450	293.1	3923.8	9.77
86	22.360	132.6	1173.1	9.80	6.228	227.5	2968.0	10.10
87	22.360	138.0	1086.8	9.77	6.194	226.1	2703.9	10.00
88	17.530	182.8	1276.0	9.73	4.794	288.6	3131.2	9.90
89	15.610	213.0	1309.2	9.70	4.269	320.2	3109.4	9.80
90	14.200	278.4	1634.9	9.73	3.833	444.1	3978.6	9.73
91	16.860	271.7	1541.8	9.77	4.422	460.7	3895.5	9.67
92	20.330	256.2	1415.4	9.80	5.413	438.2	3547.3	9.60
93	13.920	311.4	1678.4	8.73	3.574	535.9	4418.1	8.67
94	12.560	275.5	1429.4	7.67	3.222	452.6	3842.0	7.73
95	15.460	167.3	811.3	6.60	3.782	264.8	2371.1	6.80
96	18.180	168.6	663.2	6.93	5.153	186.5	1292.2	7.13
97	19.490	181.9	593.8	7.27	3.850	239.1	1130.0	7.47
98	14.700	273.8	754.3	7.60	3.205	274.5	637.1	7.80
99	13.770	321.1	1216.0	8.03	3.320	431.4	2647.8	8.37
100	15.510	310.5	1444.2	8.47	3.742	530.4	4152.7	8.93
101	34.180	152.5	820.8	8.90	6.934	365.9	3214.3	9.50
102	21.330	221.9	1309.6	9.17	4.131	479.4	4331.2	9.63
103	17.520	242.9	1587.6	9.43	3.485	408.5	3872.7	9.77
104	14.500	260.5	1910.0	9.70	3.096	279.9	2939.4	9.90
105	15.520	230.7	1500.0	9.70	3.727	259.0	2442.5	9.70
106	16.700	202.7	1129.7	9.70	4.855	219.1	1875.6	9.50
107	12.850	248.2	1124.7	9.70	3.400	341.9	2679.0	9.30
108	11.740	263.7	1158.3	9.70	2.993	374.0	2906.9	9.37
109	10.910	275.1	1168.2	9.70	2.742	392.6	3024.1	9.43
110	10.350	280.8	1148.9	9.70	2.564	403.1	3074.8	9.50
111	9.804	223.3	1121.5	9.70	2.407	405.5	2818.5	9.60
112	9.395	303.4	1195.3	9.63	2.286	495.2	3153.5	9.37

Table 3
Interpolated Input Data For FBA/WW Algal Model
Combined NRA/Wimpey Laboratory Data

	<-----TAFF-----				><-----ELY-----			>
JD	Mean Q m3/s	Av PO4.O mg/m3	Av TON.N mg/m3	Temp C	Mean Q m3/s	Av PO4.P mg/m3	Av TON.N mg/m3	Temp C
113	9.085	386.5	1262.0	9.57	2.210	582.9	3454.2	9.13
114	8.721	478.4	1341.6	9.50	2.125	679.7	3792.3	8.90
115	8.377	577.0	1424.8	9.43	2.014	794.6	4212.2	8.67
116	9.889	555.6	1230.7	9.37	2.255	778.9	3950.4	8.43
117	9.004	683.6	1377.8	9.30	2.222	860.7	4200.3	8.20
118	8.293	668.8	1530.3	10.18	1.920	907.9	4806.5	9.00
119	8.295	595.1	1564.3	11.07	2.064	762.4	4420.6	9.80
120	8.140	531.6	1629.0	11.95	1.980	709.2	4555.3	10.60
121	8.086	459.8	1675.2	12.83	2.163	570.9	4121.6	11.40
122	7.458	416.8	1854.4	13.72	1.896	561.9	4646.9	12.20
123	7.115	351.3	1983.9	14.60	1.735	516.4	5017.9	13.00
124	6.812	353.7	2042.1	14.48	1.553	601.3	5578.9	13.27
125	6.604	351.2	2075.5	14.37	1.434	677.6	6012.4	13.53
126	6.295	354.2	2145.0	14.25	1.339	754.0	6407.5	13.80
127	6.178	346.4	2152.5	14.13	1.302	804.5	6557.2	14.07
128	5.953	344.4	2199.6	14.02	1.273	852.6	6673.5	14.33
129	5.874	333.7	2194.4	13.90	1.226	916.2	6895.0	14.60
130	5.756	338.9	2147.0	13.98	1.186	942.9	6839.0	14.67
131	6.064	320.2	1950.2	14.07	1.296	859.1	5994.5	14.73
132	5.915	326.7	1909.4	14.15	1.268	874.2	5857.0	14.80
133	5.988	321.2	1797.3	14.23	1.352	816.2	5240.0	14.87
134	5.715	334.9	1790.1	14.32	1.266	867.8	5325.6	14.93
135	5.391	353.3	1799.0	14.40	1.147	953.6	5579.8	15.00
136	5.399	353.6	1742.9	15.10	1.140	971.5	5405.1	15.72
137	5.317	359.9	1715.6	15.80	1.103	1016.6	5370.5	16.43
138	5.250	365.4	1682.6	16.50	1.081	1050.0	5259.4	17.15
139	5.124	375.3	1667.8	17.20	1.035	1110.0	5263.0	17.87
140	4.969	387.9	1661.8	17.90	.982	1184.0	5304.5	18.58
141	4.924	392.4	1618.5	18.60	.938	1254.2	5299.4	19.30
142	4.742	403.2	1748.0	18.25	.910	1286.8	5455.3	18.72
143	4.690	403.5	1835.6	17.90	.898	1297.8	5521.0	18.13
144	4.839	386.9	1845.2	17.55	.865	1341.0	5724.1	17.55
145	4.503	411.4	2053.9	17.20	.847	1363.0	5838.1	16.97
146	4.336	422.7	2206.7	16.85	.794	1447.0	6219.6	16.38
147	4.169	434.8	2371.8	16.50	.767	1490.8	6430.1	15.80
148	4.187	400.4	1940.5	16.97	.748	1336.3	5766.8	15.93
149	4.080	377.5	1559.3	17.43	.744	1150.1	4966.7	16.07
150	4.017	349.6	1144.9	17.90	.746	954.1	4124.6	16.20
151	4.012	357.3	1299.9	16.87	.745	1371.4	7741.9	15.17
152	4.193	348.9	1390.7	15.83	1.314	1013.4	6437.2	14.13
153	4.435	336.4	1453.7	14.80	.895	1834.2	12457.2	13.10
154	4.235	359.2	1667.8	14.57	.842	1603.1	10535.2	13.40
155	4.146	374.0	1852.2	14.33	.800	1322.6	8240.0	13.70
156	4.134	382.2	2006.5	14.10	.804	953.1	5364.9	14.00
157	4.652	449.0	1881.1	13.93	.923	944.0	4903.8	13.85
158	3.965	655.0	2322.0	13.77	.769	1269.5	6162.6	13.70
159	5.280	588.2	1830.1	13.60	.889	1216.3	5570.2	13.55
160	4.666	801.8	4199.7	13.77	.887	1337.4	5822.7	13.40
161	4.985	878.0	5923.6	13.93	.994	1005.8	5686.9	13.80
162	4.135	1212.2	9543.5	14.10	.767	1060.2	8006.3	14.20
163	3.979	1038.2	7430.7	16.17	.733	1169.4	7607.5	15.93
164	3.827	849.2	5140.2	18.23	.704	1280.1	7118.9	17.67
165	3.730	635.1	2620.9	20.30	.693	1363.9	6417.3	19.40
166	3.643	681.7	2853.9	20.67	.648	1326.1	1785.1	19.47
167	3.617	718.4	3046.0	21.03	.622	827.8	2345.3	19.53
168	3.582	757.5	3249.1	21.40	.592	288.0	2974.3	19.60

Table 3

Interpolated Input Data For FBA/WW Algal Model
Combined NRA/Wimpey Laboratory Data

	<---TAFF---				><---ELY---			>
JD	Mean Q m3/s	Av PO4.O mg/m3	Av TON.N mg/m3	Temp C	Mean Q m3/s	Av PO4.P mg/m3	Av TON.N mg/m3	Temp C
169	3.543	693.9	2864.0	21.93	.569	199.8	2063.0	20.73
170	3.449	639.0	2509.7	22.47	.562	101.1	1044.4	21.87
171	3.333	579.7	2130.5	23.00	.556	.0	.0	23.00
172	3.240	558.1	2238.2	22.80	.567	485.7	1370.2	22.20
173	3.238	514.9	2266.4	22.60	.552	997.8	2814.9	21.40
174	3.192	478.2	2326.2	22.40	.526	1570.7	4431.0	20.60
175	3.222	906.0	4132.6	21.30	.527	1281.6	3863.2	19.90
176	3.131	1377.2	6133.9	20.20	.566	926.8	3076.1	19.20
177	4.868	1171.9	5155.1	19.10	.934	400.2	1548.4	18.50
178	3.859	1314.6	5814.4	18.43	.977	827.9	3429.8	18.07
179	5.362	828.3	3689.1	17.77	1.053	1181.4	4991.0	17.63
180	5.308	717.6	3226.0	17.10	1.563	1074.3	4581.0	17.20
181	7.445	410.0	1990.7	16.80	1.779	677.7	3023.2	16.80
182	6.089	377.1	2055.7	16.50	2.061	355.3	1745.1	16.40
183	4.211	365.6	2425.6	16.20	.928	279.0	1955.7	16.00
184	3.724	492.3	2710.9	18.47	.765	516.8	2594.9	17.33
185	3.503	607.2	2848.0	20.73	.672	791.4	3207.3	18.67
186	3.595	673.3	2742.0	23.00	.630	1060.7	3691.3	20.00
187	7.778	248.2	2161.2	22.46	1.293	489.3	2395.0	19.66
188	11.630	123.8	2043.2	21.92	6.845	87.2	565.1	19.32
189	8.036	167.8	2438.7	21.38	5.436	103.3	853.4	18.98
190	5.374	233.9	2871.5	20.84	1.935	271.8	2796.0	18.64
191	4.632	251.6	2432.2	20.30	1.363	359.7	4535.1	18.30
192	4.242	348.1	2481.0	20.73	1.116	618.7	5663.7	18.67
193	3.987	448.5	2453.7	21.17	.980	908.8	6591.8	19.03
194	3.767	557.4	2400.2	21.60	.895	1218.8	7373.6	19.40
195	3.610	546.2	2398.4	22.40	.807	1195.0	7403.3	19.97
196	3.488	528.6	2372.5	23.20	.752	1114.3	7113.8	20.53
197	3.434	499.6	2298.3	24.00	.708	1005.0	6673.4	21.10
198	3.376	546.0	2317.0	24.03	.728	1077.4	6251.9	21.57
199	3.337	590.5	2323.0	24.07	.690	1242.2	6345.0	22.03
200	3.237	648.1	2373.1	24.10	.676	1375.6	6219.9	22.50
201	3.156	643.8	2438.1	24.03	.613	1411.9	5984.1	23.00
202	3.093	635.4	2491.8	23.97	.622	1287.8	5035.2	23.50
203	3.011	630.7	2563.9	23.90	.578	1274.4	4490.5	24.00
204	3.011	620.1	2331.5	24.20	.557	1231.8	4234.9	23.77
205	3.018	608.0	2094.2	24.50	.539	1179.2	3937.3	23.53
206	2.955	610.1	1902.1	24.80	.536	1091.6	3517.9	23.30
207	2.936	512.4	2046.3	23.43	.553	1101.2	3480.6	22.20
208	2.874	419.5	2225.2	22.07	.556	1138.1	3532.3	21.10
209	2.840	319.4	2388.2	20.70	.521	1260.3	3844.8	20.00
210	6.614	118.7	1036.8	19.47	1.182	546.1	1979.4	18.83
211	4.138	160.3	1675.2	18.23	1.050	604.0	2548.9	17.67
212	3.260	166.1	2149.4	17.00	.632	985.8	4767.2	16.50
213	3.031	215.6	2165.7	17.63	.579	1134.6	5453.1	17.27
214	2.980	256.8	2054.1	18.27	.557	1240.4	5927.7	18.03
215	2.966	295.7	1914.5	18.90	.531	1365.0	6490.0	18.80
216	2.873	336.9	1966.8	18.93	.510	1283.7	6249.4	19.03
217	2.806	377.3	2003.9	18.97	.485	1205.3	6037.5	19.27
218	2.861	401.8	1955.7	19.00	.472	1090.0	5655.0	19.50
219	2.772	559.6	1908.6	19.23	.471	1146.6	5392.2	19.77
220	2.792	475.1	1873.3	19.47	.484	1168.6	4979.9	20.03
221	4.231	260.4	1221.9	19.70	.847	698.0	2692.9	20.30
222	4.474	233.1	1198.1	19.97	1.074	512.4	2332.6	20.03
223	4.212	233.5	1317.9	20.23	1.034	492.8	2639.8	19.77
224	3.107	297.6	1848.0	20.50	.587	798.6	5032.2	19.50

Table 3

Interpolated Input Data For FBA/WW Algal Model
Combined NRA/Wimpey Laboratory Data

	<------	------TAFF	------	------>	<------	------ELY	------	------>
JD	Mean Q m3/s	Av PO4.O mg/m3	Av TON.N mg/m3	Temp C	Mean Q m3/s	Av PO4.P mg/m3	Av TON.N mg/m3	Temp C
225	3.943	271.4	1928.7	20.00	.984	714.8	3870.9	19.23
226	5.287	229.9	1790.8	19.50	1.166	804.5	3999.9	18.97
227	4.882	278.8	2321.0	19.00	.906	1294.3	6091.5	18.70
228	4.990	226.0	1821.7	18.33	.769	1161.9	6876.7	17.70
229	4.566	195.8	1500.2	17.67	4.498	136.6	1124.4	16.70
230	3.257	202.9	1415.1	17.00	1.119	299.6	4313.3	15.70
231	3.121	304.2	1818.7	17.60	.809	502.5	6048.5	16.90
232	3.747	330.4	1799.6	18.20	.741	644.8	6693.5	18.10
233	3.285	464.7	2377.5	18.80	.760	722.4	6613.8	19.30
234	2.891	447.2	2603.8	18.40	.639	837.7	6929.3	18.80
235	2.805	377.6	2582.9	18.00	.605	862.1	6329.1	18.30
236	2.823	292.5	2466.4	17.60	.601	845.0	5375.0	17.80
237	2.813	380.6	2486.7	17.67	.622	948.5	5071.4	17.37
238	2.833	464.3	2480.6	17.73	.612	1098.3	5030.2	16.93
239	2.659	586.8	2655.2	17.80	.559	1349.4	5371.2	16.50
240	2.540	605.1	2782.3	17.63	.529	1447.5	6690.7	16.70
241	2.775	545.4	2549.2	17.47	.619	1255.6	6585.3	16.90
242	3.252	458.2	2177.4	17.30	.714	1104.6	6461.0	17.10
243	2.901	496.5	2551.7	16.77	.661	1199.8	6272.8	17.03
244	2.616	531.6	2952.6	16.23	.551	1447.2	6677.7	16.97
245	2.578	520.1	3120.8	15.70	.521	1539.0	6166.1	16.90
246	2.598	598.5	1764.8	16.30	.508	1591.6	6081.8	16.40
247	2.597	681.1	433.1	16.90	.526	1550.0	5639.8	15.90
248	2.591	765.2	3092.3	17.50	.513	1602.4	5542.9	15.40
249	2.528	733.9	2785.1	17.17	.507	1656.0	5656.0	15.90
250	2.480	696.7	2447.2	16.83	.490	1749.3	5901.4	16.40
251	2.447	654.0	2083.2	16.50	.474	1845.4	6151.5	16.90
252	2.392	680.7	2195.0	16.18	.463	2000.5	6022.7	16.60
253	2.368	699.3	2281.8	15.87	.460	2125.4	5785.2	16.30
254	2.335	721.0	2379.5	15.55	.470	2189.7	5391.3	16.00
255	2.292	746.6	2490.8	15.23	.483	2237.4	4982.6	15.70
256	2.593	670.7	2260.6	14.92	.493	2296.4	4623.3	15.40
257	6.870	257.2	875.5	14.60	2.319	510.4	928.0	15.10
258	8.229	182.1	1188.8	14.53	1.945	603.8	3839.8	15.27
259	14.150	87.0	957.6	14.47	3.123	1782.2	6857.4	15.43
260	14.670	65.6	1180.6	14.40	6.927	1437.5	5105.1	15.60
261	10.520	179.9	1483.6	14.55	2.290	2392.7	9820.3	15.55
262	7.557	373.7	1838.8	14.70	1.987	503.7	4838.5	15.50
263	5.954	442.0	2147.7	15.00	1.313	720.2	6627.7	15.73
264	5.224	467.0	2235.7	15.30	1.120	794.8	6955.5	15.97
265	5.199	432.3	2033.3	15.60	1.103	756.9	6235.9	16.20
266	4.663	440.7	2029.4	15.90	1.153	676.1	5174.6	16.43
267	4.216	441.9	1981.7	16.20	.953	759.9	5303.6	16.67
268	3.894	429.1	1861.0	16.50	.878	761.8	4718.0	16.90
269	3.714	449.9	1951.2	16.50	.833	802.9	4972.9	16.90
270	3.545	471.3	2044.2	16.50	.786	850.9	5270.2	16.90
271	3.368	496.1	2151.7	16.50	.722	926.3	5737.4	16.90
272	3.293	507.4	2200.7	16.50	.692	966.5	5986.1	16.90
273	3.260	512.5	2222.9	16.50	.661	1011.8	6266.8	16.90
274	3.205	521.3	2261.1	16.50	.659	1014.9	6285.9	16.90
275	3.149	530.6	2301.3	16.50	.657	1018.0	6305.0	16.90
276	3.131	533.6	2314.5	16.50	.642	1041.8	6452.3	16.90
277	3.120	535.5	2322.7	16.50	.626	1068.4	6617.2	16.90
278	3.151	530.2	2299.8	16.50	.709	943.3	5842.6	16.90
279	3.500	477.4	2070.5	16.50	.899	744.0	4607.8	16.90
280	3.193	523.3	2269.6	16.50	.719	930.2	5761.3	16.90

Table 3
Interpolated Input Data For FBA/WW Algal Model
Combined NRA/Wimpey Laboratory Data

	<------------------	TAFF	------------------>		<------------------	ELY	------------------>	
JD	Mean Q m3/s	Av PO4.O mg/m3	Av TON.N mg/m3	Temp C	Mean Q m3/s	Av PO4.P mg/m3	Av TON.N mg/m3	Temp C
281	3.024	552.5	2396.4	16.50	.637	1050.0	6502.9	16.90
282	2.879	580.3	2517.1	16.50	.619	1080.5	6692.0	16.90
283	2.846	587.1	2546.3	16.50	.606	1103.7	6835.6	16.90
284	2.872	581.8	2523.3	16.50	.683	979.2	6065.0	16.90
285	2.917	572.8	2484.3	16.50	.667	1002.7	6210.4	16.90
286	2.971	562.4	2439.2	16.50	.669	999.7	6191.9	16.90
287	2.772	602.7	2614.3	16.50	.610	1096.4	6790.8	16.90
288	2.725	613.1	2659.4	16.50	.607	1101.8	6824.3	16.90
289	2.743	609.1	2641.9	16.50	.629	1063.3	6585.6	16.90
290	2.670	625.8	2714.2	16.50	.558	1198.6	7423.6	16.90
291	2.603	641.9	2784.0	16.50	.532	1257.2	7786.4	16.90
292	12.870	129.8	563.1	16.50	3.324	201.2	1246.2	16.90
293	105.300	15.9	68.8	16.50	12.490	53.5	331.7	16.90
294	87.120	19.2	83.2	16.50	19.820	33.7	209.0	16.90
295	45.650	36.6	158.7	16.50	9.813	68.2	422.1	16.90
296	22.680	73.7	319.5	16.50	5.211	128.3	794.9	16.90
297	16.560	100.9	437.6	16.50	3.695	181.0	1121.1	16.90
298	20.820	80.2	348.1	16.50	5.378	124.4	770.2	16.90
299	20.080	83.2	360.9	16.50	5.423	123.3	763.9	16.90
300	20.870	80.1	347.2	16.50	3.874	172.6	1069.3	16.90
301	156.900	10.6	46.2	16.50	18.960	35.3	218.5	16.90
302	119.700	14.0	60.5	16.50	30.000	22.3	138.1	16.90
303	64.210	26.0	112.9	16.50	14.250	46.9	290.7	16.90
304	41.380	40.4	175.1	16.50	10.510	63.6	394.1	16.90

TAFF NUTRIENT DATA
PHOSPHATE LOAD (1989)

CARDIFF BAY ALGAL MODEL

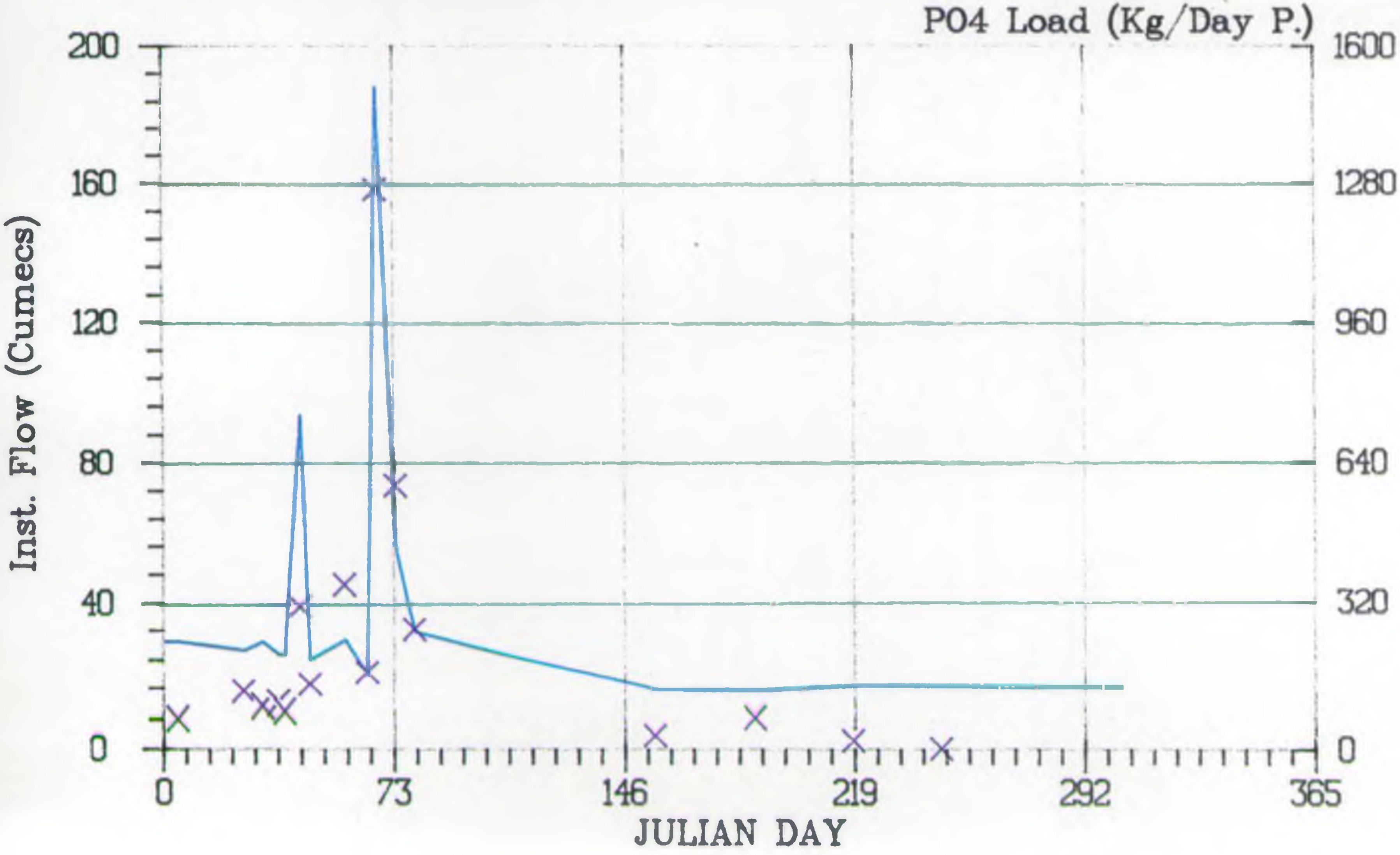
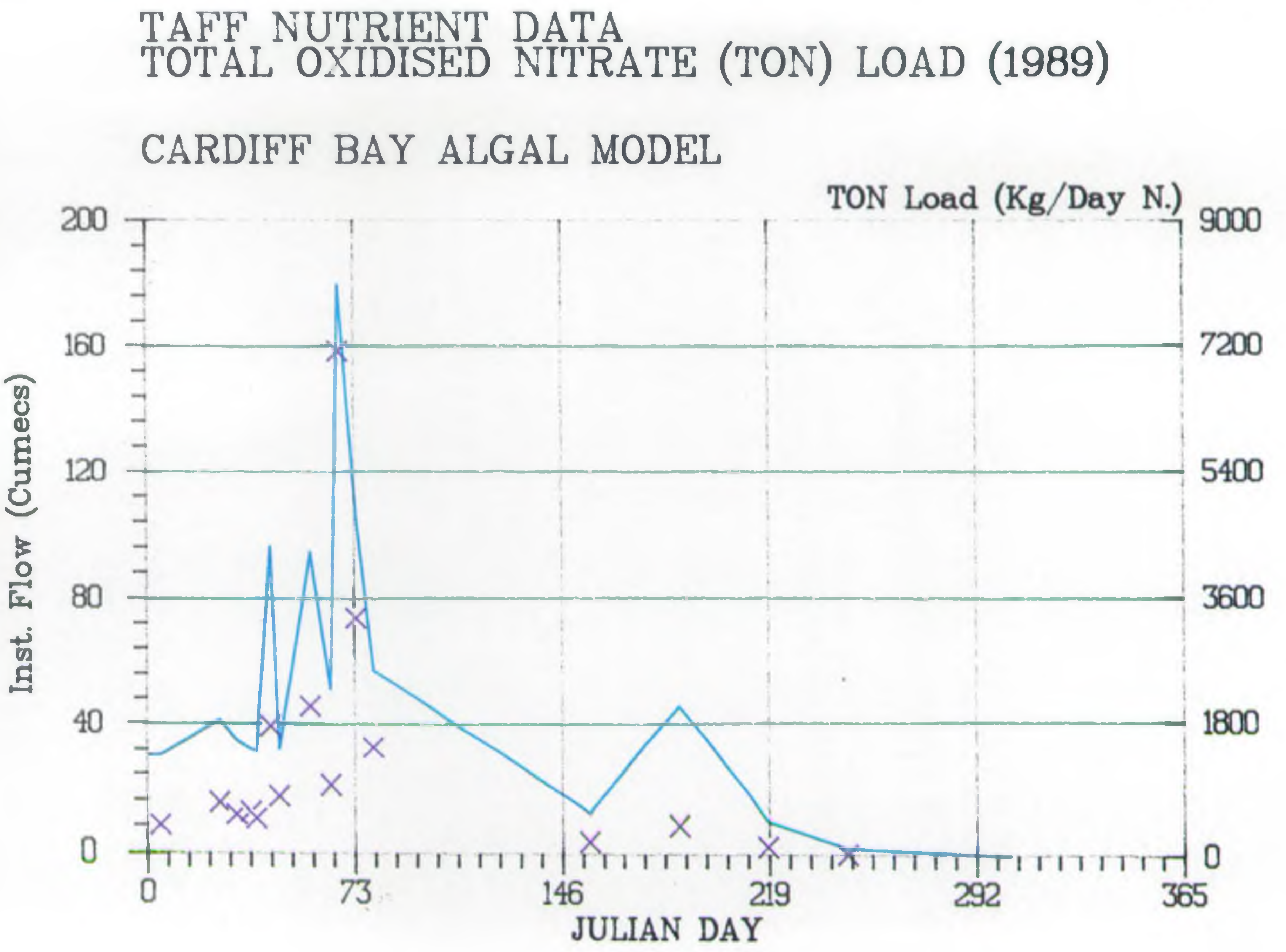


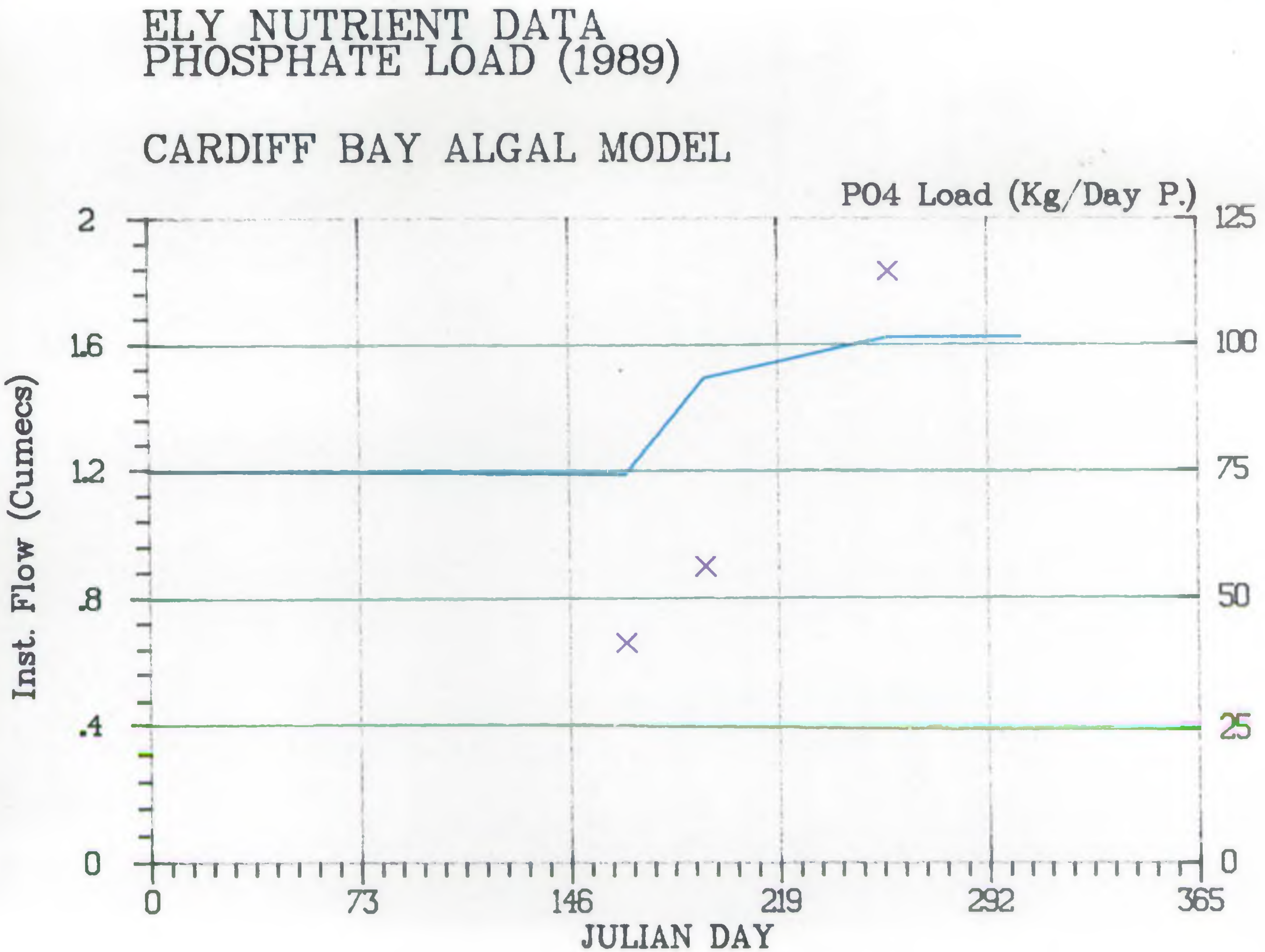
Fig. 1a

7/12/89


TAFF NUTRIENT DATA
TOTAL OXIDISED NITRATE (TON) LOAD (1989)
CARDIFF BAY ALGAL MODEL
TON Load (Kg/Day N.)
Inst. Flow (Cumecs)
200
160
120
80
40
0
9000
7200
5400
3600
1800
0
0
73
146
219
292
365
JULIAN DAY

7/12/89

Fig. 1b



ELY NUTRIENT DATA
PHOSPHATE LOAD (1989)
CARDIFF BAY ALGAL MODEL
P04 Load (Kg/Day P.)
Inst. Flow (Cumecs)
2
1.6
1.2
.8
.4
0
125
100
75
50
25
0
0
73
146
219
292
365
JULIAN DAY

Fig. 2a

7/12/89

ELY NUTRIENT DATA
TOTAL OXIDISED NITRATE (TON) LOAD (1989)

CARDIFF BAY ALGAL MODEL

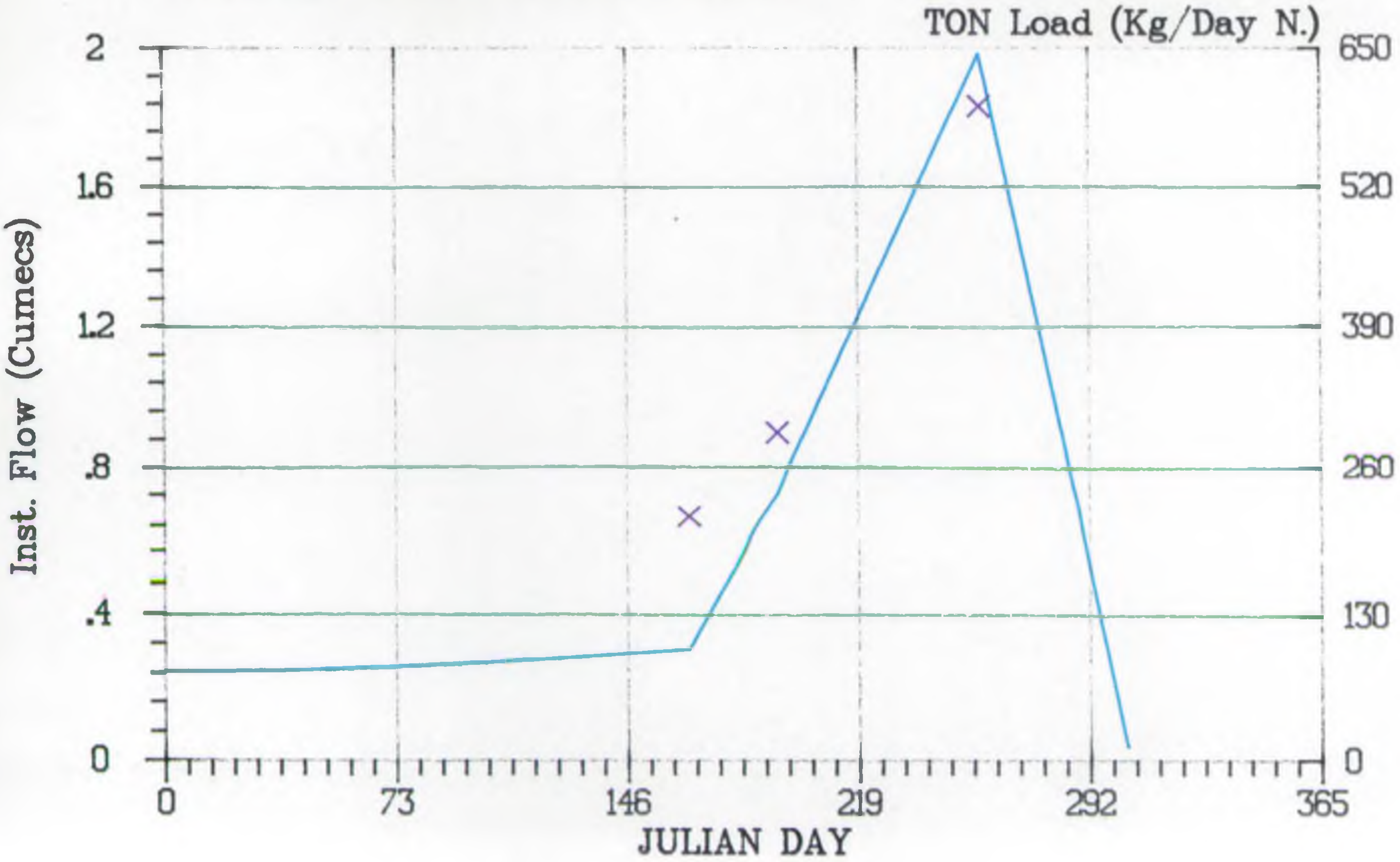
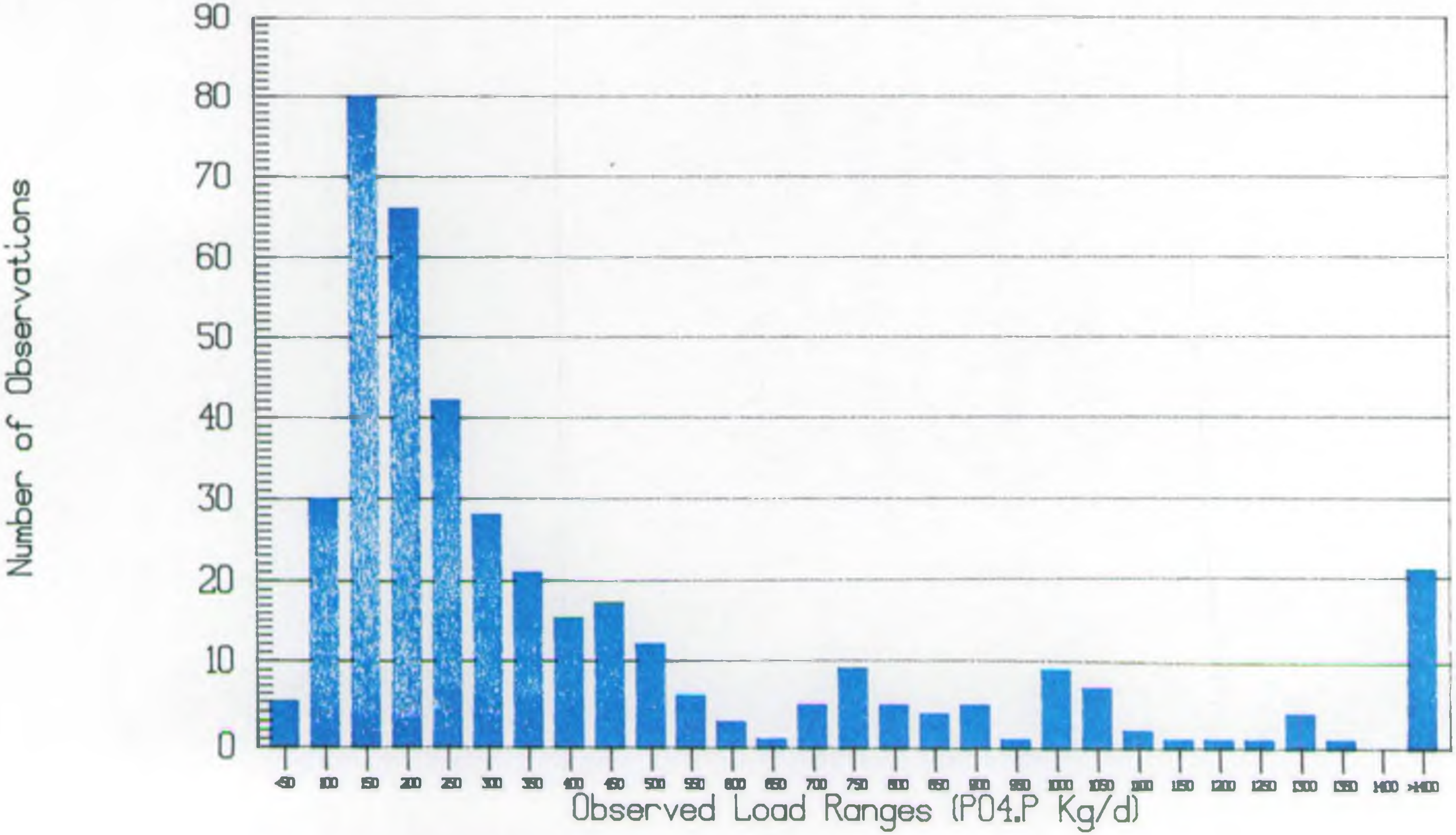


Fig. 2b

7/12/89

Taff Nutrient Data 1976 - 1987
Distribution of Daily Phosphorus Loads

Daily loads calculated from instantaneous values
Total number of observations: 402



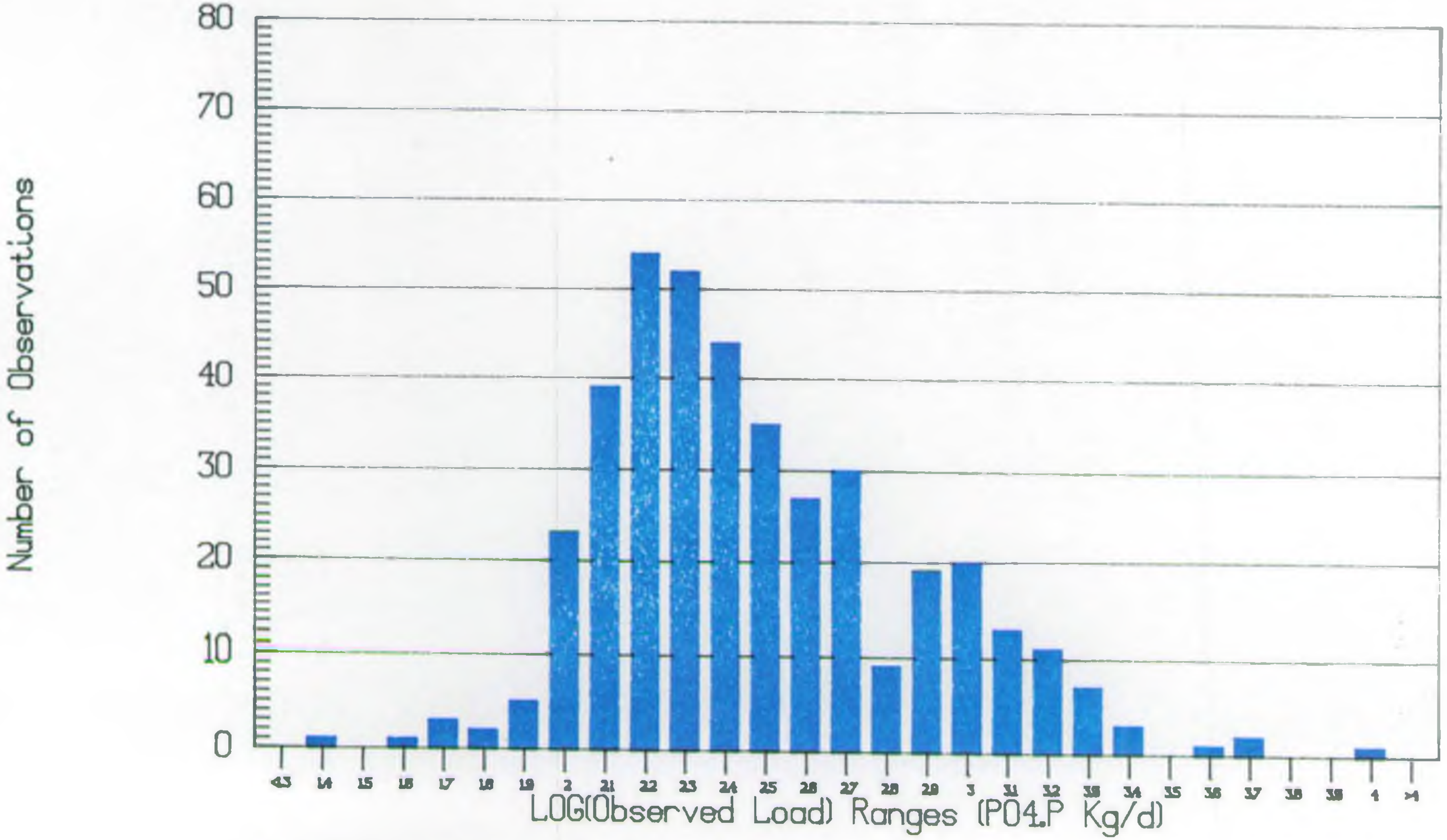
Flow guaged at Pontypridd
Concentrations measured at Blackweir

7/12/89

Fig.3a

Taff Nutrient Data 1976 - 1987
Distribution of LOG(Daily Phosphorus Loads)

Daily loads calculated from instantaneous values
Total number of observations: 402



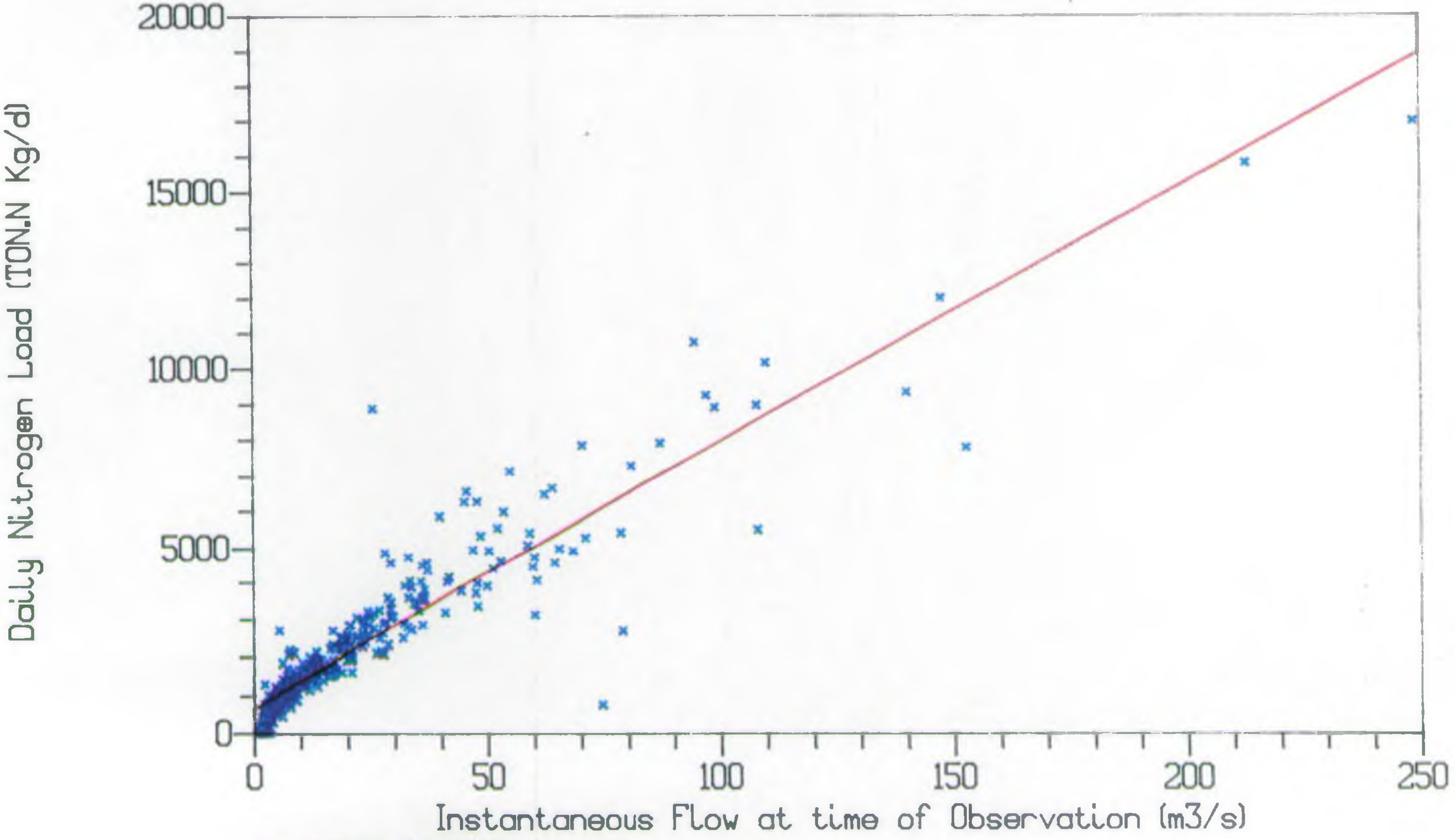
Flow guaged at Pontypridd
Concentrations measured at Blackweir

7/12/89

Fig. 3b

Taff Nutrient Data 1976 - 1987
Distribution of Daily Nitrogen Loads
Regression Line: m - 73.0, c - 651.8 (R2 - 0.865)

Daily loads calculated from instantaneous values
Total number of observations: 424

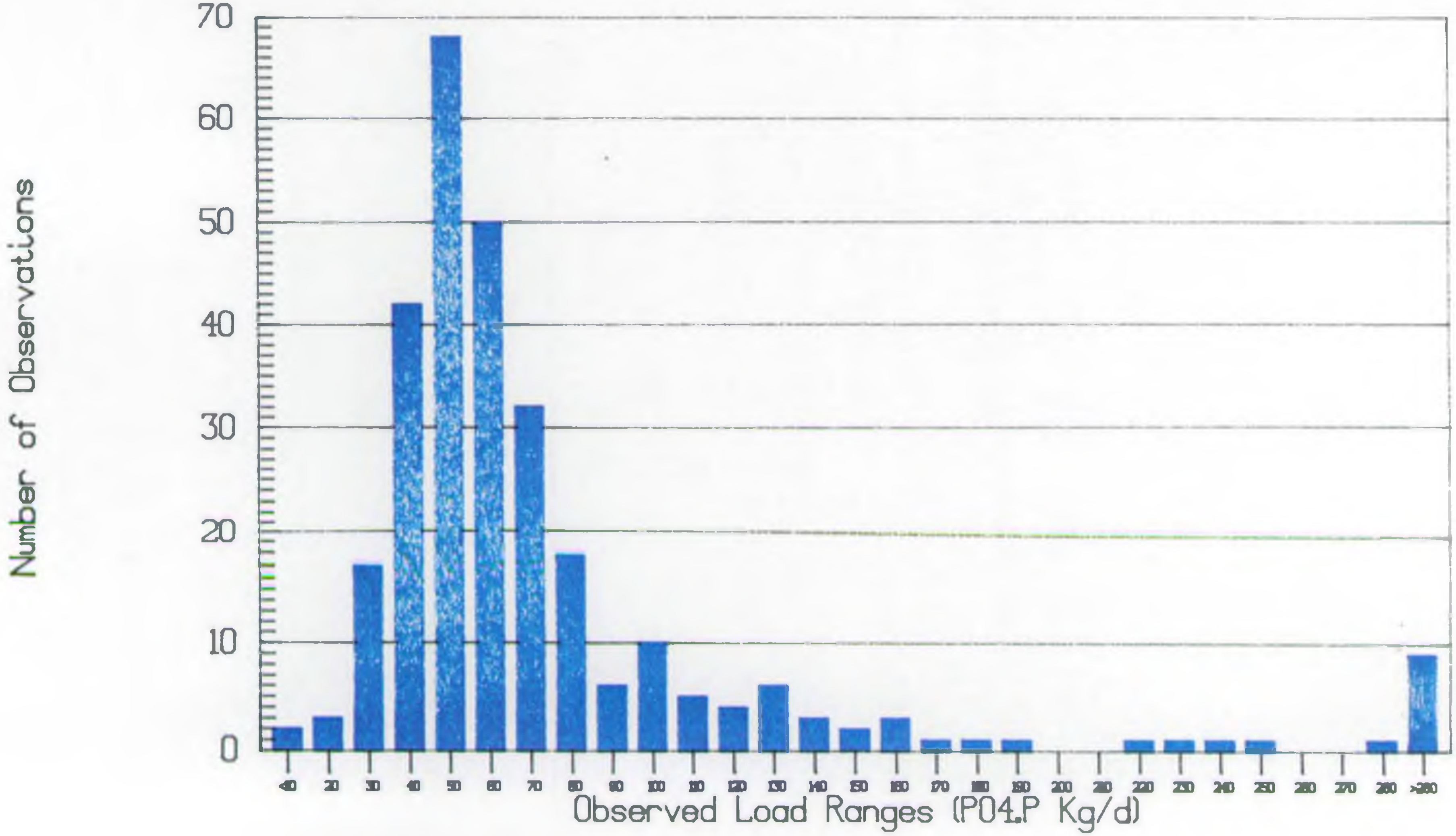


Flow gauged at Pontypridd
Concentrations measured at Blackweir

Fig. 3c

Ely Nutrient Data 1976 - 1987
Distribution of Daily Phosphorus Loads

Daily loads calculated from instantaneous values
Total number of observations: 288



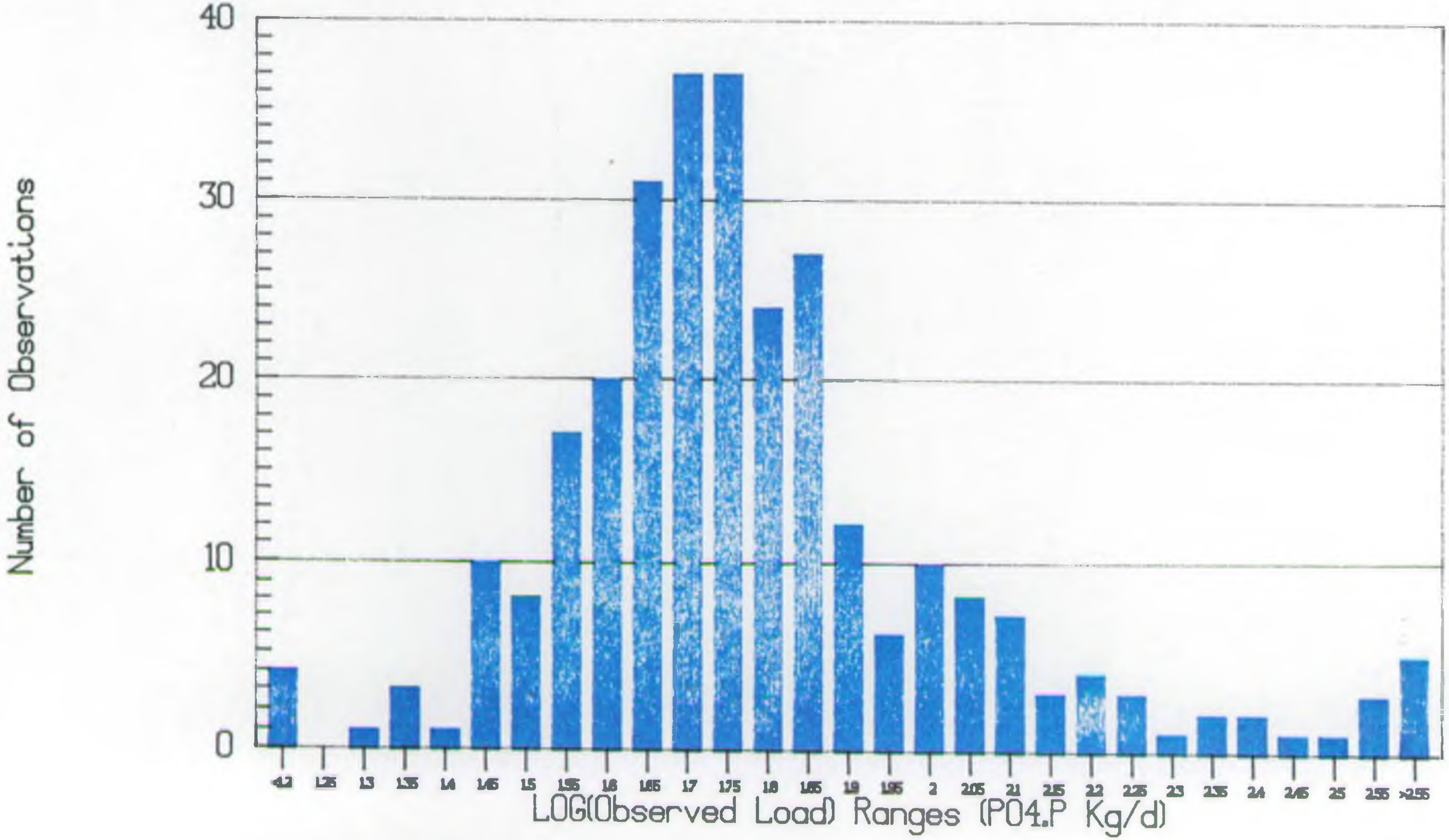
Flow guaged at St. Fagans
Concentrations measured at St. Fagans

7/12/89

Fig. 4 a

Ely Nutrient Data 1976 - 1987
Distribution of LOG(Daily Phosphorus Loads)

Daily loads calculated from instantaneous values
Total number of observations: 288



Flow guaged at St. Fagans
Concentrations measured at St. Fagans

7/12/89

Fig. 4b

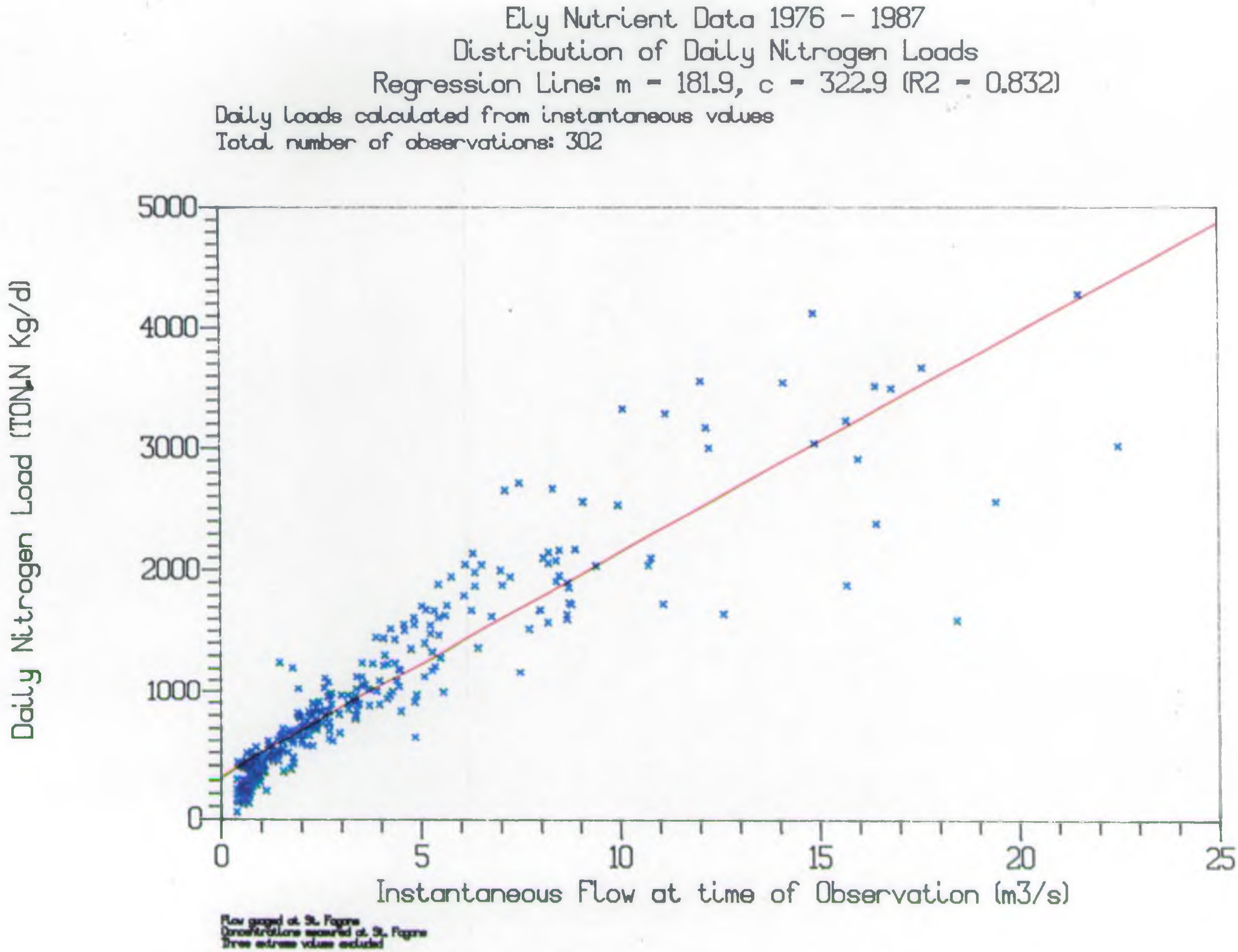
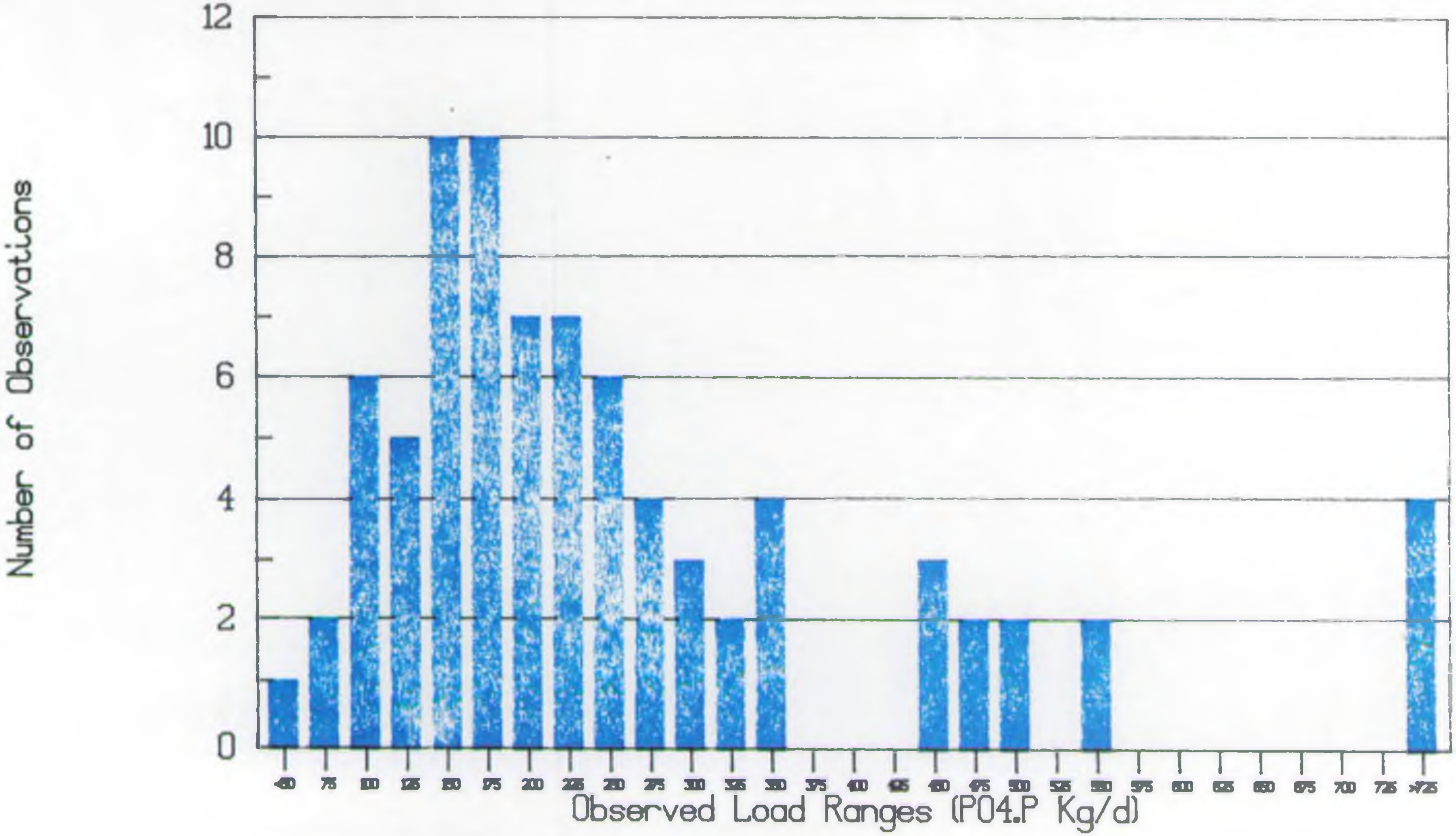

Ely Nutrient Data 1976 - 1987
Distribution of Daily Nitrogen Loads
Regression Line: m = 181.9, c = 322.9 (R2 = 0.832)
Daily loads calculated from instantaneous values
Total number of observations: 302
Daily Nitrogen Load (TON.N Kg/d)
0
1000
2000
3000
4000
5000
0
5
10
15
20
25
Instantaneous Flow at time of Observation (m3/s)
Flow gauged at St. Fagans
Concentrations measured at St. Fagans
Three extreme values excluded

Fig. 4c

Taff Nutrient Data 1989
Distribution of Daily Phosphorus Loads

Daily loads calculated from instataneous values
Total number of observations: 80



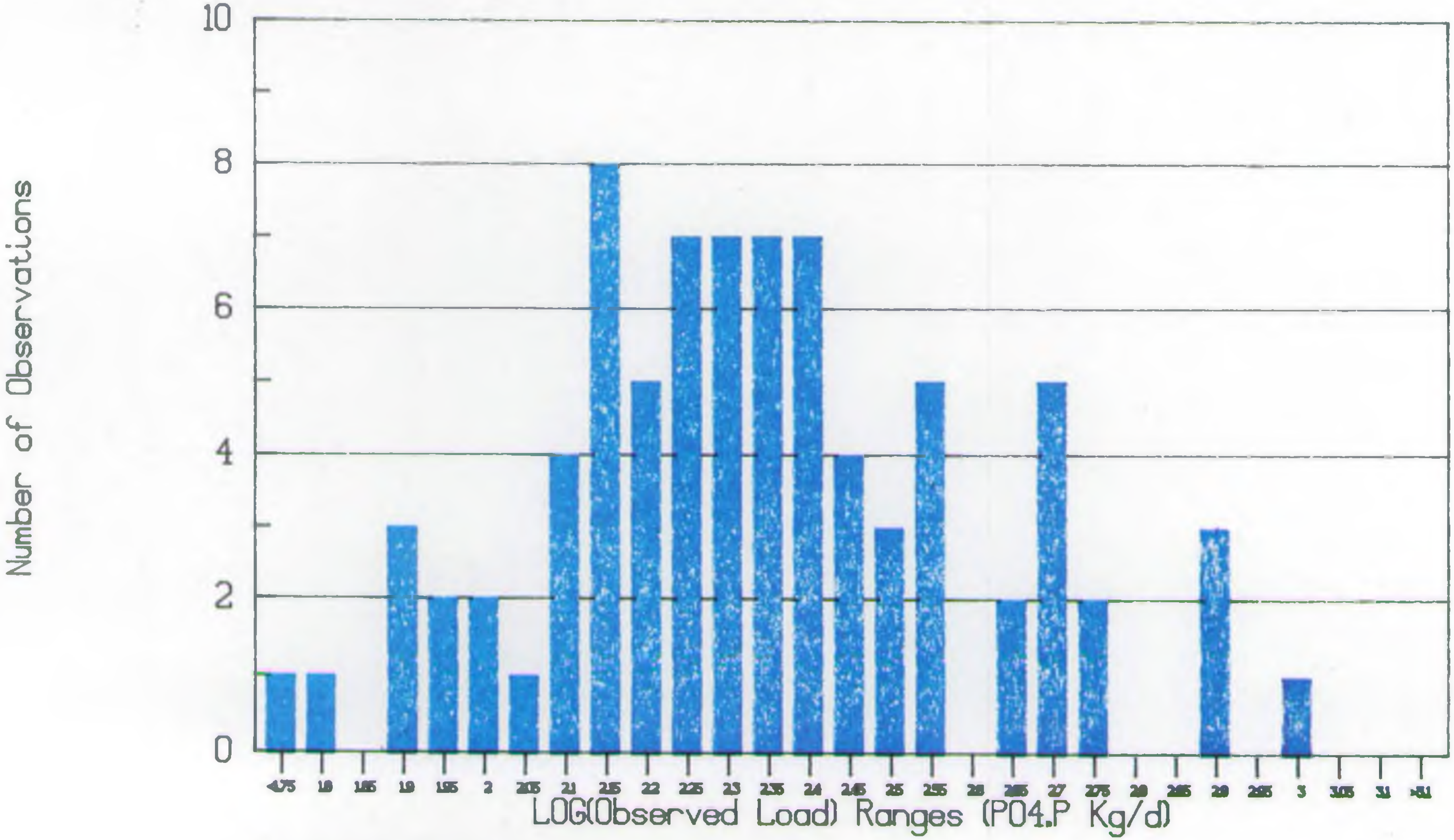
Flow gauged at Pontypridd
NRA data from Blackweir, Wimpey data as per report

7/12/89

Fig. 5a

Taff Nutrient Data 1989
Distribution of LOG(Daily Phosphorus Loads)

Daily loads calculated from instatanseous values
Total number of observations: 80



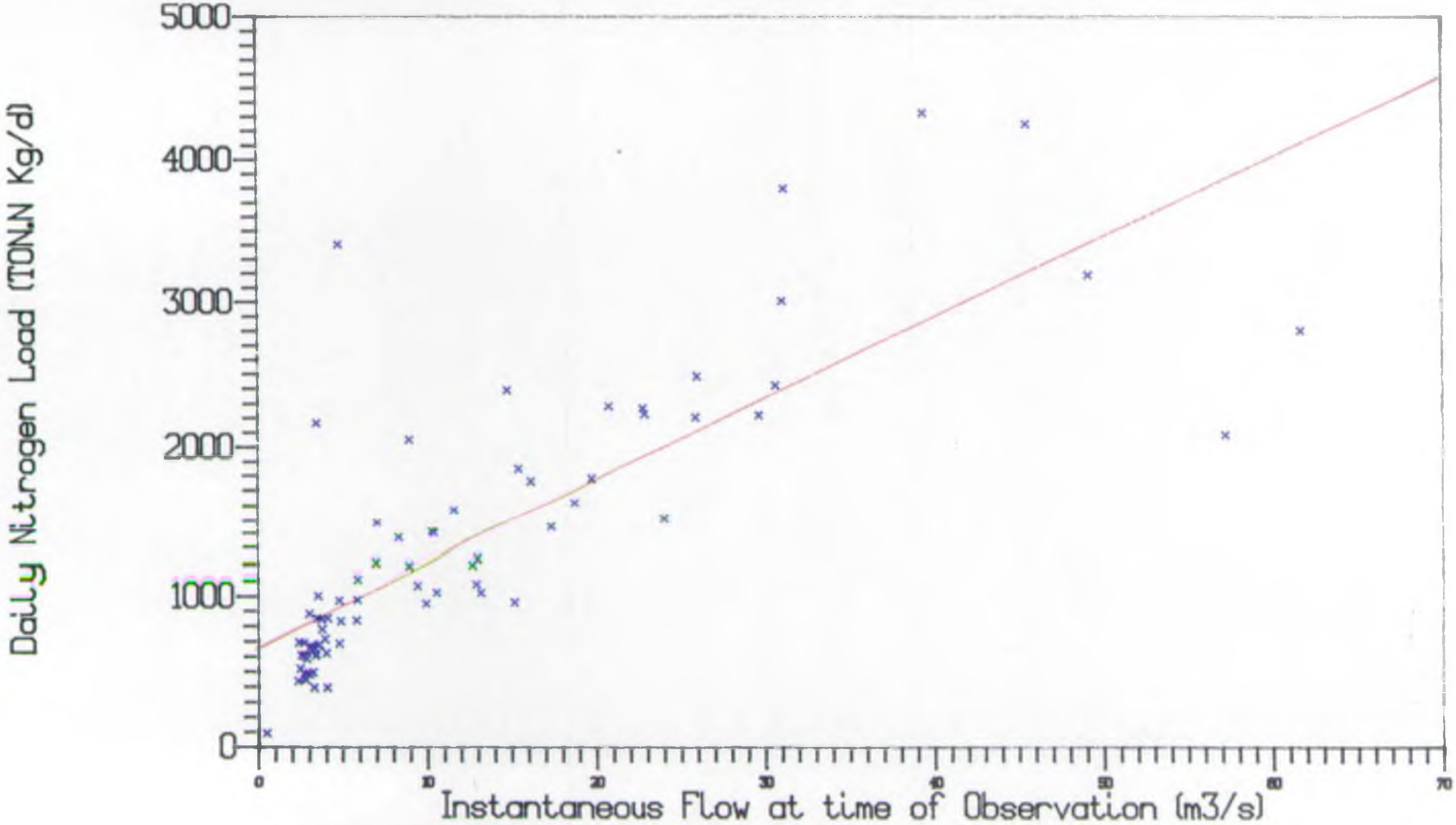
Flow guaged at Pontypridd
NRA data from Blackweir, Wimpey data as per report

7/12/89

Fig. 5b

Taff Nutrient Data 1989
Distribution of Daily Nitrogen Loads
Regression Line: m = 56.1, c = 657.4 (R^2 = 0.624)

Daily loads calculated from instataneous values
Total number of observations: 81



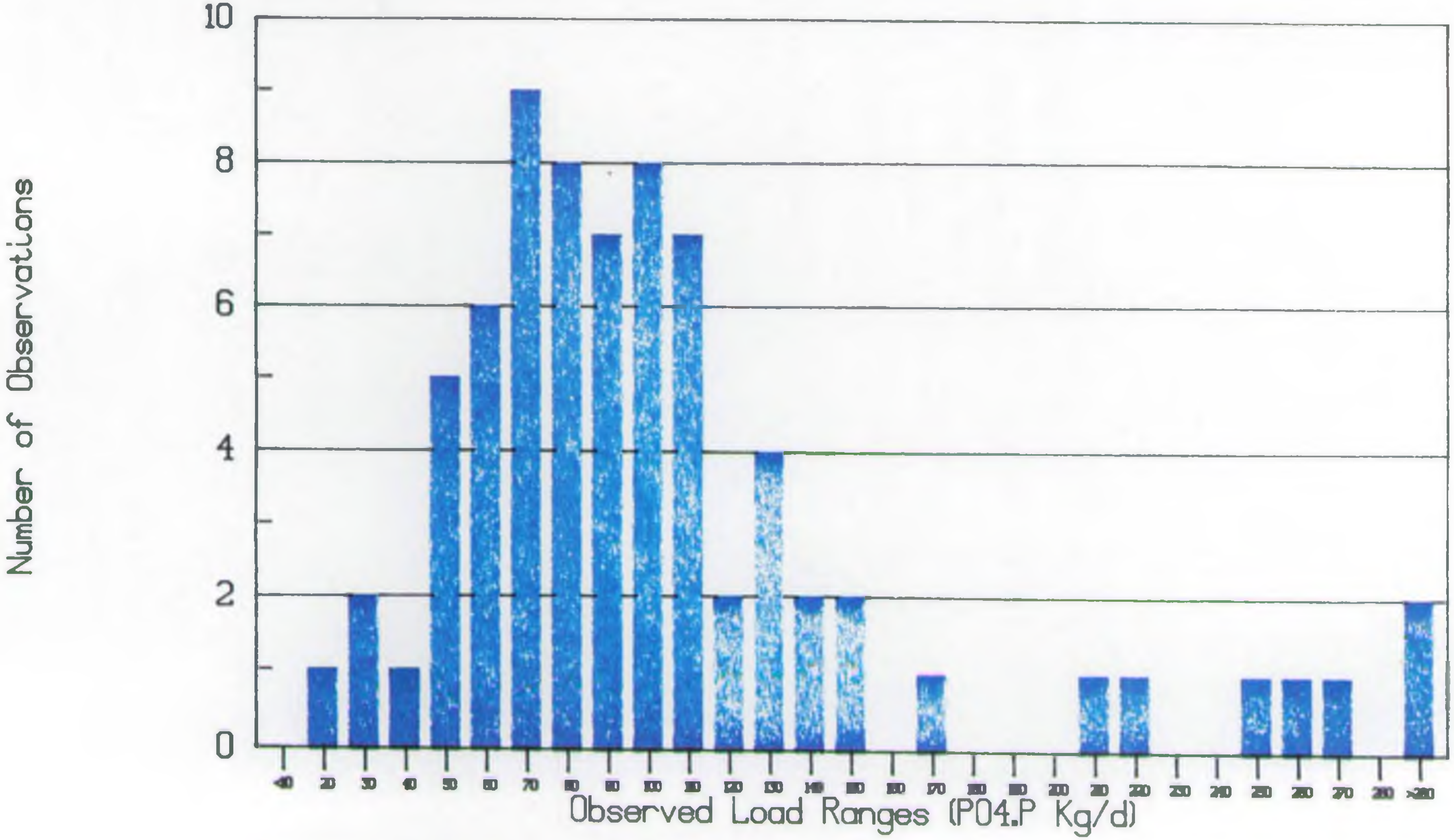
Flow gauged at Pontypridd
[illegible] data from [illegible], [illegible] data as per report.
For Values Excluded Flow > 100 m3/s

7/12/89

Fig. 5c

Ely Nutrient Data 1989
Distribution of Daily Phosphorus Loads

Daily loads calculated from instataneous values
Total number of observations: 72



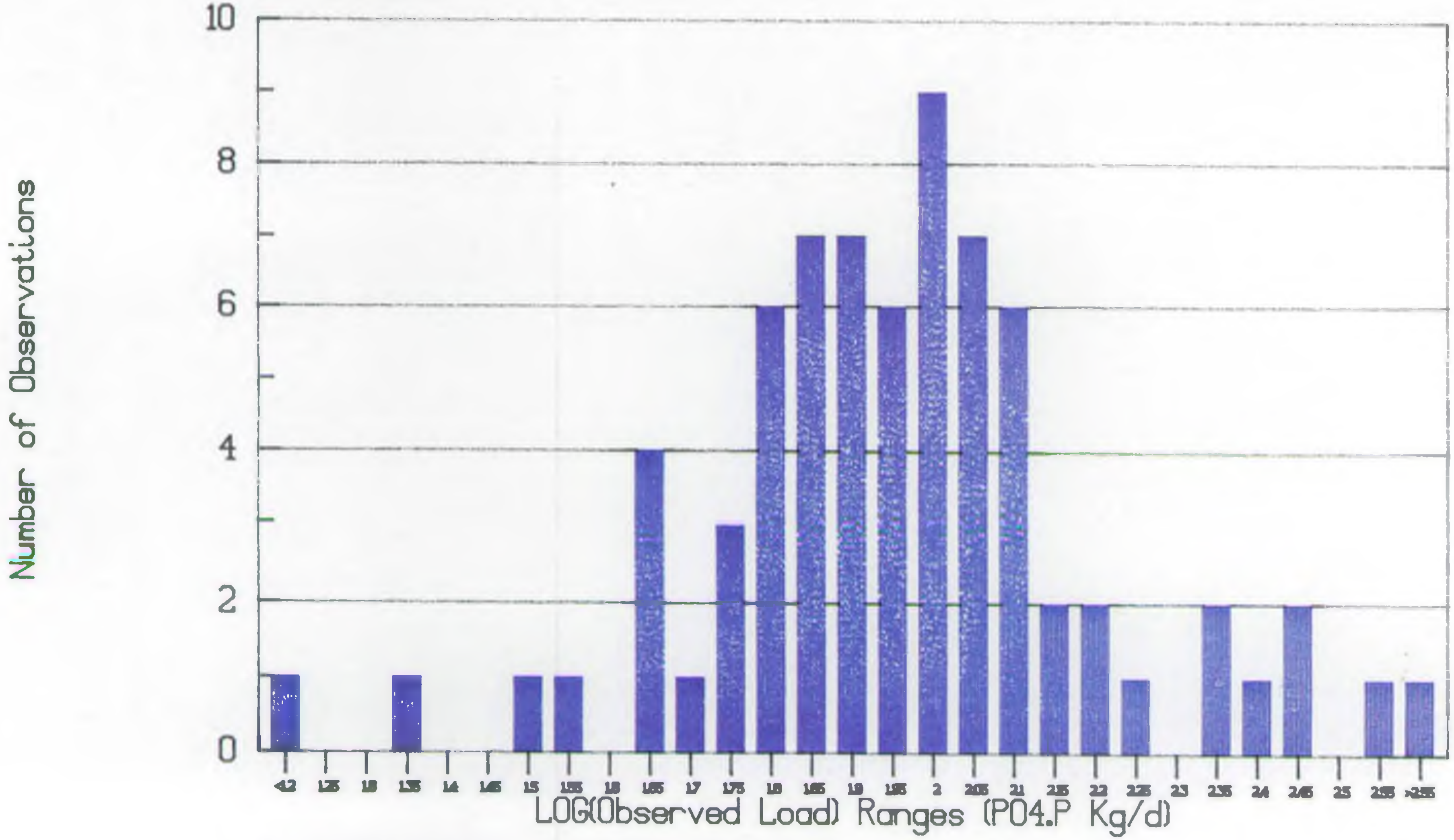
Flow guaged at St Fagans
NRA data from St Fagans, Wimpey data as per report

7/12/89

Fig.6a

Ely Nutrient Data 1989
Distribution of LOG(Daily Phosphorus Loads)

Daily loads calculated from instataneous values
Total number of observations: 72



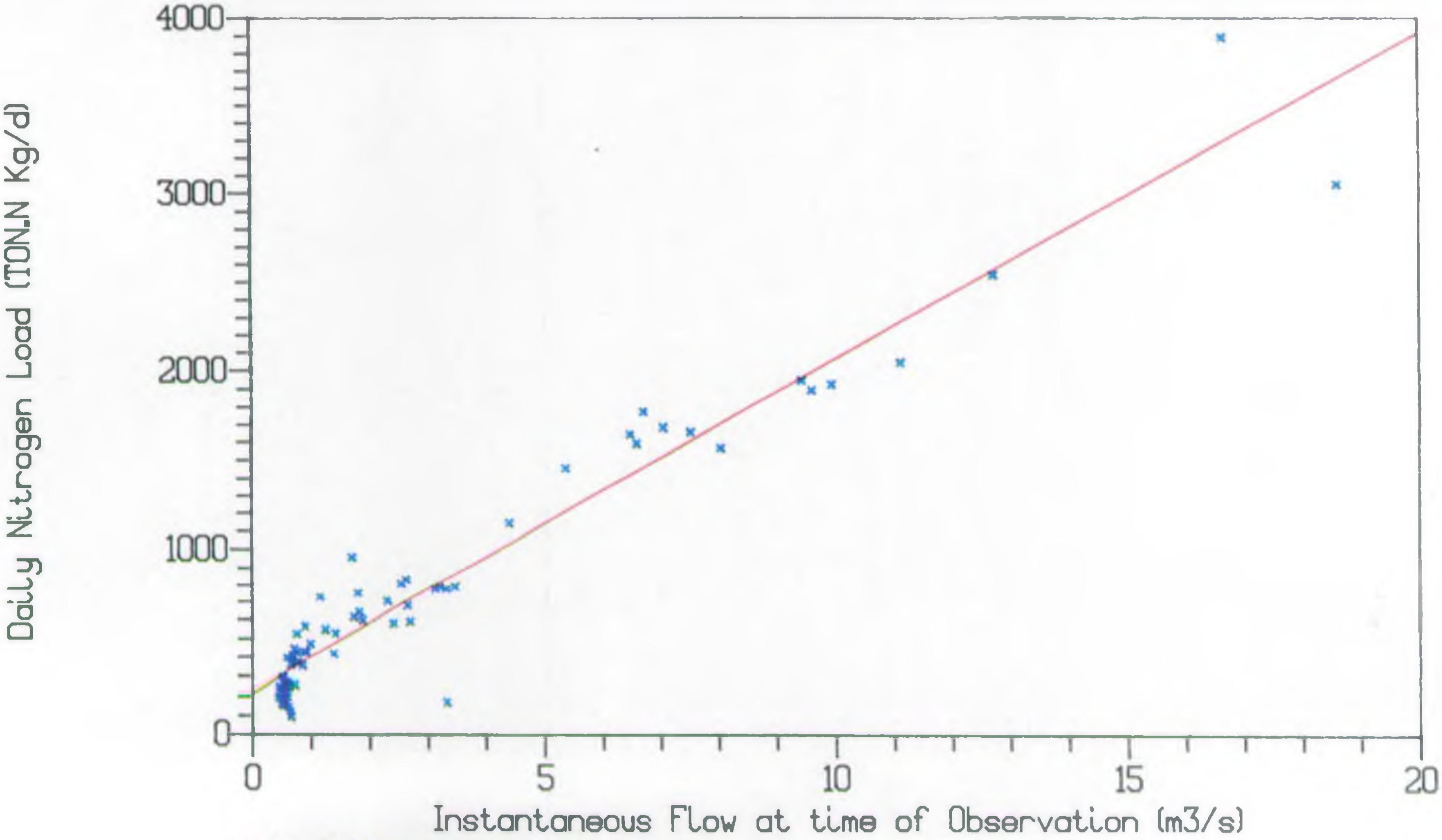
Flow guaged at St Fagans
NRA data from St Fagans, Hupey data as per report

7/12/89

Fig.6b

Ely Nutrient Data 1989
Distribution of Daily Nitrogen Loads
Regression Line: m - 184.9, c - 213.6 (R2 - 0.937)

Daily loads calculated from instataneous values
Total number of observations: 72

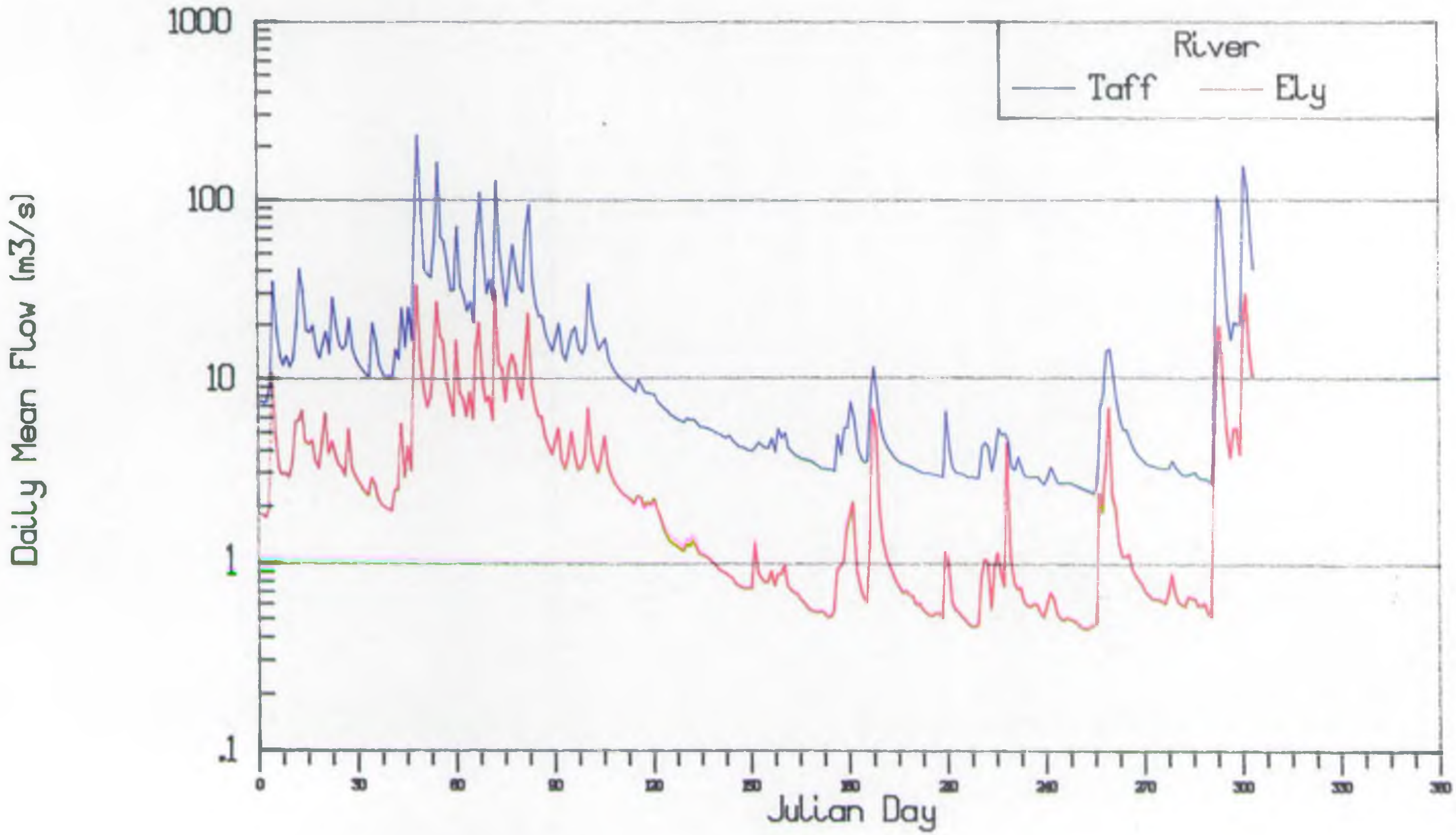


Flow gauged at St. Fagans
[illegible] data from St. Fagans, [illegible] data as per report.
Three values excluded (flow > 20.0 m3/s)

Fig. 6c

Rivers Taff and Ely Flows - 1989
Daily Mean River Flow

Taff flows measured at Pontypridd
Ely flows measured at St Fagans

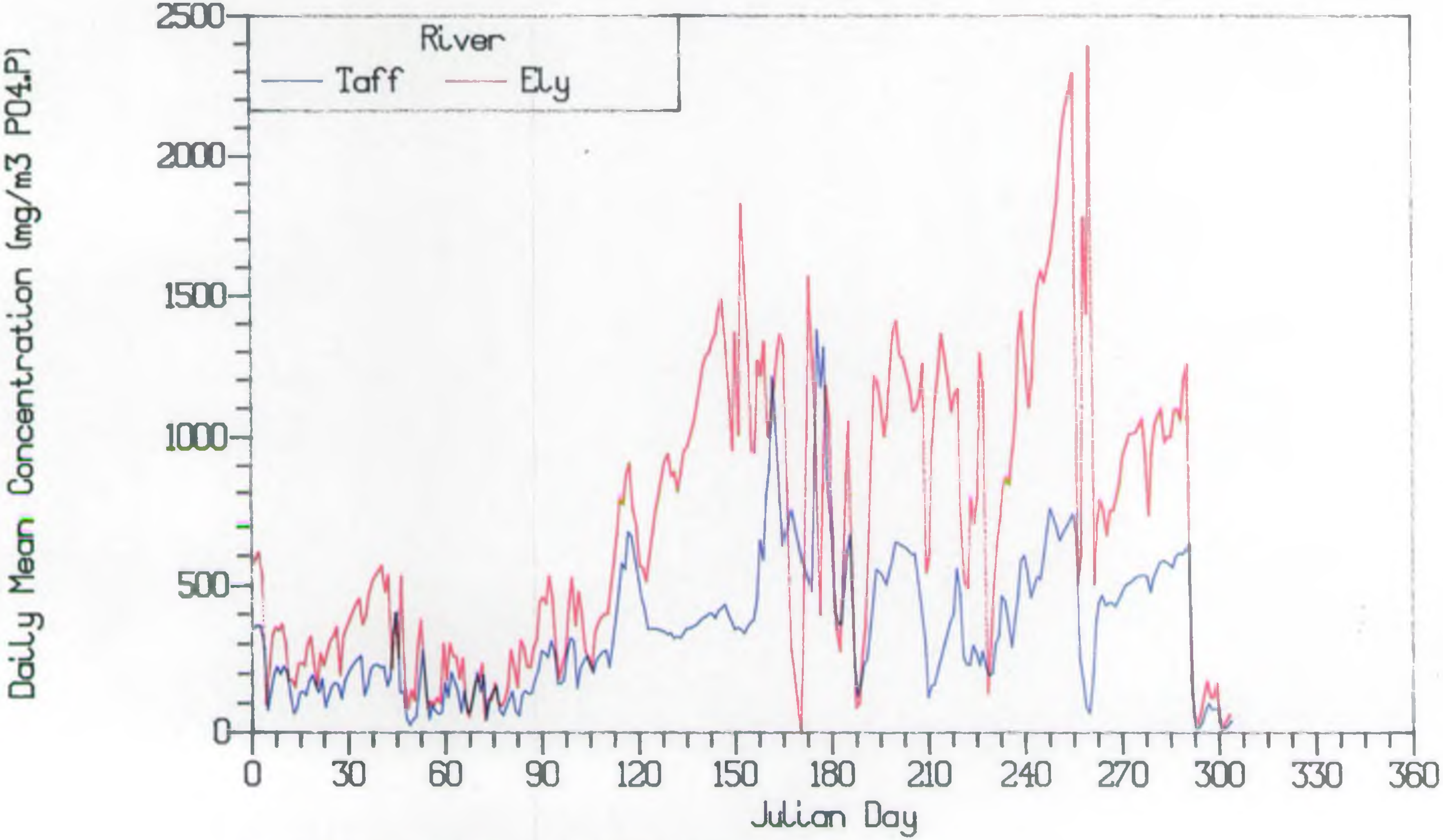


Data supplied by NRA

Fig.7a

Rivers Taff and Ely - Nutrient Inputs 1989
Daily Mean Phosphorus Concentration

Taff concentrations normally measured at Blackweir
Ely concentrations normally measured at St Fagans



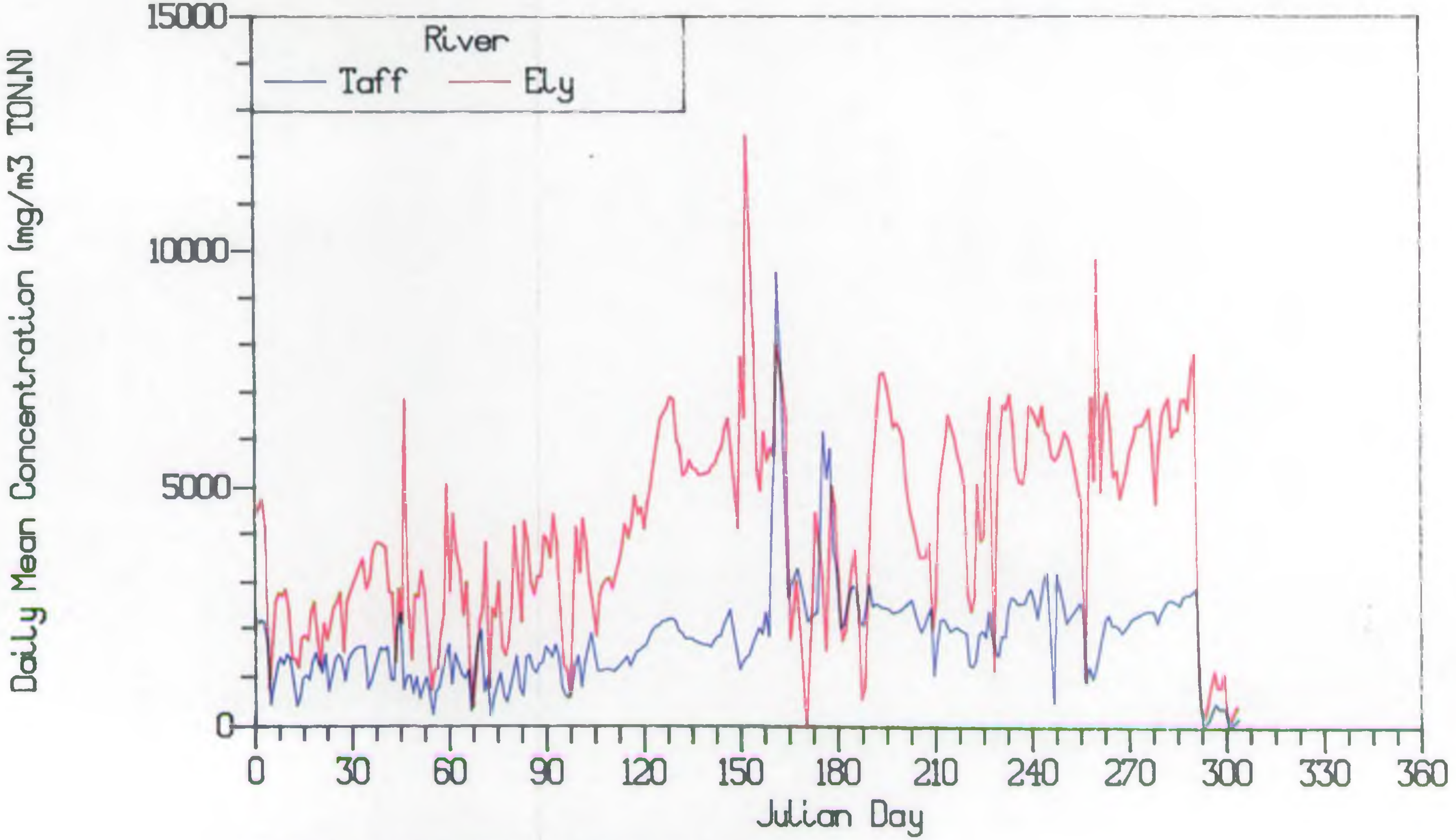
Data from both NRA and Wimpey Laboratories report

8/12/89

Fig. 7b

Rivers Taff and Ely - Nutrient Inputs 1989
Daily Mean Nitrogen Concentration

Taff concentrations normally measured at Blackweir
Ely concentrations normally measured at St Fagans



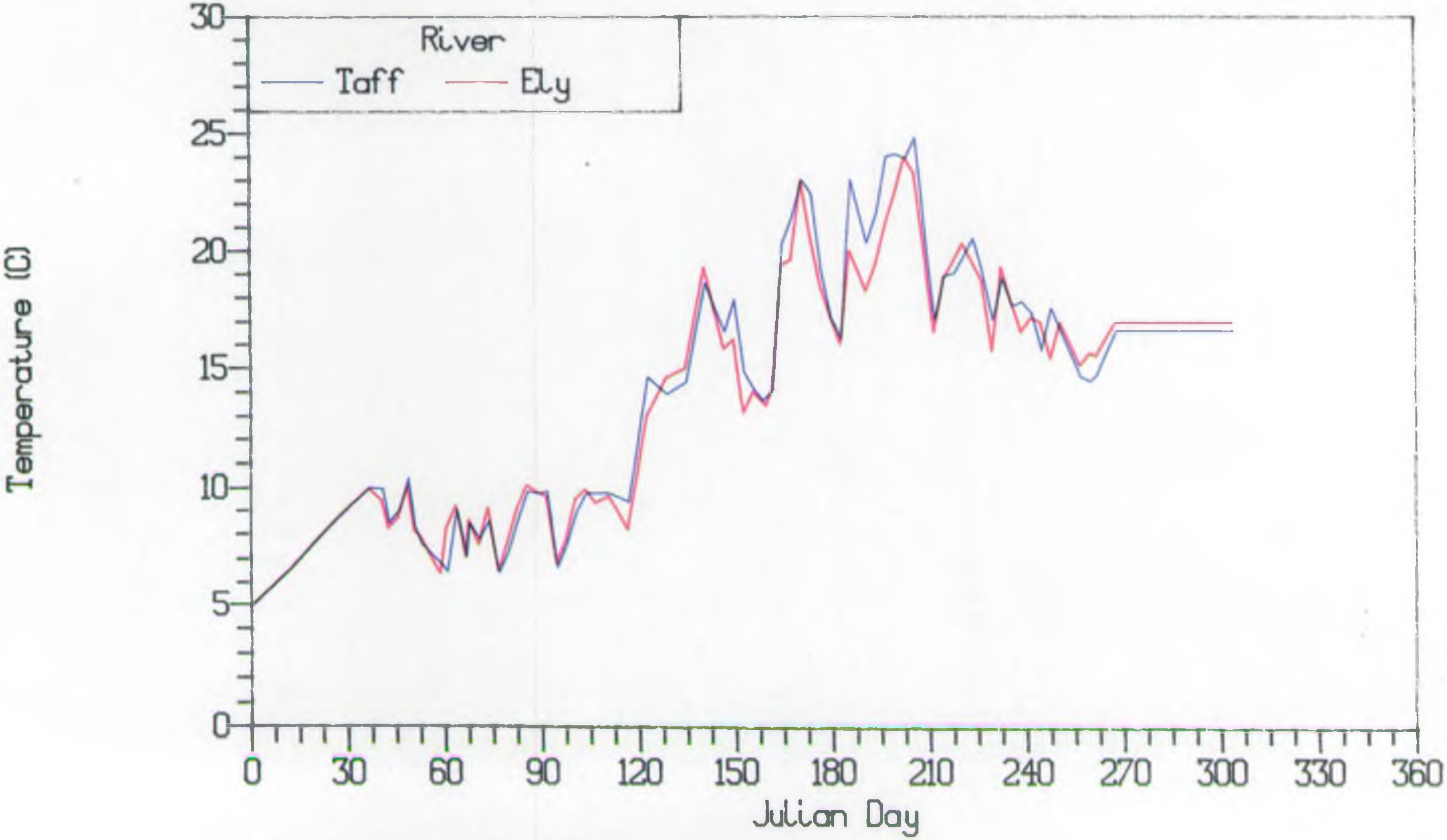
Data from both NRA and Wimpey Laboratories report

8/12/89

Fig. 7c

Rivers Taff and Ely - Inputs Data 1989
Daily River Water Temperatures

Taff normally measured at Blackweir
Ely normally measured at St Fagans



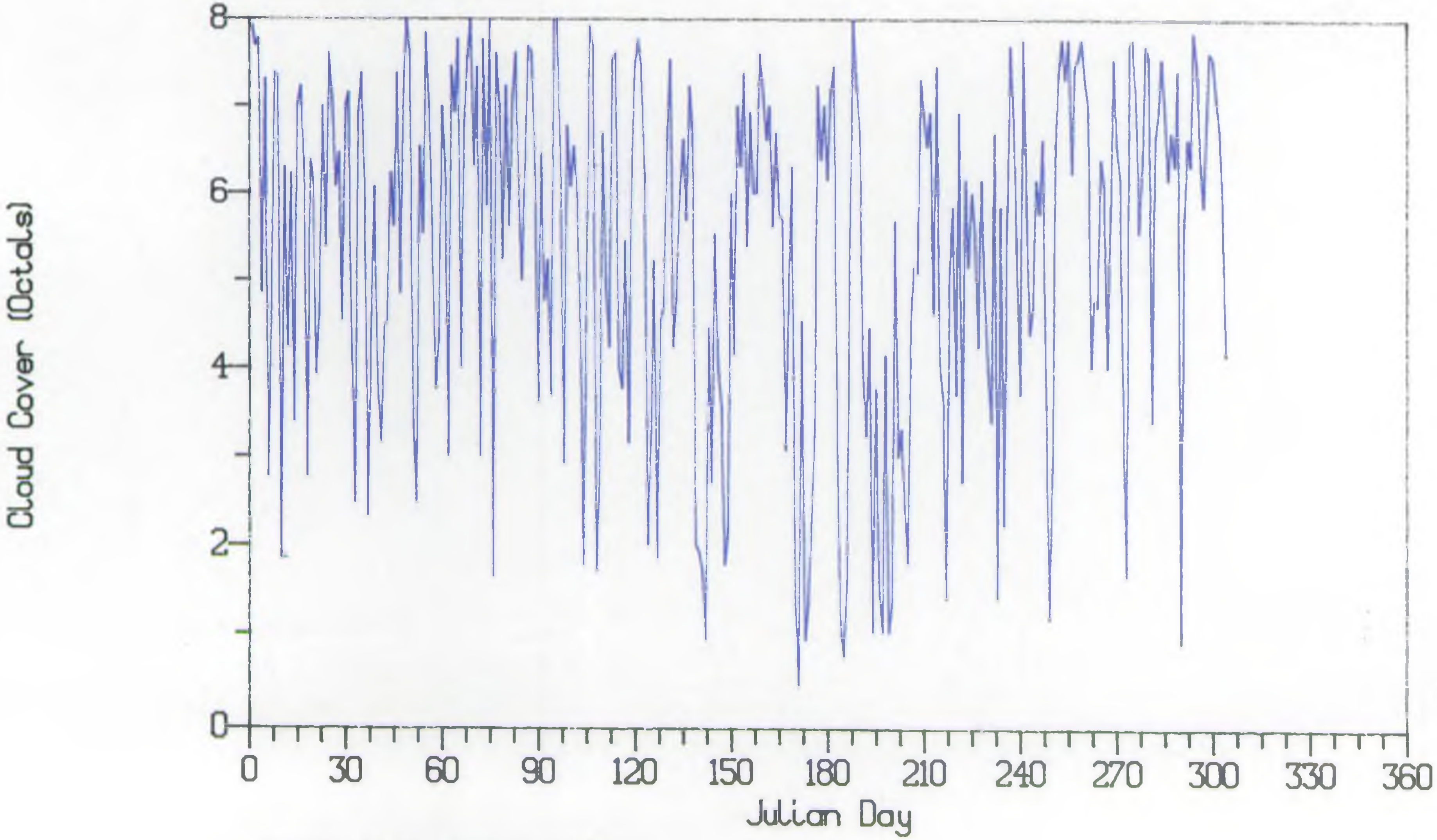
Data from both NRA and Wimpey Laboratories report

8/12/89

Fig. 7d

Cardiff Bay Lake - Algal Simulation 1989
Mean Cloud Cover - 0600 to 1900 hrs

Data measured at Rhoose Airport
Supplied by Meteorological Office, Bracknell



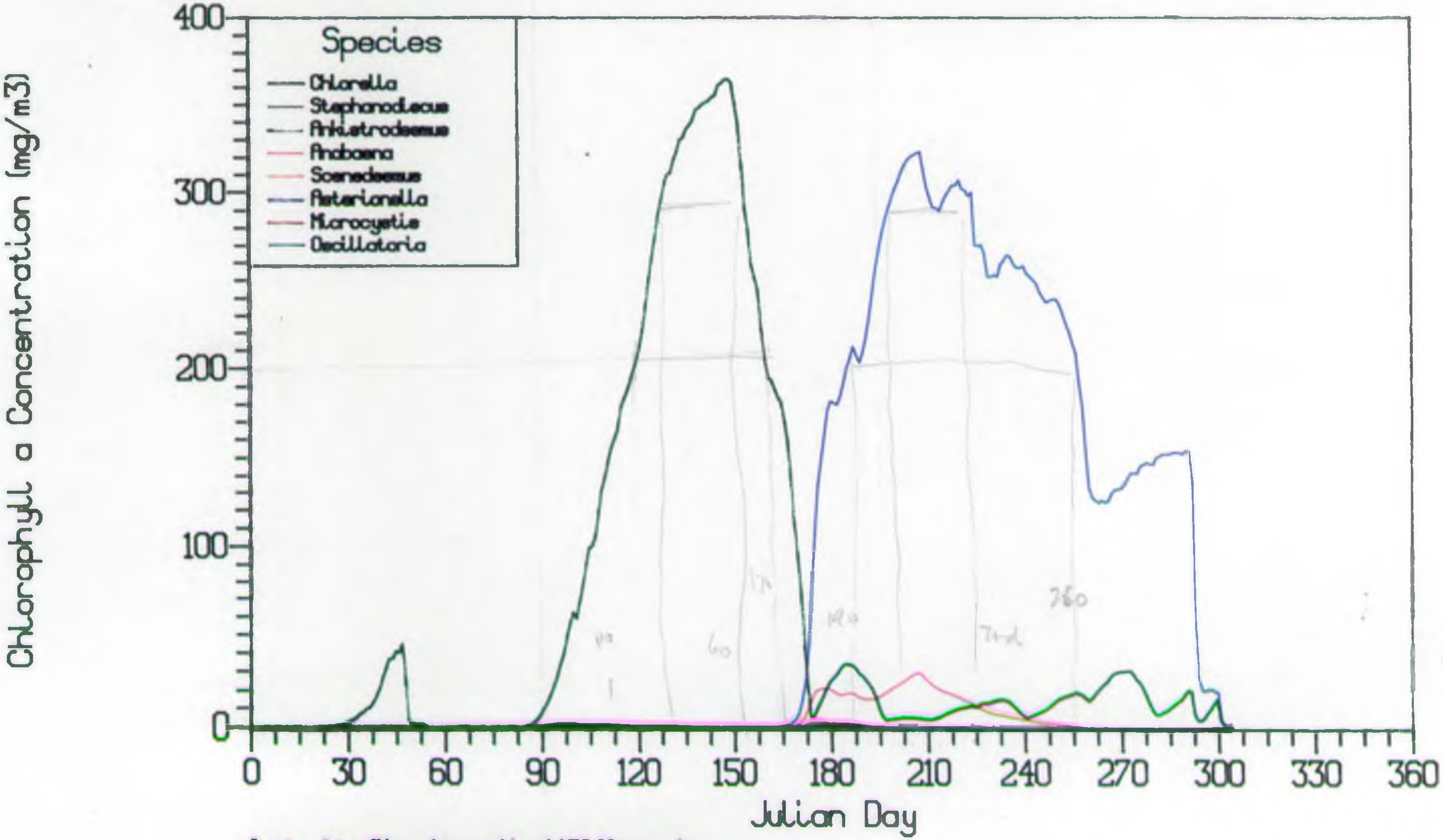
Average of 13 hourly readings

8/12/89

Fig.7e

Cardiff Bay Lake - Algal Simulation 1989
Species Chlorophyll Predictions from FBA/WW model
Run 1 - Baseline Prediction

Standard defaults adopted
No stripping of nutrients



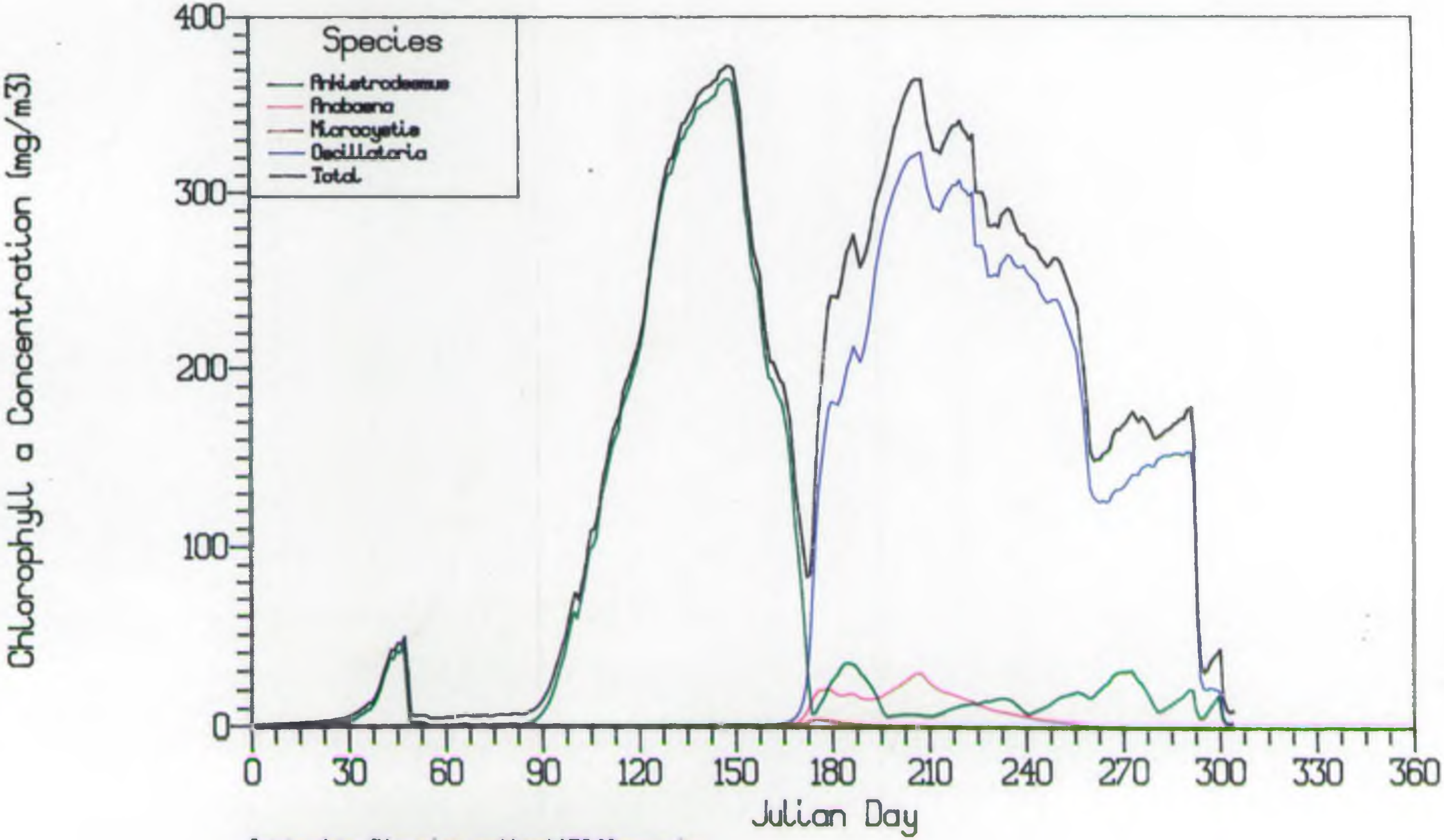
Inputs data file using combined NRA/[illegible] obs.
Input algae uses equal quantities of all species

8/12/89

Fig. 8a

Cardiff Bay Lake - Algal Simulation 1989
Species Chlorophyll Predictions from FBA/WW model
Run 1 - Baseline Prediction Significant Species

Standard defaults adopted
No stripping of nutrients



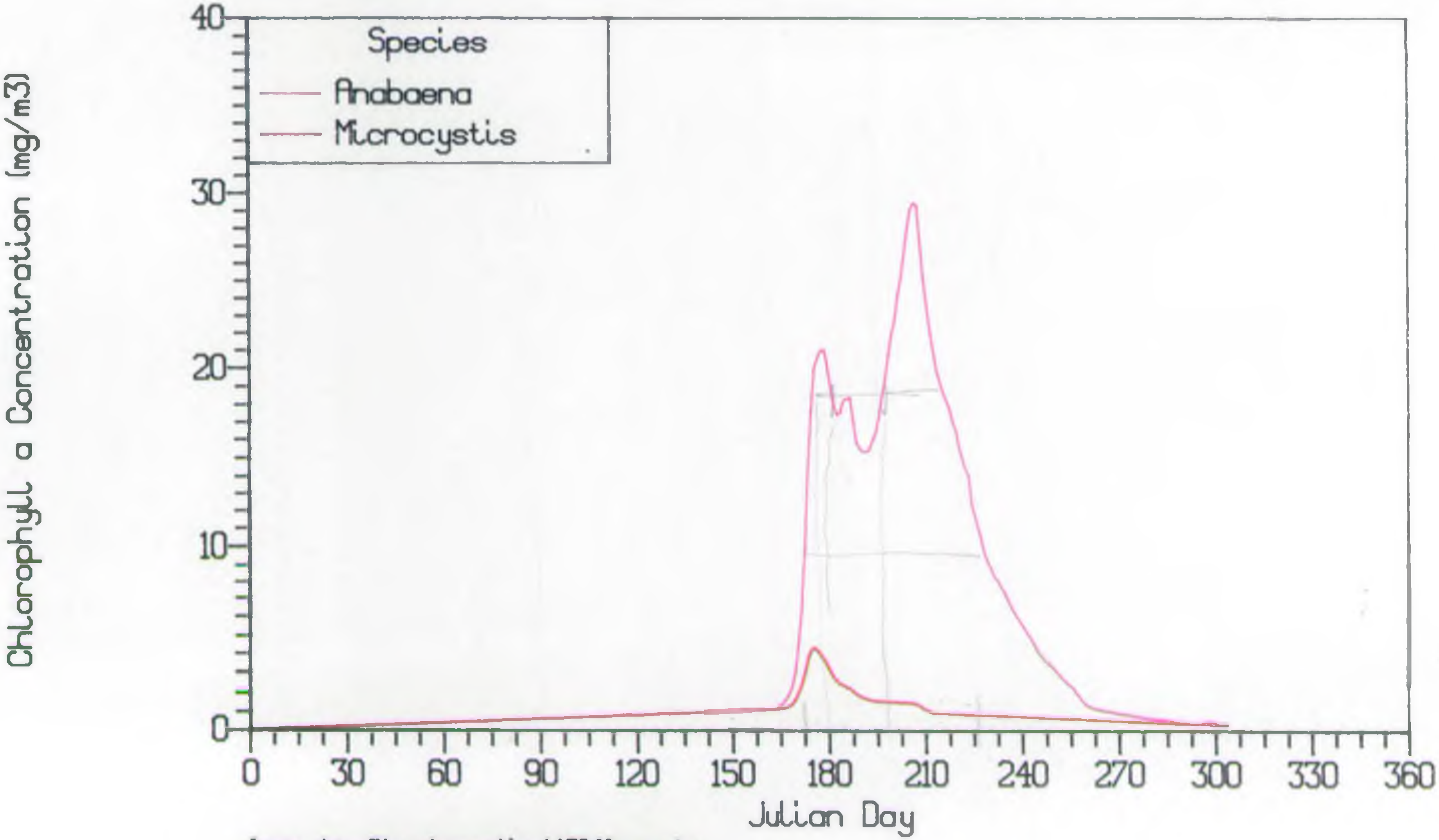
Inputs data file using combined NRA/Hapey obs.
Input algae uses equal quantities of all species

8/12/89

Fig. 8b

Cardiff Bay Lake - Algal Simulation 1989
Species Chlorophyll Predictions from FBA/WW model
Run 1 - Baseline Prediction Species Detail

Standard defaults adopted
No stripping of nutrients



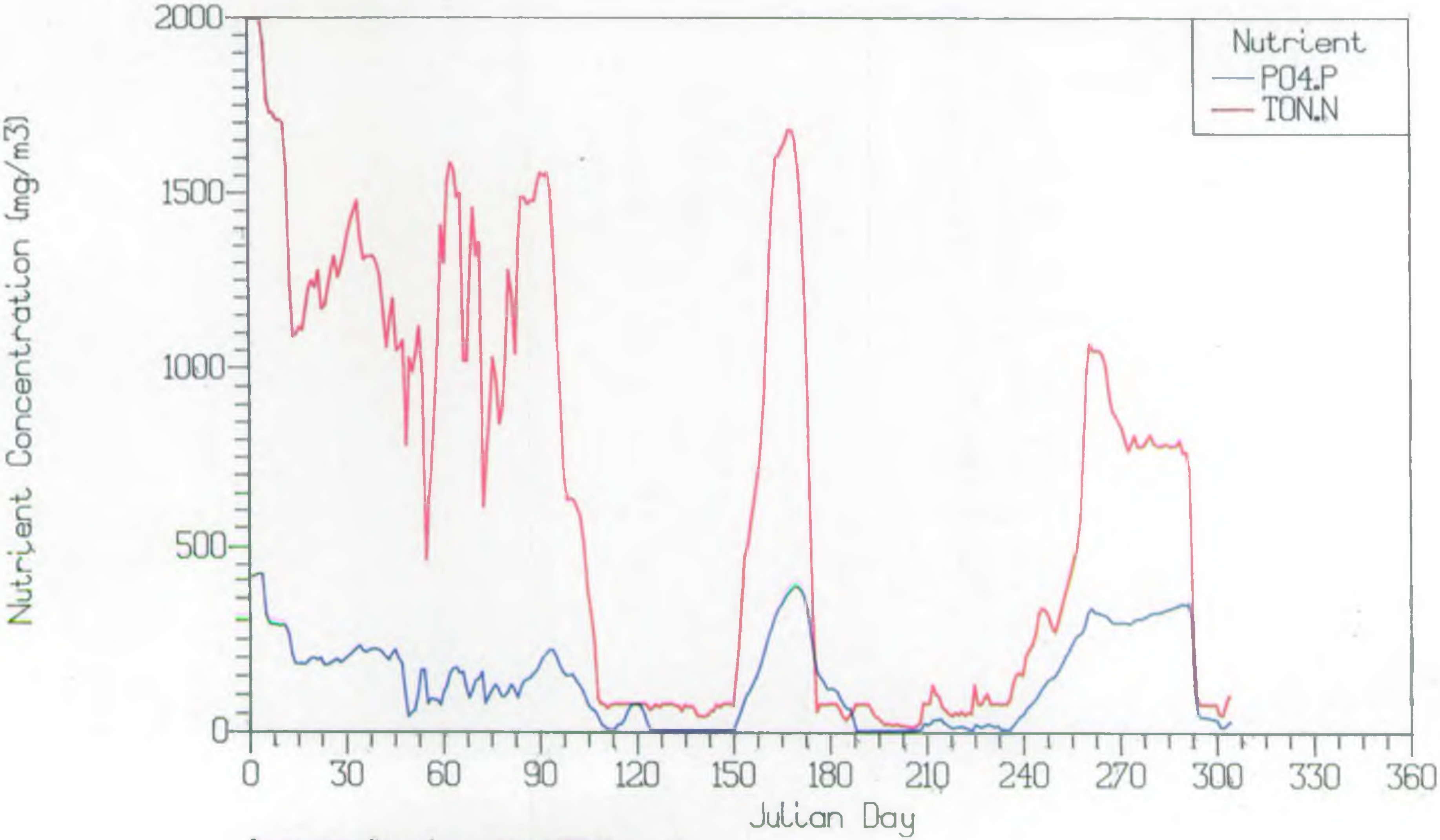
Inputs data file using combined NRA/Wimpey obs.
Input algae uses equal quantities of all species

8 / 12 / 89

Fig. 8 c

Cardiff Bay Lake - Algal Simulation 1989
Residual Nutrient Concentrations from FBA/WW model
Run 1 - Baseline Prediction

Standard defaults adopted
No stripping of nutrients



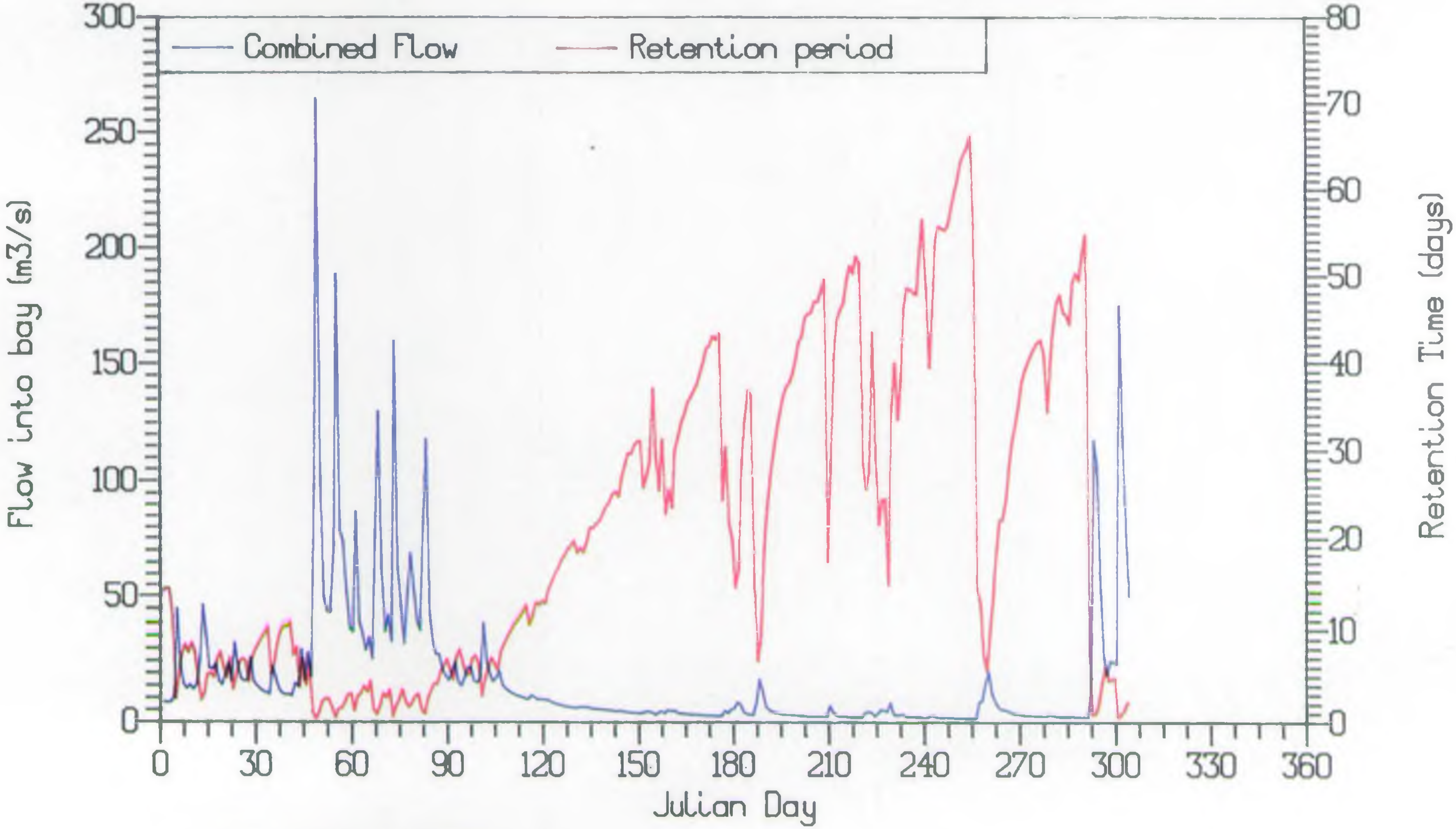
Inputs data file using combined NRA/Wimpey obs.
Input algae uses equal quantities of all species

8/12/89

Fig. 8d

Cardiff Bay Lake - Algal Simulation 1989
Combined River Flows and Equivalent Retention Time
Reduced by 1 m3/s to Simulate ABP Abstrction

Taff flows measured at Pontypridd
Ely flows measured at St Fagans



All data supplied by NRA

Fig.8e

Cardiff Bay Lake - Algal Simulation 1989
Species Chlorophyll Predictions from FBA/WW model
Run 2 - Unlimited Nutrient Availability

pflag = 0, nflag = 0
All other defaults

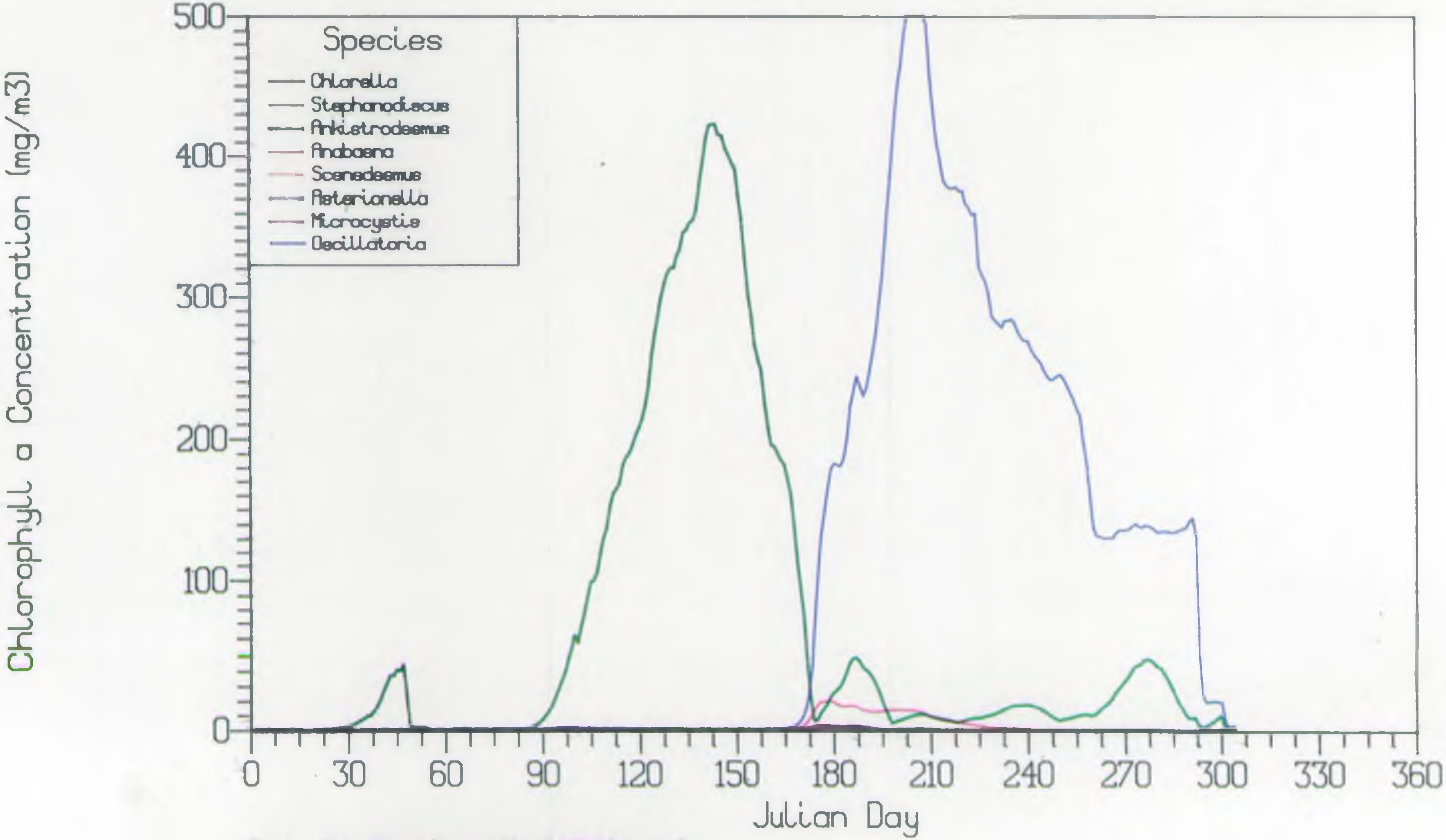


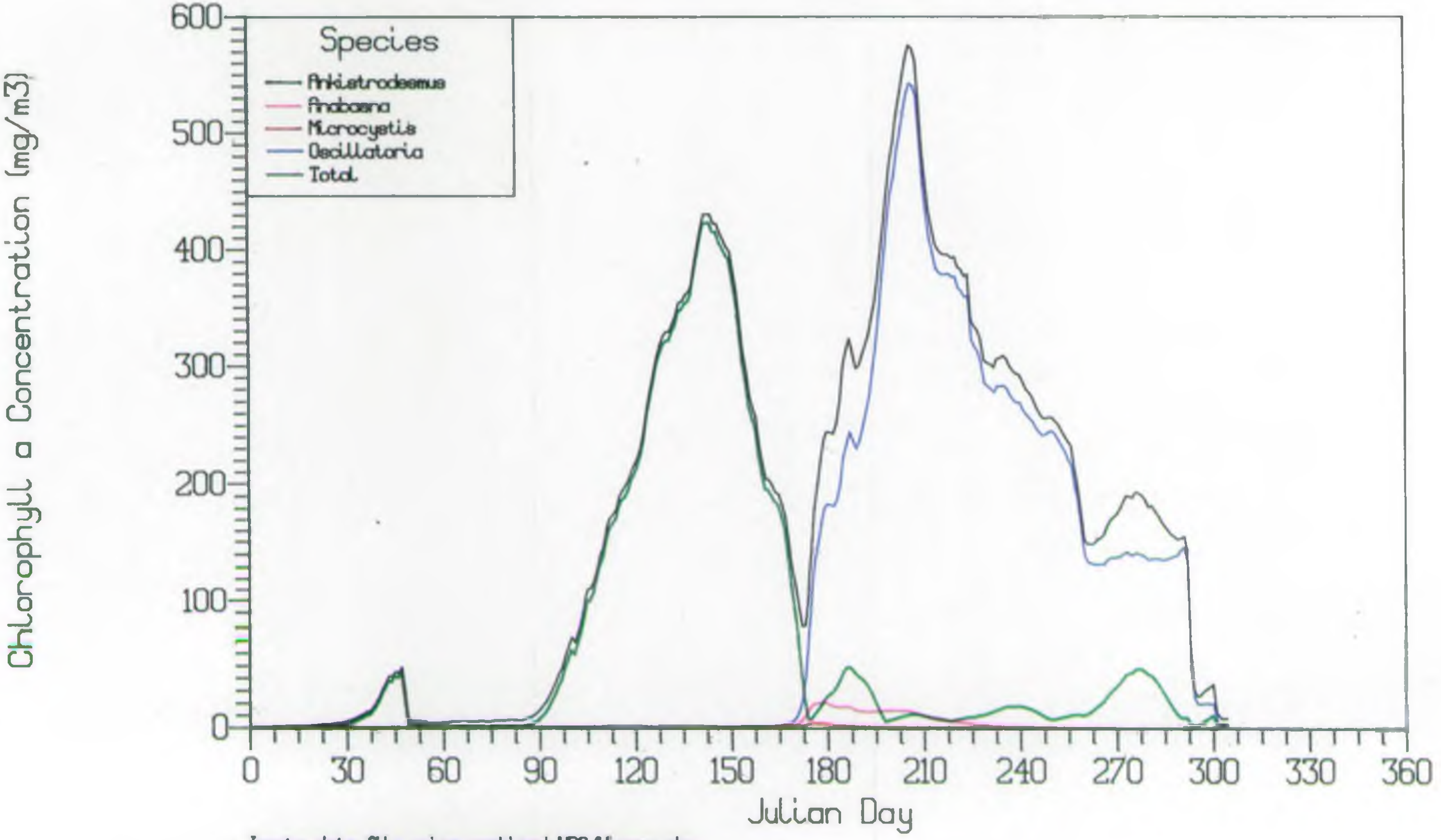
Fig. 9 a

Inputs data file using combined NRA/Wimpey obs.
Input algae uses equal quantities of all species

8/12/89

Cardiff Bay Lake - Algal Simulation 1989
Species Chlorophyll Predictions from FBA/WW model
Run 2 - Unlimited Nutrient Availability

pflag = 0, rflag = 0
All other defaults



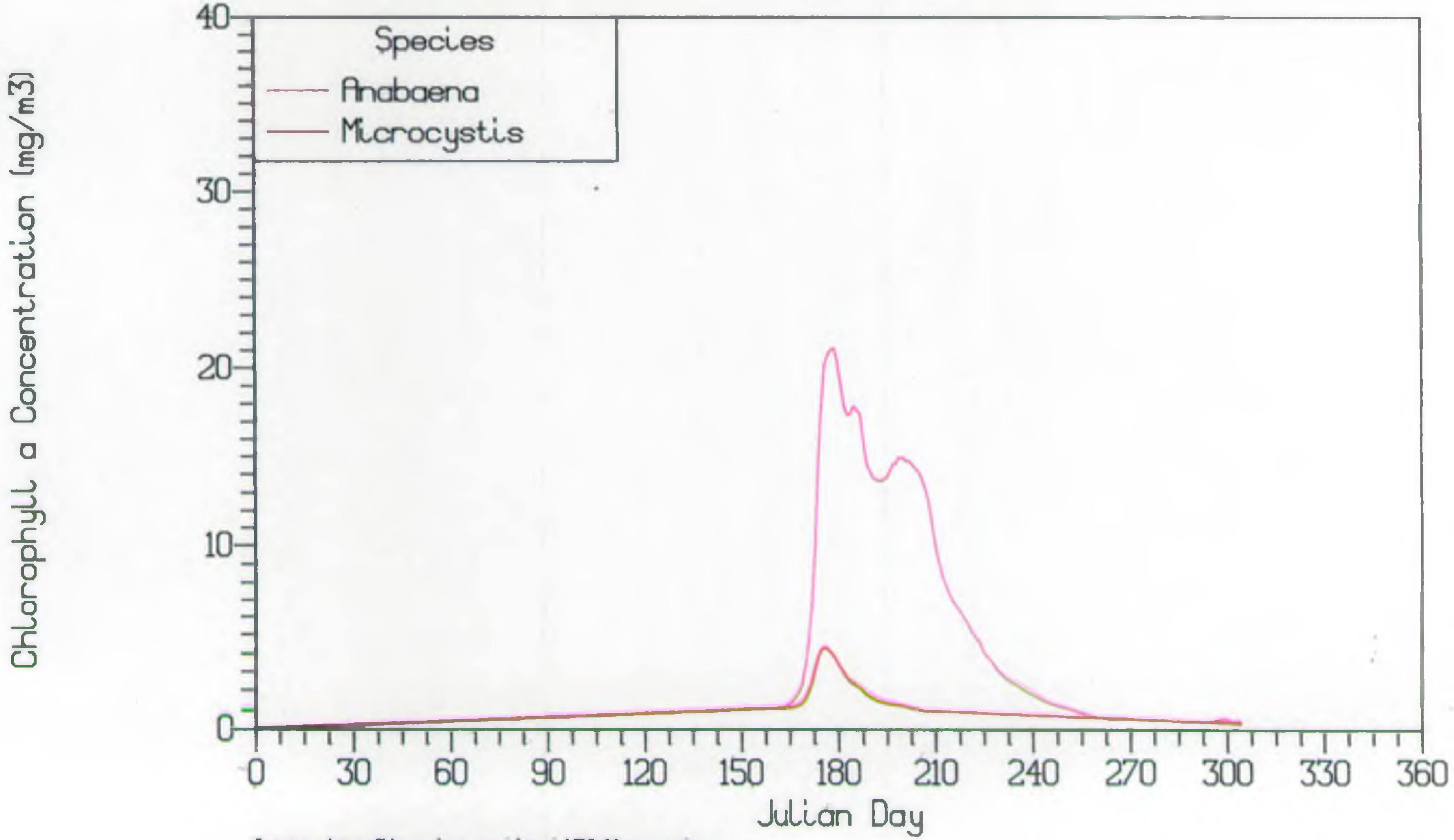
Inputs data file using combined NRA/Wimpey obs.
Input algae uses equal quantities of all species

8/12/89

Fig.9b

Cardiff Bay Lake - Algal Simulation 1989
Species Chlorophyll Predictions from FBA/WW model
Run 2 - Unlimited Nutrient Availability

pflag - 0, nflag - 0
All other defaults



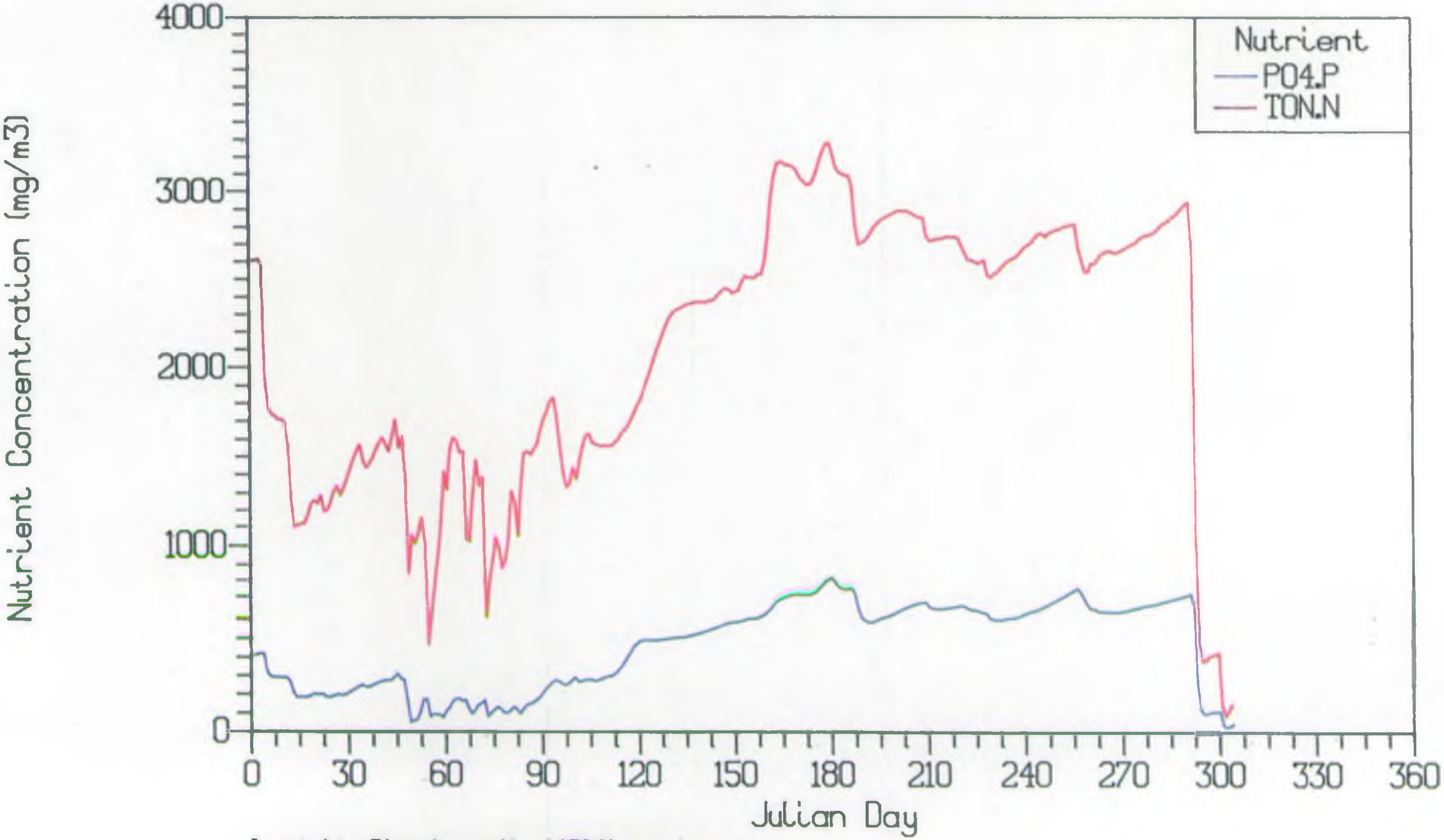
Inputs data file using combined NRA/Wimpey obs.
Input algae uses equal quantities of all species

8/12/89

Fig.9c

Cardiff Bay Lake - Algal Simulation 1989
Residual Nutrient Concentrations from FBA/WW model
Run 2 - Unlimited Nutrient Availability

pflag = 0, nflag = 0
All other defaults



Inputs data file using combined NRA/Wimpey obs.
Input algae uses equal quantities of all species

8/12/89

Fig. 9d

APPENDIX 1. Default Conditions

1: Single segment model, assumed homogenous both vertically and laterally.

2: Time step for evaluation set at 15 mins, all time steps treated equally without explicit recognition of day/night variation since kinetics of growth rates based on nett effects.

3: Bay volume set to 1.015×10^{7} m^{3}

4: Mean bay depth set at 5.4 m

5: Respiration losses for all species of algae set at 15% of the potential growth rate at the given temperature.

6: Light extinction coefficient for water, epsilon set at 0.73 m^{-1}

7: River Taff inflow reduced by 1 m^{3}/s to represent the abstraction by Associated British Ports, ABP, at Blackweir into their dock feeder canal.

8: Orthophosphate (PO_4.P) and Total Oxidisable Nitrogen (TON.N) used as the concentrations of phosphorus and nitrogen available to support algal growth.

9: No stripping of phosphorus or nitrogen.

10: The chlorophyll inoculent levels in the rivers vary linearly on an interpolation between winter solstice, vernal equinox, summer solstice, autumnal equinox and back to winter solstice.

11: Total chlorophyll inoculent levels used are:

winter solstice: 0.1 mg/m^{3}
vernal equinox: 5.0 mg/m^{3}
summer solstie: 10.0 mg/m^{3}
autumnal equinox: 5.0 mg/m^{3}

12: The eight species used in the simulation are assumed to contribute equally to the the total chlorophyll input.

13: The different species included are:

Chlorella	(green)
Stephodiscus hantz	(green)
Ankistrodesmus	(green)
Anabaena	(blue-green, capable of fixing atmospheric nitrogen,blooms can form surface accumulations)
Scenedesmus quad	(green)
Asterionella	(blue-green)

Microcystis (blue-green, blooms can form surface accumulations)

Oscillatoria (blue-green)

14: Species specific potential growth rates computed as a function of species morphology, temperature, day length and incident radiation.

15: Incident solar radiation and day length set as appropriate to the latitude of Cardiff Bay. Assumed to vary approximately linearly between winter solstice, vernal equinox, summer solstice, autumnal equinox and back to winter solstice as for river chlorophyll innoculent levels.

16: Incident solar radiation reduced as a function of cloud cover;

$$Io_{(effective)} = (0.3+((n/8)*0.7))*Io_{(potential)}$$

where n = cloud cover in octals

17: Additional phosphorus input from other sources, such as birds, set at 50 Kg/d.

18: Grazing of edible species (green) by zooplankton simulated by a grazing term with kinetics based upon observed behaviour of *Daphnia*. Growth of grazing term dependant upon temperature, available food and losses due to flushing.

19: Nutrient from algae grazed is assumed to be available again immediately.

20: Nutrient consumption ratio for chlorophyll production set at 2P:12N per unit of chlorophyll produced when nutrient plentifull, 1P:6N per unit of chlorophyll when nutrient is scarce.

21: When nutrient is scarce, available resouce is apportioned between the species according to the ratio of their relative demands.

22: When nitrogen is limited *Anabaena* can still grow using nitrogen fixed from the atmosphere.