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The chemistry of Magela Creek

A baseline for assessing change downstream of Ranger

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Executive summary

The compositions of waters in Magela Creek upstream and downstream of Ranger uranium mine were reviewed. The water quality parameters examined were pH, electrical conductivity (EC) and turbidity, and dissolved calcium, magnesium, sodium, potassium, chloride, sulphate, ammonium, nitrate, copper, lead, manganese, zinc, uranium and radium-226. The frequency distributions of each of these parameters in waters upstream of the mine were characterised and statistically described to provide a baseline which allows a change in water chemistry downstream of the mine to be assessed.

With the exception of pH, EC, turbidity, magnesium, calcium, sodium and manganese, data that comprise the baseline are not normally distributed. The frequency distributions of copper, lead, zinc, uranium and radium-226 forming the baseline are characterised by a large proportion of values at or near analytical detection limits and contamination in a relatively large proportion of the remainder.

A comparison of upstream and downstream data shows that there is good conformity in pH, EC, turbidity, sodium, potassium and chloride. For calcium, nitrate, ammonium, lead, uranium, radium and zinc less than 40% of the downstream data fall outside the 20^{th} and 80^{th} baseline percentiles but in the case of U, data are biased towards relatively high values. More than 40% of downstream magnesium and sulphate data are outside these percentile boundaries and are skewed towards relatively high concentrations.

Copper, lead and zinc in mine waters (characterised by the composition of waters contained in the former RP4) do not appear to pose a risk as contaminants based upon the results of toxicity testing and water quality guideline trigger levels with risk minimised for greater than 1 in 20 dilution.

Keywords: water quality, Magela Creek, Ranger uranium mine, Commonwealth environmental requirements

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The chemistry of Magela Creek: A baseline for assessing change downstream of Ranger

DA Klessa

1 Introduction

Since the granting of the Authority by the Commonwealth to Energy Resources of Australia Pty Ltd in January 1979 to mine uranium from the Ranger Project Area (under s.41 of the *Atomic Energy Act 1953*), the company has been required to observe the *Ranger Environmental Requirements* which are set out in *Schedule 2* of the Authority. Amongst the clauses of the *Ranger Environmental Requirements* are those dealing with compliance in the 'control of water' and 'monitoring' which concern, in part, the chemistry of mine and receiving waters. The 'Working Arrangements', between the Commonwealth and NT Governments for consultation and approval of operations at Ranger having environmental aspects, are specified in a *Memorandum of Understanding* which determines the consultative framework between the Supervising Authority, Commonwealth Government and Northern Land Council.

Recently, and following a period of discussion with stakeholders, the Commonwealth Government reviewed its environmental requirements (ERs) for the operation of Ranger. These new ERs define primary and secondary environmental objectives but with minimum prescription so as to allow flexibility in achieving the highest standards of protection for people and ecosystems. The timetable for implementing the new Commonwealth ERs was 9 January 2000 when the renewed Authority to mine at Ranger under the *Atomic Energy Act 1953* will take effect.

In the new ERs, water quality forms an integral part of secondary environmental objectives. Importantly, compared with the original *Ranger Environmental Requirements*, the new ERs do not categorise mine waters on the basis of source into *restricted release zone* and *non-restricted release zone* waters. Rather, the focus is placed on the management of mine waters to protect the environment. To this end, clause 3.3 of the ERs states:

> 3.3 Background values for key variables in water quality, including values for conductivity, pH and uranium, are determined by the Supervising Scientist from time to time and communicated to the company and other major stakeholders. Should the values for these variables measured at Gauging Station GS8210009, or other key locations, show trends away from, or be abruptly divergent from, those background values, and if, in the opinion of the Minister, with the advice of the Supervising Scientist, the results may be attributable to mining operations, then the company must undertake such investigations and remedial actions as required by the Supervising Authority after consultation with the Supervising Scientist and other major stakeholders.

In turn, this requires an interpretative framework and response strategy which recognises a departure from baseline conditions, understands its significance and, when necessary, implements an action to remedy the change. Under the new ERs, the interpretive framework is provided by information gained from the long-term record and continued monitoring of Magela Creek upstream and downstream of the mine (clause 13.1). In addition, the development of a National Water Quality Strategy through the revision of the Australian and New Zealand guidelines for fresh and marine water quality, to be published in mid-2000, provides the philosophy of approach by which a change in water quality from baseline conditions can be recognised and evaluated.

This report examines the chemistry of Magela Creek waters upstream and downstream of Ranger uranium mine. It has the following objectives:

1 To collate data on the chemistry of Magela Creek both upstream and downstream of Ranger.

2 To characterise and describe the frequency distribution of water quality parameters.

3 To compare the water quality characteristics of upstream and downstream sites.

4 To delineate those water quality parameters that deviate between upstream and downstream sites.

2 Methods

2.1 Sources of data

Data were derived from three main sources: the Ranger water quality database, the NTDME check monitoring water quality database and the NT Water Resources Division. Details of the sites and time spans covered are summarised in table 2.1. In addition, some data related to these same sites were provided by ***eriss*** but these were not extensive, limited by project constraints to specific times and parameters, and hence were not used.

Table 2.1 Details of data used

Data source	Site	Time span
Ranger	GS 8210028	30/7/80–10/2/99
	GS 8210067	19/2/91–5/5/99
	GS 8210009	23/6/80–4/8/99
NTDME	GS 8210028	11/1/79–11/5/99
	GS 8210067	12/4/83–18/4/96
	GS 8210009	5/12/78–9/6/99
NT Water Resources Division	GS 8210009	6/7/71–10/7/79

2.2 Parameters

The parameters which were investigated were pH, electrical conductivity (EC), turbidity, sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), ammonium (NH_4), chloride (Cl), nitrate (NO_3), sulphate (SO_4), copper (Cu), manganese (Mn), lead (Pb), radium (^{226}Ra), uranium (U) and zinc (Zn). With the exception of the physico-chemical parameters pH, EC and turbidity which are measured in unfiltered solutions, only dissolved constituents were considered in the data analysis since this fraction, in the absence of speciation refinement, is assumed to be totally bioavailable. However, preliminary investigations were first undertaken to establish whether residual (ie non-filterable) fractions were an important component of total metal concentrations in the Magela Creek system and Ranger mine waters.

For pH, EC and turbidity, analysis was limited to laboratory measurements because these data were common to all the databases unlike counterpart field determinations.

Dissolved material (operationally defined as the <0.45 µm fraction) dominates metal loads in Magela Creek. For example Hart et al (1981) found that around 70% of Cu, Mn and Zn, and almost all Cd were present in dissolved forms. According to the Ranger database, at GS 8210009 (GS 009) an average (±σ) 68.5% (±19.6)[1] of uranium is filterable compared with a mean of 48.4% (±20.8)[2] based upon NTDME data. Most of the time, residual U is present in low concentrations. For example at GS009 (Ranger database), almost 75% of data showed residual U at less than the detection limit (ie <0.1 µg/L). This is in keeping with findings by ***eriss*** (leGras, unpublished data; pers comm) which have shown that of the U present as a 'pseudo-total' (as determined by acidification of unfiltered waters to pH1) in Magela Creek, and effectively representative of potentially labile U, commonly >70% of the 'pseudo-total' is accounted for in the <15 nm fraction and is akin to the truly dissolved fraction.[3] Similarly for released mine waters at Ranger, data for the former RP4 has showed that virtually all the U is present consistently in the filterable fraction.[4] Consequently, the development of water quality objectives for Magela Creek, in which the characterisation of water chemistry is the first stage, has proceeded on the basis that the filterable metal fraction dominates its residual counterpart.

According to clause 3.3 of the ERs, there is a specific requirement on the company to determine values for conductivity, pH and uranium at GS8210009 and other key locations which are to be compared with background values. It also requires the determination of other 'key variables'. In this report, 'key variables' are delineated based either upon evidence of change to the chemistry of waters downstream of the mine, and:

1 water quality objectives in relation to averting potential hazards; or

2 their importance as 'master' variables or confounding factors in influencing the toxicity of contaminants.

2.3 Data handling, filtering and assumptions

Before the data were analysed, they were scanned and obvious transcription errors were removed. In cases where data were reported as being less than the detection limit, values equal to half the detection limit were substituted.

For heavy metals, uranium and radium in the Ranger database, only data collected from, but inclusive of, the start of the 1985–86 wet season was used for analysis. This is because prior to this time, metals were determined as 'pseudo-total' concentrations in acidified (<pH2) samples.

An initial inspection of the Ranger and NTDME databases revealed that the majority of samples taken upstream of Ranger were derived from GS 8210067 (GS 067). For example, in the case of pH which has been one of the most frequently measured parameters, only 54 data came from GS 8210028 (GS 028) but 245 from GS 067. For heavy metals in particular, the relative proportion of data which could be used in the Ranger database from GS 028 was

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[1] Median = 73.1% and range 10.0–99.8%; n = 244

[2] Median = 50.0% and range 3.6–93.6%; n = 143

[3] The 0.015–0.45 µm size range represents a colloidal fraction but operationally is rarely measured.

[4] Mean (±σ) = 95.7±5.3% of total U; median = 97.3%; range = 69.5–100%; n = 197.

much smaller since the majority of samples (>60%) pre-dated determination of soluble (<0.45 µm) metal concentrations. Consequently, datasets for GS 028 and 067 were combined to represent the chemistry of Magela Creek upstream of Ranger. In the absence of a larger dataset for GS 028, the validity of this approach cannot be tested but intuitively there is no reason to expect the chemistry of GS 028 and 067 to differ.

Similarly, the Ranger and NTDME databases were combined to provide upstream and downstream ie GS 8210009 (GS 009) datasets. This can be justified as follows. Firstly, there are more than 20 years of check monitoring by the NTDME of Ranger data that show good correspondence. For example in the most recent report (NTDME 1999) the following statement is made:

> There continues to be general agreement between the company's data and DME's check monitoring results. It is rare that discrepancies are found in the data, and where these occur they are often due to transcription errors or to contamination of samples. Should the difference not be due to a simple error, an investigation is initiated to verify the real values.

Secondly, the NTDME data are independent of the Ranger data in that they are derived from different sampling days and times, and sampling and analytical procedures and cannot be regarded as pseudo-replicates.

Data which pre-date mining at Ranger of relevance to this study are limited to GS 009 and were collected by the NT Water Resources Division (NTWRD). Whilst a number of analytes were recorded, the data derive from insensitive analytical techniques which render them virtually useless for the purposes of this study. The only exceptions are pH and EC. The potential usefulness of these data is in augmenting the baseline dataset but again raises the issue, discussed above in relation to GS 028 and 067, as to whether the data can be justifiably combined. This is discussed in more detail in section 3.2. As a record of pre-mining, only data that preceded and included the 1976–77 wet season were referred to.

2.4 Data analyses

Untransformed baseline data (incorporating the Ranger and NTDME databases for GS 067 and GS 028, and NTWRD GS 009 data) were first subjected to frequency distribution analysis in which their conformity to normality was tested using the Ryan and Joiner (R_p) statistic (Ryan & Joiner 1976). Where distributions were deemed appropriate, data were also log transformed and tested using the R_p statistic. No other data transformations were conducted. Untransformed or transformed data that approached normality were subsequently filtered no more than two times to remove outliers.[5] Descriptive statistics were then derived from these data.

Untransformed, unfiltered data for each parameter in the baseline dataset were also sorted and the median and 20th and 80th percentile values determined according to recommendations provided by the draft Australian water quality guidelines (ANZECC 1998) for non-normal data.

All data gathered from GS 009 during mining operation were also sorted and the median and mean values calculated. The proportion of values for each parameter which fell outside the 20th and 80th percentiles which described the baseline dataset were then determined for the GS 009 data and the values then listed so that any pattern in their temporal distribution might be discerned.

5 Defined as values lying >1.5 times away from the low (25th percentile) and high (75th percentile) boundaries set by the range of the middle 50% of the data.

3 Results

3.1 Overview

Results are summarised in tables 3.1–3.5. In subsequent sections, detail is provided on the properties of each parameter in the baseline dataset including data distribution and descriptive statistics. In the sections dealing with pH and EC, the inclusion of GS 009 pre-mining data is examined and in those dealing with Cu, Pb and Zn an historic assessment of toxicity testing of RP4 water on the interpretation of baseline values and risk is discussed.

3.2 pH and EC

Frequency distributions and descriptive statistics are provided for filtered pH and log normalised EC data in figures 3.1 and 3.2.

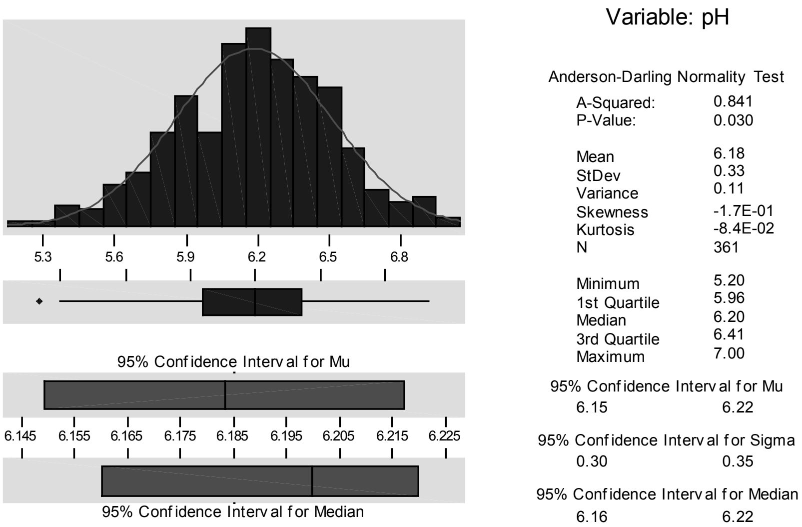

Figure 3.1 Frequency distribution of baseline pH values

Justification for including pre-mining data for GS 009 in the baseline dataset was investigated by conducting a one-way ANOVA against the Ranger and NTDME upstream datasets. The results are summarised in table 3.6.

The results indicate that for both pH and EC, the pre-mining GS 009 mean was significantly different ($p<0.05$) from the Ranger (upstream of the minesite) mean but not from the NTDME (upstream of the minesite) mean. Whilst there was no difference ($p>0.95$) in the average pH between the upstream datasets, the mean EC was significantly ($p<0.05$) lower for Ranger compared with NTDME data.

However, in effect, the differences in means between datasets for each parameter were relatively small spanning pH 6.05–6.20 and 14.2–19.6 µS/cm. Whether these differences arose out of operational procedures (eg differences in analytical protocols, pH probe calibration and response, time for degassing), environmental conditions or location is impossible to say.

Table 3.1 Baseline values at the 20th and 80th percentiles derived from sorting (non-parametric) and normalising data

Parameter	Non-parametric approach			Normal distribution approach		
	n	20th percentile	80th percentile	n	20th percentile	80th percentile
pH	366	5.90	6.45	361	5.91	6.46
EC (µS/cm)	493	12	21	490	12†	22†
Turbidity (NTU)	356	2.4	9.9	356	2.4†	10.3†
SO_4 (mg/L)	232	0.14	0.78	–	–	–
Mg (mg/L)	266	0.41	0.88	240	0.44†	0.89†
Ca (mg/L)	214	0.34	0.80	204	0.34†	0.80†
Na (mg/L)	150	1.03	1.70	141	1.02	1.67
K (mg/L)	149	0.15	0.40	–	–	–
Cl (mg/L)	125	1.80	3.00	–	–	–
NO_3 (mg/L)	122	0.01	0.05	–	–	–
NH_4 (mg/L)	76	0.010	0.025	–	–	–
Cu (µg/L)	105	0.50	1.00	–	–	–
Mn (µg/L)	224	3.3	10.4	211	3.3†	9.9†
Pb (µg/L)	122	0.20	0.50	–	–	–
U (µg/L)	260	0.05	0.30	–	–	–
Zn (µg/L)	93	1.0	13.0	–	–	–
^{226}Ra (mBq/L)	101	1.0	18.0	–	–	–

† Denotes log normal distribution with outliers removed

Table 3.2 Mean and standard deviation of normally distributed baseline parameters

	pH	EC (µS/cm)†	Turb (NTU)†	Mg (mg/L)†	Ca (mg/L)†	Na (mg/L)	Mn (µg/L)†
Mean	6.18	1.2073	0.6982	-0.2014	-0.2828	1.34	0.7601
SD	0.33	0.1544	0.3737	0.1779	0.2217	0.39	0.2826

† Denotes log values

Table 3.3 Median, range and mean values for the baseline unfiltered data

Parameter	n	Median	Minimum	Maximum	Mean
pH	366	6.20	4.20	7.00	6.16
EC (µS/cm)	493	16	5	75	18
Turbidity (NTU)	356	5.0	0.5	82.0	7.4
SO_4 (mg/L)	232	0.27	0.03	9.30	0.62
Mg (mg/L)	266	0.64	0.05	8.10	0.72
Ca (mg/L)	214	0.52	0.05	6.00	0.65
Na (mg/L)	150	1.30	0.05	5.50	1.40
K (mg/L)	149	0.22	0.05	1.80	0.30
Cl (mg/L)	125	2.1	0.8	24.0	2.8
NO_3 (mg/L)	122	0.03	0.002	0.43	0.049
NH_4 (mg/L)	76	0.01	0.01	0.18	0.022
Cu (µg/L)	105	0.60	0.1	3.49	0.84
Mn (µg/L)	224	5.6	0.5	180.0	10.3
Pb (µg/L)	122	0.50	0.01	22.00	0.98
U (µg/L)	260	0.10	0.013	24.95	0.62
Zn (µg/L)	93	2.5	0.5	81.0	9.4
^{226}Ra (mBq/L)	101	3.0	0.6	43.2	9.8

Table 3.4 Median, range and mean values at GS 8210009 during mining (unfiltered data)

Parameter	n	Median	Minimum	Maximum	Mean
pH	597	6.10	4.50	7.70	6.13
EC (µS/cm)	694	18	7	231	20
Turbidity (NTU)	612	4.0	0.5	89.0	6.0
SO_4 (mg/L)	417	0.79	0.05	18.58	1.68
Mg (mg/L)	545	0.80	0.05	5.30	0.98
Ca (mg/L)	417	0.45	0.05	2.40	0.48
Na (mg/L)	300	1.40	0.05	6.90	1.44
K (mg/L)	309	0.26	0.05	1.70	0.31
Cl (mg/L)	271	2.4	0.9	31.0	3.0
NO_3 (mg/L)	267	0.025	0.001	1.36	0.054
NH_4 (mg/L)	142	0.010	0.010	0.61	0.028
Cu (µg/L)	211	0.70	0.10	12.00	0.85
Mn (µg/L)	489	6.7	0.4	98.0	9.2
Pb (µg/L)	179	0.40	0.005	6.90	0.49
U (µg/L)	564	0.13	0.002	15.01	0.26
Zn (µg/L)	211	2.6	0.5	410.0	10.6
^{226}Ra (mBq/L)	237	2.74	0.76	63.0	7.13

Table 3.5 Proportion (%) of Ranger and NTDME 009 mining phase data that fall outside the upstream derived 20th and 80th percentiles

Parameter	ERA data	NTDME data
pH	37	42
EC (µS/cm)	41•	25•
Turbidity (NTU)	•31	38
SO_4 (mg/L)	59•	62•
Mg (mg/L)	50•	41•
Ca (mg/L)	•28	•17
Na (mg/L)	35	36
K (mg/L)	40	32•
Cl (mg/L)	33	41•
NO_3 (mg/L)	17	7
NH_4 (mg/L)	6	16
Cu (µg/L)	10	•52
Mn (µg/L)	29	44•
Pb (µg/L)	17	10
U (µg/L)	23•	20•
Zn (µg/L)	12	26•
^{226}Ra (mBq/L)	7	3

• Denotes distribution skewed towards 20th (left) or 80th (right) percentile

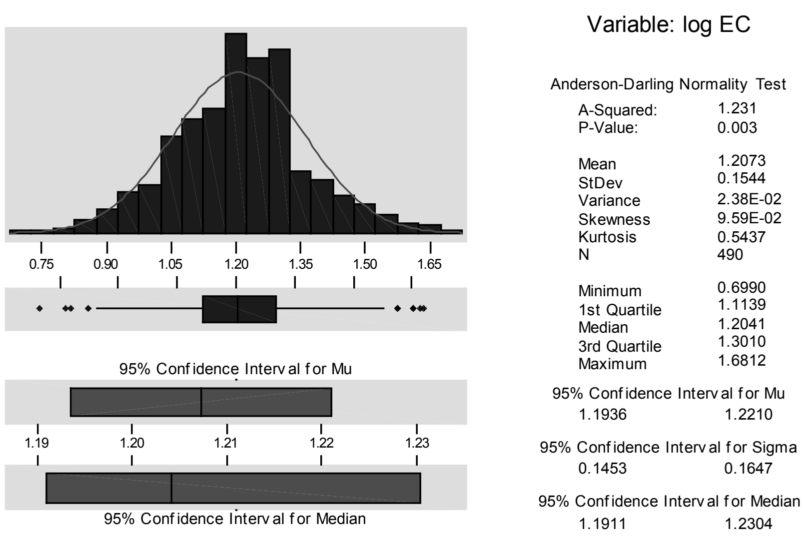

Figure 3.2 Frequency distribution of logged EC baseline values

Table 3.6 Results of one-way ANOVA of pH and log EC contained in the component parts of the baseline dataset showing means and least significant differences

	Dataset			LSD (95% level)		
Parameter	**Ranger (1)**	**NTDME (2)**	**NTWRD (3)**	**1 vs 2**	**1 vs 3**	**2 vs 3**
pH	6.20	6.15	6.05	0.14	0.14	0.11
log EC (uS/cm)	1.1533	1.2481	1.2921	0.0414	0.0561	0.0574

To assess whether the inclusion of GS 009 pre-mining data had a large influence on the features of the frequency distributions of baseline pH and EC, the GS 009 data were removed and the baseline data re-analysed (table 3.7). Changes resulting from removing this data were found to be minor and had no effect on the distributional features of pH and EC in the baseline dataset (ie compare tables 3.1 & 3.7). Consequently the results of the original data analysis for pH and EC as contained in tables 3.1–3.3 were retained.

Table 3.7 The effect of removing pre-mining GS 009 data from the baseline dataset on descriptive statistics

	Non-parametric approach				Normal distribution approach				
Variable	**n**	**Median**	**20th percentile**	**80th percentile**	**n**	**Mean**	**SD**	**20th percentile**	**80th percentile**
pH	299	6.20	5.90	6.45	296	6.20	0.30	5.92	6.49
EC	418	15.9	11.8	20.0	417	14.4†	1.4†	11.1†	21.9†

† Denotes a conversion from logged values

3.3 Turbidity

Data are summarised in figure 3.3.

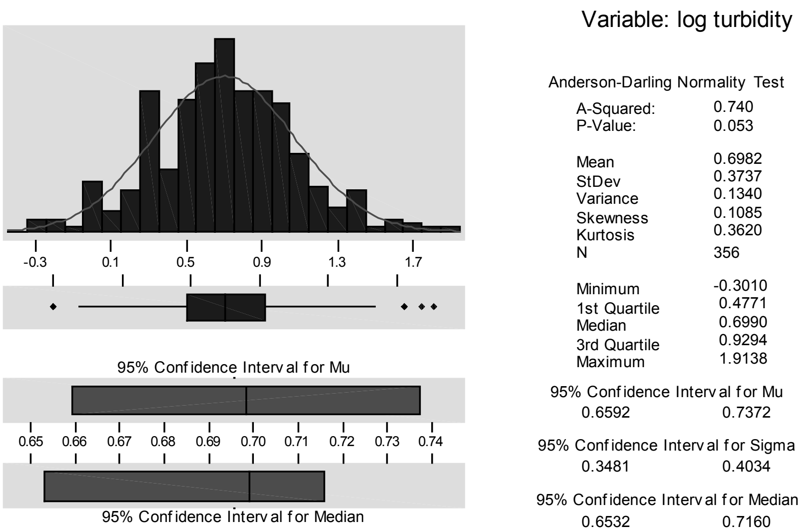

Figure 3.3 Frequency distribution of logged turbidity baseline values

3.4 Sulphate and chloride

Data are summarised in figures 3.4–3.7. The large majority of sulphate data (90%) were <1 mg/L SO_4^{2-} with values >2 mg/L probably suspect. The possibility of erroneous conclusions being drawn from the inclusion of early sulphate data for which detection limits were relatively high at 1 mg/L was checked. It was found that relatively few suspect data were present (n≈20) and that their inclusion had a very small effect on data distribution (of around 0.02 mg/L on the median). Consequently, it was decided not to exclude these data. For chloride, around 91% of the data were <4 mg/L, with values >6 mg/L suspect.

3.5 Magnesium and calcium

Magnesium and calcium data were normalised by taking logarithms and frequency distributions are shown in figures 3.8 and 3.9.

3.6 Sodium and potassium

Sodium data were found to be normal after filtering outliers (figure 3.10). Potassium data were non-normal and are shown in figures 3.10 and 3.11.

3.7 Ammonium and nitrate

Results are shown in figures 3.13–3.16. Most samples in the Ranger database were at or below the detection limits for ammonium (ie 0.05 mg NH_4^+/L) and nitrate (0.05–0.1 mg NO_3^-/L).

3.8 Manganese

Transformation by taking logarithms provided an approximately normal distribution and this is shown in figure 3.17.

3.9 Uranium and radium-226

Uranium and ^{226}Ra data are given in figures 3.18–3.21. Around 60% of the U data were at or below the detection limit of 0.1 µg/L. The majority of samples >0.1 µg U/L probably reflect contamination to varying degrees. For ^{226}Ra, about 95% of samples showed concentrations <0.02 Bq/L. The stepped form to the cumulated frequency distribution for ^{226}Ra most likely reflects differences in the analytical procedures that were used and their sensitivities.

3.10 Copper, lead and zinc

Data are summarised in figures 3.22–3.27. For Cu, most (~90%) samples were around the detection limit of 0.5–1.0 µg/L (figure 3.23). Similarly for Pb, over 90% of samples were ≤1 µg/L (figure 3.25) which was the detection limit that applied to most of the Ranger database. Whilst Cu and Pb showed relatively few spurious data, a large proportion of the Zn data was suspect. Taking 5 µg Zn/L as an upper limit for pristine waters upstream of the mine, this implies that at least 40% of the samples showed Zn contamination from sample handling or laboratory procedures.

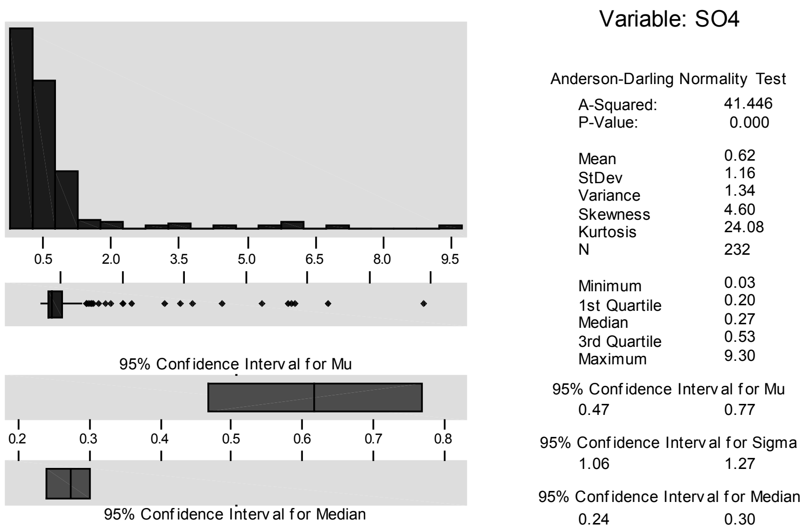

Figure 3.4 Frequency distribution of sulphate baseline values

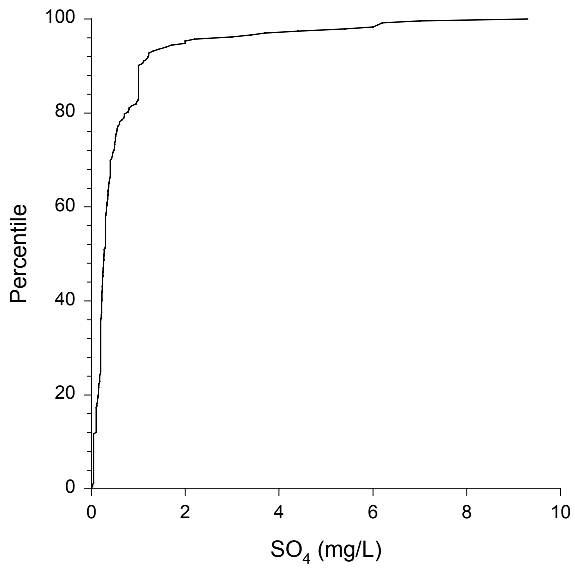

Figure 3.5 Percentile values for sulphate

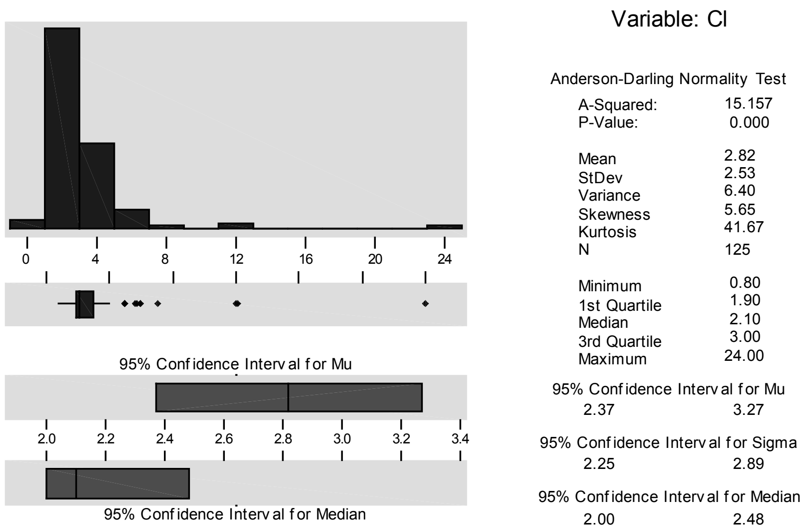

Figure 3.6 Frequency distribution of chloride baseline values

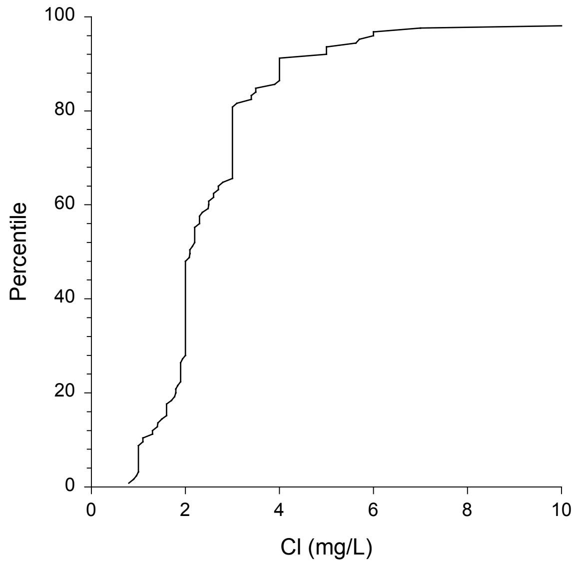

Figure 3.7 Percentile values for chloride

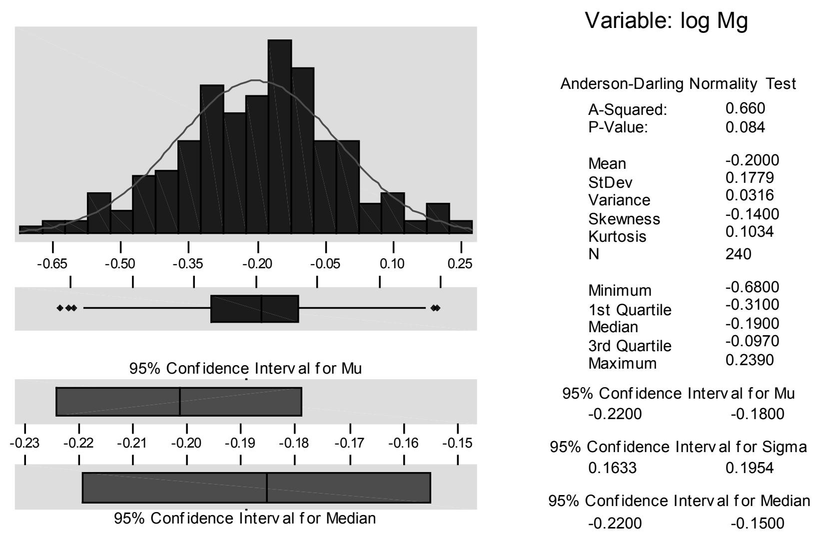

Figure 3.8 Frequency distribution of logged magnesium baseline values

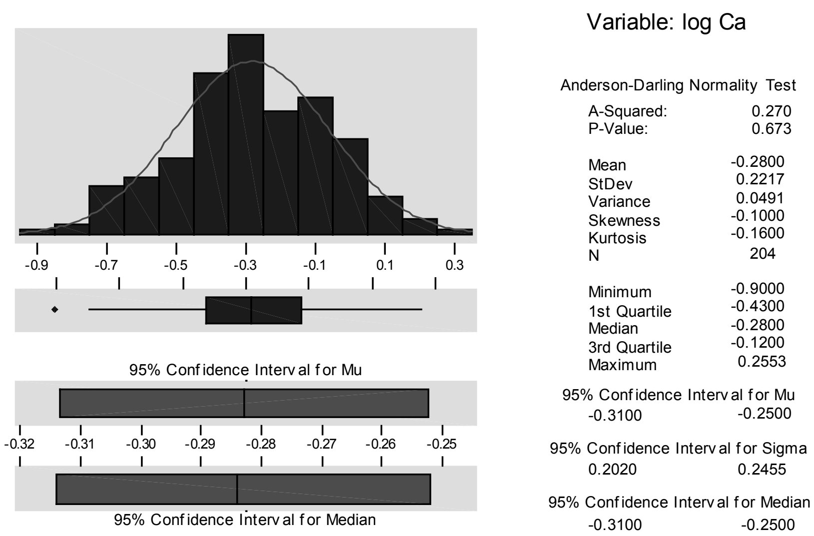

Figure 3.9 Frequency distribution of logged calcium baseline values

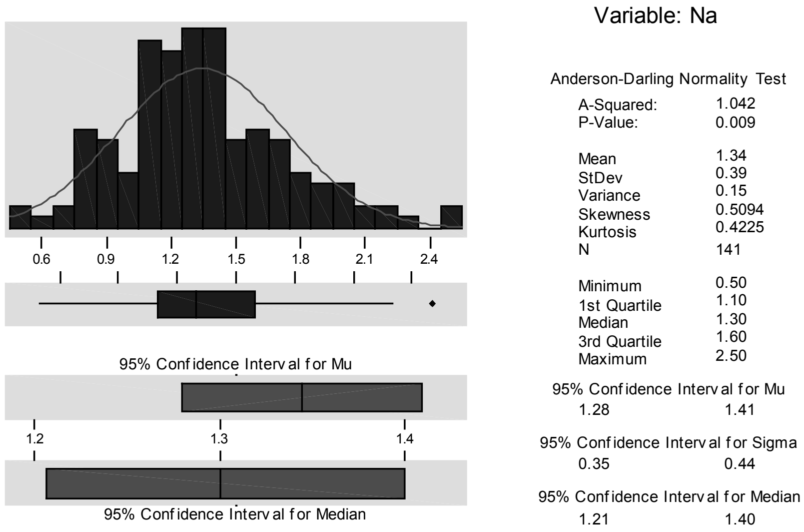

Figure 3.10 Frequency distribution of sodium baseline values

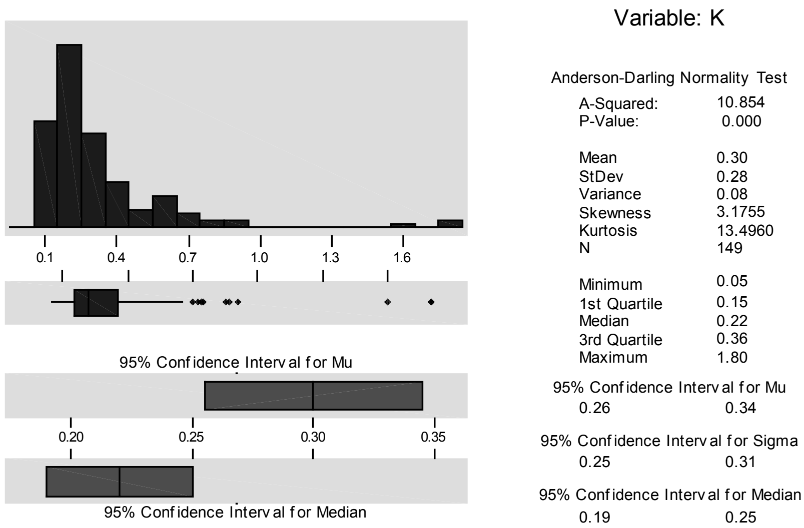

Figure 3.11 Frequency distribution of potassium baseline values

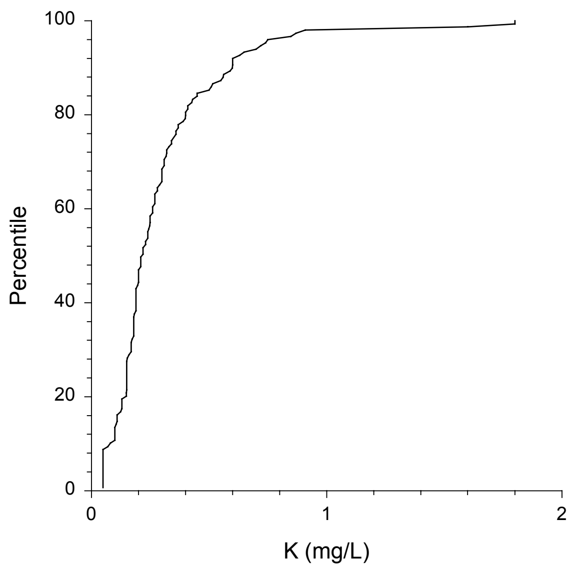

Figure 3.12 Percentile values for potassium

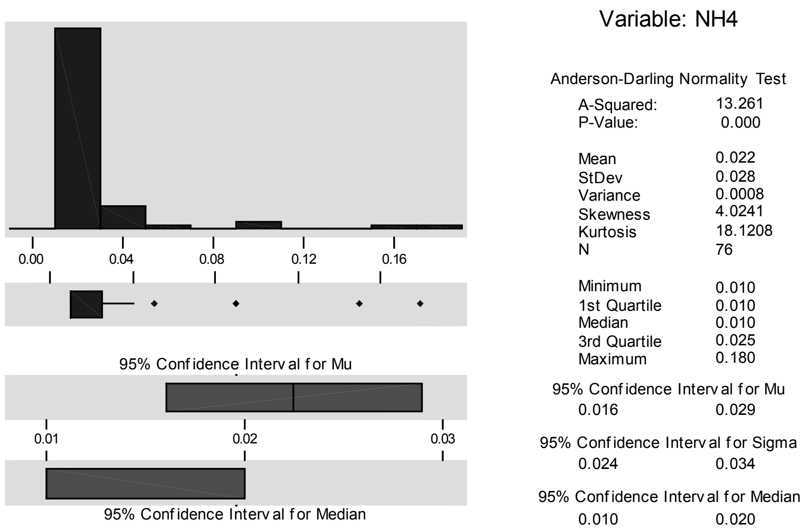

Figure 3.13 Frequency distribution of ammonium baseline values

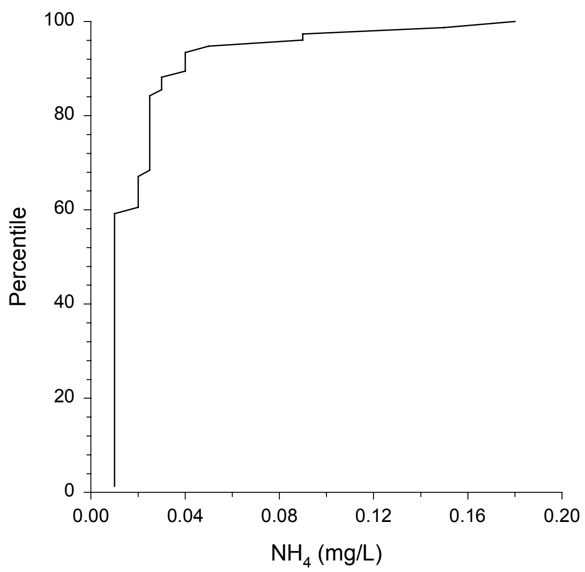

Figure 3.14 Percentile values for ammonium

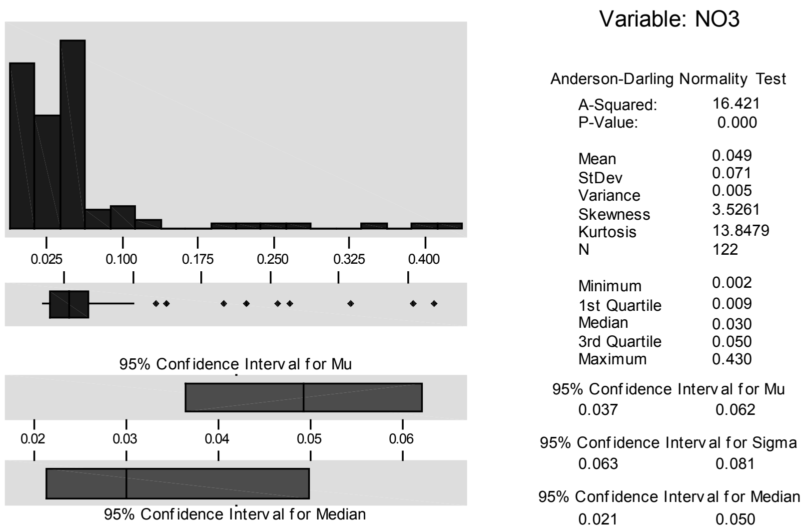

Figure 3.15 Frequency distribution of nitrate baseline values

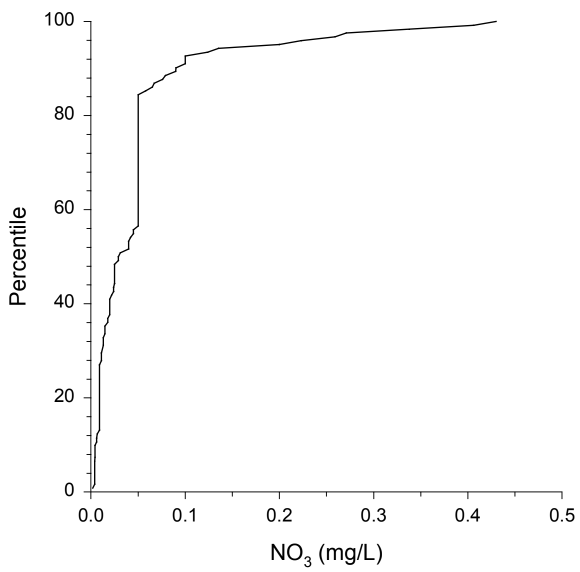

Figure 3.16 Percentile values for nitrate

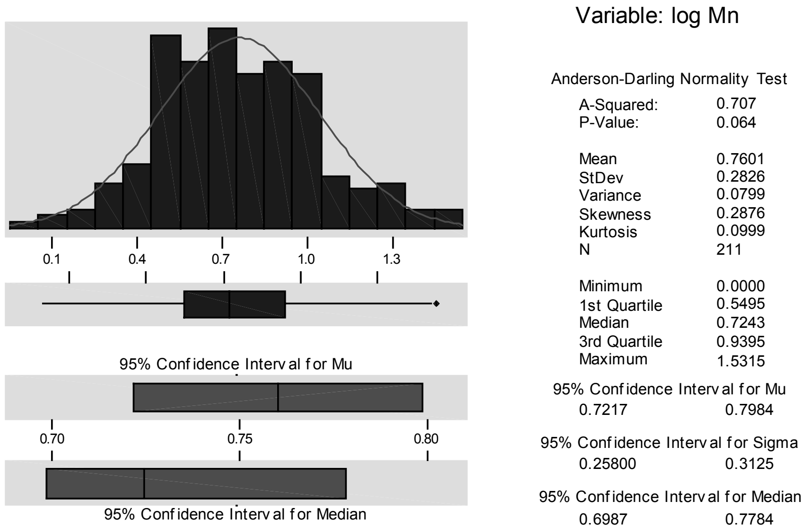

Figure 3.17 Frequency distribution of logged manganese baseline values

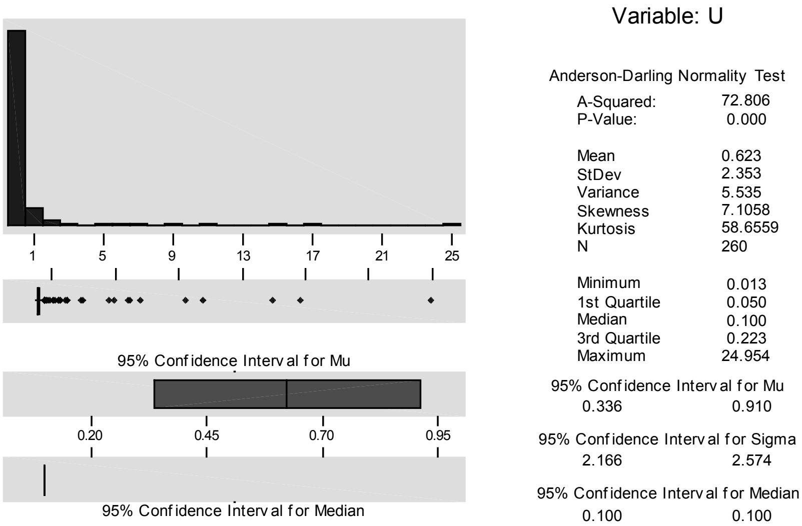

Figure 3.18 Frequency distribution of uranium baseline values

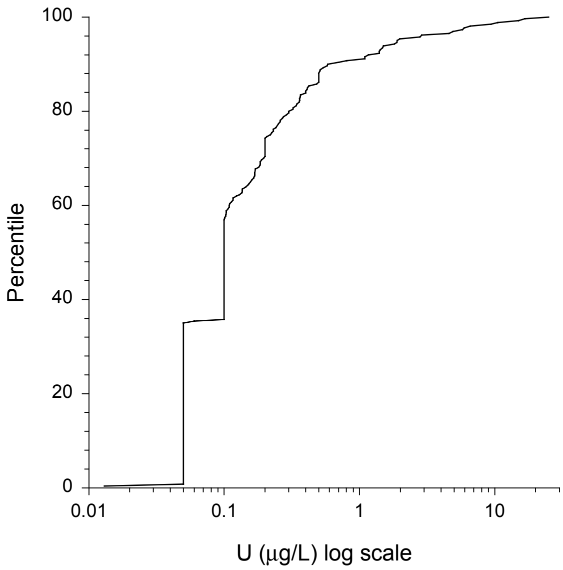

Figure 3.19 Percentile values for uranium (note the log scale)

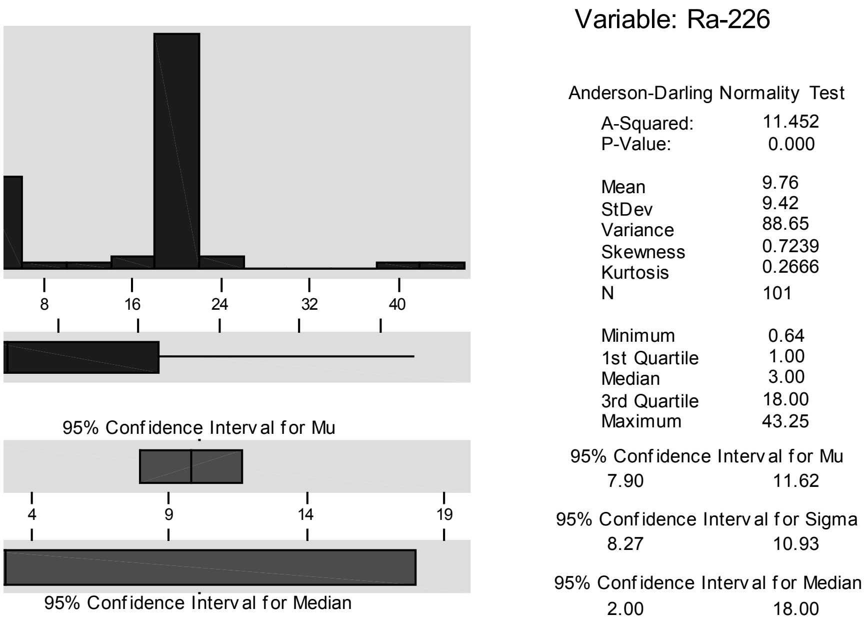

Figure 3.20 Frequency distribution of radium-226 baseline values

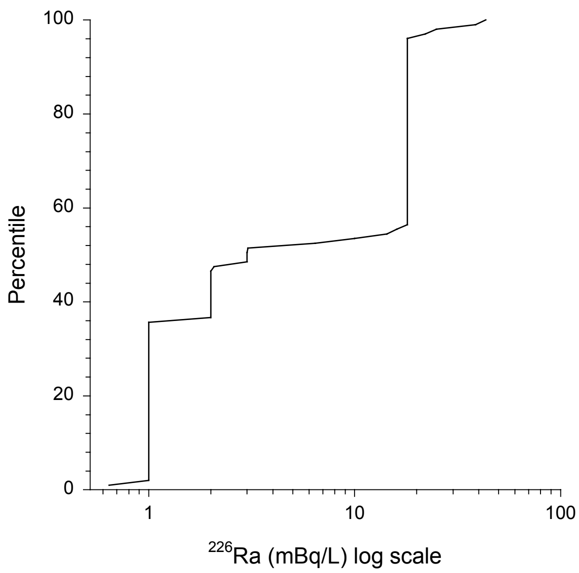

Figure 3.21 Percentile values for radium-226 (note the log scale)

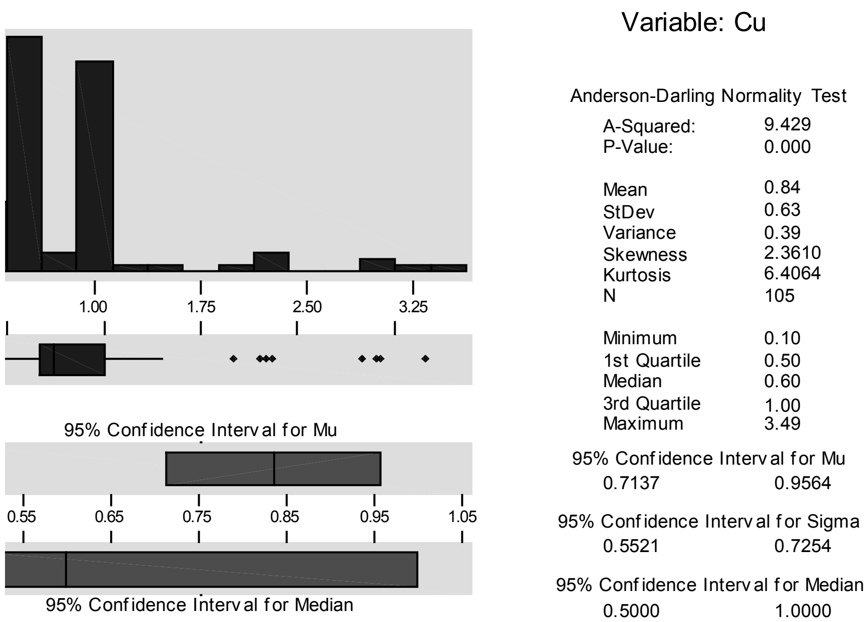

Figure 3.22 Frequency distribution of copper baseline values

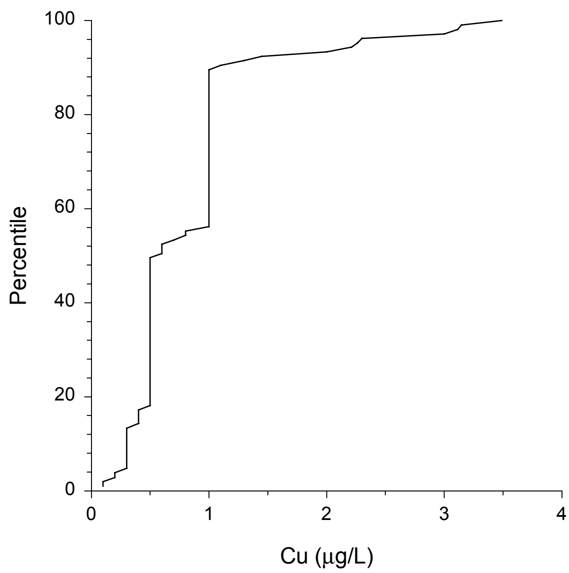

Figure 3.23 Percentile values for copper

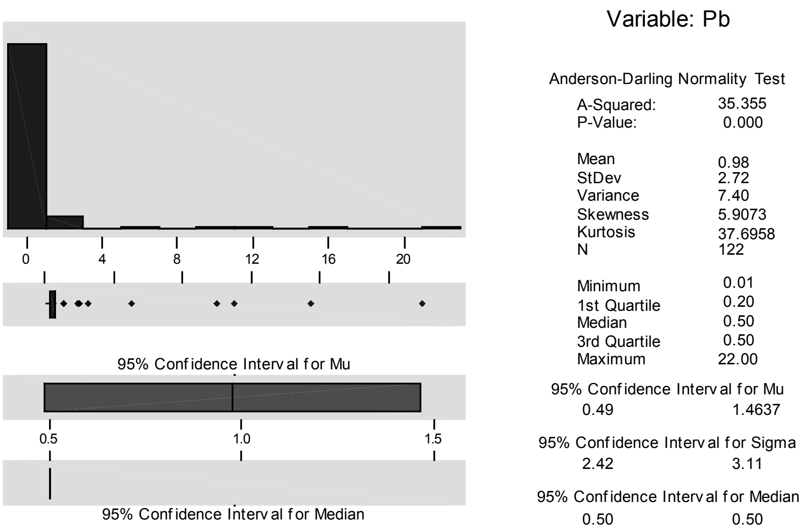

Figure 3.24 Frequency distribution of lead baseline values

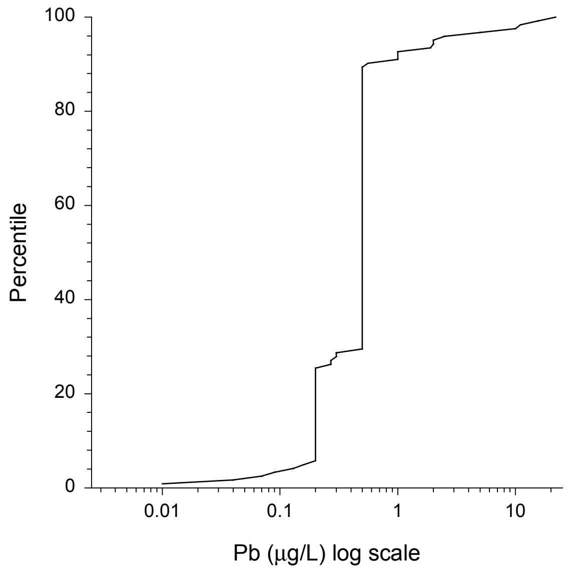

Figure 3.25 Percentile values for lead

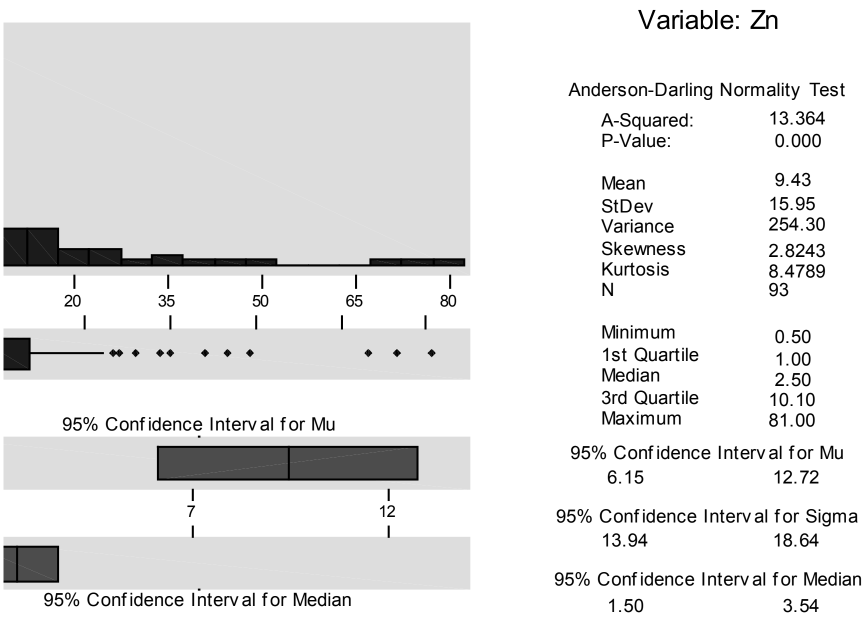

Figure 3.26 Frequency distribution of zinc baseline values

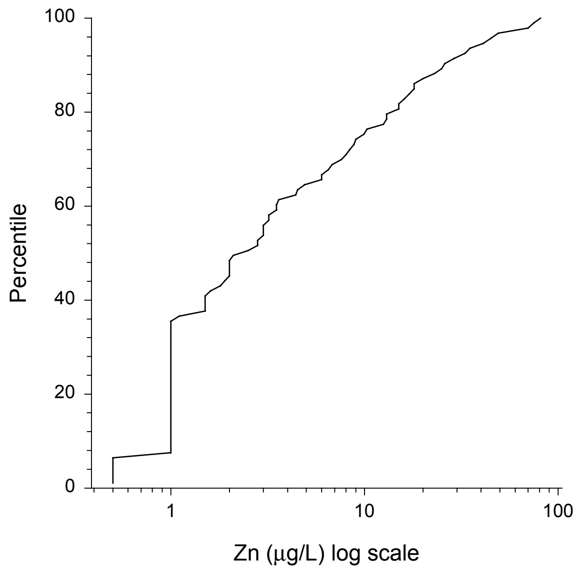

Figure 3.27 Percentile values for zinc

In the absence of a clear baseline for Cu, Pb and Zn, reference was made to the proposed ANZECC water quality guideline trigger values for toxicants (ANZECC 1998). Trigger values for freshwater are given in table 3.8 and are level 1 except for Mn and U which are level 2. In addition, no water hardness correction has been made for Cu, Pb and Zn so that the values given in table 3.8 are conservative.

Table 3.8 Trigger values for inorganic toxicants

	Cu (µg/L)	Mn (µg/L)	Pb (µg/L)	U (µg/L)	Zn (µg/L)
Trigger value	0.33	47	1.2	3.5	2.4

In each case the baseline is too ill-defined for Cu, Pb and Zn to assess risk based only on metal concentrations in Magela Creek upstream and downstream of the mine. Consequently, the composition of retention pond waters at Ranger was examined to ascertain the effect their release might have on the concentration of dissolved metals in Magela Creek (table 3.9). In addition, the results of over 10 years of whole-effluent toxicity testing of RP4 release waters were reviewed to determine the dilutions at which the No-Observed-Effect-Concentration (NOEC) and Lowest-Observed-Effect-Concentration (LOEC) were shown.

Table 3.9 Copper, lead and zinc contents of retention pond waters (derived from the ERA Ranger database)

Metal	Summary statistics	RP4	RP4W	RP2
Cu	n	168	32	131
	Median (µg/L)	1.00	1.00	3.00
	Range (µg/L)	0.50–6.54	0.42–5.66	1.00–15.00
	Mean±SD (µg/L)	1.40±0.99	1.19±0.89	3.80±3.02
Pb	n	149	25	112
	Median (µg/L)	0.50	0.50	0.50
	Range (µg/L)	0.005–10.00	0.10–3.00	0.10–10.00
	Mean±SD (µg/L)	0.69±0.98	0.94±0.71	0.98±1.26
Zn	n	171	34	132
	Median (µg/L)	1.00	1.00	6.81
	Range (µg/L)	0.50–20.00	1.00–33.68	1.00–115.9
	Mean±SD (µg/L)	1.62±1.90	5.42±9.05	12.26±16.39

From a check of ***eriss*** records, there was often no toxicity response at concentrations of 0, 0.3, 1.0, 3.2, 10, 32% RP4 water (Rick van Dam, pers comm). When there was a response, the NOEC and LOEC were usually 10 and 32% RP4 water, respectively. Data for Cu, Pb and Zn in RP4 water (figures 3.26–3.29) indicate that ≥90% were either ≤2 µg Cu/L, ≤1 µg Pb/L or ≤5 µg Zn/L. Hence any differences between baseline concentrations in Magela Creek and the waters of the former RP4 cannot be differentiated but that does not discount the possibility that differences in Cu, Pb and Zn might exist which might only be quantified by a sufficiently sensitive analytical technique. In practical terms, however, the results demonstrate that Cu, Pb and Zn are unlikely to be of concern in mine waters (represented by RP4 in table 3.9) entering the Magela Creek given dilutions of greater than 1 in 20 with Cu are achieved.[6]

[6] Compare the ratios of maximum RP4 concentrations (table 3.9) to ANZECC trigger values (table 3.8)

3.11 GS 009

The proportions of GS 009 data that fall within the 20th and 80th baseline percentiles are summarised in table 3.5. There was good conformity between upstream and downstream data in pH, EC, turbidity, Na, K, and Cl. In addition, for Ca, NO_3, NH_4, Pb, U and Zn less than 40% of the GS 009 data set fell outside the percentile boundaries but in the case of U the data were skewed towards relatively high values. A larger proportion of Mg and SO_4 data from GS 009 were outside the 20^{th} and 80^{th} baseline percentiles and these were also skewed towards high values. There were some differences between the Ranger and NTDME data notably in the distributions of Mn and ^{226}Ra values.

Data that fell outside the 20th and 80th percentiles are listed for each parameter and database in appendix 1. These data are important for discerning and verifying the temporal patterns of, or environmental effects on, measured parameters. For example, taking account of first flush and its manifestations to elevated salt load and active acidity (ie lower pH) may account for abnormal results.

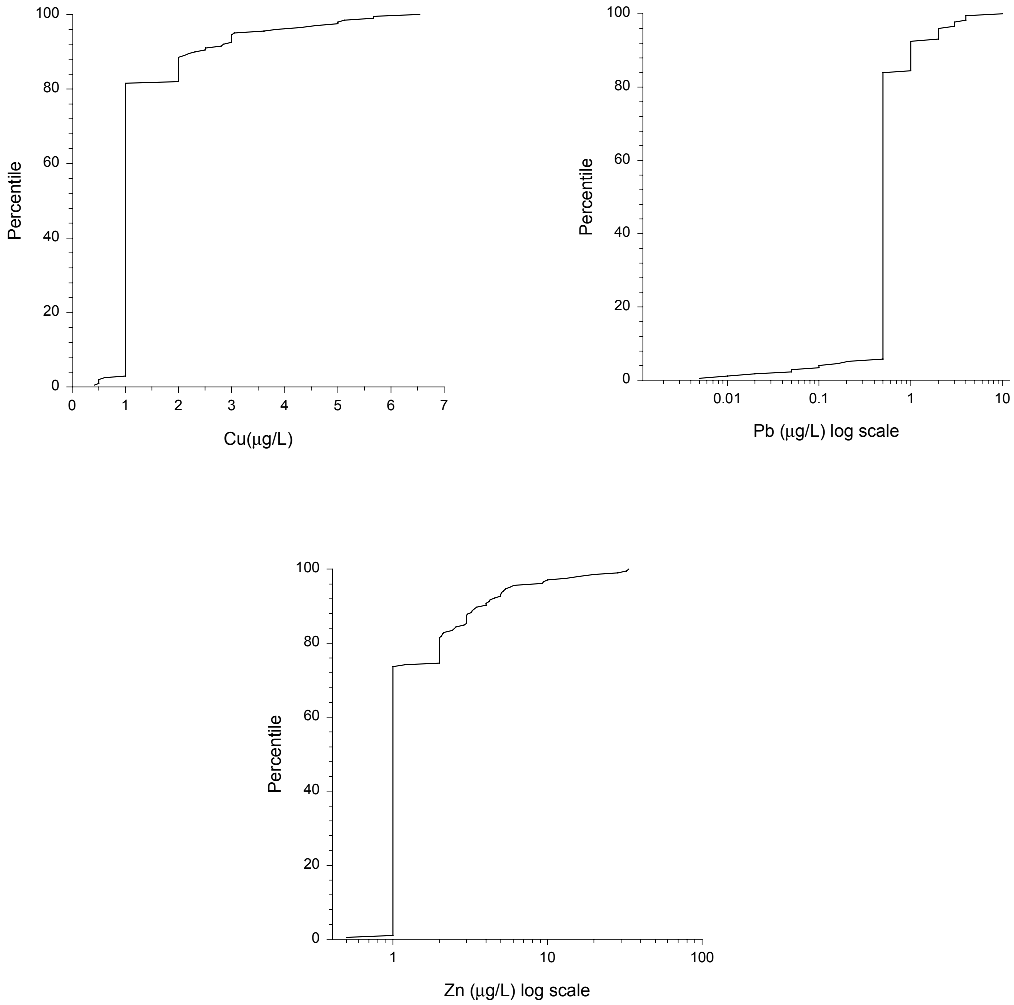

Figure 3.28 Percentile values for copper, lead and zinc in RP4 water

Conclusions

The following conclusions are reached:

- With the exception of pH, EC (logged), turbidity (logged), magnesium (logged), calcium (logged), sodium and manganese (logged), data that comprised the baseline were not normally distributed.
- The frequency distributions of copper, lead, zinc, uranium and radium-226 forming the baseline were characterised by (1) a large proportion of values at or near analytical detection limits and (2) contamination in a relatively large proportion of the remainder.
- A comparison of upstream and downstream data showed that there was good conformity in pH, EC, turbidity, sodium, potassium and chloride. For calcium, nitrate, ammonium, lead, uranium and zinc less than 40% of the downstream data fell outside the 20th and 80th baseline percentiles but in the case of U, data were biased towards relatively high values. For magnesium and sulphate measured downstream, more than 40% of data were outside these percentile boundaries and were skewed towards relatively high concentrations.
- Copper, lead and zinc do not appear to pose a risk as contaminants given that a dilution ratio of greater than 1 in 20 of mine waters, characterised by the composition of dissolved metals in waters contained in the former RP4, is achieved in Magela Creek.

References

Australian and New Zealand Environment and Conservation Council (ANZECC) 1998. Australian water quality guidelines for fresh and marine water. Volume 1: The guidelines. Draft, ANZECC & ARMCANZ, August 1998.

Hart BT, Davies SHR & Thomas PA 1981. *Transport of trace metals in the Magela Creek system, Northern Territory: I Concentrations and loads of iron, manganese, cadmium, copper, lead and zinc during flood periods in the 1978–1979 Wet season.* Technical memorandum 1, Supervising Scientist for the Alligator Rivers Region, AGPS, Canberra.

Northern Territory Supervising Authorities, Alligator Rivers Region 1999. Environmental surveillance monitoring in the Alligator Rivers Region. Report for the period ending 31 March 1999. Report 37, Northern Territory Department of Mines and Energy, Darwin.

Ryan TA & Joiner BL 1976. Normal probability plots and tests for normality. http://www.minitab.com/resources/whitepapers/normprob.htm. accessed November 1999.

Appendix 1

GS009 sample dates and concentrations of values <20th and >80th percentiles as derived from baseline (upstream) data for water quality parameters

The analyses listed in the following pages derive from Ranger (pp 30–41) and NTDME (pp 42–55) data.

Ranger 009								
Date	**pH<5.9**	**Date**	**pH<5.9**		**Date**	**pH>6.45**	**Date**	**pH>6.45**
06-Dec-80	5.8	25-Feb-93	5.86		23-Jun-80	6.9	03-Jun-98	6.53
27-Jan-81	5.8	26-Feb-93	5.62		26-Mar-81	7.7	01-Jul-98	6.59
22-Apr-81	5.6	27-Feb-93	5.5		19-May-81	6.7	13-Jan-99	6.46
07-Dec-83	5.6	28-Feb-93	5.62		05-Apr-82	6.6	20-Jan-99	6.67
05-Jan-84	5.8	01-Mar-93	5.62		04-May-82	6.6	12-Feb-99	6.57
08-Feb-84	5.7	02-Mar-93	5.8		07-Jun-82	6.6	14-Feb-99	6.59
17-Apr-85	5.8	03-Mar-93	5.47		13-Mar-85	6.5	18-Feb-99	6.54
28-Jan-86	5.8	05-Mar-93	5.54		15-Mar-85	6.5	24-Feb-99	6.48
29-Jan-86	5.8	06-Mar-93	5.82		19-Mar-85	6.7	27-Feb-99	6.46
03-Feb-86	5.7	07-Mar-93	5.78		03-Apr-85	6.5	28-Feb-99	6.63
04-Feb-86	5.6	09-Mar-93	5.72		02-May-85	6.6	01-Mar-99	6.85
05-Feb-86	5.8	21-Mar-93	5.88		04-Jun-85	6.5	22-Mar-99	6.69
11-Feb-86	5.8	11-Dec-95	5.72		09-Jul-85	6.7	29-Mar-99	6.86
11-Feb-86	5.8	31-Jan-96	5.88		03-Mar-86	6.5	07-Apr-99	6.48
10-Mar-86	5.7	05-Mar-97	5.6		06-Apr-87	6.5	09-Apr-99	6.85
20-Jan-87	5.7	28-Jan-98	5.84		09-Mar-89	6.5	12-Apr-99	6.69
02-Feb-87	5.8		n =74		06-Feb-94	6.62	14-Apr-99	6.63
03-Feb-87	5.7				07-Feb-94	6.59	16-Apr-99	6.78
04-Feb-87	5.7				08-Feb-94	6.46	19-Apr-99	6.92
07-Feb-87	5.7		N = 421		24-Feb-94	6.89	21-Apr-99	6.84
20-Feb-89	5.8				16-Mar-94	6.73	28-Apr-99	6.62
21-Feb-89	5.5				23-Mar-94	6.55	05-May-99	6.82
22-Feb-89	5.8				30-Mar-94	6.59	03-Jun-99	6.69
11-Mar-89	5.7				06-Apr-94	6.5	07-Jul-99	6.63
12-Mar-89	5.7				20-Apr-94	6.61		n = 82
17-Mar-89	5.8				12-May-94	6.61		
21-Mar-89	5.8				22-Feb-95	6.81		
26-Mar-89	5.8				08-Mar-95	6.76		
06-Jun-90	5.8				22-Mar-95	6.85		
02-Jan-91	5.8				29-Mar-95	6.52		
05-Feb-91	5.6				05-Apr-95	6.88		
22-Feb-91	5.8				13-Apr-95	7.13		
23-Feb-91	5.6				04-May-95	6.9		
24-Feb-91	5.8				06-Jun-95	7.03		
26-Feb-91	5.8				03-Jul-95	6.64		
28-Feb-91	5.3				02-Aug-95	7.12		
01-Mar-91	5.3				27-Mar-96	6.51		
03-Mar-91	5.4				01-Apr-96	6.53		
10-Mar-91	5.5				24-Apr-96	6.55		
17-Mar-91	5.8				08-May-96	6.75		
02-Apr-91	5.8				15-May-96	6.91		
04-Apr-91	5.8				04-Jun-96	6.72		
04-Apr-91	5.7				08-Jan-97	6.46		
07-Apr-91	5.5				22-Jan-97	6.56		
08-Apr-91	5.8				05-Feb-97	6.8		
10-Apr-91	5.3				12-Feb-97	7		
14-Apr-91	5.7				19-Feb-97	6.8		
16-Apr-91	5.1				12-Mar-97	7		
26-Apr-91	5.5				19-Mar-97	6.9		
07-Jun-91	5.7				26-Mar-97	7		
06-Jan-92	5.77				09-Apr-97	7		
06-Feb-92	5.59				02-Jun-97	7.1		

Ranger 009								
Date	**EC<12**		**Date**	**EC>21**	**Date**	**EC>21**	**Date**	**EC>21**
27-Jan-81	9.981		23-Jun-80	26.616	24-Apr-91	21.071	02-Apr-97	24
27-Jan-81	8.872		06-Dec-80	22.18	09-Dec-91	33.27	22-Apr-98	21.1
05-Apr-83	9.981		30-Dec-80	23.289	27-Feb-93	25.7	18-Nov-98	30.4
08-Feb-84	11.09		04-May-82	21.071	06-Mar-93	39	13-Jan-99	23.8
12-Mar-85	11.09		05-Feb-87	21.071	07-Mar-93	31.5	20-Jan-99	28.8
03-Mar-93	7.32		11-Feb-87	27.725	18-Mar-93	25.2	03-Feb-99	23.2
09-Mar-94	11.48		12-Feb-87	24.398	20-Mar-93	27.1	14-Feb-99	23.6
05-Apr-95	11.05		13-Feb-87	22.18	21-Mar-93	25.3	18-Feb-99	22.3
31-Jan-96	11.9		14-Feb-87	25.507	22-Mar-93	23.2	24-Feb-99	26.8
07-Feb-96	11.23		15-Feb-87	22.18	05-Apr-93	22.5	27-Feb-99	25.4
03-Jan-97	8		16-Feb-87	22.18	05-May-93	24.8	09-Apr-99	26.3
29-Jan-97	9		18-Feb-87	28.834	05-Feb-94	33.6	12-Apr-99	31.4
12-Feb-97	10		18-Feb-87	25.507	06-Feb-94	24.6	14-Apr-99	34.2
19-Feb-97	8		24-Feb-87	28.834	07-Feb-94	34.6	16-Apr-99	38.3
26-Feb-97	10.66		26-Feb-87	23.289	08-Feb-94	38	19-Apr-99	37.1
05-Mar-97	9		27-Feb-87	22.18	09-Feb-94	34.7		n = 131
21-Jan-98	11.16		07-May-87	22.18	12-Feb-94	32		
28-Jan-98	9.25		01-Dec-88	21.071	13-Feb-94	25.3		
11-Feb-98	11.66		13-Mar-89	37.706	15-Feb-94	41.4		N = 422
18-Feb-98	11.93		14-Mar-89	24.398	17-Feb-94	46.8		
25-Feb-98	8.78		15-Mar-89	37.706	18-Feb-94	34.6		
04-Mar-98	8.79		16-Mar-89	21.071	19-Feb-94	39.4		
30-Dec-98	11.63		17-Mar-89	24.398	20-Feb-94	44.8		
10-Feb-99	7.22		18-Mar-89	26.616	24-Feb-94	23.6		
11-Feb-99	11.45		19-Mar-89	26.616	16-Mar-94	36.4		
15-Feb-99	10.19		20-Mar-89	43.251	23-Mar-94	56		
16-Feb-99	9.08		21-Mar-89	39.924	30-Mar-94	33.9		
25-Feb-99	8.13		22-Mar-89	31.052	06-Apr-94	27.4		
02-Mar-99	9.91		23-Mar-89	39.924	13-Apr-94	29.9		
03-Mar-99	9.17		24-Mar-89	31.052	18-Apr-94	22.9		
04-Mar-99	9.86		25-Mar-89	24.398	20-Apr-94	22.5		
05-Mar-99	10.24		19-Dec-89	24.398	12-May-94	33		
08-Mar-99	7.79		19-Feb-91	65.431	06-Jun-94	62.8		
10-Mar-99	8.05		20-Feb-91	26.616	02-Aug-94	47.3		
11-Mar-99	8.72		21-Feb-91	59.886	23-Dec-94	26.4		
12-Mar-99	7.72		22-Feb-91	45.469	06-Jan-95	23.8		
15-Mar-99	6.92		24-Feb-91	23.289	25-Jan-95	26.4		
19-Mar-99	9.65		25-Feb-91	55.45	01-Feb-95	40.3		
22-Mar-99	11.56		26-Feb-91	42.142	08-Feb-95	21.6		
30-Mar-99	11.7		27-Feb-91	44.36	15-Feb-95	26.3		
31-Mar-99	9.9		28-Feb-91	26.616	22-Feb-95	33.7		
05-Apr-99	10.52		01-Mar-91	22.18	01-Mar-95	24		
	n = 42		02-Mar-91	25.507	08-Mar-95	22.9		
			03-Mar-91	23.289	15-Mar-95	22.6		
			04-Mar-91	21.071	22-Mar-95	21.8		
			05-Mar-91	22.18	29-Mar-95	25.8		
			08-Mar-91	22.18	12-Apr-95	46.6		
			11-Mar-91	22.18	13-Apr-95	44.1		
			24-Mar-91	24.398	18-Apr-95	23.9		
			08-Apr-91	34.379	06-Jun-95	21.4		
			09-Apr-91	25.507	03-Jul-95	23.2		
			10-Apr-91	22.18	02-Aug-95	28.8		

Ranger 009					
Date	Turb<2.4	Date	Turb<2.4	Date	Turb>9.9
19-May-81	2	04-May-95	2	23-Jun-80	50
04-Jan-82	2	06-Jun-95	0.5	06-Dec-80	28
05-Apr-82	2	03-Jul-95	0.5	26-Mar-81	49
04-May-82	0.5	02-Aug-95	1	06-Mar-84	10
07-Jun-82	1	06-Feb-96	2	12-Mar-85	18
07-Feb-83	2	06-Mar-96	2	25-Jan-86	11
01-Mar-83	2	01-May-96	2	03-Feb-86	56
06-Jun-83	1	08-May-96	2	04-Feb-86	16
05-Jul-83	1	15-May-96	1	10-Mar-86	11
04-May-84	2	04-Jun-96	1	20-Jan-87	16
05-Jun-84	2	04-Jul-96	0.5	02-Feb-87	10
05-Mar-85	2	09-Apr-97	2	03-Feb-87	10
04-Jun-85	1	08-May-97	1	04-Feb-87	10
09-Jul-85	1	02-Jun-97	1	06-Feb-87	20
03-Mar-86	2	01-Apr-98	2	07-Feb-87	13
04-Apr-86	2	15-Apr-98	2	10-Feb-87	15
08-May-86	1	22-Apr-98	2	11-Feb-87	10
06-Apr-87	2	29-Apr-98	1	12-Feb-87	10
04-Mar-88	2	06-May-98	2	13-Feb-87	12
13-Apr-88	2	13-May-98	1	17-Mar-89	10
05-May-88	1	03-Jun-98	1	03-Mar-93	13
01-Dec-88	2	01-Jul-98	1	17-Mar-93	24
12-Jan-89	2	18-Nov-98	2	23-Dec-93	13
09-Mar-89	2	21-Apr-99	2	04-Feb-94	15
13-Mar-89	2	05-May-99	1.5	16-Feb-94	11
27-Mar-89	2	03-Jun-99	0.9	09-Mar-94	13
19-Apr-89	2	07-Jul-99	0.8	16-Jan-95	13
15-May-89	0.5		n = 85	11-Dec-96	37
19-Jun-89	0.5			22-Jan-97	11
19-Jan-90	2			25-Feb-98	10
05-Feb-90	1		N = 381	01-Dec-98	11
10-May-90	1			16-Dec-98	18.75
06-Jun-90	1			10-Feb-99	30.6
01-Mar-91	2				n = 33
26-Mar-91	0.5				
28-Mar-91	2				
22-Apr-91	2				
24-Apr-91	2				
29-Apr-91	2				
03-May-91	1.54				
07-May-91	1				
13-May-91	1				
07-Jun-91	1.03				
06-Feb-92	1.151				
15-Apr-92	2.34				
13-May-92	1.2				
05-Apr-93	2				
05-May-93	2				
30-Mar-94	2				
18-Apr-94	2				
20-Apr-94	2				
12-May-94	1				

Ranger 009				
Date	**Ca<0.34**		**Date**	**Ca>0.80**
27-Jan-81	0.2		23-Jun-80	0.83
27-Jan-81	0.21		06-Dec-80	1.1
25-Feb-81	0.3		30-Nov-81	0.9
02-Mar-82	0.3		20-Mar-89	0.86
05-Apr-82	0.28		21-Mar-89	0.82
04-Jan-83	0.32		23-Mar-89	0.93
17-Mar-83	0.32		19-Dec-89	1.1
05-Apr-83	0.2		19-Feb-91	1.2
03-May-83	0.32		21-Feb-91	1.2
19-Apr-85	0.28		22-Feb-91	1
22-Jan-86	0.3		25-Feb-91	1.1
14-Jan-88	0.29		26-Feb-91	0.82
04-Mar-88	0.29		27-Feb-91	0.94
13-Apr-88	0.3		05-Mar-91	0.82
21-Feb-89	0.28		07-Mar-91	1.3
09-Mar-89	0.33		17-Apr-91	0.84
11-Mar-89	0.27			n = 16
12-Mar-89	0.27			
19-Jun-89	0.32			N = 224
04-Apr-91	0.31			
21-Jan-93	0.32			
23-Feb-93	0.33861			
25-Feb-93	0.05			
26-Feb-93	0.33778			
28-Feb-93	0.31876			
01-Mar-93	0.27191			
03-Mar-93	0.14203			
05-Mar-93	0.31184			
16-Feb-94	0.2074			
18-Feb-94	0.05			
16-Jan-95	0.31			
05-Apr-95	0.25213			
20-Mar-96	0.2971			
24-Apr-96	0.29968			
03-Jan-97	0.13			
29-Jan-97	0.27683			
12-Feb-97	0.28338			
26-Feb-97	0.32196			
21-Jan-98	0.2884			
28-Jan-98	0.22924			
04-Mar-98	0.2451			
30-Dec-98	0.3			
09-Feb-99	0.33594			
10-Feb-99	0.27217			
03-Mar-99	0.23354			
10-Mar-99	0.22369			
	n = 46			

Ranger 009				
Date	Cl<1.8		Date	Cl>3
27-Jan-81	1.2		01-Dec-88	3.1
27-Jan-81	1.5		19-Dec-89	3.7
25-Feb-81	1.4		08-Apr-91	4.1
22-Apr-81	1.5			n = 3
02-Mar-82	1.5			
05-Apr-82	1.5			N = 86
04-May-82	1.5			
05-Apr-83	1.4			
07-Dec-83	1			
08-Feb-84	1.1			
06-Mar-84	0.9			
03-Apr-84	1.4			
05-Mar-85	1.3			
19-Mar-85	1.5			
15-Apr-85	1.3			
19-Apr-85	1.5			
28-Feb-87	1.7			
20-Mar-96	1.6990378			
11-Dec-96	1.19			
05-Feb-97	1.6329286			
21-Jan-98	1.441794			
28-Jan-98	1.129405			
04-Mar-98	0.905352			
01-Apr-98	1.676201			
07-Apr-99	1.364			
	n = 25			

Ranger 009				
Date	Cu<0.5		Date	Cu>1.0
04-Dec-98	0.32		19-Apr-89	2
			08-Feb-95	2.55913
			07-Jan-98	2.5
	N = 79		04-Mar-98	4.50537
			16-Dec-98	1.66
			06-Jan-99	2.45
			17-Feb-99	2.34224

Ranger 009					
Date	K<0.15			Date	K>0.4
27-Jan-81	0.13			23-Jun-80	0.79
25-Feb-81	0.11			06-Dec-80	1.1
26-Mar-81	0.1			30-Dec-80	0.42
03-May-83	0.07			03-Feb-82	1.2
03-Mar-93	0.10909			04-Jan-83	0.42
05-Mar-93	0.13176			07-Dec-83	0.43
15-Feb-94	0.05			06-Mar-84	0.64
15-Feb-95	0.05			24-Jan-86	0.49
05-Feb-97	0.05			27-Jan-86	0.51
12-Feb-97	0.05			02-Feb-87	0.55
05-Mar-97	0.05			18-Feb-87	0.47
12-Mar-97	0.05			23-Feb-87	0.43
04-Mar-98	0.05			24-Feb-87	0.59
16-Dec-98	0.05			28-Feb-87	0.48
06-Jan-99	0.05			14-Jan-88	0.71
09-Feb-99	0.05			01-Dec-88	0.88
10-Feb-99	0.05			19-Dec-89	0.78
24-Feb-99	0.12423			06-Mar-93	0.67571
24-Feb-99	0.05			11-Dec-96	0.7492
03-Mar-99	0.05			03-Jan-97	0.795
03-Mar-99	0.05			08-Jan-97	0.76364
17-Mar-99	0.05				n = 21
17-Mar-99	0.11				
07-Apr-99	0.05				N = 120
07-Apr-99	0.05				
05-May-99	0.05				
07-Jul-99	0.14933				
	n = 27				

Ranger 009								
Date	**Mg<0.41**		**Date**	**Mg>0.88**	**Date**	**Mg>0.88**	**Date**	**Mg>0.88**
25-Feb-81	0.4		23-Jun-80	1.3	02-Mar-91	1.5	29-Mar-95	1.39178
03-Feb-82	0.31		06-Dec-80	1.2	03-Mar-91	1.2	12-Apr-95	3.9
02-Mar-82	0.34		22-Apr-81	1.4	04-Mar-91	0.96	13-Apr-95	3.62
05-Apr-82	0.33		19-May-81	1	05-Mar-91	0.92	04-May-95	0.90727
05-Apr-83	0.37		04-Jan-82	1.6	08-Mar-91	1	06-Jun-95	1.07056
25-Feb-93	0.05		04-May-82	1.1	11-Mar-91	1.1	03-Jul-95	1.25297
01-Mar-93	0.39091		06-Mar-84	0.95	12-Mar-91	1	02-Aug-95	1.66344
03-Mar-93	0.18915		05-Jun-84	0.89	25-Mar-91	0.94	02-Jan-96	1.14004
09-Mar-94	0.39195		14-Mar-85	0.92	08-Apr-91	1.9	16-Jan-96	1.08001
03-Jan-97	0.29		04-Jun-85	0.94	09-Apr-91	1.4	13-Mar-96	0.91468
29-Jan-97	0.23389		04-Feb-87	0.92	10-Apr-91	1	20-Mar-96	1.63654
12-Feb-97	0.32737		05-Feb-87	0.9	11-Apr-91	0.99	27-Mar-96	1.00558
19-Feb-97	0.20785		06-Feb-87	0.9	12-Apr-91	1.2	01-Apr-96	0.93063
26-Feb-97	0.28798		08-Feb-87	1	14-Apr-91	1.1	17-Apr-96	1.42416
05-Mar-97	0.29357		11-Feb-87	1.3	15-Apr-91	1.1	24-Apr-96	1.33498
28-Jan-98	0.2573		12-Feb-87	1.2	17-Apr-91	1.2	01-May-96	0.96154
25-Feb-98	0.32657		13-Feb-87	0.98	19-Apr-91	1.1	04-Jun-96	0.9
04-Mar-98	0.34662		14-Feb-87	1.3	22-Apr-91	0.91	04-Jul-96	0.91235
30-Dec-98	0.37		15-Feb-87	1.1	24-Apr-91	0.98	08-Jan-97	2.42691
10-Feb-99	0.05		16-Feb-87	1.1	27-Feb-93	1.3649	15-Jan-97	1.528
03-Mar-99	0.3		17-Feb-87	0.93	06-Mar-93	2.4803	22-Jan-97	1.35384
10-Mar-99	0.35		18-Feb-87	1.5	07-Mar-93	1.79817	02-Apr-97	1.285
	n = 22		18-Feb-87	1.3	18-Mar-93	1.2981	09-Apr-97	0.972
			23-Feb-87	1.1	20-Mar-93	1.54924	22-Apr-98	0.96
	N = 347		24-Feb-87	1.6	21-Mar-93	1.39298	29-Apr-98	0.90998
			25-Feb-87	0.91	22-Mar-93	1.1149	06-May-98	0.9
			26-Feb-87	1.2	05-Apr-93	1.1307	03-Jun-98	0.9
			27-Feb-87	1.2	05-Feb-94	2.02	01-Jul-98	1.1
			28-Feb-87	1.1	06-Feb-94	1.43	13-Jan-99	1.337
			06-Apr-87	0.91	07-Feb-94	2.33	20-Jan-99	2.09
			07-May-87	1.1	08-Feb-94	2.37	27-Jan-99	1.02
			01-Dec-88	1.1	12-Feb-94	2.17455	03-Feb-99	1.54977
			13-Mar-89	2.2	13-Feb-94	1.43919	24-Feb-99	1.8014
			14-Mar-89	1.4	14-Feb-94	0.93522	21-Apr-99	1.04964
			15-Mar-89	2.2	15-Feb-94	3.02276		n = 150
			16-Mar-89	1	17-Feb-94	3.33656		
			17-Mar-89	1.4	18-Feb-94	2.32562		
			18-Mar-89	1.5	19-Feb-94	2.90144		
			20-Mar-89	2.9	20-Feb-94	3.76		
			21-Mar-89	2.7	24-Feb-94	2.13419		
			22-Mar-89	1.8	16-Mar-94	2.94135		
			23-Mar-89	2.3	23-Mar-94	4.05345		
			24-Mar-89	1.9	30-Mar-94	2.71267		
			25-Mar-89	1.4	06-Apr-94	1.64727		
			27-Mar-89	1.1	13-Apr-94	1.8664		
			28-Mar-89	1.1	18-Apr-94	1.15		
			19-Dec-89	1.1	20-Apr-94	1.13605		
			19-Feb-91	3.5	23-Dec-94	1.25739		
			20-Feb-91	1.5	06-Jan-95	1.24734		
			21-Feb-91	4.3	25-Jan-95	1.73366		
			22-Feb-91	3.2	01-Feb-95	3.11		
			23-Feb-91	0.9	08-Feb-95	1.03947		

Ranger 009				
Date	**Mn<3.33**		**Date**	**Mn>10.41**
19-Mar-85	3		03-Jan-85	19
20-Mar-85	3		27-Jan-86	11
09-Feb-87	0.5		03-Feb-86	17
10-Feb-87	0.5		05-Feb-86	14
20-Feb-91	1		20-Jan-87	21
03-Mar-91	0.5		02-Feb-87	12
04-Mar-91	3		04-Feb-87	14
24-Mar-91	0.5		05-Feb-87	13
25-Mar-91	3		08-Feb-87	15
26-Mar-91	3		15-Feb-87	13
02-Apr-91	3		16-Feb-87	12
08-Apr-91	2		06-Apr-87	11
11-Feb-94	0.5		07-May-87	31
16-Feb-94	1.59767		14-Jan-88	18
17-Feb-94	3.3		01-Dec-88	19
18-Feb-94	0.5		20-Feb-89	16
03-Mar-94	3.14449		19-Jun-89	11
09-Mar-94	1.0085		19-Dec-89	13
16-Mar-94	2.74251		19-Feb-91	15
23-Mar-94	2.19012		21-Feb-91	13
06-Apr-94	2.80241		27-Feb-91	13
16-Jan-95	3.12		28-Feb-91	21
22-Feb-95	2.2412		01-Mar-91	41
01-Mar-95	2.84145		02-Mar-91	17
08-Mar-95	3.29354		18-Mar-91	11
29-Mar-95	3		04-Apr-91	24
13-Apr-95	1.85		10-Apr-91	40
13-Apr-95	2.74		16-Apr-91	41
26-Feb-97	3.308		27-Feb-93	32.74604
05-Mar-97	2.849		28-Feb-93	18.79579
26-Mar-97	3.23		06-Mar-93	12.45109
08-May-97	1.021645		07-Mar-93	14.56955
13-Jan-99	1.362		12-Mar-93	11.14586
20-Jan-99	2.35		06-Feb-94	12.06
03-Feb-99	1.68518		12-May-94	13.25138
09-Feb-99	1.5378		06-Jun-94	24.94327
10-Feb-99	1.99117		02-Aug-94	31.49089
17-Feb-99	2.97878		23-Dec-94	22.10782
17-Mar-99	2.84		06-Jan-95	12.39608
	n = 39		25-Jan-95	20.37
			01-Feb-95	11.43
	N = 305		16-Jan-96	11.70707
			20-Mar-96	14.37441
			11-Dec-96	16.71024
			07-Jan-98	15
			14-Jan-98	18.698
			01-Dec-98	11.84
			16-Dec-98	10.44
			10-Mar-99	12.35
			07-Jul-99	13.13991
				n = 50

Ranger 009				
Date	Na<1.03		Date	Na>1.70
27-Jan-81	0.9		23-Jun-80	2.2
27-Jan-81	0.9		18-Feb-87	1.8
02-Mar-82	0.8		24-Feb-87	1.9
07-Feb-83	1		07-May-87	1.8
01-Mar-83	1		19-Dec-89	1.9
17-Mar-83	1		06-Mar-93	1.9549
05-Apr-83	0.9		07-Mar-93	1.85822
03-May-83	1		08-Jan-97	1.75795
08-Feb-84	0.8		06-May-98	2.2
06-Mar-84	1			n = 9
11-Feb-85	1			
03-Apr-85	1			
10-Mar-86	1			N = 112
03-Mar-93	0.65458			
03-Jan-97	0.374			
22-Jan-97	1.00141			
29-Jan-97	0.66771			
12-Feb-97	0.83605			
26-Feb-97	0.87193			
12-Mar-97	0.9297			
21-Jan-98	1.00458			
28-Jan-98	0.76347			
04-Mar-98	0.701			
16-Dec-98	1			
30-Dec-98	0.98			
09-Feb-99	0.87882			
10-Feb-99	0.322			
03-Mar-99	0.78			
10-Mar-99	0.65			
17-Mar-99	0.86			
	n = 30			

Ranger 009				
Date	NH4<0.01		Date	NH4>0.025
			04-Dec-98	0.1
				n = 1
	N = 18			

Ranger 009			
Date	NO3<0.01	Date	NO3>0.05
		06-Dec-80	0.29
		26-Mar-81	0.14
	N = 83	22-Apr-81	0.16
		11-Feb-86	0.1
		10-Mar-86	0.1
		12-Mar-86	0.1
		02-Feb-87	0.13
		09-Feb-87	0.11
		05-May-88	0.16
		09-Feb-89	1
		09-Mar-89	0.07
		19-Dec-89	0.06
		07-Jan-98	0.164496
		04-Feb-98	0.141224
			n = 14

Ranger 009

Date	SO4<0.14
23-Jun-80	0.1
27-Jan-81	0.1
25-Feb-81	0.1
22-Apr-81	0.1
19-May-81	0.1
03-Feb-82	0.1
02-Mar-82	0.05
05-Apr-82	0.1
04-May-82	0.1
07-Jun-82	0.1
03-May-83	0.1
05-Jul-83	0.05
05-Jun-84	0.1
19-Mar-85	0.05
20-Mar-85	0.05
22-Mar-85	0.05
10-Mar-86	0.1
04-Apr-86	0.05
08-May-86	0.1
05-Jun-86	0.05
02-Feb-87	0.05
03-Feb-87	0.05
09-Feb-87	0.1
07-May-87	0.05
13-Apr-88	0.05
05-May-88	0.05
21-Feb-89	0.05
19-Jun-89	0.05
06-Jun-90	0.05
07-May-91	0.05
09-Dec-91	0.05
06-Jan-92	0.05
06-Feb-92	0.1391
13-May-92	0.11108
28-Jan-93	0.05
04-Feb-94	0.05
09-Feb-94	0.05
10-Feb-94	0.05
03-Jan-97	0.05
12-Feb-97	0.05
19-Feb-97	0.05
02-Jun-97	0.05

n = 42

N = 371

Date	SO4>0.78	Date	SO4>0.78	Date	SO4>0.78
14-Mar-85	0.8	03-Mar-91	2.4	06-Apr-94	3.6617
15-Mar-85	0.8	04-Mar-91	1.8	13-Apr-94	4.94446
15-Apr-85	1	05-Mar-91	1.7	18-Apr-94	16.44
17-Apr-85	1	07-Mar-91	1	20-Apr-94	1.95
18-Apr-85	1	08-Mar-91	1.9	12-May-94	4.98962
19-Apr-85	0.8	11-Mar-91	2.8	06-Jun-94	18.5812
29-Jan-86	0.8	12-Mar-91	1.8	02-Aug-94	5.26263
03-Feb-86	4.3	13-Mar-91	1	23-Dec-94	4.58901
11-Feb-86	0.9	17-Mar-91	0.8	06-Jan-95	3.18131
05-Feb-87	1	03-Apr-91	1.1	25-Jan-95	2.8077
08-Feb-87	1.4	09-Apr-91	3.6	01-Feb-95	8.73315
11-Feb-87	2.2	10-Apr-91	1.7	08-Feb-95	2.10728
12-Feb-87	1.6	11-Apr-91	1.6	15-Feb-95	4.80741
13-Feb-87	1.3	12-Apr-91	2.4	22-Feb-95	8.17376
14-Feb-87	2.3	14-Apr-91	2	01-Mar-95	4.6511
15-Feb-87	1	15-Apr-91	2.1	08-Mar-95	4.59182
16-Feb-87	1	16-Apr-91	1	15-Mar-95	3.48321
17-Feb-87	1	17-Apr-91	2.2	22-Mar-95	2.95813
18-Feb-87	2.8	19-Apr-91	1.6	29-Mar-95	2.67226
18-Feb-87	2.7	22-Apr-91	1.1	05-Apr-95	1.13363
23-Feb-87	1.7	24-Apr-91	0.9	12-Apr-95	11.9
24-Feb-87	3.3	02-Feb-93	1.24791	13-Apr-95	10.6
25-Feb-87	1.2	27-Feb-93	1.45539	18-Apr-95	2.77
26-Feb-87	2.3	05-Mar-93	1.21725	04-May-95	0.8905
27-Feb-87	2.6	06-Mar-93	5.54935	06-Jun-95	1.24818
28-Feb-87	1.6	07-Mar-93	3.07001	03-Jul-95	2.10002
01-Dec-88	0.8	08-Mar-93	1.27506	02-Aug-95	2.95138
09-Feb-89	1	09-Mar-93	1.12982	11-Dec-95	1.34821
13-Mar-89	5	10-Mar-93	0.85246	02-Jan-96	2.87909
14-Mar-89	2.4	11-Mar-93	0.9518	16-Jan-96	2.91969
15-Mar-89	4.9	12-Mar-93	0.91803	31-Jan-96	0.82948
16-Mar-89	1.8	18-Mar-93	3.01068	13-Mar-96	2.23547
17-Mar-89	2.6	19-Mar-93	1.09048	20-Mar-96	3.69393
18-Mar-89	3.4	20-Mar-93	3.77982	27-Mar-96	1.69662
19-Mar-89	3.9	21-Mar-93	3.32361	01-Apr-96	1.0536
20-Mar-89	8.8	22-Mar-93	2.7185	03-Apr-96	1.05017
21-Mar-89	7.1	05-Apr-93	0.86941	10-Apr-96	1.11292
22-Mar-89	4.8	05-May-93	1.91308	17-Apr-96	2.91805
23-Mar-89	6.4	23-Dec-93	1.02427	24-Apr-96	2.69916
24-Mar-89	4.9	25-Jan-94	0.96917	01-May-96	1.34559
25-Mar-89	3.3	05-Feb-94	5.945	08-May-96	0.82331
26-Mar-89	1.2	06-Feb-94	4.68	04-Jul-96	0.83089
27-Mar-89	2.1	07-Feb-94	7.75	08-Jan-97	6.74757
28-Mar-89	1.9	08-Feb-94	6.02	15-Jan-97	3.87628
19-Dec-89	1.3	12-Feb-94	6.08644	22-Jan-97	3.24574
05-Feb-90	1.1	13-Feb-94	3.46818	05-Feb-97	0.86164
19-Feb-91	14	14-Feb-94	1.29063	05-Mar-97	1.47561
20-Feb-91	4.2	15-Feb-94	8.43801	02-Apr-97	1.512
21-Feb-91	17	16-Feb-94	1.7169	07-Jan-98	1.6
22-Feb-91	12	17-Feb-94	8.44207	04-Feb-98	0.81924
23-Feb-91	1.6	18-Feb-94	4.88691	22-Apr-98	1.1
24-Feb-91	2.8	19-Feb-94	6.3	29-Apr-98	1.06979
25-Feb-91	15	20-Feb-94	11.94	01-Jul-98	1.5
26-Feb-91	9	24-Feb-94	6.79014	01-Dec-98	1.5
27-Feb-91	10	03-Mar-94	0.96028	04-Dec-98	1
28-Feb-91	4	16-Mar-94	7.63702	13-Jan-99	3.05
01-Mar-91	1.7	23-Mar-94	16.13603	20-Jan-99	4.86
02-Mar-91	1.9	30-Mar-94	6.5836	27-Jan-99	1.53
				03-Feb-99	4.07775
				09-Feb-99	1.13144

n = 176

Ranger 009	
Date	**U<0.05**
03-May-91	0.04
	n = 1
	N = 369

Date	U>0.3	Date	U>0.3
13-Mar-85	0.4	02-Aug-94	0.33943
14-Mar-85	0.5	16-Jan-95	0.3186
15-Mar-85	0.4	06-Jun-95	0.62644
18-Mar-85	0.4	02-Jan-96	0.36841
19-Mar-85	0.4	16-Jan-96	0.34346
20-Mar-85	0.6	06-Feb-96	0.34976
22-Mar-85	0.4	27-Mar-96	0.44128
15-Apr-85	0.6	17-Apr-96	2.1888
16-Apr-85	0.8	08-Jan-97	0.6486545
17-Apr-85	0.5	15-Jan-97	0.3851093
19-Apr-85	0.4	22-Jan-97	0.509
24-Jan-86	0.4	19-Feb-97	0.5338266
25-Jan-86	0.5	12-Mar-97	0.5574439
26-Jan-86	0.4	07-Jan-98	0.5993709
28-Jan-86	0.4	03-Feb-99	0.7834215
29-Jan-86	0.4	04-Feb-99	0.4785191
03-Feb-86	0.6	12-Feb-99	0.445922
04-Feb-86	0.4	21-Feb-99	0.4358815
11-Feb-86	0.6	23-Feb-99	0.3468841
02-Feb-87	0.4	07-Apr-99	1.244467
04-Feb-87	0.5	09-Apr-99	0.3841605
05-Feb-87	0.4	12-Apr-99	0.318682
06-Feb-87	0.4	14-Apr-99	0.3666264
11-Feb-87	0.6	16-Apr-99	0.4408422
12-Feb-87	0.4	19-Apr-99	0.437181
13-Feb-87	0.5		n = 83
14-Feb-87	0.4		
15-Feb-87	0.4		
17-Feb-87	0.4		
23-Feb-87	0.4		
24-Feb-87	0.4		
26-Feb-87	0.4		
27-Feb-87	0.8		
06-Apr-87	0.4		
03-Feb-88	0.4		
24-Mar-89	0.4		
19-Feb-91	0.5		
20-Feb-91	1.7485		
21-Feb-91	1.4373		
22-Feb-91	1.1774		
24-Feb-91	0.6		
25-Feb-91	1.7296		
26-Feb-91	0.98288		
27-Feb-91	0.7946		
28-Feb-91	0.55016		
01-Mar-91	0.30576		
02-Mar-91	0.36131		
03-Mar-91	0.30355		
04-Mar-91	0.31167		
08-Mar-91	0.56501		
25-Mar-91	15.013		
04-Apr-91	0.41969		
16-Feb-94	0.32		

Ranger 009				
Date	Pb<0.2		Date	Pb<0.5
07-Jan-98	0.05		04-Mar-98	1
01-Dec-98	0.16		10-Feb-99	0.83
04-Dec-98	0.13			n = 2
03-Feb-99	0.08			
03-Mar-99	0.07			
03-Jun-99	0.02			N = 54
07-Jul-99	0.005			
	n = 7			

Ranger 009				
Date	Ra<1		Date	Ra>18
09-Dec-91	0.76		09-Feb-94	19.69
06-Feb-92	0.79		09-Mar-94	37.39
			05-Feb-97	37.57
			07-Apr-99	23.65

Ranger 009				
Date	Zn<1.00		Date	Zn>13
			01-Dec-98	38.2
				n =1
	N = 80			

DME 009				
Date	**pH<5.9**		**Date**	**pH>6.45**
05-Dec-78	5.4		21-Mar-79	6.7
08-Jan-81	4.5		17-Apr-79	7
22-Dec-81	5.6		15-May-79	6.8
29-Mar-83	5.7		12-Jun-79	6.9
06-Dec-83	5.8		10-Jul-79	6.7
30-Jan-85	5.8		21-Feb-80	6.6
12-Feb-85	5.8		01-Apr-80	6.7
10-Mar-86	5		07-May-80	6.8
11-Mar-86	5.4		05-Jun-80	6.8
24-Mar-86	5.6		02-Jul-80	6.9
09-Apr-86	5.7		14-May-81	6.5
19-Jan-87	5.6		02-Jun-81	6.5
19-Jan-87	5.4		04-Jan-82	6.7
19-Jan-87	5.7		06-Jun-83	6.5
20-Jan-87	5.5		04-Jul-83	6.5
20-Jan-87	5.4		08-May-84	6.5
09-Feb-87	5.8		05-Jun-84	6.6
17-Feb-87	5.6		01-May-85	6.5
03-Mar-87	5.1		08-May-85	6.5
14-Jan-88	5.8		19-Jun-85	6.5
15-Feb-88	5.7		03-Jun-86	6.5
11-Mar-88	5.3		05-Mar-87	6.6
18-Mar-88	5.8		09-Apr-87	6.6
06-Apr-88	5.1		15-Apr-87	6.5
14-Apr-88	5.7		21-Apr-87	6.5
29-Apr-88	5.3		28-Apr-87	6.5
06-May-88	5.4		14-Jan-88	6.5
30-Nov-88	5.3		18-Jan-88	6.5
01-Dec-88	5.3		29-Mar-89	6.7
14-Dec-88	5.7		01-Feb-91	6.6
29-Dec-88	5.7			n = 30
03-Jan-89	5.8			
03-Feb-89	5.1		N = 177	
22-Feb-89	5.6			
10-Mar-89	5.8			
17-Mar-89	5.8			
20-Mar-89	5.5			
10-Apr-89	5.2			
16-May-89	5.8			
20-Dec-89	5.8			
03-Jan-90	5.7			
22-Feb-90	5.7			
12-Jun-90	5.8			
04-Feb-92	5.6			
12-Mar-92	5.4			
	n =45			

DME 009				
Date	**EC <12**		**Date**	**EC >21**
06-Feb-80	9		05-Dec-78	22
02-Mar-82	7		12-Jun-79	25
05-Apr-82	11		10-Jul-79	32
15-Mar-83	9		07-May-80	23
05-Mar-84	11		05-Jun-80	22
14-Mar-84	9		02-Jul-80	26
21-Mar-84	10		08-Jan-81	26
12-Feb-85	11		04-Aug-81	31
04-Mar-85	11		06-Jul-82	24
	n = 9		30-Jul-84	23
			19-Dec-84	23
			09-Jan-85	26
			17-Jan-85	22
	N = 272		20-May-85	22
			18-Dec-85	23
			01-May-86	23
			12-Feb-87	24
			05-Mar-87	26
			13-Mar-87	22
			19-Mar-87	40
			01-Apr-87	25
			21-Apr-87	22
			28-Apr-87	22
			05-May-87	24
			05-May-87	23
			14-Jan-88	32
			14-Jan-88	54
			14-Jan-88	35
			18-Jan-88	34
			30-Nov-88	23
			01-Dec-88	23
			19-Dec-88	24
			03-Feb-89	23
			15-Mar-89	37
			20-Mar-89	59
			21-Mar-89	37
			23-Mar-89	24
			29-Mar-89	23
			06-Apr-89	22
			10-Apr-89	38
			16-May-89	136
			20-Dec-89	27
			03-Jan-90	38
			22-Feb-90	26
			12-Mar-90	69
			12-Jun-90	24
			01-Feb-91	22
			21-Feb-91	27
			22-Feb-91	64
			05-Mar-91	28
			13-Nov-91	149
			17-Dec-91	26
			20-Feb-92	23
			21-Jan-93	231
			28-Apr-93	26
			25-May-93	35
			28-Apr-94	29
			01-Jul-94	42
				n = 58

DME 009				
Date	**Turbidity <2.4**		**Date**	**Turbidity >9.9**
05-Dec-78	1.7		08-Jan-80	10
21-Mar-79	1.9		06-Feb-80	24
17-Apr-79	1.7		04-Feb-81	11
15-May-79	1.8		08-Dec-81	61
12-Jun-79	1.7		08-Dec-81	42
10-Jul-79	1.8		22-Dec-81	14
07-May-80	0.8		07-Mar-83	16
05-Jun-80	1.5		15-Mar-83	31
02-Jul-80	2.2		22-Feb-84	11
08-Jan-81	2.2		24-Feb-84	37
30-Mar-81	1.6		29-Feb-84	14
14-May-81	1.5		02-Mar-84	10
02-Jun-81	1.5		09-Mar-84	15
07-Jul-81	2		14-Mar-84	10
04-Jan-82	2		30-Jan-85	30
08-Jun-82	1.4		31-Jan-85	16
06-Jul-82	1.2		01-Feb-85	17
06-Jun-83	1.4		04-Feb-85	22
04-Jul-83	1		20-Feb-85	14
17-Apr-84	2.1		07-Mar-85	14
18-Apr-84	2		12-Mar-85	23
26-Apr-84	1.5		15-Apr-85	11
30-Apr-84	1.5		09-Dec-85	55
02-May-84	1.5		23-Jan-86	13
08-May-84	1.2		25-Jan-86	15
05-Jun-84	1.5		19-Jan-87	48
02-Jul-84	1.2		19-Jan-87	89
30-Jul-84	1.9		20-Jan-87	39
22-Feb-85	1.8		20-Jan-87	41
24-Mar-86	2.2		28-Jan-87	35
26-Mar-87	1.6		09-Feb-87	13
01-Apr-87	1.3		18-Jan-88	14
09-Apr-87	1.3		27-Jan-89	15
15-Apr-87	1.5		20-Mar-89	10
21-Apr-87	1.1		21-Mar-89	10
28-Apr-87	1.3			n = 35
05-May-87	1.6			
14-Jan-88	2.1			N = 231
11-Mar-88	2.2			
18-Mar-88	2			
14-Apr-88	1			
29-Apr-88	1.5			
06-May-88	1.3			
29-Dec-88	2			
08-Feb-89	2			
09-Mar-89	1.7			
29-Mar-89	2.2			
10-Apr-89	2.4			
24-May-89	0.8			
31-May-89	1			
14-Jun-89	1			
20-Dec-89	2			

DME 009						
Date	**SO4 <0.14**		**Date**	**SO4 >0.78**	**Date**	**SO4 >0.78**
05-Mar-87	0.1		05-Dec-78	1	20-Jun-95	1.5
13-Mar-87	0.1		05-Dec-78	3	24-Jul-95	3.6
19-Mar-87	0.1		08-Jan-80	1	09-Jan-96	1.8
09-Apr-87	0.1		05-Apr-82	1	13-Feb-96	1.7
15-Apr-87	0.1		04-May-82	1	12-Mar-96	2.5
21-Apr-87	0.1		08-Jun-82	1	17-Apr-96	3.5
28-Apr-87	0.1		06-Jul-82	2	19-Jun-96	1.2
29-Apr-88	0.1		05-Jan-83	1	18-Dec-96	1.9
16-May-89	0.1		07-Feb-83	1	20-Jan-97	2.3
20-Aug-97	0.1		07-Mar-83	1	20-Feb-97	4.1
23-Jun-98	0.05		15-Mar-83	1	17-Feb-98	2.6
			29-Mar-83	1	08-Mar-98	0.8
	n = 11		06-Apr-83	1	16-Nov-98	6.4
			27-Apr-83	1	14-Dec-98	0.9
			04-May-83	1	12-Jan-99	3.2
			06-Jun-83	1	22-Feb-99	2.3
			04-Jul-83	1	13-Apr-99	2.5
			06-Dec-83	2		
			03-Jan-84	1		n = 75
			06-Feb-84	1		
			07-Mar-84	1		
			02-Apr-84	1		
			08-May-84	1		
			05-Jun-84	1		
			02-Jul-84	1		
			30-Jul-84	1		
			13-Jan-86	1		
			14-Jan-88	3		
			30-Nov-88	2		
			01-Dec-88	1		
			03-Feb-89	5		
			07-Feb-89	14		
			28-Feb-89	1		
			15-Mar-89	3.1		
			17-Mar-89	0.89		
			21-Mar-89	4.8		
			23-Mar-89	2.1		
			29-Mar-89	1.6		
			10-Apr-89	2.1		
			13-Feb-91	1		
			22-Mar-91	1.8		
			13-Nov-91	1		
			17-Dec-91	2		
			17-Mar-92	1		
			19-Mar-92	1.6		
			20-Mar-92	0.8		
			23-Apr-92	1		
			21-Jan-93	6		
			28-Apr-93	1.6		
			25-May-93	6.3		
			28-Apr-94	1.6		
			01-Jul-94	5.6		

DME 009						
Date	Mg		Date	Mg	Date	Mg
05-Dec-78	0.2		14-Feb-79	1.66	06-Jul-97	1.5
05-Dec-78	0.24		12-Jun-79	1.05	20-Aug-97	1.3
06-Feb-80	0.33		10-Jul-79	1.55	31-Aug-97	1.4
03-Mar-81	0.08		07-May-80	1.1	08-Oct-97	1.7
02-Mar-82	0.25		05-Jun-80	1.05	17-Feb-98	0.9
15-Mar-83	0.37		02-Jul-80	1.25	26-Jul-98	1.2
06-Feb-84	0.4		04-Aug-81	2.25	10-Aug-98	1.2
06-Feb-85	0.39		08-Jun-82	0.89	16-Nov-98	2.5
12-Feb-85	0.34		06-Jul-82	1.3	12-Jan-99	1.3
09-Jan-92	0.34		05-Jan-83	1	22-Feb-99	1.2
20-Feb-92	0.33		04-Jul-83	1	13-Apr-99	1.4
23-Jun-98	0.2		07-Mar-84	0.9	09-Jun-99	0.9
	n = 12		30-Jul-84	1.2		n = 70
			19-Dec-84	2		
	N = 198		01-May-85	0.92		
			09-Dec-85	0.95		
			13-Jan-86	0.94		
			19-Mar-87	1		
			26-Mar-87	1.8		
			21-Apr-87	2.8		
			28-Apr-87	0.93		
			05-May-87	1		
			30-Nov-88	0.89		
			01-Dec-88	0.94		
			27-Jan-89	1.4		
			07-Feb-89	1.3		
			15-Mar-89	1.9		
			17-Mar-89	1.2		
			21-Mar-89	2.5		
			23-Mar-89	1.2		
			29-Mar-89	1.1		
			10-Apr-89	1.6		
			27-Apr-89	0.97		
			13-Nov-91	0.89		
			17-Dec-91	1.4		
			21-Jan-93	1.6		
			28-Apr-93	1		
			25-May-93	1.7		
			23-Jun-93	1.6		
			28-Apr-94	1.2		
			01-Jul-94	2.4		
			16-Dec-94	1.3		
			17-Jan-95	5.3		
			16-Feb-95	1.1		
			08-Mar-95	2.20		
			17-May-95	0.92		
			20-Jun-95	1.6		
			24-Jul-95	1.4		
			13-Feb-96	1		
			12-Mar-96	1.2		
			17-Apr-96	1.3		
			08-May-96	0.9		

DME 009				
Date	Ca		Date	Ca
05-Dec-78	0.27		14-Feb-79	1.65
22-Jan-80	0.27		04-Aug-81	1.7
06-Feb-80	0.14		17-Jan-95	2.4
21-Feb-80	0.29		16-Feb-95	1.1
08-Jan-81	0.3		18-Dec-96	0.89
03-Mar-81	0.31		17-Feb-98	1.4
07-Jul-81	0.3			n = 6
18-Jan-82	0.3			
17-Feb-82	0.3			
02-Mar-82	0.2			N = 194
29-Mar-83	0.29			
06-Dec-83	0.28			
06-Feb-84	0.1			
02-Jul-84	0.3			
30-Jan-85	0.27			
12-Feb-85	0.2			
01-May-85	0.14			
09-Dec-85	0.33			
19-Jan-87	0.33			
24-Mar-88	0.33			
06-Apr-88	0.32			
29-Dec-88	0.33			
04-Feb-92	0.13			
20-Feb-92	0.07			
12-Mar-92	0.32			
17-Apr-96	0.3			
09-Mar-99	0.2			
	n = 27			

DME 009				
Date	K <0.15		Date	K >0.40
01-Apr-80	0.05		05-Dec-78	0.63
05-Jun-80	0.05		05-Dec-78	0.62
14-Mar-85	0.12		05-Dec-78	0.57
26-Mar-85	0.05		12-Jun-79	0.42
01-Apr-85	0.07		10-Jul-79	0.78
04-Feb-92	0.13		08-Jan-80	0.41
25-Jan-95	0.05		22-Jan-80	0.56
17-Apr-96	0.05		04-Aug-81	0.5
08-May-96	0.1		08-Dec-81	0.54
11-Jun-97	0.13		06-Jul-82	0.5
17-Feb-98	0.1		05-Jan-83	0.62
08-Mar-98	0.1		15-Mar-83	0.58
13-May-99	0.1		29-Mar-83	0.44
09-Jun-99	0.1		06-Apr-83	0.53
	n = 14		07-Mar-84	0.47
			30-Jul-84	0.41
	N = 182		19-Dec-84	1.1
			19-Feb-85	0.42
			17-Apr-85	0.44
			09-Dec-85	0.83
			09-Dec-85	0.71
			19-Jan-87	0.66
			20-Jan-87	0.49
			14-Jan-88	0.73
			14-Jan-88	0.74
			14-Jan-88	0.77
			18-Jan-88	0.58
			15-Feb-88	0.46
			30-Nov-88	0.89
			01-Dec-88	0.87
			14-Dec-88	0.56
			16-Jan-89	0.51
			15-Mar-89	0.51
			21-Mar-89	0.74
			21-Jan-93	0.53
			03-Feb-93	0.49
			16-Dec-94	0.43
			17-Jan-95	1
			06-Aug-96	0.5
			18-Dec-96	0.46
			20-Jan-97	0.43
			23-Jun-98	1.7
			26-Jul-98	0.6
			10-Aug-98	0.6
			16-Nov-98	0.7
				n = 45

DME 009				
Date	**Na**		**Date**	**Na**
14-Feb-79	0.9		15-May-79	1.8
06-Feb-80	0.5		12-Jun-79	1.8
21-Feb-80	1		10-Jul-79	2.5
08-Jan-81	0.8		05-Jun-80	4.7
03-Mar-81	0.4		02-Jul-80	5
02-Mar-82	0.5		07-Jul-81	2
05-Apr-82	1		04-Aug-81	6.9
07-Mar-83	1		05-Jun-84	2.3
15-Mar-83	0.6		30-Jul-84	1.9
06-Dec-83	0.1		19-Dec-84	2
03-Jan-84	0.9		01-May-85	2
06-Feb-84	0.8		13-Jan-86	3
07-Mar-84	0.8		03-Jun-86	1.9
30-Jan-85	1		05-May-87	1.9
12-Feb-85	0.7		14-Jan-88	1.8
26-Feb-85	1		18-Mar-88	1.8
13-Mar-85	0.8		29-Apr-88	1.9
14-Mar-85	0.8		30-Nov-88	2.1
17-Apr-96	0.05		01-Dec-88	3
17-Feb-98	0.8		29-Dec-88	2
08-Mar-98	0.9		03-Jan-89	1.8
23-Jun-98	0.9		09-Mar-89	1.8
09-Mar-99	0.8		15-Mar-89	2.4
	n = 23		17-Mar-89	1.9
			21-Mar-89	1.9
	N = 188		10-Apr-89	1.9
			27-Apr-89	1.9
			13-Nov-91	2.6
			28-Apr-93	1.9
			25-May-93	2.3
			23-Jun-93	2.5
			23-Jun-93	2.4
			28-Apr-94	2
			01-Jul-94	2.5
			17-Jan-95	3.4
			17-May-95	2.2
			06-Aug-96	1.8
			18-Dec-96	2
			06-Jul-97	2
			20-Aug-97	2
			31-Aug-97	2
			20-Apr-98	1.8006232
			26-Jul-98	2
			16-Nov-98	2.0
				n = 45

DME 009				
Date	**Cl <1.80**		**Date**	**Cl>3.00**
05-Dec-78	1		05-Dec-78	4
21-Mar-79	1		10-Jul-79	4
04-Feb-81	1		01-Apr-80	4
08-Dec-81	1		07-May-80	5
17-Feb-82	1		05-Jun-80	4
02-Mar-82	1		02-Jul-80	5
05-Apr-82	1		08-Jan-81	4
07-Mar-83	1		07-Jul-81	4
15-Mar-83	1		04-Aug-81	4
06-Apr-83	1		22-Dec-81	4
06-Feb-84	1		04-Jan-82	4
30-Jan-85	1		06-Jul-82	21
12-Feb-85	1		05-Jan-83	4
26-Feb-85	1		07-Feb-83	4
05-Mar-85	1		30-Jul-84	4
12-Mar-92	1.5		19-Dec-84	4.3
13-Feb-96	1.1		14-Mar-85	6
17-Apr-96	1.6		01-Apr-85	5
20-Feb-97	1.4		13-Jan-86	5
17-Feb-98	1.4		09-Apr-87	4
08-Mar-98	1.7		15-Apr-87	4
09-Mar-99	1.6		14-Jan-88	5
	n = 22		14-Jan-88	9
			14-Jan-88	6
	N = 185		30-Nov-88	4
			01-Dec-88	3.8
			16-Jan-89	3.4
			15-Mar-89	3.2
			27-Apr-89	3.3
			16-May-89	14
			12-Mar-90	9.6
			13-Nov-91	16
			17-Dec-91	3.7
			04-May-92	3.2
			21-Jan-93	17
			23-Mar-93	7.8
			23-Mar-93	4.2
			25-May-93	3.1
			23-Jun-93	13
			23-Jun-93	4.6
			01-Jul-94	31
			16-Dec-94	13
			17-Jan-95	5
			16-Feb-95	5
			20-Jun-95	3.2
			24-Jul-95	4.1
			18-Dec-96	3.6
			20-Aug-97	7
			31-Aug-97	3.3
			08-Oct-97	3.3
			23-Jun-98	3.05
			12-Jan-99	7.04

DME 009				
Date	**NO3<0.01**		**Date**	**NO3>0.05**
01-Jul-94	0.00226		25-Jan-95	0.83
20-Apr-98	0.0011		16-Feb-95	0.26
20-May-98	0.0011		17-May-95	0.089
	n = 3		12-Mar-96	0.13
			19-Jun-96	0.08
	N = 185		20-Jan-97	0.07
			20-Aug-97	0.0835946
			31-Aug-97	0.19
			22-Feb-99	0.24
			09-Mar-99	0.05
				n = 10

DME 009				
Date	**NH4<0.01**		**Date**	**NH4>0.025**
			12-Jun-79	0.05
			22-Dec-81	0.06
			05-Jan-83	0.11
	N = 126		06-Jun-83	0.03
			05-Jun-84	0.08
			19-Dec-84	0.11
			19-Feb-85	0.04
			05-Mar-85	0.03
			14-Mar-85	0.07
			17-Apr-85	0.03
			01-May-85	0.04
			09-Dec-85	0.1
			17-Feb-86	0.03
			19-Jan-87	0.4
			15-Feb-88	0.04
			01-Dec-88	0.3
			27-Jan-89	0.03
			03-Feb-89	0.61
			07-Feb-89	33
			23-Mar-89	0.03
				n = 20

DME 009				
Date	**Cu<0.5**		**Date**	**Cu>1.0**
05-Apr-82	0.3		05-Mar-80	3
04-May-82	0.3		07-May-80	4
08-Jun-82	0.2		04-Feb-81	2
06-Jul-82	0.3		27-Apr-83	4.3
07-Mar-83	0.4		19-Dec-84	1.2
06-Apr-83	0.4		13-Mar-85	12
04-May-83	0.3		26-Mar-85	3.2
06-Jun-83	0.3		01-May-85	2
04-Jul-83	0.3		19-Jan-87	1.4
03-Jan-84	0.3		20-Jan-87	1.1
06-Feb-84	0.4		18-Jan-88	1.5
07-Mar-84	0.3		15-Feb-88	1.1
02-Apr-84	0.3		29-Apr-88	1.2
08-May-84	0.3		16-Jan-89	1.8
05-Jun-84	0.3		17-Jan-95	2.5
02-Jul-84	0.4		16-Feb-95	2.3
09-Jan-85	0.4			n = 16
22-Jan-85	0.4			
30-Jan-85	0.4			N = 132
19-Feb-85	0.4			
26-Feb-85	0.3			
05-Mar-85	0.3			
10-Apr-85	0.4			
24-Apr-85	0.3			
19-Jun-85	0.3			
09-Dec-85	0.3			
13-Jan-86	0.4			
06-Feb-86	0.3			
01-May-86	0.4			
03-Jun-86	0.4			
09-Feb-87	0.2			
05-Mar-87	0.1			
13-Mar-87	0.2			
19-Mar-87	0.2			
26-Mar-87	0.3			
01-Apr-87	0.1			
09-Apr-87	0.1			
15-Apr-87	0.1			
21-Apr-87	0.3			
28-Apr-87	0.1			
05-May-87	0.4			
14-Apr-88	0.4			
30-Nov-88	0.4			
14-Dec-88	0.3			
07-Feb-89	0.4			
09-Mar-89	0.4			
15-Mar-89	0.4			
23-Mar-89	0.4			
29-Mar-89	0.4			
13-Apr-89	0.3			
16-May-89	0.3			
14-Jun-89	0.3			

DME 009						
Date	Mn<3.33		Date	Mn>10.41	Date	Mn>10.41
21-Mar-79	3		05-Dec-78	17.7	01-Jul-94	25
06-Feb-80	2		05-Dec-78	18.5	06-Aug-96	41
03-Mar-81	3		05-Dec-78	15.9	18-Dec-96	17
02-Mar-82	2.5		12-Jun-79	10.6	06-Jul-97	13
05-Apr-82	3.2		10-Jul-79	39	20-Aug-97	21.60
04-May-83	3.2		02-Jul-80	16	31-Aug-97	13.40
07-Mar-84	1.7		04-Aug-81	25	08-Oct-97	79.27
10-Apr-85	0.8		22-Dec-81	13	23-Jun-98	23.82
01-May-85	2.6		06-Jul-82	23	10-Aug-98	48.08
08-May-85	2.5		05-Jan-83	24	16-Nov-98	16.66
09-Dec-85	0.9		07-Feb-83	14		n = 61
03-Jun-86	2.3		07-Mar-83	13		
17-Jan-95	1.2		06-Dec-83	13		
16-Feb-95	2.4		02-Apr-84	12		
08-Mar-95	3.00		05-Jun-84	12		
12-Mar-96	2.8		19-Dec-84	27		
20-Feb-97	2.9		22-Jan-85	13		
12-Mar-97	3.3		30-Jan-85	13		
26-Jul-98	0.42		06-Feb-85	15		
09-Mar-99	3.30		26-Feb-85	11		
	n = 20		09-Dec-85	28		
			19-Jan-87	98		
			20-Jan-87	46		
	N = 185		09-Feb-87	11		
			09-Apr-87	11		
			21-Apr-87	13		
			28-Apr-87	16		
			05-May-87	34		
			14-Jan-88	41		
			14-Jan-88	36		
			15-Feb-88	20		
			11-Mar-88	11		
			06-Apr-88	13		
			29-Apr-88	17		
			30-Nov-88	25		
			01-Dec-88	19		
			14-Dec-88	12		
			29-Dec-88	12		
			03-Jan-89	13		
			27-Jan-89	15		
			03-Feb-89	18		
			07-Feb-89	28		
			10-Apr-89	13		
			13-Nov-91	40		
			17-Dec-91	21		
			20-Feb-92	11		
			04-May-92	45		
			21-Jan-93	30		
			03-Feb-93	13		
			25-May-93	33		
			23-Jun-93	35		

DME 009				
Date	Pb<0.2		Date	Pb>0.5
			05-Dec-78	2.3
			15-May-79	6.9
			06-Feb-80	2
			05-Jun-80	3
			08-Jan-81	5.5
			03-Mar-81	1
			22-Dec-81	2.5
			27-Apr-83	1.3
			06-Feb-85	17
			01-May-85	1
			09-Dec-85	15
			17-Jan-95	2.2
			16-Feb-95	2.7
				n = 13

DME 009				
Date	U<0.05		Date	U>0.3
28-Apr-94	0.009		17-Apr-79	3.1
01-Jul-94	0.024		08-Jan-80	0.4
16-Feb-95	0.01		05-Apr-82	0.5
20-Aug-97	0.032		04-May-82	0.5
31-Aug-97	0.03		08-Jun-82	0.5
08-Oct-97	0.027		06-Jul-82	0.5
08-Mar-98	0.029		19-Dec-84	0.5
20-Apr-98	0.025		30-Jan-85	0.4
20-May-98	0.015		06-Feb-85	1.4
23-Jun-98	0.025		12-Feb-85	1.3
26-Jul-98	0.002		26-Mar-85	0.5
10-Aug-98	0.019		01-Apr-85	0.6
13-May-99	0.031		17-Apr-85	0.7
09-Jun-99	0.021		08-May-85	1.5
	n = 14		19-Jun-85	0.6
			19-Jan-87	0.9
	N = 197		14-Jan-88	0.5
			16-Jan-89	0.5
			13-Nov-91	0.4
			05-Mar-92	0.5
			17-Mar-92	1.8
			20-Mar-92	0.4
			23-Apr-92	1.5
			21-Jan-93	5
			03-Feb-93	1.6
				n = 25

DME 009				
Date	**Zn**		**Date**	**Zn**
05-Dec-78	0.9		01-Apr-80	20
17-Apr-79	0.5		07-May-80	21
06-Feb-80	0.5		18-Jan-82	26
05-Jun-80	0.5		27-Apr-83	60
07-Jul-81	0.5		06-Jun-83	18
	n = 5		09-Jan-85	57
			06-Feb-85	410
			24-Apr-85	71
	N = 132		09-Dec-85	190
			12-Feb-86	21
			01-Apr-87	15
			05-May-87	15
			14-Jan-88	17
			14-Jan-88	36
			14-Jan-88	24
			18-Jan-88	87
			15-Feb-88	20
			11-Mar-88	32
			18-Mar-88	15
			24-Mar-88	43
			06-Apr-88	15
			14-Apr-88	30
			29-Apr-88	15
			29-Dec-88	41
			03-Jan-89	27
			16-Jan-89	120
			03-Feb-89	49
			09-Mar-89	38
			12-Mar-90	22
				n = 29

DME 009				
Date	**Ra<1**		**Date**	**Ra>18**
			22-Dec-81	63
			05-Jun-84	27
			05-May-87	28
			18-Mar-88	30
			13-Feb-96	19