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Supervising Scientist

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Review of water quality triggers, November 2003 progress report

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Preface

This is a progress report on the review of trigger values being undertaken by the Office of the Supervising Scientist, it is not a report on the final position of the Supervising Scientist.

Apart from recording progress to date for documenting purposes, this report informs internal parties and external stakeholders of the issues identified so far and the proposed work to be done in the final stage of the review. Thus providing internal and external stakeholders with a document on which to base discussion and offer feedback on the process.

The Office of the Supervising Scientist does not recommend any changes to the existing trigger values at this stage but proposes to finalise the review (with input from stakeholders) and recommend new values to the Ranger and Jabiluka Minesite Technical Committees prior to the end of the current financial year. The updated trigger values will then be published in the Supervising Scientist's Annual Report 2003–2004.

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1 Introduction

1.1 Background

Receiving water standards, in the form of a hierarchy of trigger values, have previously been set for key variables in the Magela Creek on the Ranger Project Area (Klessa 2000 & 2001a,b) and Ngarradj (Swift Creek) in the Jabiluka Mineral Lease (Jabiluka Minesite Technical Committee minutes 21/09/2001). The trigger values were set in accordance with the philosophy of the draft Australian Water Quality Guidelines (ARMECC & ARMCANZ 1998) which where available at the time – the Guidelines have since been published as ANZECC and ARMCANZ (2000).

The trigger values are reviewed annually by the Supervising Scientist and updated as necessary. An extensive review of the datasets and methods used to set the trigger values has been undertaken with reference to the Water Quality Guidelines (ANZECC & ARMCANZ 2000). This report documents the rationale, data and methods used in the first stages of the current review process. Several issues are identified and further work recommended – stage 2 of the review process. Note, the radium-226 trigger values, based on a different approach, were not reviewed in this work.

1.2 Water Quality Guidelines approach to setting triggers

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (ANZECC & ARMCANZ 2000), referred to as the *Water Quality Guidelines,* or simply the *Guidelines*, have been prepared as part of Australia's National Water Quality Management Strategy (NWQMS). The *Water Quality Guidelines* provide a framework that water managers can use to implement the broad national management strategy at a local level.

The Guidelines are not mandatory. Rather, they provide recommendations for environmental regulation and management through *co-operative best management* – a system that involves a shift from control to prevention. The focus is no longer on direction and prescriptive regulation but on co-operation and outcomes. For example the focus is now more on the toxicity of a chemical and the ecosystems health rather than on the concentration of that chemical. Therefore, biological assessments of ecosystems are very important in assessing impacts on ecosystem health, and should accompany investigations of physical and chemical indicators. Impact assessment and monitoring are tools of cooperative best management.

In reviewing the trigger values the framework for applying the Guidelines (figure 1.1) has been followed and the recommendations interpreted to establish a conservative process for implementing the Guidelines. The process is based on the following hierarchical approach:

1. Base maximum allowable limits on ecotoxicological data.
2. Base management triggers – guideline, action and focus levels – on statistical distributions of reference site data.

3. If triggers based on reference site data are inappropriate to guide management of water quality, then refer to knowledge of the system, based on extensive chemical and biological monitoring, to adjust the triggers.

The basis of this approach can be found in the following sections where each step in the framework is discussed. The main focus of this work is step 2, *Determine appropriate water quality guidelines*. More detail on the Supervising Scientist monitoring program and its relationship to the Guidelines is available in the ‘environmental monitoring background paper’ on the SSD website (Supervising Scientist 2002b).

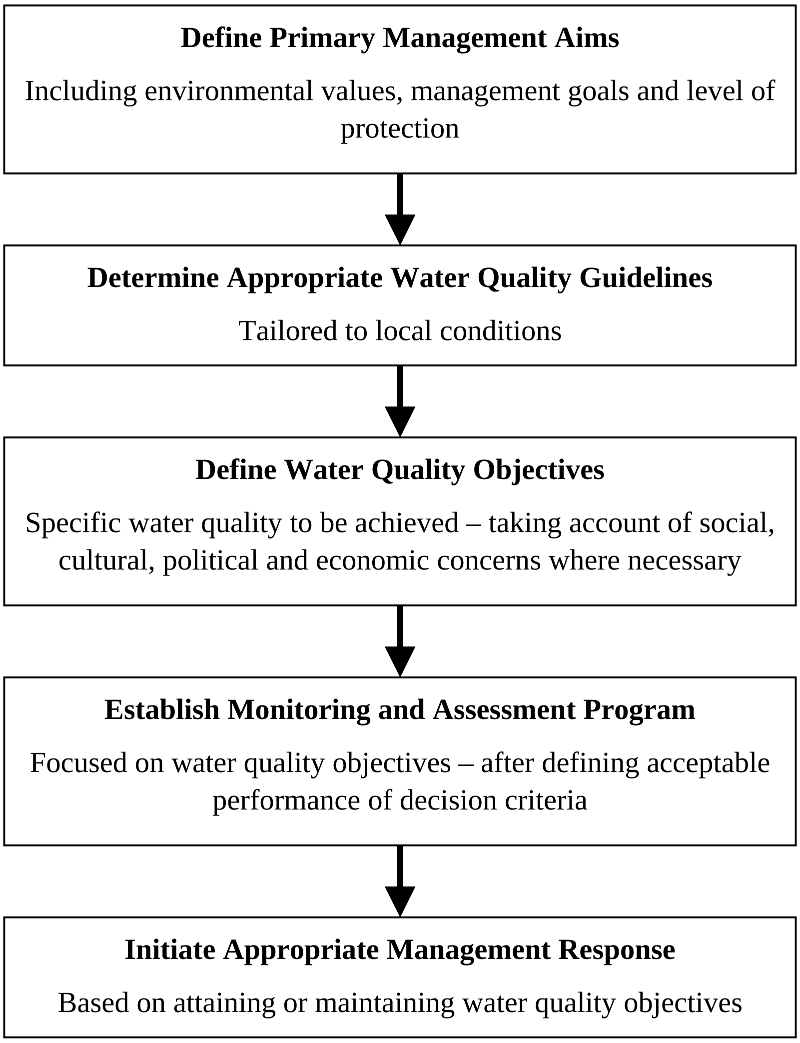

Figure 1.1 The framework for applying the Guidelines (from ANZECC & ARMCANZ 2000)

Step 1: Define the primary management aims

Define the water body

The Guidelines recognises six classes of ecosystems for the purposes of defining physical and chemical stressor trigger values. The systems being considered here are classified as *Lowland rivers and streams*. The systems have been further defined by the many site-specific studies that have been carried out over the years.

The boundaries of the water body, with respect to measuring the trigger values for physical and chemical stressors, are the downstream compliance point on each creek (section 1.3). However, the entire system of water bodies downstream of the Ranger and Jabiluka sites will be afforded the highest level of protection under the water quality management system that the trigger values system forms part of.

Determine the environmental values[1] to be protected

The stakeholders have previously recognised *aquatic ecosystems* as the dominant environmental value to be protected. *Cultural and spiritual values* are recognised in the Guidelines as an environmental value though no specific guidelines for the protection of this value have been developed. While the Traditional Owners views are taken into consideration this is an area that requires further development.

Determine the level of protection

The ecosystem condition has been recognised by stakeholders, via the Ranger and Jabiluka Minesite Technical Committees (MTCs), as a *high conservation/ecological value* system – a condition 1 ecosystem. The recommended level of protection for such a system is such that:

- the values of the indicators of biological diversity should not change markedly, and
- there is no detectable change in the levels of chemical and physical stressors – this condition can be relaxed where there is considerable biological assessment data showing that such changes will not affect biological diversity in the system.

Identify environmental concerns

The main issues of concern are; toxicity of chemical contaminants to the biota and downstream Aboriginal population, increased turbidity from erosion, unnatural changes in the physical properties of the water bodies (eg pH, temperature), and eutrophication through nutrient export from the minesites (mainly through blasting residues).

Determine management goals

The level of protection for a condition 1 system recommended in the Guidelines, ie that the values of the indicators of biological diversity should not change markedly, has been adopted as the primary management goal. A further management goal is that the variation in the chemical and physical stressors be kept as close as practical to the natural variations. Although variation away from the natural condition is considered acceptable if it is known that such a degradation in water quality will not affect the primary management goal of protecting biological diversity, this secondary management goal reflects the request by the Traditional Owners of the area that the water quality in the creeks change as little as possible.

Step 2: Determine appropriate Water Quality Guidelines

The Guidelines describe a water quality guideline as ‘a numerical concentration limit or narrative statement recommended to support and maintain a designated water use. The guidelines are used as a general tool for assessing water quality and are the key to determining water quality objectives that protect and support the designated environmental values of our water resources, and against which performance can be measured’ (ANZECC & ARMCANZ 2000). The following steps are involved:

Determine a balance of indicator types

The monitoring program comprises a mix of:

- early warning components – for early detection of short- and long-term changes through water chemistry monitoring, pre-release toxicity testing, bioaccumulation studies, creekside biological monitoring and biological disturbance gradient measures, and

[1] previously known as ‘beneficial uses’

- long-term change assessments – to detect any changes to biodiversity through macroinvertebrate and fish community monitoring.

Select relevant indicators

Details of the relevant indicators for biological monitoring are described elsewhere (Supervising Scientist 2002b). The chemical and physical stressors with the potential to degrade the environment were identified in assessments conducted prior to, or in the early stages of mining (eg Supervising Scientist 2003a). The potential stressors of most concern are termed 'key variables'. Trigger values have been set for the key variables, which are pH, EC, turbidity, uranium, radium-226 and manganese in Magela Creek, plus magnesium, sulfate and nitrate, but not turbidity or radium-226, in Ngarradj. The key variables applicable to Ranger creeks are described in table 1.1 below. Nitrate has been identified as an extra key variable for Ngarradj Creek, due to its presence as blast residues on waste rock.

Table 1.1 Relevance of key variables (from Klessa 2001)

Key Variable	Relevance
pH	Stipulated under ER23.3; master variable influencing speciation and toxicity of potential contaminants
EC	As above for pH
U	Stipulated under ER3.3; principal contaminant of public concern; potential ecological impact
Turbidity	No evidence of mine effect but becomes increasingly important as physico-chemical indicator of potential ecological impact from surface disturbance during rehabilitation
Mg	Evidence of mine effect; potential water potability impacts; potential ecological impact unclear
SO4	As above for Mg
Mn	Evidence of mine effect; contaminant arising primarily from use of pyrolusite in U3O8 production; potential ecological impact
226Ra	No evidence of mine effect; potential human health impact
Ca	No direct effect envisaged but required for the interpretation of potential ecological impact from Mg imbalance (i.e. Ca:Mg ratio)

Determine appropriate guideline trigger values

For physical and chemical stressors and toxicants in water, the preferred hierarchy for deriving trigger values follows the order:

1. Use of local biological effects data, eg ecotoxicity tests, including multiple species toxicity tests, mesocosms.
2. Use of local reference site data.
3. Use of default values provided in the Guidelines.

Direct biological effects data, in the form of a high-reliability site-specific toxicity value is available for uranium. For all other key variables the natural distributions of local reference site data have been assessed for suitability as trigger values. This is the main focus of this work and detail is given in the sections 'Methodology' and 'Results and discussion'.

Where trigger values were derived based on local reference site data the rolling monthly average method (where a minimum of 24 monthly averages is updated continuously by adding the most recent monthly average value, dropping the oldest value and recalculating the

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[2] Environmental Requirements

50th percentile) recommended in the guidelines was not adopted. Such a system would be difficult to implement in the situation where three agencies (ERA, Supervising Scientist and DBIRD) are collecting data at different times and real time management decisions need to be made. It is considered more suitable to have a stable set of trigger values for each site for an entire Wet season and to revise these values regularly rather than constantly.

Step 3: Define Water Quality Objectives

A water quality objective is defined in the guidelines as ‘A water quality guideline, defined above as a numerical concentration limit or descriptive statement *recommended* for the support and maintenance of a designated water use. Water quality objectives take this a step further. They are the specific water quality targets agreed between stakeholders, or set by local jurisdictions, that become the indicators of management performance. Normally, only those indicators considered relevant to the environmental issues or problems facing the resource are selected for deriving water quality objectives. They serve to protect the designated environmental values of a resource and would normally be based on the information from these Guidelines. A water quality objective is a numerical concentration limit or descriptive statement to be measured and reported back on. It is based on scientific water quality criteria or water quality guidelines but may be modified by other inputs such as social, cultural, economic or political constraints.’

The guideline trigger values from step 4 above will be presented to the Minesite Technical Committees as the proposed water quality objectives. Economic and cultural aspects will be considered by the MTC when adopting, or modifying, the trigger values as water quality objectives.

Step 4: Establish Monitoring and Assessment Program

Full details of the monitoring and assessment program are given in Supervising Scientist 2002b.

Step 5: Initiate appropriate management response

The hierarchy of triggers applied to Magela Creek and Ngarradj and are ***Focus, Action and Limit***; some limits are ***Guideline*** values rather than strict *Limits*. These terms and the responses they invoke are described below.

The *focus* and *action* triggers and *guideline* values, based on statistical properties of the range of values that occur naturally at a reference site, aid management of the site. It is known when setting these triggers that they will be exceeded occasionally due to natural causes (the number of times exceedances can be expected is dictated by statistical probability).

Limits are maximum permissible levels not to be exceeded due to mining activities. Previously, limits based on a statistical property of the natural range of values were applied to some parameters. Given that values set in this manner will occasionally be exceeded due to natural causes, it is now considered more appropriate[3] that guidelines, rather than strict limits apply, unless the maximum level has been defined by ecotoxicological testing or dietary modelling (as for uranium and radium).

The response invoked by an exceedance of a focus, action or limit trigger, or guideline, is prescribed in the *Explanatory Material relating to Section 3.3 of the Ranger Environmental Requirements* (Klessa 2001). The main points are reproduced below. Note, though the wording refers to Ranger, the same responses apply to Ngarradj (Jabiluka Minesite Technical Committee 21/09/2001).

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3 Ranger Minesite Technical Committee 17/10/2003.

[Supervising Scientist action]

If in the opinion of the Supervising Scientist the exceedance of a limit, with the possible exception of [a guideline] is, due to operations at Ranger the Supervising Scientist will advise the Minister with regard to

- *the circumstances surrounding the exceedance of the limit, and*
- *whether there has been a breach of the Ranger ERs.*

Company action

Focus level

Values which are maintained higher than the focus level *but lower than the* action level *will result in a watching brief and may require further sampling to verify whether an upward trend is occurring.*

Action level

- *Values which are maintained higher than the* action level *but lower than the* limit *will result in investigation and corrective action. Confirmation of such a value by virtue of*
  - *an abrupt change away from background values, or*
  - *a trend away from background values (other than associated with first flush)*

  Must be reported[4] *to the Supervising Authorities immediately.*
- *Interpretation of notifiable high values should take account of the composition of samples taken upstream…*

Limit

- *With the possible exception of* [guidelines], *values in excess of the* limit *will result in the company providing a written report to the Supervising Authorities detailing*
  - *all relevant data,*
  - *the circumstances surrounding the exceedance of the limit,*
  - *the corrective actions taken to date; and*
  - *options for further corrective action.*

Guideline limit

… the limit is a guideline *whose exceedance will be interpreted with regard to the values of the other key variables.*

Values which exceed the guideline limit *will result in a watching brief and prompt liaison with the Supervising Authorities. Further sampling will be undertaken to verify a trend and interpretation of values should take account of the composition of samples taken upstream…*

[4] The method of reporting is not prescribed. Reporting by way of verbal communication is acceptable (Ranger Minesite Technical Committee 17/10/2003).

1.3 Site descriptions

The Jabiluka Mineral Lease is located in the Ngarrradj (Swift Creek) catchment. Ngarradj, a major downstream right-bank tributary of Magela Creek, flows directly into the Magela Creek floodplain. The Ngarradj upstream site is 'JSCUS' (Jabiluka Swift Creek Upstream), the downstream compliance point, 'JSC' (Jabiluka Swift Creek), lies just outside the lease boundary in Kakadu National Park. The total area of the catchment upstream of JSC is approximately 43.5 km^2 (Boggs et al 2001). Several tributaries enter Ngarradj between the upstream and downstream sites from both sides. North and Central Tributaries pass through the mineral lease while South and East Tributaries are isolated from any influence of the Jabiluka site. The water chemistry at the downstream site is affected by inputs from these tributaries. The site has been described in detail elsewhere (eg Milnes & Jackson 1998).

Magela Creek flows from the Arnhem Land plateau to the east of Ranger mine to the East Alligator River via the Ranger Project Area, a series of billabongs and floodplains. As it passes through the project area on the northern side of the mine, Magela Creek has three main channels (West, Central and East branches) that anastomose in several places. Several upstream sites have been sampled historically (see section 2.2). The current upstream site is known as 'MCUS'. The downstream compliance point ('009' or 'MG009') is in the central channel of the creek several kilometres downstream of the mine, inside the project area. The area of the Magela catchment upstream of 009 is ~600 km^2 (Water Division, 1982). Nansen et al (1990) give a detailed description of Magela Creek. Camilleri et al (2003) describe some of the key sampling sites related to Magela Creek inputs.

Gulungul Creek, a small west bank tributary of Magela Creek, flows through the western side of the Ranger Lease. The tailings dam lies partly within the Gulungul catchment and several small tributaries enter the creek from the minesite. Two larger tributaries enter the creek on the west side (ie the side opposite the mine). The upstream sampling point is known as 'GCC' (Gulungul Creek Control) or 'GCUS' (Gulungul Creek Upstream). The downstream sampling site is 'GCH' Gulungul Creek at Highway. Crossing (2002) describes the creek and catchment and hydrology in more detail.

2 Methods

Upstream-reference and downstream-compliance sites situated on Ngarradj (Swift Creek), Magela and Gulungul Creeks are monitored weekly during flow by Energy Resources Australia (ERA) and the Supervising Scientist. At least two, and up to twenty years of data have been collected from these sites by the Northern Territory Department of Business, Industry and Resource Development (DBIRD), the Northern Territory Department of Infrastructure, Planning and Environment – Water Resources Division (NTWRD) and their predecessors, ERA and Supervising Scientist. A hierarchy of trigger values, based on the distribution of the upstream reference site datasets or ecotoxicological testing, has been derived for each creek in line with the Water Quality Guideline (ANZECC & ARMCANZ 2000) recommendations.

The reference site datasets used in this review differ from those used previously to set the trigger values (Klessa 2000 & 2001). The quality of data in the various historical datasets varies within and between the datasets. The complete historical baseline dataset is very useful for comparison of trends[5] but is not ideal for setting current management trigger values and

[5] For a description of Magela Creek baseline data see Klessa (2000). For Ngarradj baseline data refer to Milnes and Jackson (1998).

compliance limits. The decision to use a reduced dataset to describe reference site conditions was influenced by issues related to (i) the reference sites, (ii) the data quality, (iii) recent changes in technology and (iv) recommended procedures in the Water Quality Guidelines (ANZECC & ARMCANZ 2000). The data included in each reference site dataset are explained in each site's section below. The issues are summarised here.

Reference sites

The selection of appropriate reference sites was influenced by the location and sampling histories of the sites. This only affected the choice of data for MCUS, the Magela Creek reference site. Details are given in Section 2.2.

Data quality

In attempting to describe a reference site condition for a uranium mine the most important data quality problem is the history of sample contamination with uranium. Some of the historic uranium values are very high, especially at the Magela Creek upstream site. It is likely that many of these high values reflect sample contamination rather than true uranium concentrations. Klessa (2000) implies that many of the ~40% of historic samples that were above the detection limit of 0.1 µg/L were possibly contaminated. Batley (1999), and LeGras (2000) discuss uranium contamination problems with the early data collected from the Jabiluka Creeks.

More information on data quality issues can be found in Klessa (2000) and Camilleri et al (2003).

Changes in technology

One of the most important considerations in defining a reference dataset is the need to be able to compare like with like, ie compare current downstream values to existing reference site values that have similar qualities. Significant changes in analytical technology and sample handling/preservation techniques have occurred, especially in the last few years, which have lead to greater quality control and most importantly, to much lower detection limits for uranium and other metals.

Sulfate and manganese detection limits have also changed since the beginning of data collection but not as drastically as uranium.

Water Quality Guidelines recommendations

Including all historic data in a reference dataset retains the legacies of these problems in the dataset[6]. A rolling dataset is recommended in the Water Quality Guidelines to keep the reference dataset current (by discarding older data in favour of new). The question of how many data to include in the reference dataset is addressed in the Water Quality Guidelines. The Guidelines recommend a minimum of two years of monthly averages from the reference site. Preliminary work not reported here showed that two years of Magela Creek reference site data had a more limited range than ten years of (reliable) data.

As was done previously (Klessa 2000), laboratory results were used for pH, turbidity and EC in preference to in-situ measurements. Results for pseudo-replicates (samples collected independently by ERA and Supervising Scientist on the same day) were averaged except,

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6 Most of the sample contamination and inappropriate sampling location problems are associated with older data.

- where the independent results were not in agreement (>20% difference), and
- for pH and uranium – differences in independent datasets have been identified before (Klessa 2001& 2002).

Records identified as 'first flush' were initially rejected from the reference site datasets but were reinstated after discussion amongst stakeholders[7]. A sensitivity analysis of the derived trigger values for Ngarradj to the first flush data is presented in Appendix 1.

Results more than 1.5 times the interquartile range (the middle 50% of the data) were identified as outliers by MINITAB™ Release 13.20. Each datum identified as an outlier was checked. The decision to retain or remove each datum is explained below.

Percentiles were calculated for each parameter using Microsoft® Excel 2000. Preliminary exploratory data analysis (not presented here) showed that many parameters fitted neither a normal nor lognormal distribution. Therefore, to standardise treatment across the parameters, it was decided to adopt a percentile approach for all parameters. The decision to base triggers on percentiles rather than other distribution parameters[8] is recommended in the Guidelines (ANZECC & ARMCANZ 2000), as percentiles, being distribution free, are robust.

Apart from uranium, the triggers are based on the 80th (focus), 95th (action) and 99.7th (guideline) percentiles. For pH the 20th (focus), 5th (action) and 0.3rd (guideline) percentiles are recommended for the lower triggers.

The uranium limit is based on high-reliability site-specific toxicity value (TV) derived from testing five local species from 4 taxanomic groups as per ANZECC & ARMCANZ (2000) Guidelines. The current uranium limit for Magela Creek and Ngarradj is 5.8 μg/L, the TV previously derived by Van Dam (2000). That TV has been updated to 5.5 μg/L (Hogan et al 2003) and is recommended as the new limit to be adopted for all downstream compliance points.

Currently the Magela Creek and Ngarradj uranium focus and action triggers are based on the 80th and 99.7th percentiles of their respective reference site datasets (Gulungul Creek does not currently have focus and action triggers applied to it). Problems with using those percentiles for uranium triggers, and alternatives, are discussed in the sections below on each creek.

To determine the expected frequency of exceedances at the downstream sites[9], control charts showing historic downstream data overlaid with the current and revised/recommended trigger values were used. These charts are useful to determine if the recommended triggers will be useful management tools. In some cases they highlight the inappropriateness of the process for particular parameters at some sites.

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7 Ranger Minesite Technical Committee meeting 17/10/2003.

8 Previously the mean and standard deviations were used for normally distributed data and percentiles used only for non-normally distributed data (Klessa 2000 & 2001).

9 For Ngarradj the trigger and guideline values reported in this document apply to the downstream compliance site (JSC) and not to the downstream tributary sites. Both North and Central Tributary feed into Ngarradj between the upstream and downstream sites and are monitored weekly while flowing. While the water quality in these tributaries is reviewed for upstream-downstream changes and trends, these streams are wholly within the lease area and have no compliance/documented management targets set against them.

2.1 Methods for Ngarradj triggers

Water quality data for the Jabiluka creeks have been collected regularly since the 1997/98 wet season by ERA and Supervising Scientist. Not all that data has been included in the upstream reference site dataset used to calculate the trigger and guideline values presented in this document.

Very few DBIRD results were available for JSCUS. Most samples DBIRD collect from this site are 'referee samples' and are not always analysed. Also, DBIRD samples are normally collected in tandem with ERA samples and are therefore replicates. While these samples are valuable for quality control purposes their inclusion would not increase the strength of the dataset for the purpose of this work.

With the exception of uranium data, the final reference dataset contains five years of ERA data and four years of Supervising Scientist data. A summary of the uranium data quality issues associated with the reference site dataset is given in table 2.1.1. For uranium, only data from the unshaded cells in the table are included in the final reference site dataset used in this study, ie ERA U data from the 2000/01–2002/03 Wet seasons and Supervising Scientist U data from the 1998/99–2002/03 Wet seasons. ERA uranium data collected prior to 2000/01 were not included in the final reference site dataset because of:

- known uranium contamination problems in 1997–1998 and 1998–1999 (Batley 1999, LeGras 2000 and Jones et al 2001), and
- the high detection limit for uranium (0.1 μg/L) in 1999–2000.

For all other parameters (pH, turbidity, EC, Mn, Mg, SO_4) the full ERA and Supervising Scientist datasets were used (ie ERA 1997/98–2002/03 data and Supervising Scientist 1998/99–2002/03 data) with the exception of the following:

- Records containing field turbidity only were removed from the dataset; laboratory turbidity results, considered more reliable than their field counterparts, are normally reported.
- Pseudo-replicates, ie samples collected by ERA and Supervising Scientist on the same day, were averaged (except for pH, and uranium values which is explained in the relevant sections below).

Nitrate is not included in this work as a problem was identified with the 2001–02 ERA and Supervising Scientist pseudo replicates. Many pseudo replicate results for this season are different by approximately a factor of 4 indicating there may be a problem with the reported units (4.4 is the conversion factor between NO_3-N and NO_3). This needs to be addressed before the trigger values can be revised, it has not been investigated at this stage because, as explained below, a second stage of work is required before the trigger values can be reset.

Table 2.1.1 A summary of uranium data quality for uranium for the Ngarradj upstream site (JSCUS)

Year	Jabiluka upstream		
	ERA	Supervising Scientist	Comments
2002–2003	[U] DL = 0.005 n = 24	[U] DL = 0.005 n = 21	ERA and Supervising Scientist sampled on different days of the week
2001–2002	[U] DL = 0.005 n = 18	[U] DL = 0.005 n = 18	ERA and Supervising Scientist sampled on the same days of the week for most of the season – pseudo replicates
2000–2001	[U] DL = 0.005 n = 26	[U] DL = 0.005 n = 13	ERA and Supervising Scientist sampled on the same days of the week for most of the season – pseudo replicates. Supervising Scientist data until April only
1999–2000	36% [U] <0.1	[U] DL = 0.005 n = 26	ERA and Supervising Scientist sampled on the same days of the week for most of the season - pseudo replicates
1998–1999	LeGras (unpublished) 'U contamination'; mixed [U] DL <10% x <0.1 2 [U]>1.5 n = 24	[U] DL = 0.005 n = 21	ERA and Supervising Scientist sampled on different days of the week
1997–1998	Batley (1999) 'U contamination'; n = 11	JSCUS site not sampled	

2.2 Methods for Magela Creek triggers

The upstream reference sites on the Ranger Mine lease are MCUS (Magela Creek Upstream) and GCC/GCUS (Gulungul Creek Control/Gulungul Creek Upstream – the ERA and Supervising Scientist names for the same site). This section deals with Magela Creek, Gulungul Creek methods are reported in section 2.3.

The reference sites selected for Magela Creek were the ERA and Supervising Scientist MCUS sites. Very few recent DBIRD results were available for MCUS. Most samples DBIRD now collects from this site are 'referee samples' and are not always analysed (pers comm. Megan Bailey, DBIRD). Previously data from G8210067 (GS-067) and G8210028 (GS-028) were included in the reference dataset. Neither of these sites was included for this work.

The GS-067 site is not considered an ideal upstream reference site as it is downstream of Georgetown Billabong and the Corridor – Magela Creek confluence. Corridor Creek has been impacted by mining activities and the proximity of an upstream billabong exposes the site to a different set of limnological conditions compared to the downstream site.

The GS–028 site has not been sampled regularly since the early nineties. And much of the available data has high detection limits. Also, a side creek converges with Magela Creek between this site and the mine.

For all parameters, other than uranium, ERA data from 1994–2002/03 and Supervising Scientist data from 2000/01–2002/03 comprise the MCUS dataset. There are several sites referred to as MCUS and doubts regarding the quality of samples collected at 'MCUS' during some periods have been raised. The first record in the ERA database for the 1993/94 Wet season has the description ‘NEW SITE’. Only data from 1994 onward have been used in the Magela Creek reference site dataset. For more detail on MCUS sampling history see Camilleri et al (2003).

A summary of the uranium data quality issues associated with the Magela Creek reference site (MCUS) dataset is given in table 2.2.1. Uranium data from the unshaded cells only in table 2.2.1 are included in the final reference site dataset used in this review. ERA uranium data prior to 2001/02 were not included in the final reference site dataset because of the high detection limit for uranium (0.1 µg/L) prior to this. Details in table 2.2.1 show that the common practice of substituting half the detection limit for ‘<DL’ values is not good practice for uranium. Results for the majority of samples analysed with the more sensitive technique employed in latter years are much less than half of the previous detection limit.

Except for pH, DBIRD data is not included in the control charts of the downstream data due to display problems caused by the data format.

Table 2.2.1 A summary of uranium data quality for the Magela Creek upstream site (MCUS)

Year	Magela Creek upstream		
	ERA	Supervising Scientist	Comments
2002–2003	>90%[U] 0.005–0.03 <5%[U] 0.03–0.05 <5%[U] >0.05 n = 22	>85%[U] 0.005–0.03 <10%[U] 0.03–0.05 <5%[U] >0.05 n = 30	Majority of samples < than 0.05, half of the old detection limit
2001–2002	>80%[U] 0.005–0.03 <20%[U] 0.03–0.05 n = 29	100%[U] 0.005–0.03 n = 23	Majority of samples < than 0.05, half of the old detection limit
2000–2001	78% [U] <0.1	>80%[U] 0.005–0.03 <20%[U] 0.03–0.05 n = 37	Majority of ***eriss*** samples < than 0.05, half of the old detection limit
1999–2000	88% [U] <0.1	Not sampled	
1998–1999	76% [U] <0.1	Not sampled	
1997–1998	81% [U] <0.1	Not sampled	

2.3 Methods for Gulungul Creek triggers

Water quality data for the Gulungul Creek reference site (GCUS/GCC) have only been collected regularly by ***eriss*** since the 2001/02 Wet season (GCUS) and by ERA since the 2002/03 Wet season (GCC). ERA collected some data from GCC in the 1998/99 (n=11) and in 2000/01 (n=3) Wet seasons. Table 2.3.1 summarises the data available for the Gulungul Creek reference site.

The Gulungul Creek reference site dataset used for this work contains Supervising Scientist 2001/02 and 2002/03 data for GCUS and the1998/99 and 2001 ERA data for GCC. During the 2002/03 Wet season the ERA samples were replicates of the Supervising Scientist samples, collected by Supervising Scientist. Consequently, the ERA 2002/03 data have not been included in the reference site dataset

Table 2.3.1 A summary of the Gulungul Creek upstream site (GCUS/GCC) data

Year	Gulungul Creek upstream		
	ERA (GCC)	*eriss* (GCH)	Comments
2002–2003	Replicates of *eriss* samples	*n* = 20	Samples collected for ERA by ***eriss***
2001–2002	Not sampled	*n* = 22	
2000–2001	*n* = 3	Not sampled	
1999–2000	Not sampled	Not sampled	
1998–1999	*n* = 11 (general parameters) *n* = 2 (metals & ions)	Not sampled	
< 1998	Not sampled	Not sampled	

ERA data, collected for the downstream site (GCH) since 1980, and Supervising Scientist data for the same site, collected since the 2001/02 Wet season, are used in the control charts for Gulungul Creek.

3 Results and discussion

The results for each creek are discussed separately below. For each creek all data on key variables for the upstream reference sites are presented on a box plot (showing outliers, the interquartile range and the 95% confidence interval around the median) and a cumulative percent histogram. Details of outlier treatment are given and derived triggers shown on control charts against historic downstream data.

3.1 Ngarradj results

3.1.1 Ngarradj pH

Because of the unsolved discrepancy between ERA and Supervising Scientist pH measurements (Klessa 2001), pH pseudo replicates were not averaged.

A box plot of pH data with outliers identified is shown in figure 3.1.1. Nothing in the ERA or Supervising Scientist database suggested the data points identified as outliers were unreliable, so no outliers were removed.

The revised pH guideline values, set at the 20th and 80th, 5th and 95th and 0.3rd and 99.7th percentiles of the reference site data are given in table 3.1.1, along with current guideline trigger values. A cumulative percent histogram of the JSCUS pH data is shown in figure 3.1.2. To illustrate the rate of expected exceedances of the guideline values, historic downstream pH data are plotted on a control chart with current and recommended trigger values (figure 3.1.3).

Table 3.1.1 Current and revised pH guideline trigger values for Ngarradj

Trigger	Percentiles	Revised trigger values	Current trigger values
Focus	20th – 80th	4.7–5.2	4.61 – 5.31
Action	5th – 95th	4.5–5.4	4.27 – 5.65
Guideline	0.3 – 99.7th	3.7–5.8	3.92 – 6.00

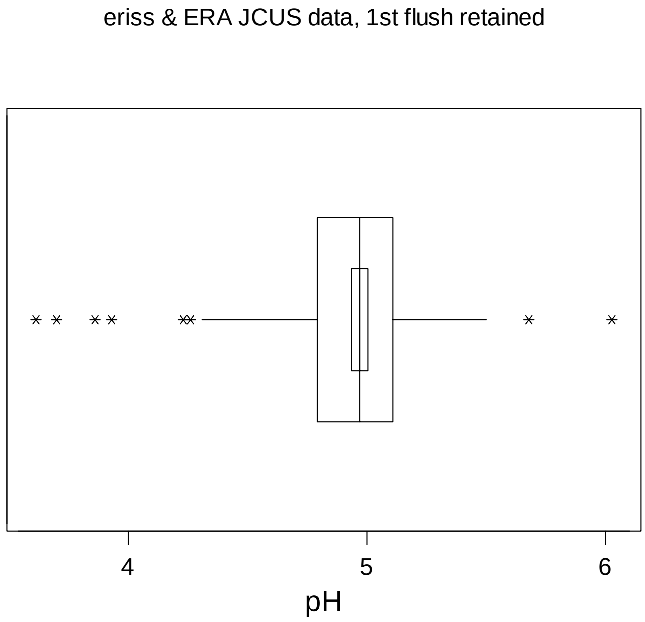

Figure 3.1.1 Box plot of JSCUS pH data showing outliers

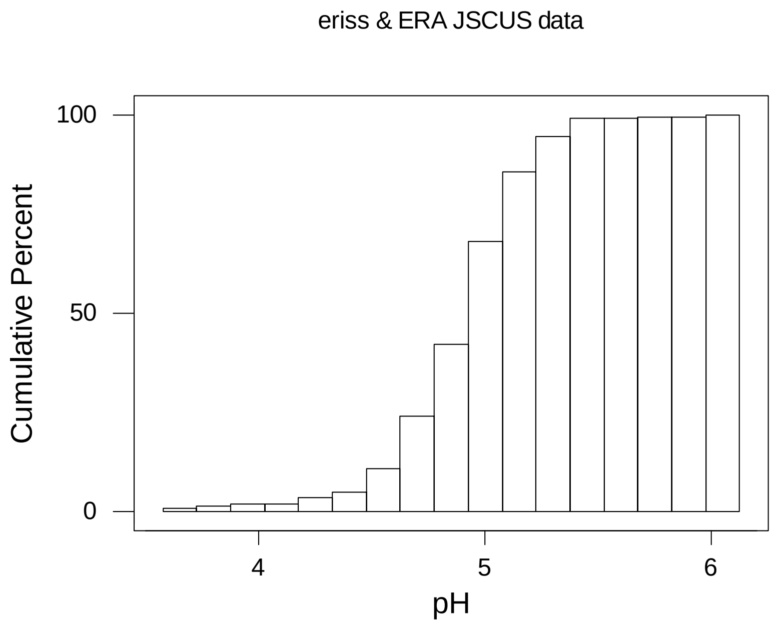

Figure 3.1.2 Cumulative percent histogram of JSCUS pH data

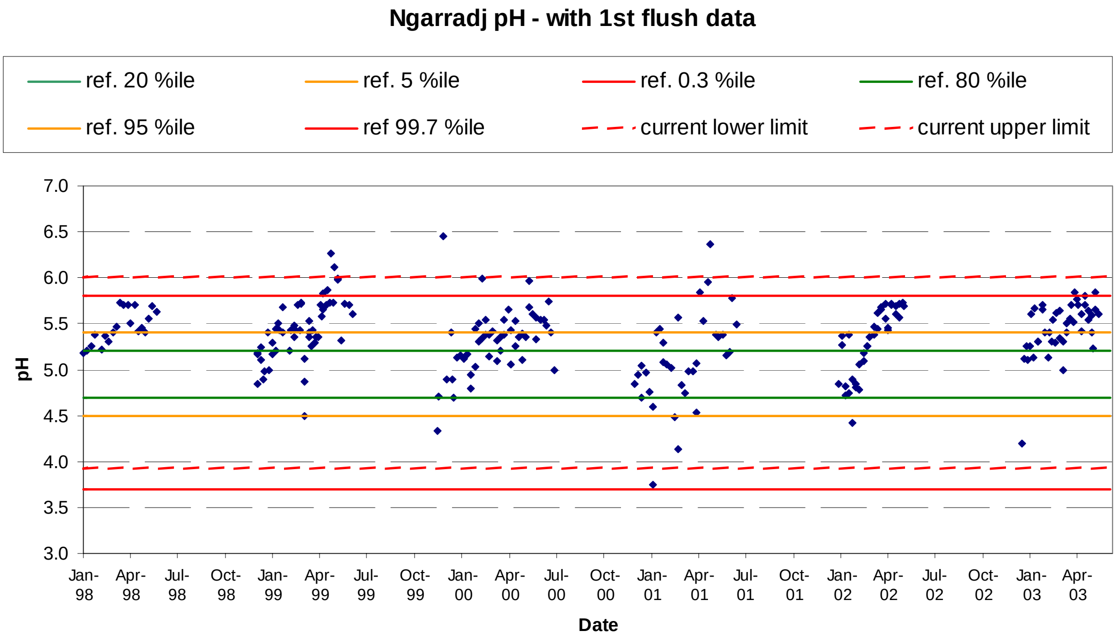

Figure 3.1.3 Control chart of all Ngarradj downstream (JSC) historic pH data showing revised and current trigger values

The range between the revised focus and action triggers has reduced (table 3.1.1) and the upper and lower guidelines have shifted down (table 3.1.1 and figure 3.1.3). Figure 3.1.3 shows that since the start of sample collection (before any change could have been caused by works on site) pH at the downstream site has fallen outside the percentiles of the upstream site more often than statistically expected. It has been noted previously (Jones et al 2001) that pH at the downstream site is naturally different from the upstream site due to inputs from the tributaries between the two sites. It is apparent that the upstream site JSCUS is not a good reference site for setting pH triggers. However it remains the ideal control site for monitoring purposes.

The Guidelines advise relaxing triggers to avoid excessive triggering only when it is known that doing so will not compromise the objective of maintaining biological diversity in the system (section 3.1.3.2 ANZECC & ARMCANZ, 2000). Biological monitoring has been conducted in the Jabiluka creeks and no impact has been detected downstream of the site (eg Supervising Scientist 2003b). Therefore, in line with this advice from the Guidelines, the downstream data collected to date could be used, instead of the upstream reference site data to set the trigger values. Percentiles could be set on either an upstream-downstream difference to date or directly on the downstream data.

Recommendation: Derive trigger values from the pH data collected from the downstream site (JSC) to date.

3.1.2 Ngarradj EC

A box plot of EC data with outliers identified is shown in figure 3.1.4. Details of outlier treatment are given in table 3.1.2.

The revised EC trigger values, set at the 80^{th}, 95^{th} and 99.7^{th} percentiles of the reference site data are given in table 3.1.3 along with current trigger values. A cumulative percent histogram of the JSCUS EC data is shown in figure 3.1.5.

To illustrate the rate of expected exceedances of the trigger values, historic downstream EC data are plotted on a control chart with current and recommended trigger values (figure 3.1.6).

Table 3.1.2 Treatment of JSCUS EC outliers

EC value (µS.cm^{-1})	Date	Source	Detail	Decision
23.6	2/1/03	***eriss***	Within range of first flush data	RETAIN
88	6/2/01	ERA	ERA in-situ value = 10	REJECT

Table 3.1.3 Current and revised Ngarradj EC trigger values

Trigger	Percentile	Current value (µS.cm^{-1})	Revised value (µS.cm^{-1})
Focus	80th	15	14
Action	95th	18	19
Guideline	99.7th	21	26

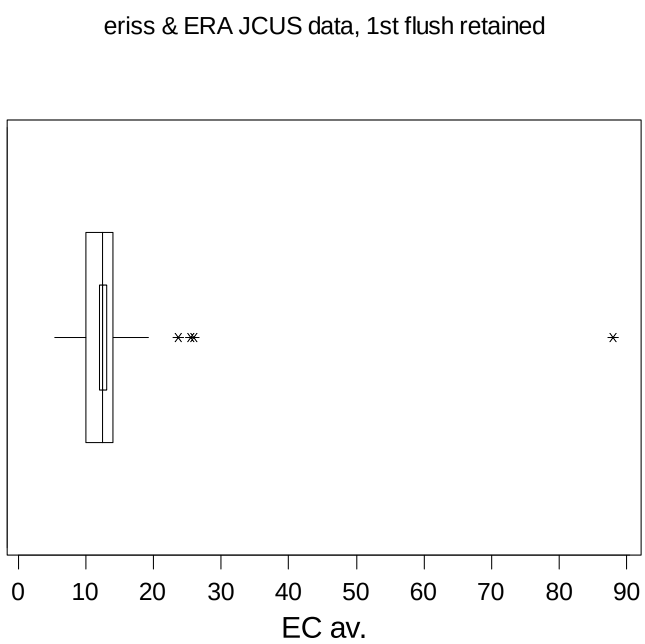

Figure 3.1.4 A box plot of JSCUS EC data (µS/cm) showing outliers

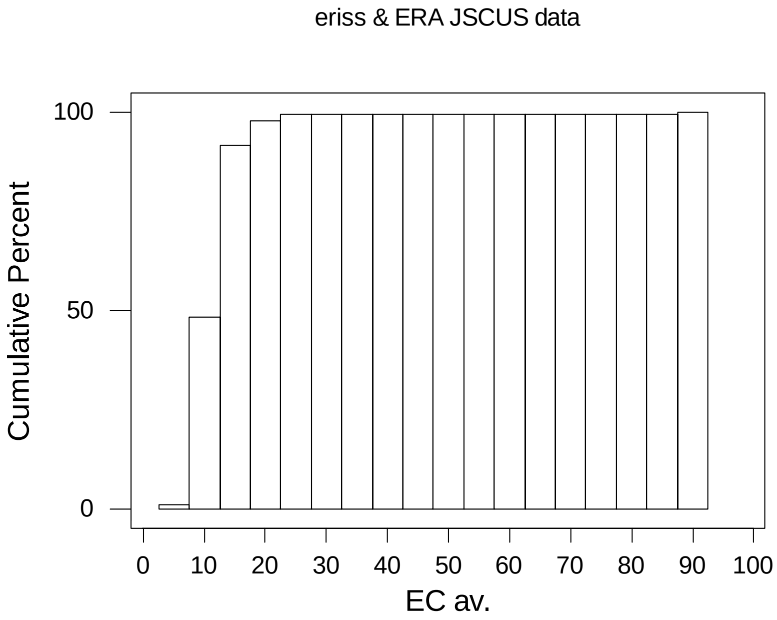

Figure 3.1.5 Cumulative percent histogram of JSCUS EC data (µS/cm)

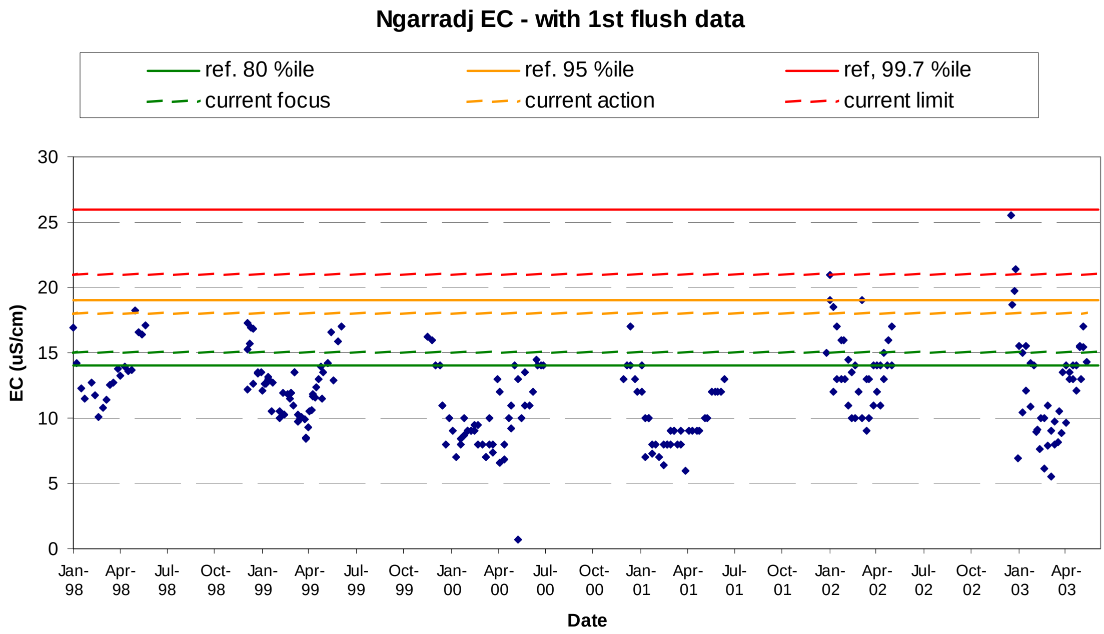

Figure 3.1.6 Control chart of all Ngarradj downstream (JSC) historic EC data showing revised and current trigger values

The revised focus and action triggers remain similar to the current values. The guideline (previously limit) is slightly higher. Figure 3.1.6 shows that the revised triggers are appropriate to aid management of EC at Ngarradj.

Recommendation: The 80th, 95th and 99.7th percentiles of the JSCUS dataset be adopted as the EC focus, action and guideline trigger values for JSC when the trigger values are reset.

3.1.3 Ngarradj turbidity

A box plot of turbidity data with outliers identified is shown in figure 3.1.7. Outliers were checked for obvious errors, none were found. The values identified as outliers are typical of values recorded during storm or high flow events and so have been retained.

Currently there are no trigger values set for Ngarradj. The derived trigger values, set at the 80th, 95th and 99.7th percentiles of the reference site data are given in table 3.1.4. A cumulative percent histogram of the JSCUS turbidity data is shown in figure 3.1.8.

To illustrate the rate of expected exceedances of the guideline values, historic downstream turbidity data (including first flush data) are plotted on a control chart with current and recommended guideline values (figure 3.1.9).

Table 3.1.4 Derived turbidity trigger values for Ngarradj

Trigger	Percentile	Current trigger values (NTU)	Derived trigger values (NTU)
Focus	80th	N/A	2
Action	95th	N/A	4
Guideline	99.7th	N/A	12

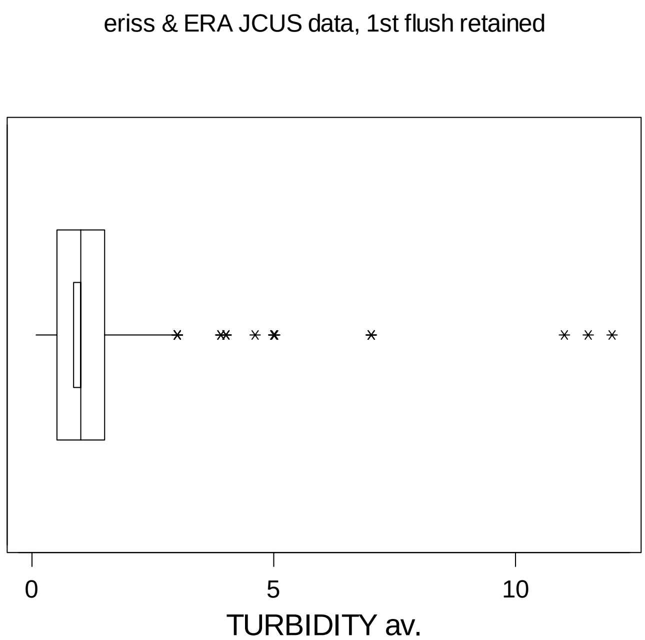

Figure 3.1.7 A box plot of turbidity data (NTU) showing outliers

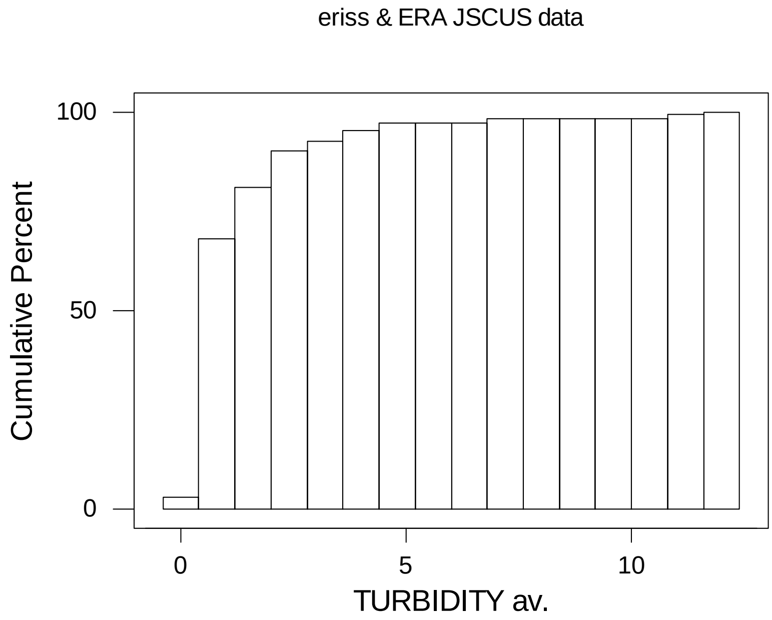

Figure 3.1.8 Cumulative percent histogram of JSCUS turbidity data (NTU)

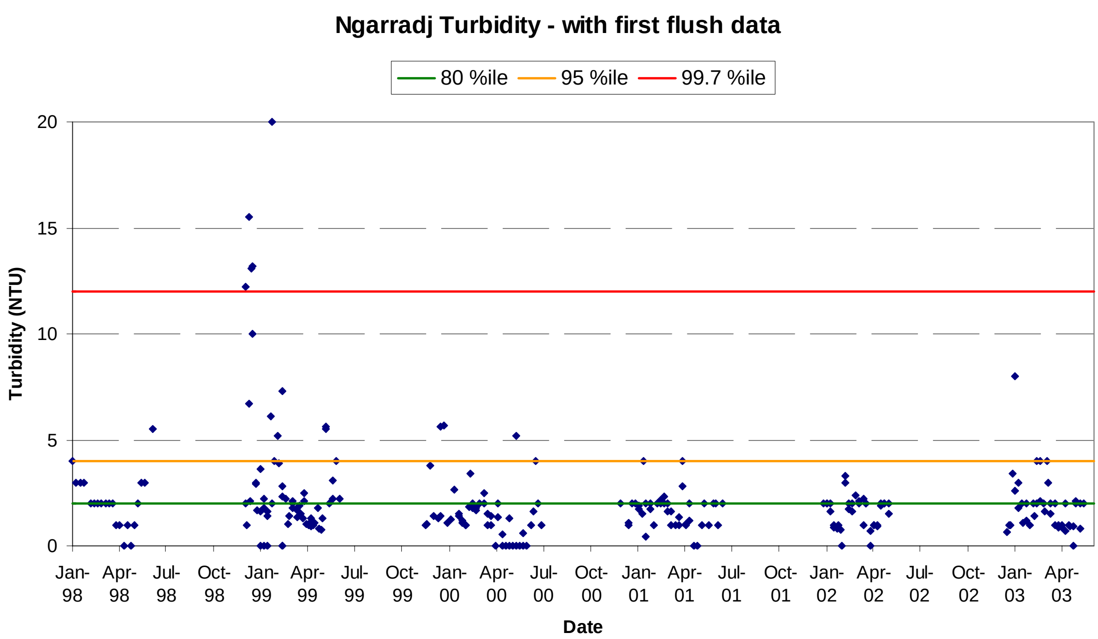

Figure 3.1.9 Control chart of all Ngarradj downstream (JSC) historic turbidity data showing recommended guideline values

Figure 3.1.9 shows how far the reference site 99.7th percentile (guideline) is above the values regularly measured at the downstream site. Observed data collected over several years in Ngarradj (Prendergast & Evans 1998) show that the upstream site has a higher sediment load, and therefore higher turbidity, than the downstream site. This is expected in a small catchment according to the sediment delivery ratio theory (eg Walling 1983).

As recommended above for pH (section 3.1.1) it might be more appropriate to base turbidity triggers on downstream data if it can be shown that there has been no increase at the downstream site since monitoring began. This is suggested in light of the Guidelines recommendations for relaxing trigger values (discussed in section 3.1.1 above) and the fact that biological monitoring has not shown an impact on the downstream ecosystems (eg Supervising Scientist 2003b).

Recommendation: Derive trigger values from the turbidity data collected from the downstream site (JSC) to date.

3.1.4 Ngarradj uranium

A box plot of uranium data with outliers identified is shown in figure 3.1.10. All data identified as outliers by Minitab have been retained. The highest concentration identified as an outlier was only 0.071µg/L collected by ERA on 3 April 2001. There is nothing in the database to indicate that this result is not reliable[10].

The uranium values in Ngarradj are close to the analytical detection limit and are two orders of magnitude lower than the ecotoxicologically derived limit (table 3.1.5). The Water Quality Guidelines (ANZECC & ARMCANZ 2000) recommend that ecological effects data be used to set trigger values when available. Uranium toxicity to five Magela Creek species has been determined previously as 5.8 µg/L (Van Dam 2000) and recently revised to 5.5µg/L (Hogan et al 2003). It is recommended that once the revised ecotoxicological limit for Magela Creek has been reviewed and accepted by stakeholders that it be adopted as the limit for Ngarradj.

The recommended focus and action limits for Ngarradj are the 95th and 99.7th percentiles of the reference site dataset for the focus[11] and action levels respectively. Table 3.1.5 shows the recommended uranium trigger values and what they represent. To illustrate the rate of expected exceedances of the trigger values, historic downstream uranium data are plotted on a control chart with current and recommended trigger values (figure 3.1.12).

Table 3.1.5 Current and recommended uranium trigger values for Ngarradj

Percentile	Ngarradj percentiles (µg/L)	Trigger	Current Ngarradj trigger values (µg/L)	Recommended Ngarradj trigger values (µg/L)
80th	0.012	**Focus**	0.02 [a]	0.03 [d]
95th	0.023	**Action**	0.03 [b]	0.06 [e]
99.7th	0.059	**Limit**	5.8 [c]	5.5 [f]

a: the previously derived 80th percentile, **b:** the previously derived 99.7th percentile, **c**: the current ecotoxicological limit, **d:** the newly derived 95th percentile, **e**: the newly derived 99.7th percentile, **f**: the revised ecotoxicological limit

[10] If this value reflects sample contamination then such levels of contamination may need to be considered normal as occasional contamination of this magnitude is difficult to avoid and likely to occur occasionally at the downstream site.

[11] The current uranium focus trigger value, set at the 80th percentile of the previous reference site dataset (column 4, table 3.1.5) is impractical – the values are so low that blank samples have exceeded the focus limit in the past (***eriss*** 31/12/02 and 4/2/03).

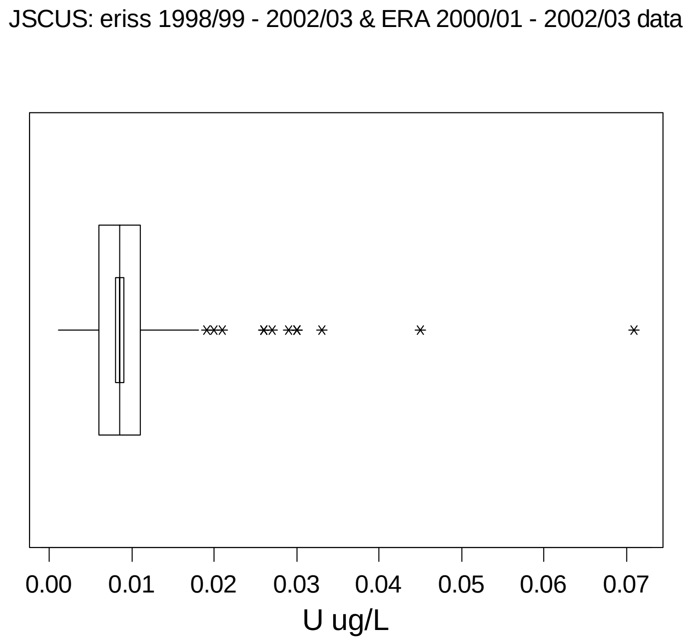

Figure 3.1.10 A box plot of JSCUS uranium data (µg/L) showing outliers

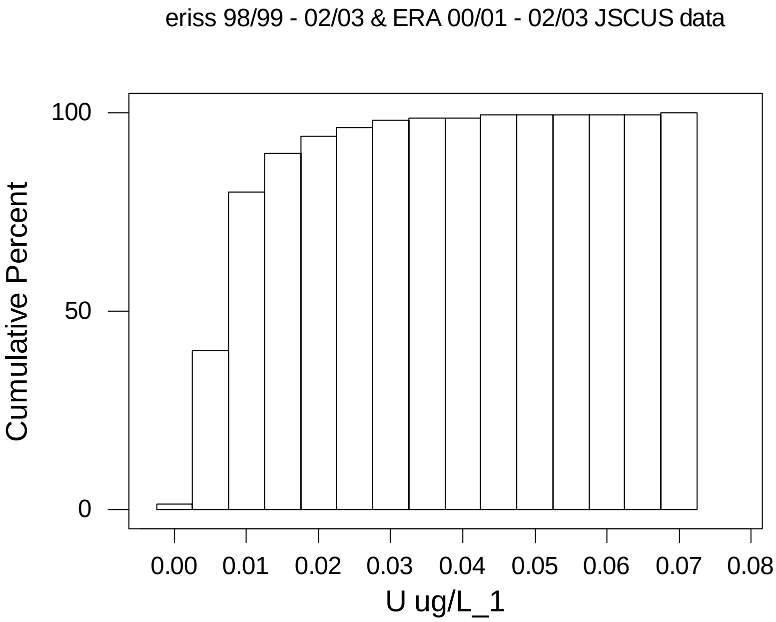

Figure 3.1.11 A cumulative percent histogram of JSCUS uranium data (µg/L)

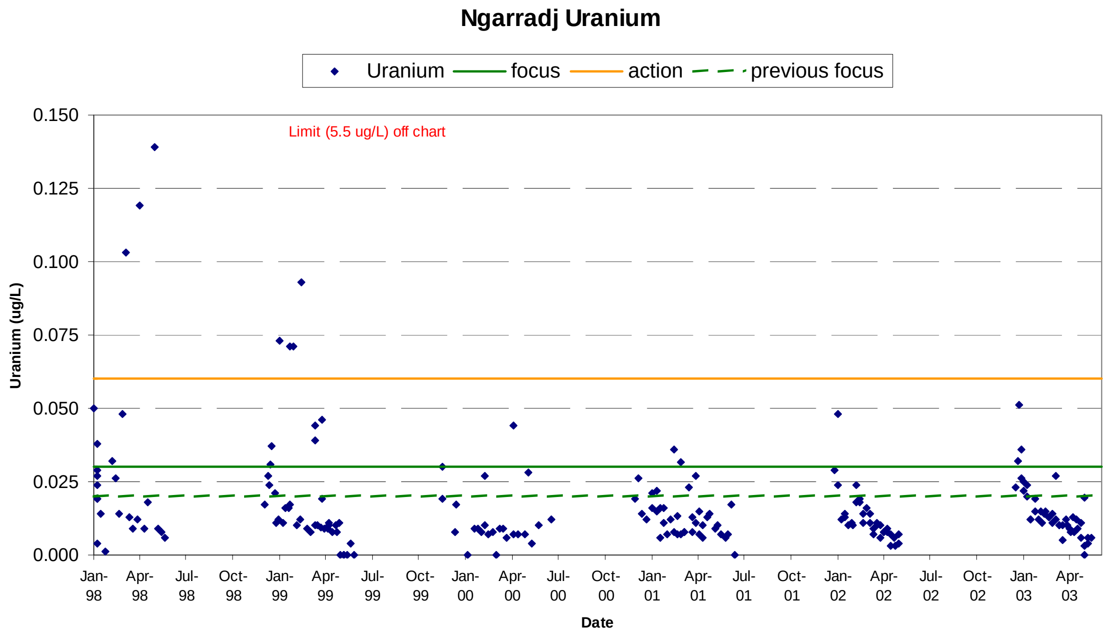

Figure 3.1.12 Control chart of all Ngarradj downstream (JSC) historic uranium data showing recommended focus and action triggers and current focus trigger (the current action trigger, overlain by the recommended focus at 0.03 µg/L, is not visible)

Figure 3.1.12 illustrates that the focus and action triggers would be a useful management tool; they would not be exceeded excessively, and when they were, investigation would be warranted. An example of how the triggers would work can be seen in figure 3.1.12 – the action exceedances in the early data probably reflect contamination, which was a problem in those years (Bately 1999, LeGras 2000). Had the recommended trigger values been in place at the time the contamination problem may have been recognised earlier.

Recommendation: Once the revised ecotoxicological limit for Magela Creek (5.5 µg/L) has been reviewed and accepted by stakeholders it be adopted as the limit for Ngarradj. And the 95th and 99.7th percentiles of the reference dataset be adopted as focus and action triggers at the same time.

3.1.5 Ngarradj Manganese

There are currently no manganese trigger values for Ngarradj as manganese is only expected to be of concern in Ngarradj if milling were to proceed at the Jabiluka site. However, manganese data is currently collected at the Ngarradj upstream and downstream sites. So, to assist in interpreting the data trigger values have been determined.

A box plot of manganese data with outliers identified is shown in figure 3.1.13. All values identified as outliers were very low and considered to reflect natural variation; they have been retained.

The 80th, 95th and 99.7th percentiles of the reference site data are given in table 3.1.6. A cumulative percent histogram of the JSCUS manganese data is shown in figure 3.1.14. To illustrate the rate of expected exceedances of these values, historic downstream manganese data are plotted on a control chart with the percentiles (figure 3.1.15).

Table 3.1.6 Derived manganese percentiles for Ngarradj

Percentile	Manganese concentration (µg/L)	Current trigger values (µg/L)
80th	6	N/A
95th	9	N/A
99.7th	15	N/A

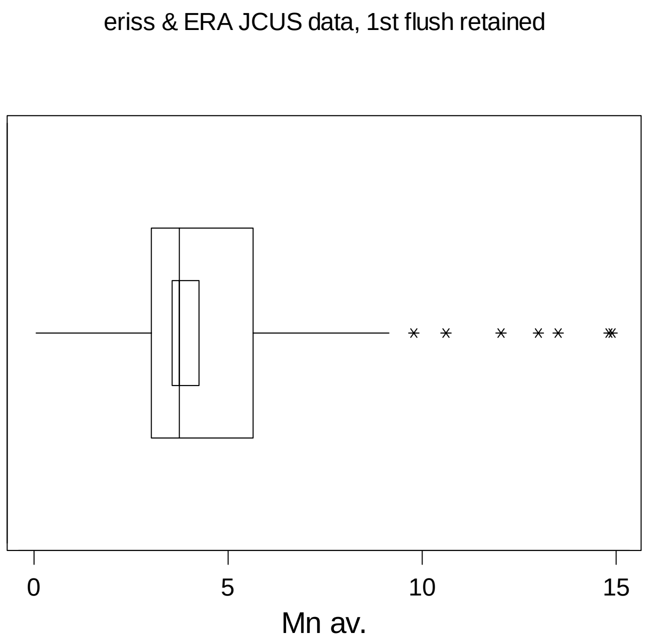

Figure 3.1.13 A box plot of JSCUS manganese data (µg/L) showing outliers

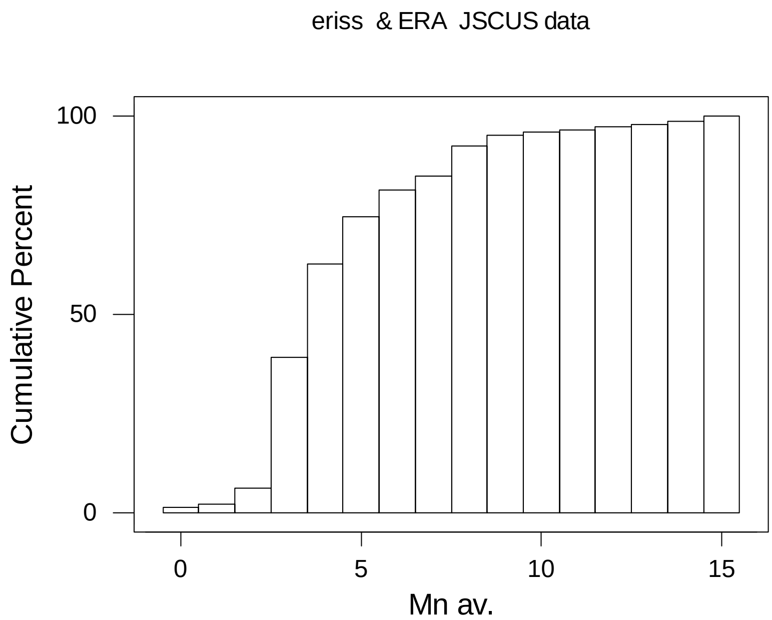

Figure 3.1.14 A cumulative percent histogram of JSCUS manganese data (µg/L)

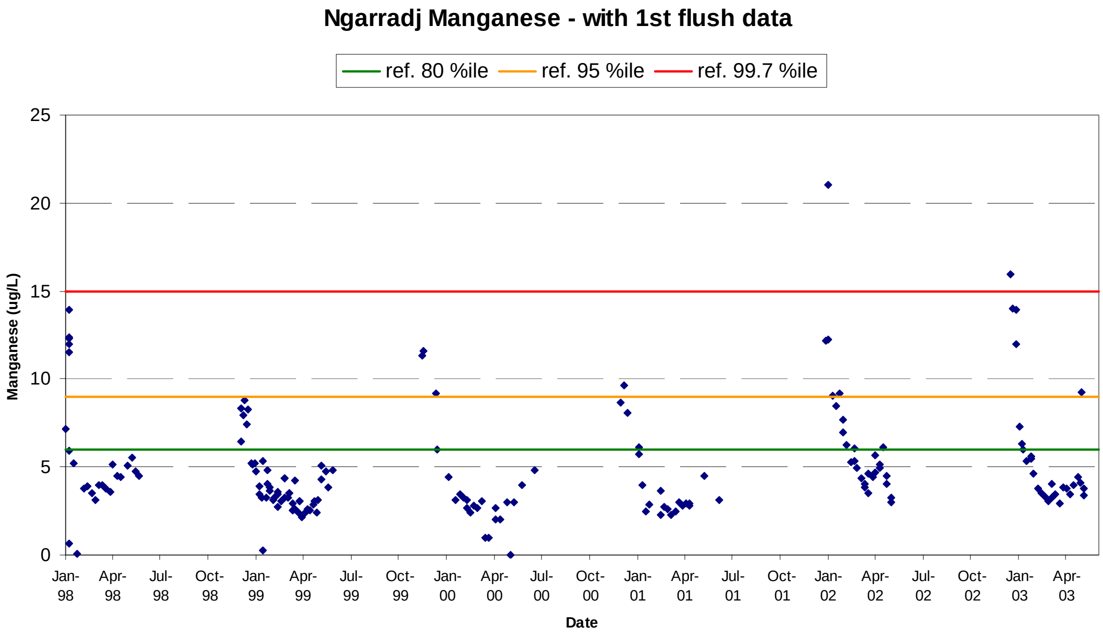

Figure 3.1.15 Control chart of all Ngarradj downstream (JSC) historic manganese data showing reference site percentiles

More exceedances of reference site percentiles are shown on the control chart (figure 3.1.15) than would be statistically expected. But, nearly all the exceedances appear in the early stages of the season during the first flush period. After the first flush period the data is nearly all data are below the 80th percentiles. The reference site percentiles could provide a good tool to interpret post first flush downstream data but exceedances during the first flush period should be expected.

Recommendation: The manganese reference site percentiles should be used internally to assist in data interpretation. There is no justification to adopt these as water quality objectives under the existing trigger values system, ie they should not become formal trigger values for Ngarradj.

3.1.6..Ngarradj magnesium

A box plot of magnesium data with outliers identified is shown in figure 3.1.16. Details of outlier treatment are given in table 3.1.7.

The magnesium guideline values, set at the 80th, 95th and 99.7th percentiles of the reference site data, are given in table 3.1.8 along with current guideline trigger values. A cumulative percent histogram of the JSCUS magnesium data is shown in figure 3.1.17.

To illustrate the rate of expected exceedances of the guideline values, historic downstream magnesium data are plotted on a control chart with current and recommended guideline values (figure 3.1.18).

Table 3.1.7 Treatment of JSCUS magnesium outliers

Value (mg/L)	Date	Source	Detail	Decision
14.2	20/2/01	ERA	No Mg result was reported for this sample in the old ERA Minewater database	REJECT
0.50	Various	ERA & ***eriss***	Several results (n=6) through several years	RETAIN
0.60	27-30/12/02	ERA	Two results in close succession	RETAIN
0.75	25/07/00	ERA	Not atypical magnitude for recessional flow periods	RETAIN

Table 3.1.8 Current and revised Ngarradj magnesium guideline values

Trigger	Current guideline value ($\mu S.cm^{-1}$)	Percentile	Revised guideline value ($\mu S.cm^{-1}$)
Focus	0.37	80^{th}	0.33
Action	0.50	95^{th}	0.50
Limit	0.76	99.7^{th}	0.68

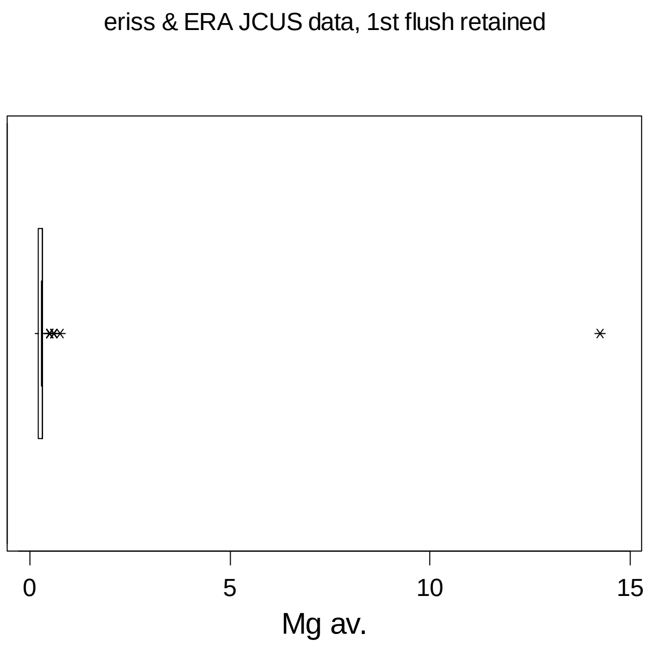

Figure 3.1.16 Box plot of JSCUS magnesium data (mg/L) showing outliers

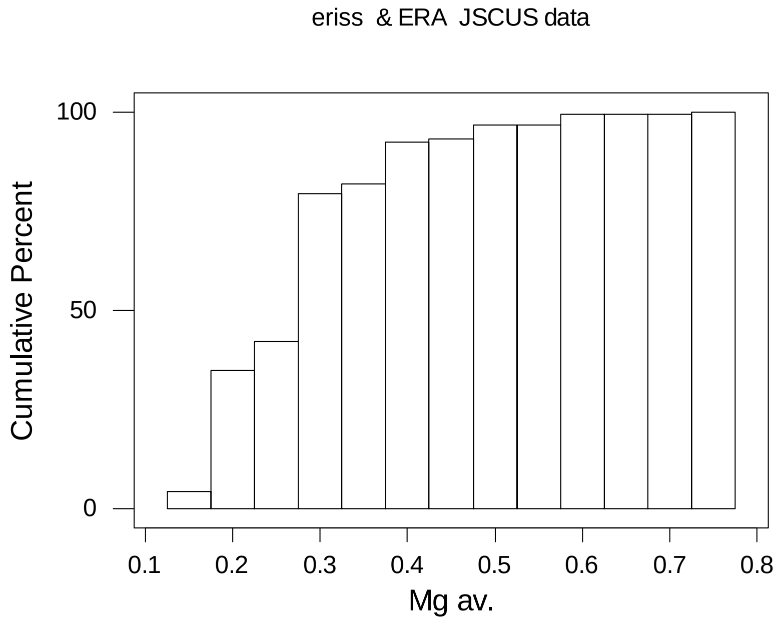

Figure 3.1.17 A cumulative percent histogram of JSCUS magnesium (mg/L) data

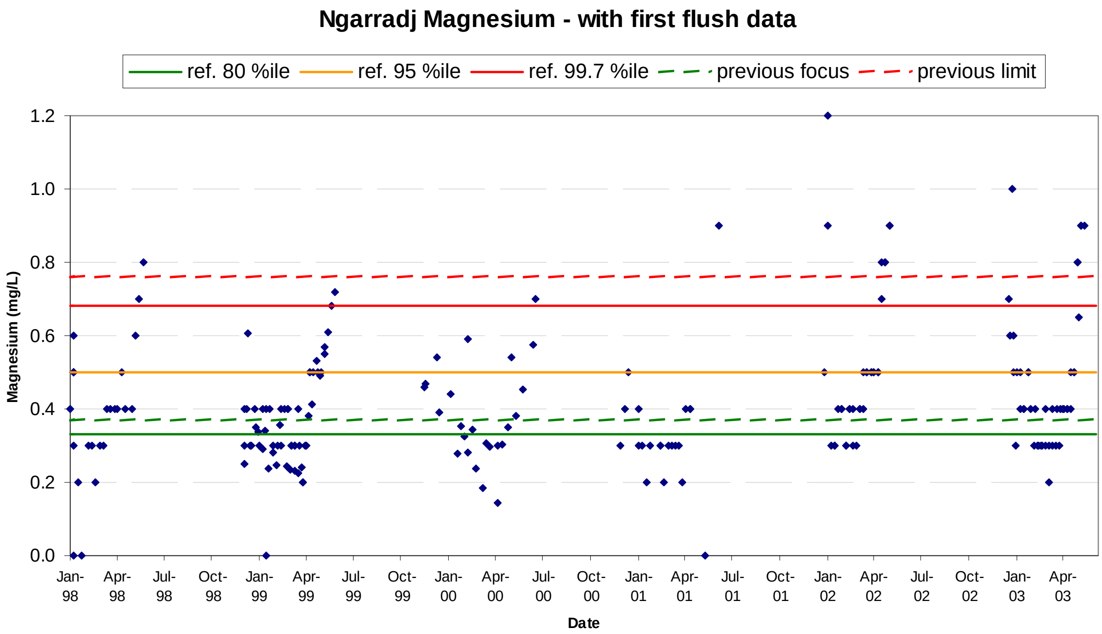

Figure 3.1.18 Control chart of all Ngarradj downstream (JSC) historic magnesium data showing revised and current guideline values

It has been previously noted that a lack of correlation for magnesium exists between the upstream and downstream sites on Ngarradj, probably due to inputs from West Tributary and groundwater (LeGras et al 2001)[12]. Figure 3.1.18 illustrates the excessive exceedances of the triggers that occur at JSC indicating JSCUS is an inappropriate reference site for setting magnesium triggers for JSC. Most of the action and guideline exceedances are during the recessional flow period. It is thought that magnesium rich groundwater contributes greater proportions of volumes to the creek under these flow conditions.

As for pH and turbidity at Ngarradj, upstream (JSCUS) percentiles are not appropriate for setting magnesium triggers. The same approach recommended for pH and turbidity should be investigated, ie basing trigger values on downstream data.

Recommendation: Derive trigger values from the magnesium data collected from the downstream site (JSC) to date.

3.1.7 Ngarradj sulfate

A box plot of sulfate data with outliers identified is shown in figure 3.1.19. Details of outlier treatment are given in table 3.1.9.

The revised sulfate guideline values, set at the 80th, 95th and 99.7th percentiles of the reference site data, are given in table 3.1.10 along with current guideline values. A cumulative percent histogram of the JSCUS sulfate data is shown in figure 3.1.20.

To illustrate the rate of expected exceedances of the trigger values, historic downstream sulfate data are plotted on a control chart with the current and revised trigger values (figure 3.1.21).

Table 3.1.9 Treatment of JSCUS sulfate outliers

Value (mg/L)	Date	Source	Detail	Decision
1.0 & 1.1	Several records	Both companies	Values not atypical of those expected in Ngarradj	RETAIN
1.20	15/12/98	ERA	Values not atypical of those expected in Ngarradj	RETAIN
3.47	25/07/00	ERA	Very late sample - order of magnitude higher than previous data - ? evapoconcentration / stagnant water	REJECT

Table 3.1.10 Current and revised sulfate trigger values for Ngarradj

Trigger	Percentile	Current trigger values (mg/L)	Revised trigger values (mg/L)
Focus	80th	0.60	0.60
Action	95th	0.91	0.90
Limit	99.7th	1.50	1.54

[12] Stakeholders agreed (Jabiluka MTC meeting 21/9/2001) that the current magnesium limits were to be treated as guideline values only, not strict limits.

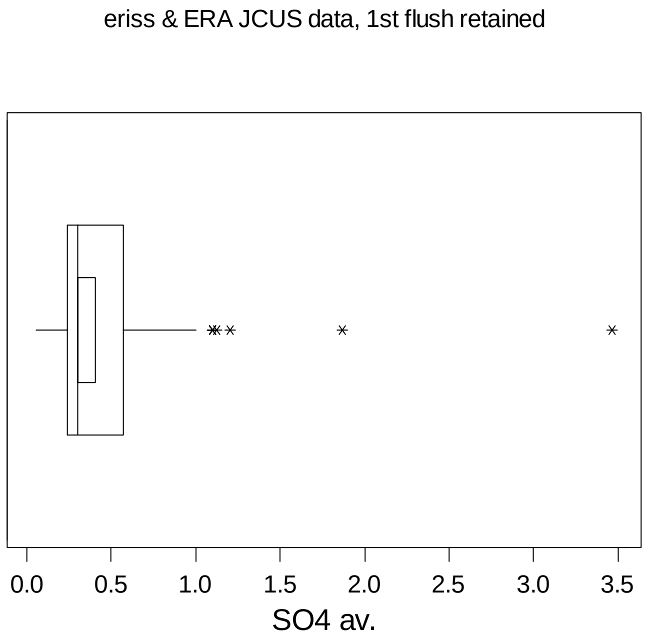

Figure 3.1.19 Box plot of JSCUS sulfate data (mg/L) showing outliers

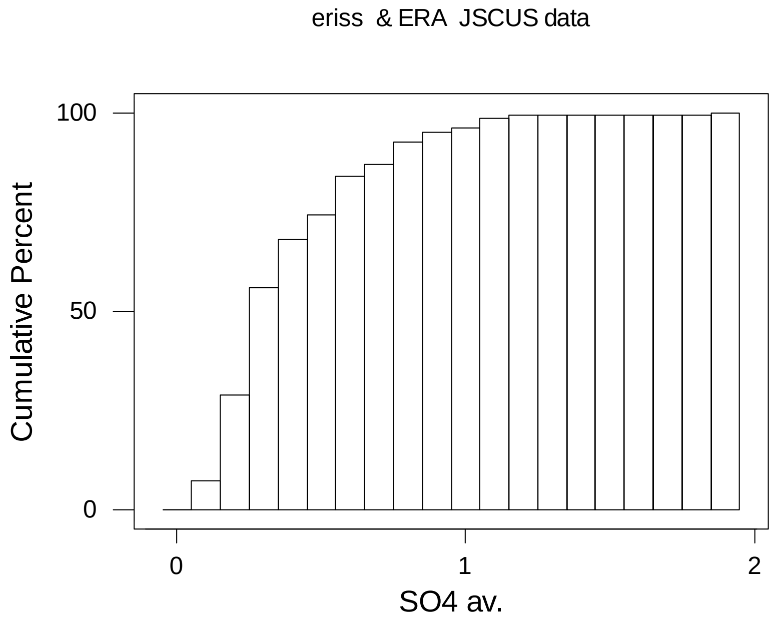

Figure 3.1.20 A cumulative percent histogram of JSCUS sulfate (mg/L) data

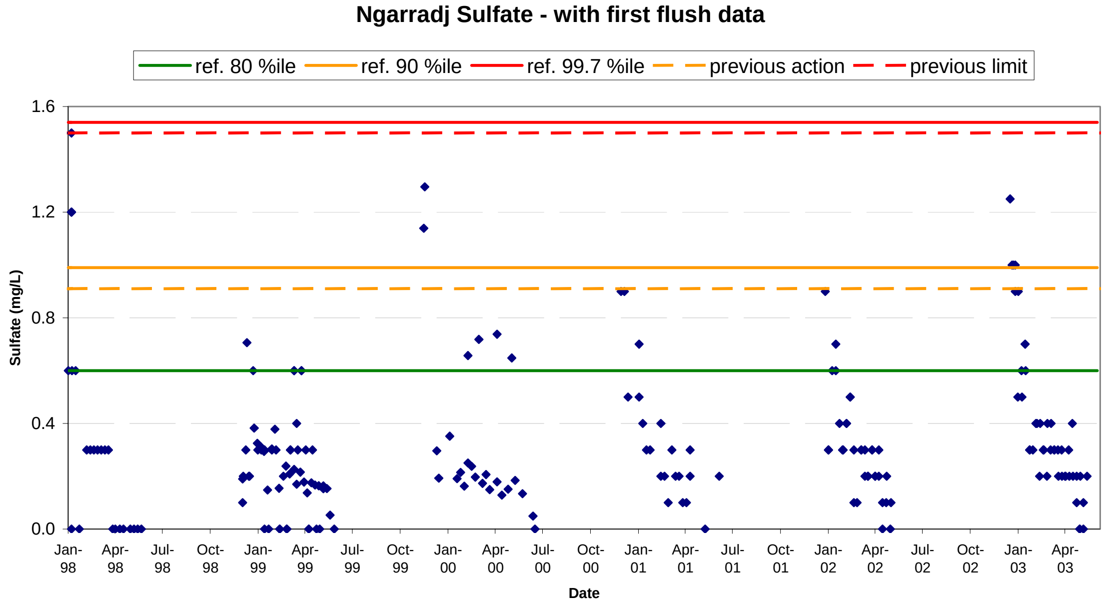

Figure 3.1.21 Control chart of all Ngarradj downstream (JSC) historic sulfate data showing revised and current trigger values

Inputs to Ngarradj from West Tributary are low in sulfate (LeGras et al 2001), which could explain why the upstream reference percentiles are exceeded less often than 20% and 5% of the time expected due to statistical variability (figure 3.1.21).

As for pH, turbidity and magnesium at Ngarradj, upstream (JSCUS) percentiles are not appropriate for setting sulfate triggers. The same approach recommended for pH, turbidity and magnesium should be investigated, ie basing trigger values on downstream data.

Recommendation: Derive trigger values from the sulfate data collected from the downstream site (JSC) to date.

3.2 Magela Creek results

3.2.1 Magela pH

As for Ngarradj, pH pseudo replicates were not averaged. A box plot of pH data with outliers identified is shown in figure 3.2.1. Only one outlier was rejected (table 3.2.1). Nothing in the ERA or Supervising Scientist databases suggested any reason for rejecting the other data points identified as outliers.

Table 3.2.1 Treatment of MCUS pH outliers

pH value	Date	Source	Detail	Decision
3.40	19/01/01	***eriss***	Laboratory blank also low same day (3.00)	REJECT

The revised pH guideline values, set at the 20th and 80th, 5th and 95th and 0.3rd and 99.7th percentiles of the reference site data are given in table 3.2.2, along with current guideline trigger values. A cumulative percent histogram of the MCUS pH data is shown in figure 3.2.2. To illustrate the rate of expected exceedances of the guideline values, historic downstream pH data are plotted on a control chart with current and recommended trigger values (figure 3.2.3).

Table 3.2.2 Current and revised pH trigger values for Magela Creek

Trigger	Statistic	Current range	Revised lower trigger values	Revised upper trigger values
Focus	20th and 80th percentiles	5.8 – 6.5	5.9	6.5
Action	5th and 95th percentiles	5.5 – 6.8	5.6	6.7
Guideline	0.3rd and 99.7th percentiles	5.2 – 7.2	4.7	6.9

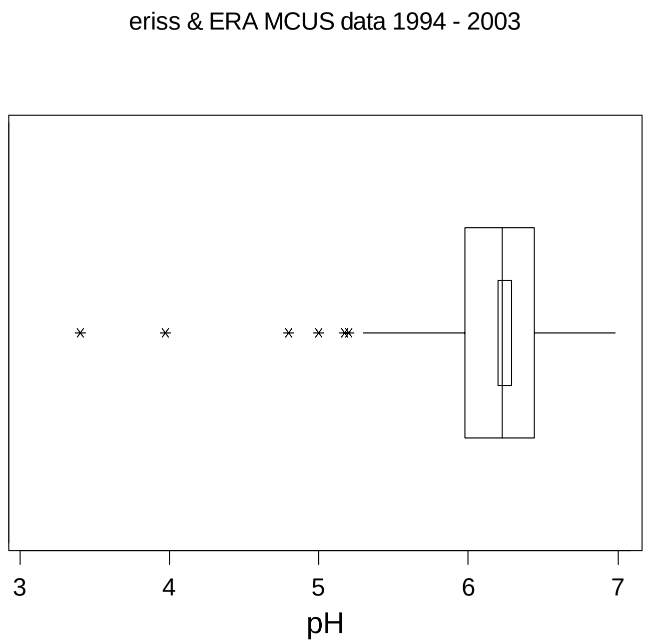

Figure 3.2.1 Box plot of MCUS pH data showing outliers

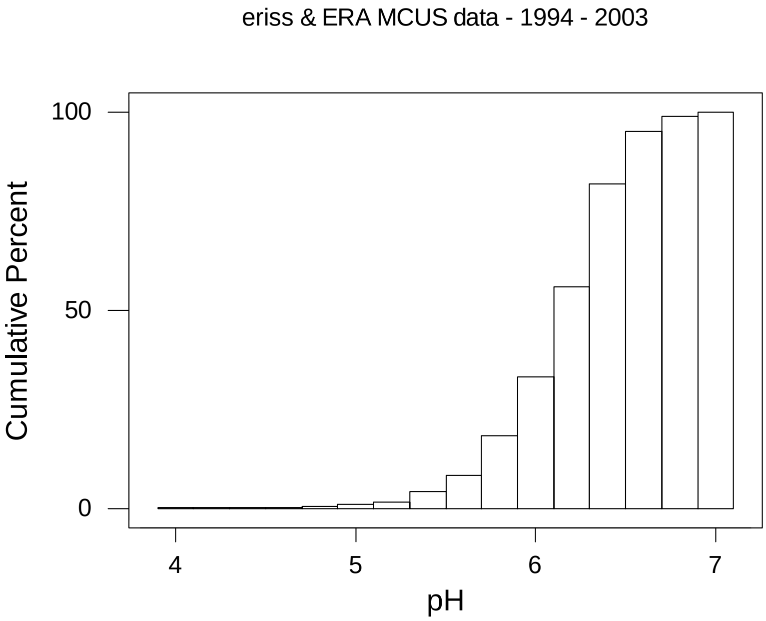

Figure 3.2.2 A cumulative percent histogram of MCUS pH data

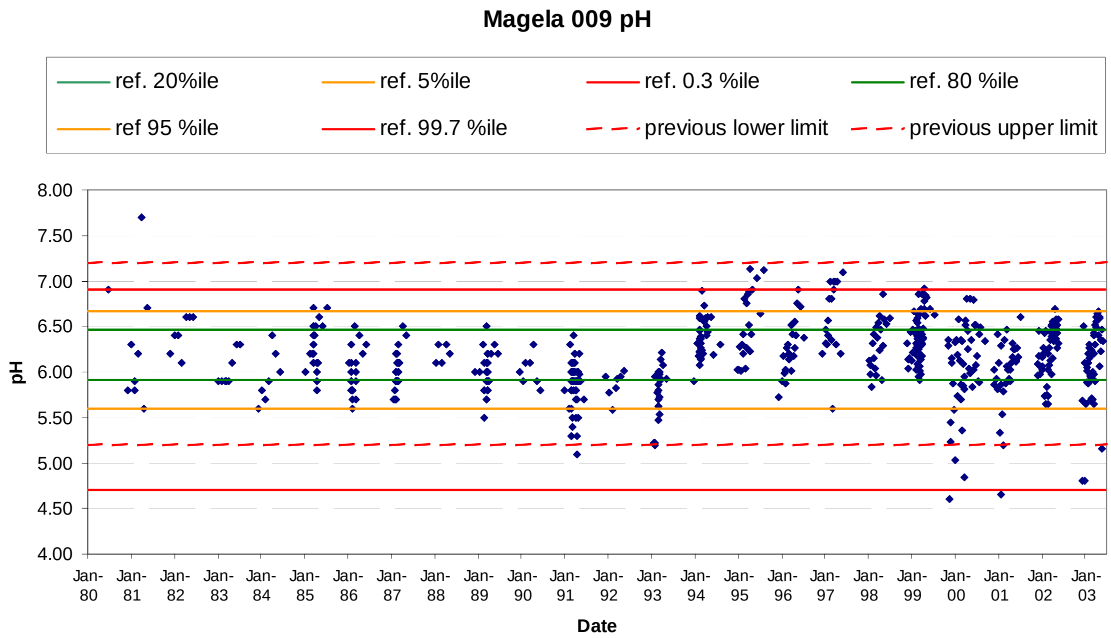

Figure 3.2.3 Control chart of Magela Creek downstream (009 central) historic pH data (DBIRD, ERA and Supervising Scientist unedited data) showing revised and current trigger values

Figure 3.2.3 shows that the recommended trigger values, based on the upstream percentiles, would be a useful management tool for interpreting downstream pH in Magela Creek.

Recommendation: The 80th, 95th and 99.7th percentiles of the MCUS dataset be adopted as the pH focus, action and guideline trigger values for MG009 when the trigger values are reset.

3.2.2 Magela EC

A box plot of EC data with outliers identified is shown in figure 3.2.4. Details of outlier treatment are given in table 3.2.3.

The revised EC trigger values, set at the 80th, 95th and 99.7th percentiles of the reference site data are given in table 3.2.4 along with current trigger values. A cumulative percent histogram of the MCUS EC data is shown in figure 3.2.5.

To illustrate the rate of expected exceedances of the trigger values, historic downstream EC data are plotted on a control chart with current and recommended trigger values (figure 3.2.6).

Table 3.2.3 Treatment of MCUS EC outliers

EC value (μS.cm^{-1})	Date	Source	Detail	Decision
26	23/12/00	ERA	First flush ?	RETAIN
20.4	13/05/98	ERA	Last sample of season	RETAIN
47	15/03/00	ERA	Comment re 'odd result'; checked next day (6.0)	**REJECT**
20.4	03/12/03	***eriss***	Not first sample of season, no comments raise doubt	RETAIN

Table 3.2.4 Current and revised EC trigger values for Magela Creek

Trigger	Current trigger values (μS.cm^{-1})	Percentile	Revised trigger values (μS.cm^{-1})
Focus	21	80	14
Action	30	95	17
Limit	43	99.7	23

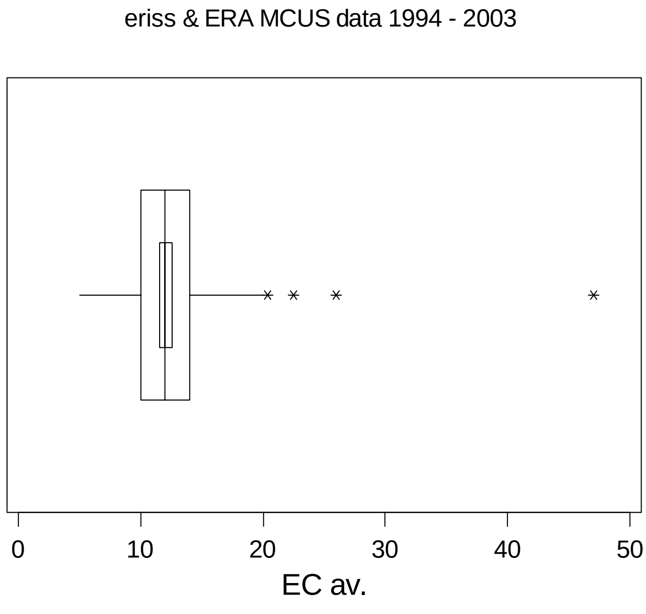

Figure 3.2.4 A box plot of MCUS EC data showing outliers

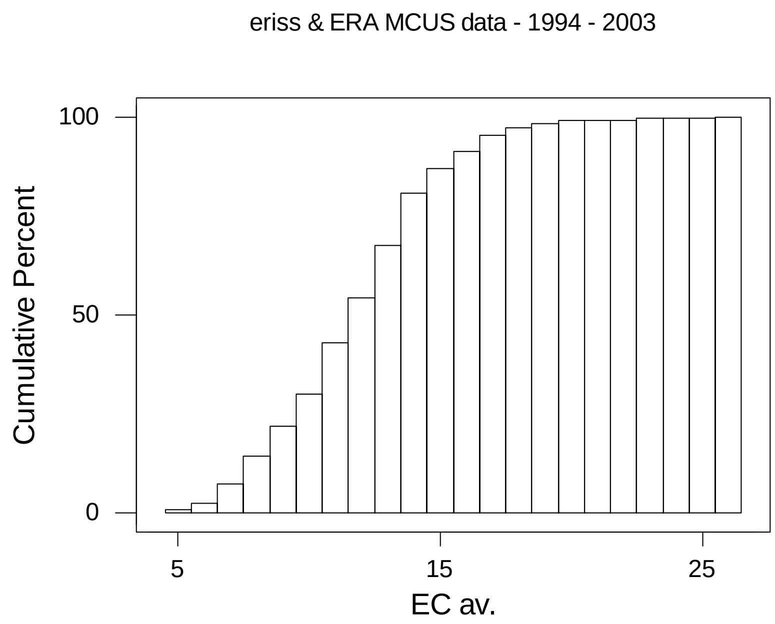

Figure 3.2.5 A histogram of MCUS EC (μS/cm) data

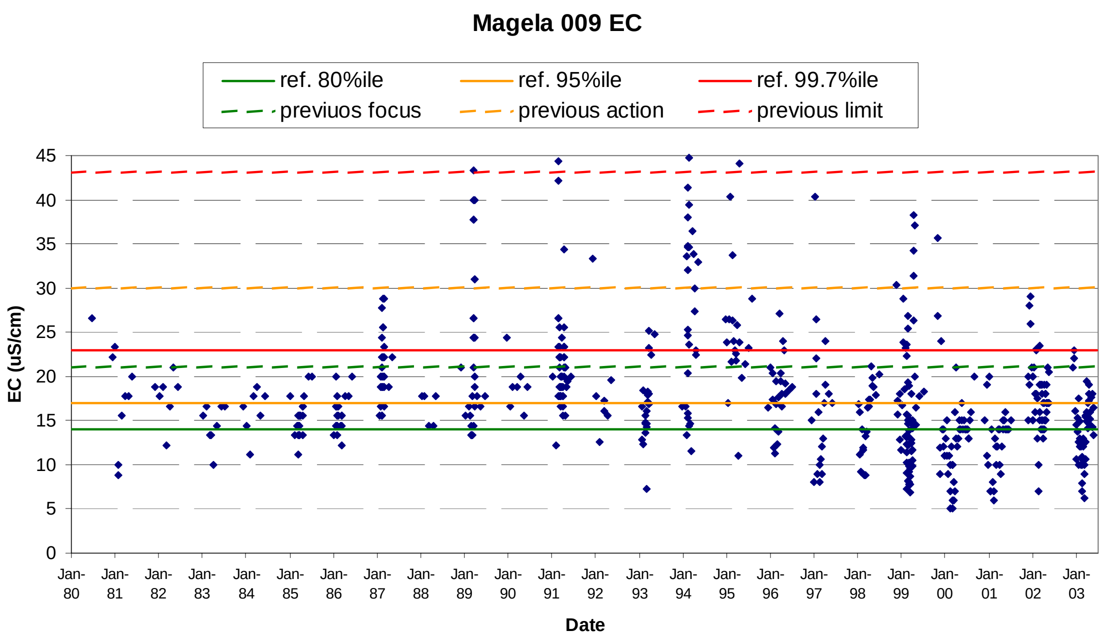

Figure 3.2.6 Control chart of Magela Creek downstream (009) historic EC data (ERA and Supervising Scientist unedited data) showing revised and current trigger values

The revised trigger values, based on the MCUS percentiles, do not provide a good management aid for EC in Magela Creek (figure 3.2.6). EC at the downstream site is elevated compared to the upstream site, possibly due to dissolved salts, including magnesium and sulfate, leaving the mine site. This elevated EC has been the case for many years and biological monitoring indicate that this has not impacted the ecosystems downstream of the mine (eg Supervising Scientist 2003b). Site-specific high-reliability toxicological values for magnesium (as Mg:Ca ratio) and sulfate are currently being determined by ***eriss***. Triggers set using these biological impacts information are preferable to those based on reference site data distributions (ANZECC & ARMCANZ 2000). Therefore, rather than adopting the EC triggers derived here, magnesium and sulfate trigger values, based on the results of the ecotoxicity work, should be used in place of EC triggers.

Before adopting this approach the risk of ecological damage caused by other ions (which may be contributing to the EC difference) needs to be assessed.

Recommendation: Assess the environmental risk of ions controlling the EC in Magela Creek. If ions other than magnesium, calcium and sulfate are considered a low risk then adopt the ecotoxicological values for magnesium and sulfate as proxies for EC triggers at MG009.

3.1.3 Magela turbidity

A box plot of turbidity data with outliers identified is shown in figure 3.2.7. Outliers were checked and no reason for rejecting them was found.

The revised trigger values, set at the 80^{th}, 95^{th} and 99.7^{th} percentiles of the reference site data are given in table 3.2.5. A cumulative percent histogram of the MCUS turbidity data is shown in figure 3.2.8.

To illustrate the rate of expected exceedances of the guideline values, historic downstream turbidity data (including first flush data) are plotted on a control chart with current and revised trigger values (figure 3.2.9).

Table 3.2.5 Treatment of MCUS turbidity outliers

Turbidity value (NTU)	Date	Source	Detail	Decision
10–26	Several samples (n = 15)	***eriss*** & ERA	Not atypical of storm/flood events. No comments in database to raise doubt as to validity of result	RETAIN
46	28/11/01	ERA	First flush?	RETAIN

Table 3.2.6 Current and revised turbidity trigger values for Magela Creek

Trigger	Percentile	Current trigger value (NTU)	Recommended value (NTU)
Focus	80^{th}	10	5
Action	95^{th}	24	10
Limit	99.7^{th}	56	31

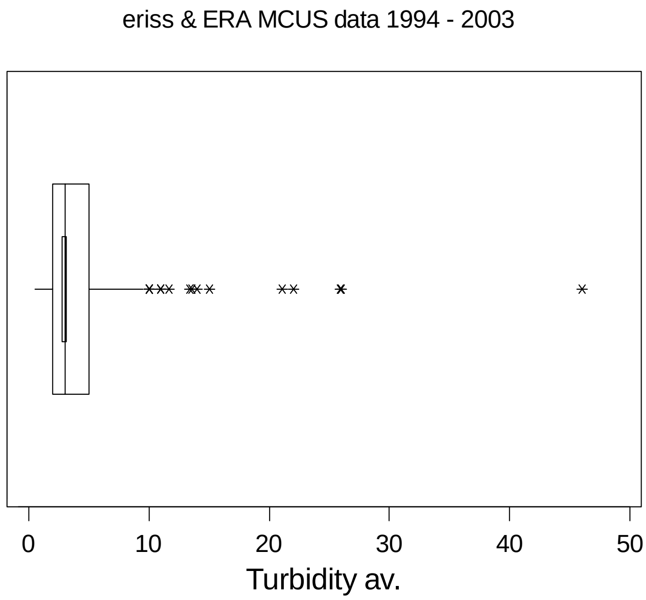

Figure 3.2.7 A box plot of MCUS turbidity data showing outliers

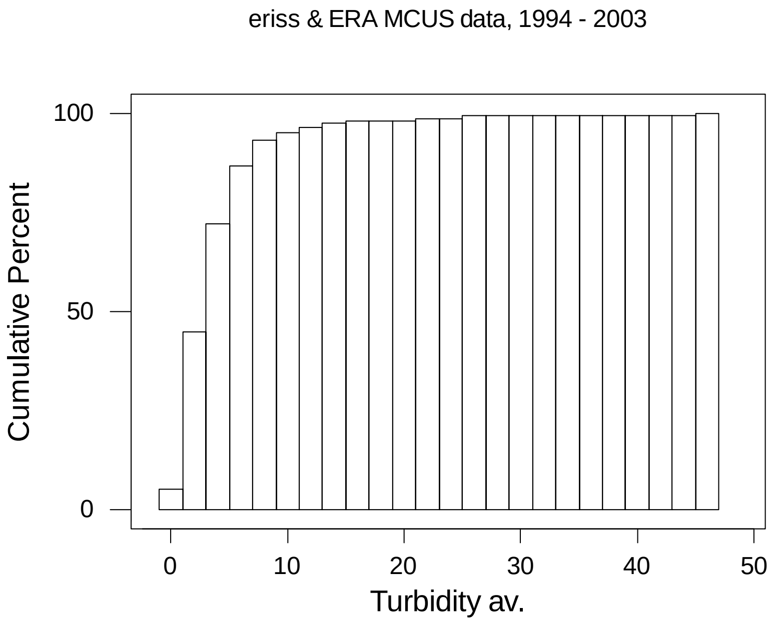

Figure 3.2.8 A cumulative percent histogram of MCUS turbidity (NTU) data

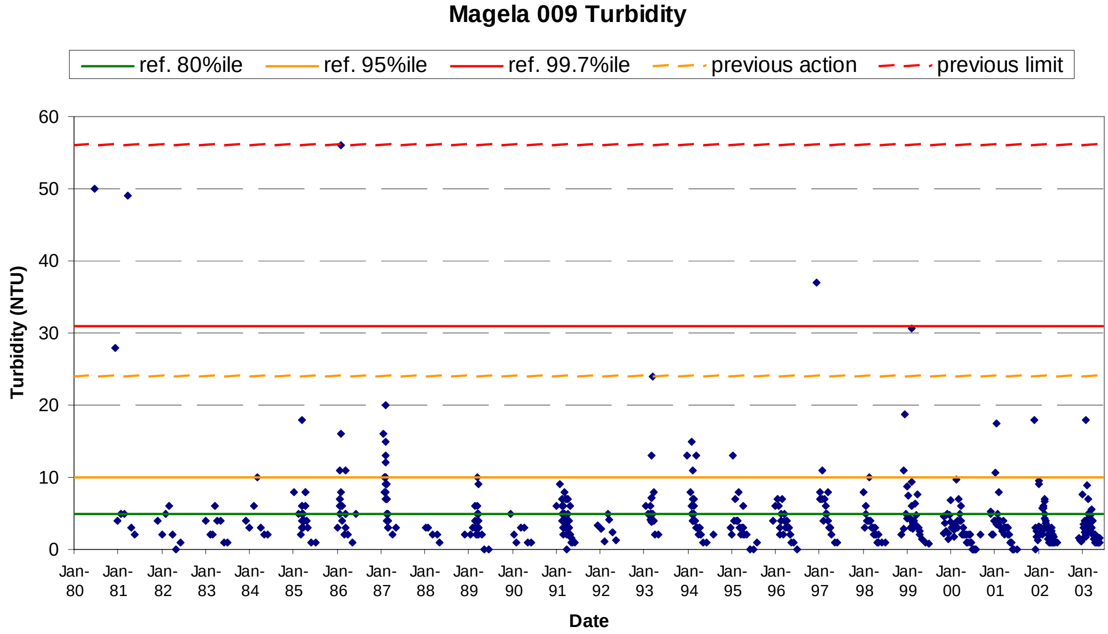

Figure 3.2.9 Control chart of Magela Creek downstream (009) historic turbidity data (ERA and Supervising Scientist unedited data) showing revised and current trigger values

The control chart of historic Magela downstream turbidity data (figure 3.2.9) indicates that the revised turbidity triggers would provide a good management tool.

Recommendation: The 80th, 95th and 99.7th percentiles of the MCUS turbidity dataset be adopted as the turbidity focus, action and guideline trigger values for MG009 when the trigger values are reset.

3.2.4 Magela uranium

A box plot of uranium data with outliers identified is shown in figure 3.2.10. All data identified as outliers by Minitab have been retained (table 3.2.7). The highest concentration identified as an outlier was only 0.079 µg/L collected by ERA on 3 December 2002 during a first flush period.

Table 3.2.7 Treatment of MCUS uranium outliers

Value (µg/L)	Date	Source	Detail	Decision
0.054	28/11/01	ERA	First flush, turbidity and manganese high also	RETAIN
0.047	1/12/02	Supervising Scientist	First flush, manganese high also	RETAIN
0.045	2/12/02	Supervising Scientist	First flush, manganese high also	RETAIN
0.079	3/12/02	Supervising Scientist	First flush, manganese and turbidity high also	RETAIN

Percentiles shown in table 3.2.8 and figure 3.2.11 could be used to set uranium trigger values. However, as can be seen in table 3.2.8, the uranium concentrations measured in Magela Creek are two orders of magnitude lower than the ecotoxicologically derived limit and an order of magnitude lower than the percentiles derived previously based on poor quality data (refer to section 2.2). The Water Quality Guidelines (ANZECC & ARMCANZ 2000) recommend, that ecological effects data be used to set trigger values when available.

Uranium toxicity to five Magela Creek species has been determined previously as 5.8 µg/L (Van Dam 2000) and recently revised to 5.5 µg/L (Hogan et al 2003). The lower 95% and 80% confidence limits of the revised ecotoxicity value are 0.3 and 0.9 µg/L respectively (Hogan et al 2003). The toxicity value, 5.5 µg/L, should be adopted as the limit in Magela, Gulungul and Swift Creeks. The lower confidence limits could be adopted as the focus and action limits in Magela and Gulungul Creeks.

To illustrate the rate of expected trigger exceedances if these values are adopted, historic downstream uranium data are plotted on a control chart with current and recommended trigger values (figure 3.2.12).

Table 3.2.8 Current and revised uranium trigger values for Magela Creek

Percentile	Revised Magela Creek percentiles (µg/L)	Trigger	Current Magela Creek trigger values (µg/L)	Recommended Magela Creek trigger values (µg/L)
80th	0.03	**Focus**	0.2 [a]	0.30 [d]
95th	0.04	**Action**	1.4 [b]	0.90 [e]
99.7th	0.07	**Limit**	5.8 [c]	5.5 [f]

a: the previously derived 80th percentile, **b:** the previously derived 99.7th percentile, **c**: the current ecotoxicological limit, **d:** the lower 95% confidence limit of the ecotoxicological limit, **e**: the lower 80% confidence limit of the ecotoxicological limit, **f**: the revised ecotoxicological limit

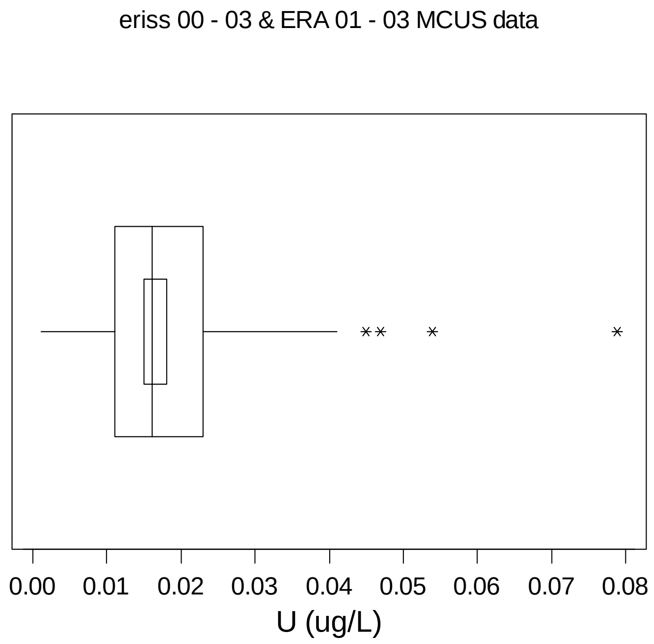

Figure 3.2.10 A box plot of MCUS uranium concentration (µg/L) data showing outliers

eriss 00 - 03 & ERA 01 - 03 MCUS data

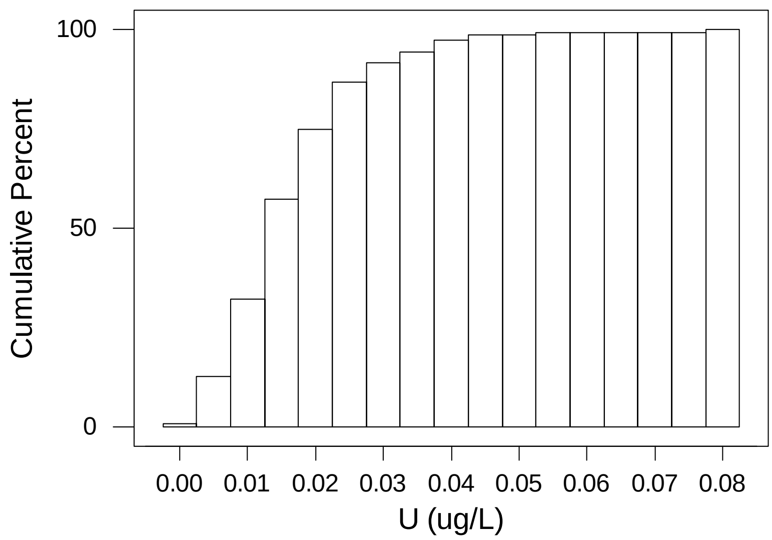

Figure 3.2.11 A cumulative percent histogram of MCUS uranium concentration (µg/L) data

Magela 009 Uranium

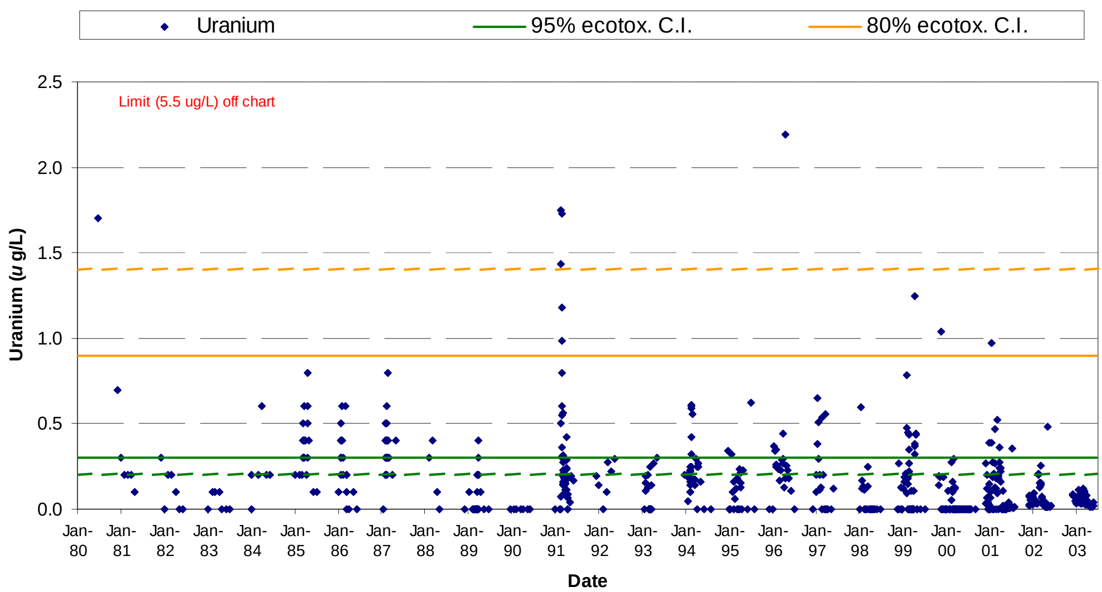

Figure 3.2.12 Control chart of Magela Creek downstream (009) historic uranium data (ERA and Supervising Scientist unedited data) showing recommended and current focus and action trigger values. Note the limit (5.5 µg/L) is off the chart

Figure 3.2.12 shows that if the triggers were set at less than 0.1µg/L (based on the percentiles of the reference site dataset) they would be triggered excessively. Despite the occurrence of uranium above these concentrations no impact has been detected on the ecosystems downstream of the mine site (eg Supervising Scientist 2003a). Therefore, adopting the lower toxicological confidence limit values as triggers is in line with the advice in the Guidelines (ANZECC & ARMCANZ 2000), to only relax reference site based triggers if the biological diversity will not be degraded, and, to preferentially adopt triggers based on biological effects data if available.

Recommendation: Once the revised ecotoxicological limit for Magela Creek (5.5 μg/L) has been reviewed and accepted by stakeholders it be adopted as the limit for Magela Creek The lower 80% and 90% confidence limits should be adopted as the focus and action limits at that time

3.2.5 Magela manganese

A box plot of manganese data with outliers identified is shown in figure 3.2.13. Details of outlier treatment are given in table 3.2.9

Triggers, set at the 80th, 95th and 99.7th percentiles of the reference site data are given in table 3.2.10. A cumulative percent histogram of the MCUS manganese data is shown in figure 3.2.14.

To illustrate the rate of expected exceedances of the guidelines values, historic downstream manganese data are plotted on a control chart with the recommended guideline values (figure 3.2.15).

Table 3.2.9 Treatment of MCUS manganese outliers

Value (μg/L)	Date	Source	Detail	Decision
12.1	17/01/96	ERA	No comment to raise doubt re validity of result	RETAIN
11.1	11/11/99	ERA	First sample of season	RETAIN
18.1	21/12/99	ERA	Not first sample of season	RETAIN
41.5	5/01/00	ERA	Not first sample of season	RETAIN
11.4	1/06/00	ERA	No comment to raise doubt re validity of result	RETAIN
26.3	29/11/00	ERA	First sample of season	RETAIN
11.7	18/12/00	Supervising Scientist	First flush period but not initial sample of season	RETAIN
24.2	28/11/01	ERA	First flush period, initial sample of season	RETAIN
12.6	5/12/01	ERA	First flush period but not initial sample of season	RETAIN
15.7	1/12/03	Supervising Scientist	First flush period, initial sample series of season	RETAIN
16.7	2/12/03	Supervising Scientist	First flush period, initial sample series of season	RETAIN
20.4	3/12/03	Supervising Scientist	First flush period, initial sample series of season	RETAIN
13.4	10/12/03	Supervising Scientist	First flush period but not initial sample of season	RETAIN

Table 3.2.10 Current and revised manganese trigger values for Magela Creek

Trigger	Current values (μg/L)	Percentiles	Revised values (μg/L)
Focus	10	80	7.0
Action	18	95	10
Limit	32	99.7	29

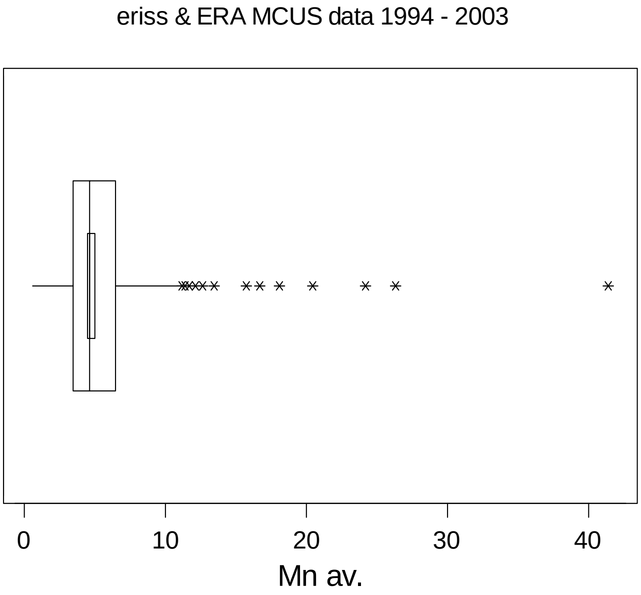

Figure 3.2.13 A box plot of MCUS manganese data (μg/L) showing outliers

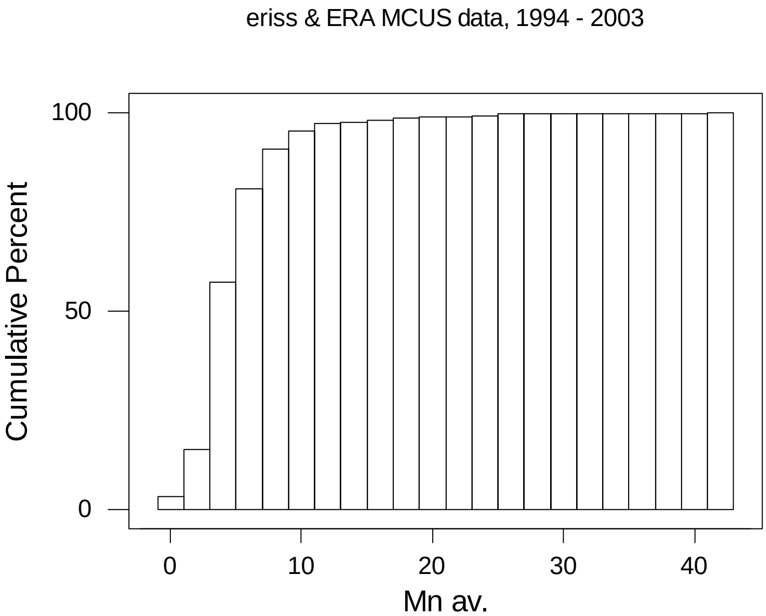

Figure 3.2.14 A cumulative percent histogram of MCUS manganese concentration (μg/L) data

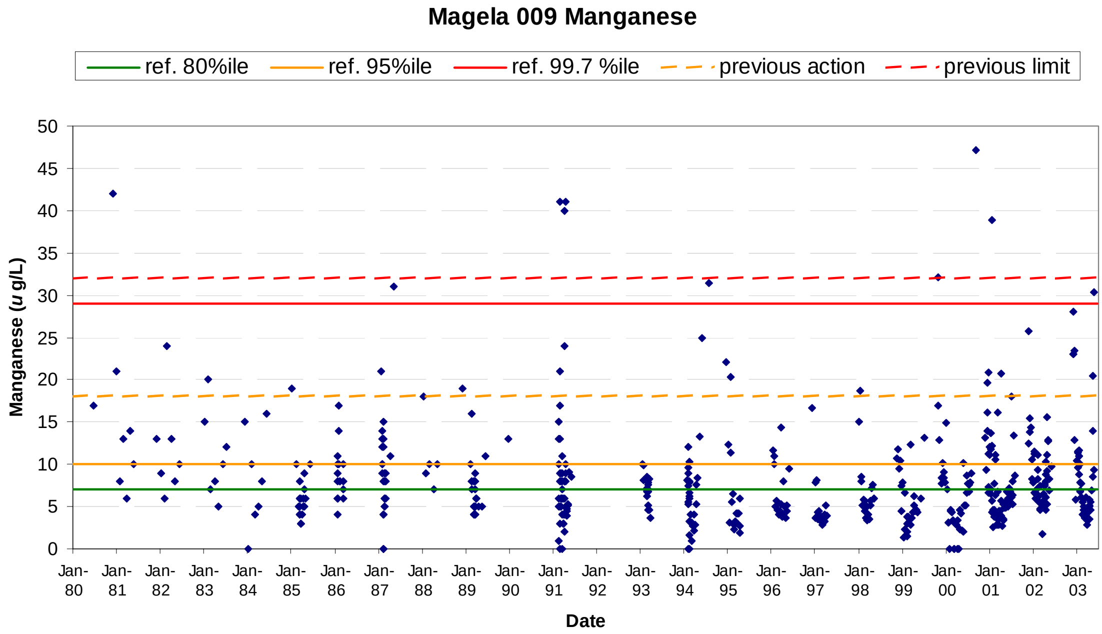

Figure 3.2.15 Control chart of Magela Creek downstream (009) historic manganese data (ERA and Supervising Scientist unedited data) showing revised and current trigger values

Figure 3.2.15 shows that the triggers set using the reference site data would be triggered excessively. Most of the exceedances occur during the first flush period and recessional flows. Manganese rich groundwater contributes more to surface volumes during recessional flow periods – the source of the manganese may be natural. Despite higher manganese concentrations downstream of the mine, biological monitoring has not detected an impact on the downstream ecosystems (eg Supervising Scientist 2003a). Supervising Scientist will investigate the toxicity of manganese in the 2003–04 research year. Information from that research can be used to set appropriate trigger values for the management of manganese in Magela Creek.

Recommendation: Wait for the outcome of the Supervising Scientist investigation into the toxicity of manganese before making any decision to change the current trigger values.

3.3 Gulungul Creek results

3.3.1 Gulungul pH

The Gulungul Creek reference site dataset has 55 pH results. No results were identified as outliers (figure 3.3.1).

Trigger values were derived using the 20th and 80th, 5th and 95th and 03 and 99.7th percentiles of the reference site data. These are shown alongside current Magela Creek trigger values (for comparison) in table 3.3.1. A cumulative percent histogram of the GCUS/GCC pH data is shown in figure 3.3.2.

To illustrate the rate of expected exceedances of the derived trigger values, historic downstream pH data are plotted on a control chart with the reference site percentiles (figure 3.3.3).

Table 3.3.1 Derived Gulungul Creek, and current Magela Creek, pH trigger values

Trigger	Percentile	Recommended lower trigger values	Revised upper trigger values	Current Magela Creek trigger values
Focus	20–80	6.2	6.9	5.8–6.5
Action	5–95	5.8	7.0	5.5–6.8
Guideline	0.3–99.7	5.4	7.1	5.2–7.2

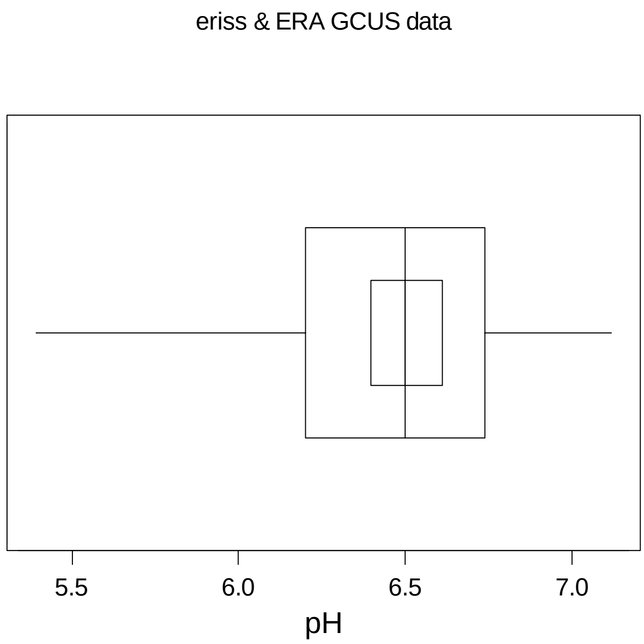

Figure 3.3.1 A box plot of GCUS/GCC pH data

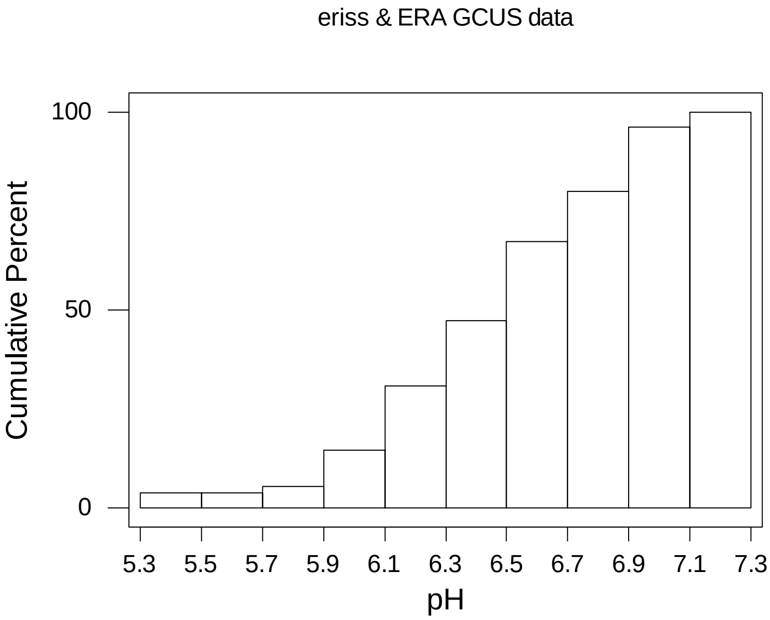

Figure 3.3.2 A cumulative percent histogram GCUS/GCC pH data

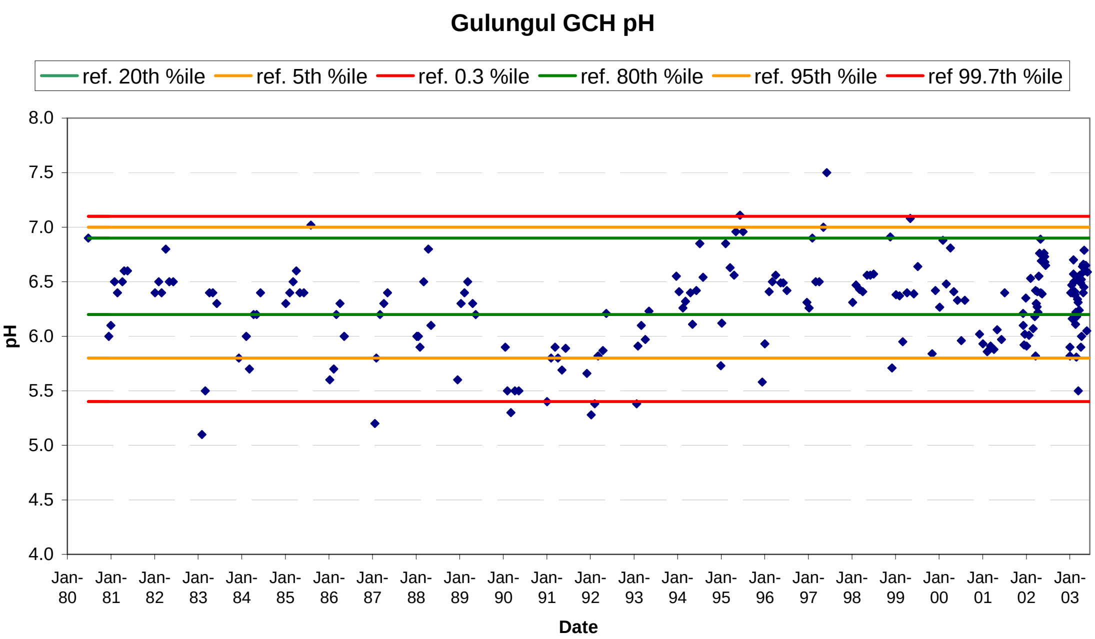

Figure 3.3.3 Control chart of Gulungul Creek downstream (GCH) historic pH data (ERA & Supervising Scientist data) showing reference site percentiles

Figure 3.3.3 illustrates that the reference site percentiles used as trigger values would provide a good management tool for pH in Gulungul Creek.

Recommendation: The 80^{th}, 95^{th} and 99.7^{th} percentiles of the GCUS pH dataset be adopted as the pH focus, action and guideline trigger values for GCH when the trigger values are reset.

3.3.2 Gulungul EC

The Gulungul Creek reference site dataset has 55 EC results. A box plot of EC data with outliers identified is shown in figure 3.3.4. Details of outlier treatment are given in table 3.3.2.

Trigger values were derived using the 80th, 95th and 99.7th percentiles of the reference site data. These are shown alongside current Magela Creek trigger values (for comparison) in table 3.3.3. A cumulative percent histogram of the GCUS/GCC EC data is shown in figure 3.3.5. To illustrate the rate of expected exceedances of the derived trigger values, historic downstream EC data are plotted on a control chart with the reference site percentiles (figure 3.3.6).

Table 3.3.2 Treatment of GCUS/GCC EC outliers

EC value (µS.cm^{-1})	Date	Source	Detail	Decision
5.9	14/12/98	ERA	Nothing in database to suggest data not reliable	RETAIN
53	2/07/01	ERA	Mg also high – supports high EC	RETAIN

Table 3.3.3 Derived Gulungul Creek , and current Magela Creek, EC trigger values

Trigger	Percentile	Derived Gulungul Creek percentiles (µS.cm^{-1})	Current Magela Creek trigger values (µS.cm^{-1})
Focus	80	22	21
Action	95	26	30
Guideline/ Limit	99.7	49	43

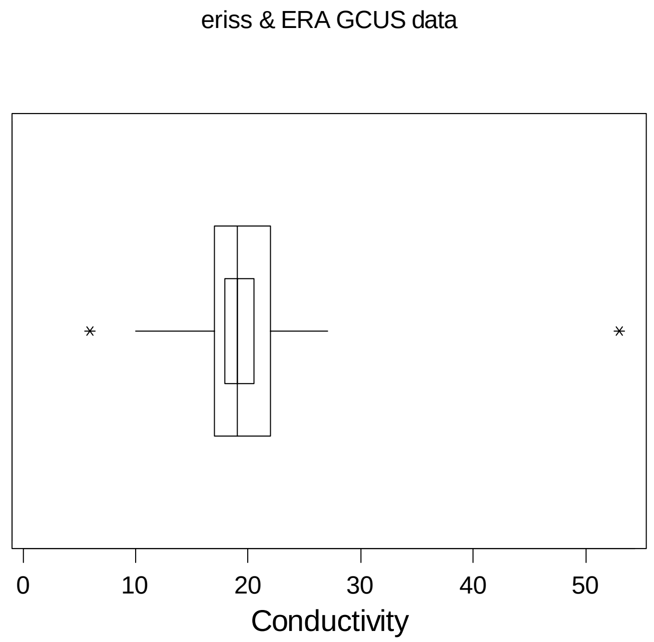

Figure 3.3.4 A box plot of GCUS/GCC EC data (µS/cm) showing outliers

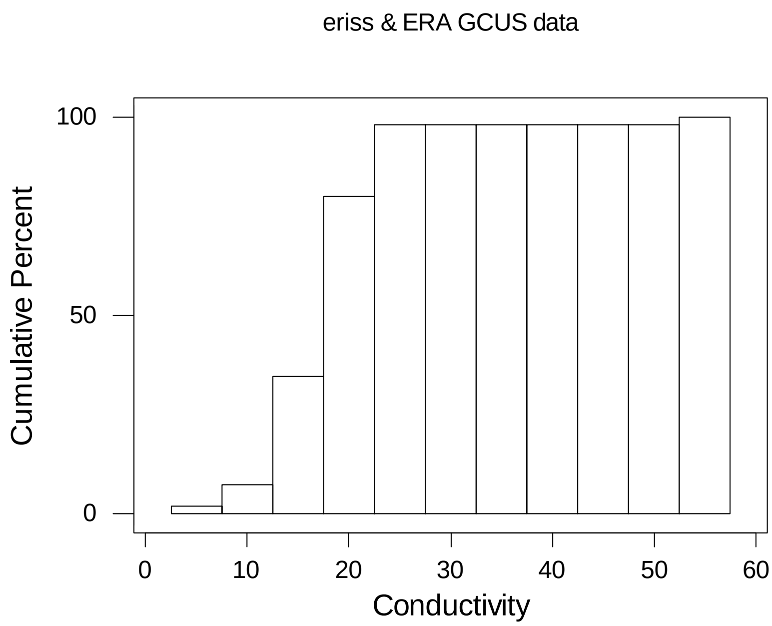

Figure 3.3.5 A cumulative percent histogram GCUS/GCC EC (µS/cm) data

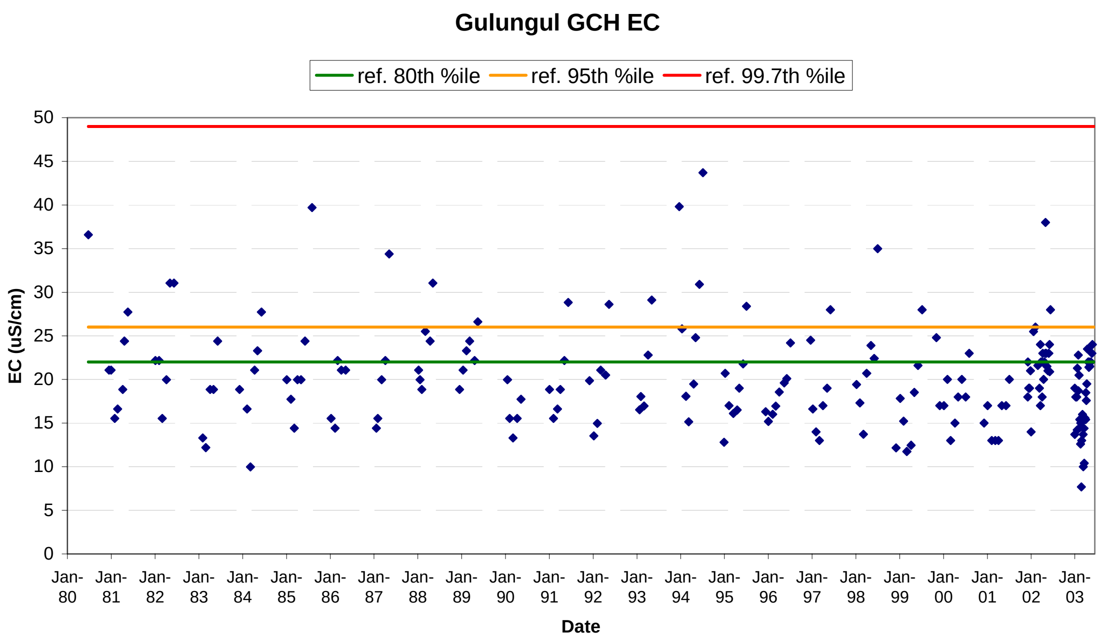

Figure 3.3.6 Control chart of Gulungul Creek downstream (GCH) historic EC data showing reference site percentiles

Figure 3.3.6 shows that the action level would be triggered excessively in some years if the 95th percentile were adopted as the action trigger. Even the very early data, from the early 1980s when no mining signature was expected in Gulungul Creek, show that to be the case.

It appears that the upstream site GCUS/GCC is not a good reference site for setting triggers. It is possible that the EC could be naturally elevated at the downstream site (compared to upstream) due to the presence of the sulfidic soils in the catchment or inputs from the three non-mine related tributaries.

Other methods need to be considered to derive EC trigger values for Gulungul Creek. Site-specific high-reliability toxicological values for magnesium (as Mg:Ca ratio) and sulfate are currently being determined by Supervising Scientist. Triggers set using these biological impacts information are preferable to those based on reference site data distributions (ANZECC & ARMCANZ 2000). Therefore, rather than adopting the statistically based EC trigger values derived here, magnesium and sulfate trigger values, based on the results of the ecotoxicity work, should be used in place of EC triggers. Before adopting this approach the risk of ecological damage caused by other ions (which may be contributing to the EC difference) needs to be assessed.

Recommendation: Assess the environmental risk of ions controlling the EC in Gulungul Creek. If ions other than magnesium, calcium and sulfate are considered a low risk then adopt the ecotoxicological values for magnesium and sulfate as proxies for EC triggers at GCH.

3.3.3 Gulungul turbidity

The Gulungul Creek reference site dataset has 55 turbidity results. A box plot of GCUS/GCC turbidity data with outliers identified is shown in figure 3.3.7. Details of outlier treatment are given in table 3.3.4.

Trigger values were derived using the 80th, 95th and 99.7th percentiles of the reference site data. These are shown alongside current Magela Creek trigger values (for comparison) in table 3.3.5. A cumulative percent histogram of the GCUS/GCC turbidity data is shown in figure 3.3.8. To illustrate the rate of expected exceedances of the derived trigger values, historic downstream turbidity data are plotted on a control chart with the reference site percentiles (figure 3.3.9).

Table 3.3.4 Treatment of GCUS/GCC turbidity outliers

Turbidity value (NTU)	Date	Source	Detail	Decision
3.50	25/03/02	Supervising Scientist	Nothing in database to suggest the values are errors. Within normal range of values seen during storm and high flow events	RETAIN
3.90	8/01/03	Supervising Scientist		
4.50	26/02/03	Supervising Scientist		
>10 (*n* = 12)	1998/99	ERA	Nearly all ERA values >10, nothing in database suggests data is not valid	RETAIN

Table 3.3.5 Derived Gulungul Creek, and current Magela Creek, turbidity trigger values

Trigger	Current Magela Creek trigger values (NTU)	Percentile	Derived Gulungul Creek percentiles (NTU)
Focus	10	80th	11
Action	24	95th	17
Limit	56	99.7th	19

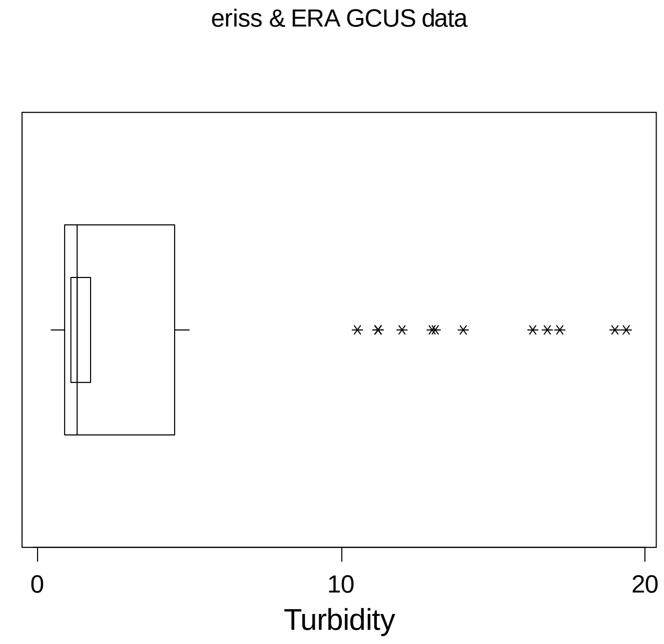

Figure 3.3.7 A box plot of GCUS/GCC turbidity data showing outliers

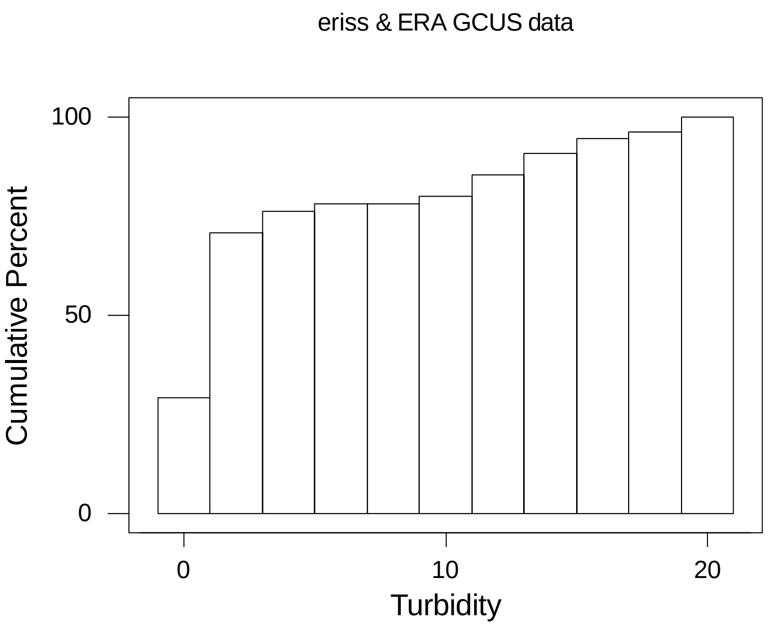

Figure 3.3.8 A cumulative percent histogram GCUS/GCC turbidity (NTU) data

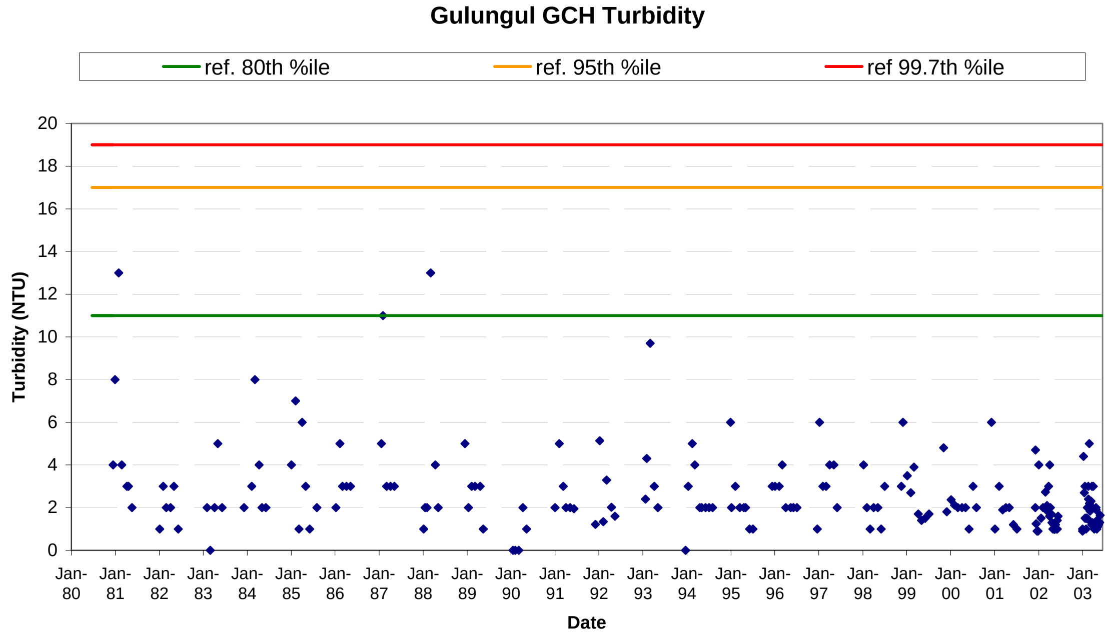

Figure 3.3.9 Control chart of Gulungul Creek downstream (GCH) turbidity data showing reference site percentiles

Figure 3.3.9 shows how far the reference site 99.7th percentile (guideline) is above the values regularly measured at the downstream site. It is known that the headwaters of creeks have a higher load of suspended solids than sites further downstream, this is expected in a small catchment according to the sediment delivery ratio theory (eg Walling 1983). Therefore the Gulungul Creek upstream site does not provide a good reference dataset against which to set turbidity triggers for the downstream site.

The Guidelines advise relaxing triggers to avoid excessive triggering only when it is known that doing so will not compromise the objective of maintaining biological diversity in the system. Bishop and Walden (2003) report that Gulungul Creek fish habitat and communities have undergone some changes since baseline data were collected. Those changes that could not be explained by non-mining disturbances were considered highly unlikely to be associated with contamination of Gulungul Creek from the mine. Macroinvertebrate and fish community studies carried out under the Supervising Scientist monitoring program support the conclusion that no adverse impacts have resulted from minesite discharges to Gulungul Creek (Supervising Scientist 2003a).

Therefore, instead of the upstream reference site data, the downstream data could be used to set the trigger values. Percentiles could be set on either an upstream-downstream difference to date or directly on the downstream data. This approach would be strengthened if the downstream data were shown to be unchanged since data collection began, otherwise data collected prior to any change could possibly be used.

As recommended for turbidity in Ngarradj, triggers for Gulungul Creek could be set on either an upstream-downstream difference or directly on the downstream data. This approach would be strengthened if the downstream data were shown to be unchanged since data collection began, otherwise data collected prior to any change could possibly be used.

Recommendation: Derive trigger values from the turbidity data collected from the downstream site (GCH) to date or prior to any significant change.

3.3.4 Gulungul uranium

The Gulungul Creek reference site dataset has 45 uranium results. A box plot of GCUS/GCC uranium data with outliers identified is shown in figure 3.3.10. Details of outlier treatment are given in table 3.3.6.

The reference site percentiles (shown in table 3.3.7 and figure 3.3.11) could be used to set uranium trigger values. However, as can be seen in table 3.2.7, the uranium concentrations measured in Gulungul Creek are an order of magnitude lower than the ecotoxicologically derived limit. As was recommended for Magela Creek (section 3.3.4), ecological effects data could be used to set trigger values for Gulungul Creek. The revised toxicity value, 5.5 µg/L[13], should be the limit, and the lower 95% and 80% confidence limits of the revised ecotoxicity value (0.3 and 0.9 µg/L respectively, Hogan et al, 2003) could be adopted as the focus and action limits.

To illustrate the rate of expected trigger exceedances if these values are adopted, historic downstream (GCH) uranium data are plotted on a control chart against these recommended trigger values (figure 3.3.12).

Table 3.3.6 Treatment of GCUS/GCC uranium outliers

Uranium concentration (µg/L)	Date	Source	Detail	Decision
0.292	27/12/01	Supervising Scientist	Not first flush (week 4). Downstream = 0.117	RETAIN
0.197	8/01/03	Supervising Scientist	Downstream = 0.251	RETAIN
0.157	26/02/03	Supervising Scientist	Downstream = 0.159	RETAIN
2.12	27/11/98	ERA	Suspected contamination of U & Mn	**REJECT**

Table 3.3.7 Recommended Gulungul Creek uranium trigger values and Magela Creek current values

Percentile	Gulungul Creek percentiles (µg/L)	Trigger	Recommended Gulungul trigger values (µg/L)	Current Magela Creek trigger values (µg/L)
80th	0.085	Focus	0.30 **d**	0.2 **a**
95th	0.152	Action	0.90 **e**	1.4 **b**
99.7th	0.279	Limit	5.5 f	5.8 **c**

a: the previously derived 80th percentile, **b:** the previously derived 99.7th percentile, **c**: the current ecotoxicological limit, **d:** the lower 95% confidence limit of the ecotoxicological limit, **e**: the lower 80% confidence limit of the ecotoxicological limit, **f**: the revised ecotoxicological limit

[13] A value of 5.8 µg/L was previously derived (Van Dam 2000)

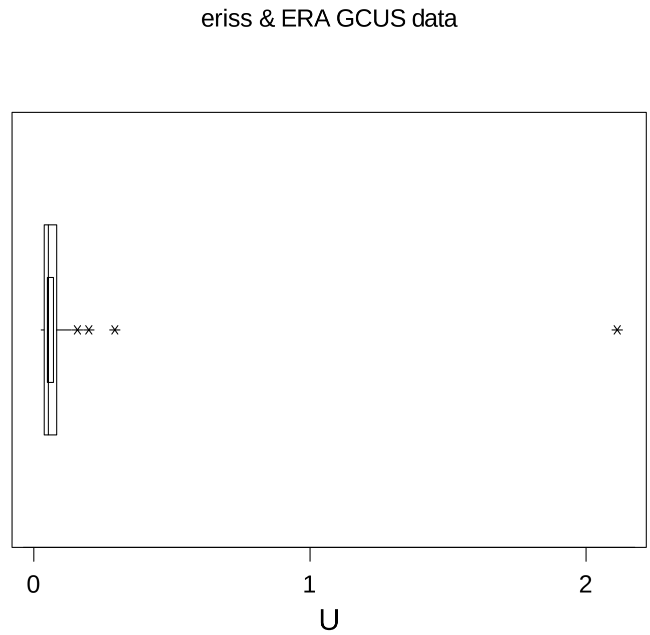

Figure 3.3.10 A box plot of GCUS/GCC uranium concentration (μg/L) data showing outliers

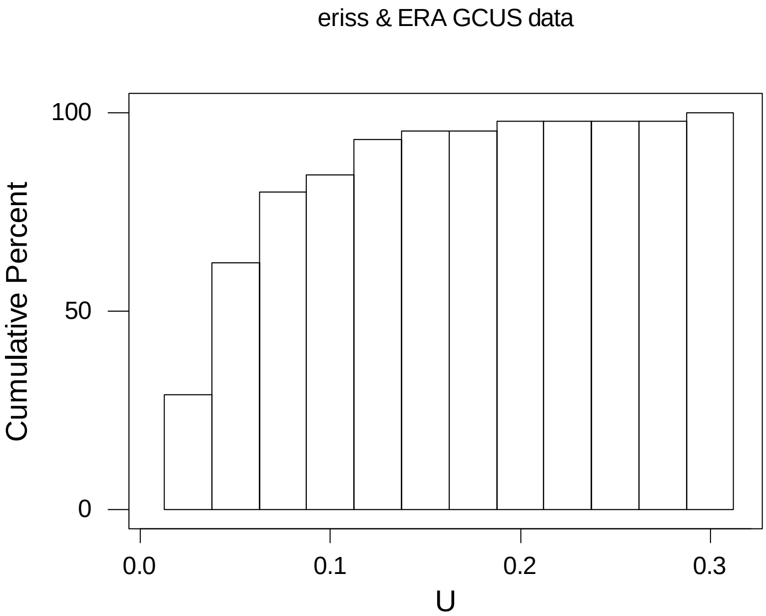

Figure 3.3.11 A cumulative percent histogram of GCUS/GCC uranium concentration (μg/L) data

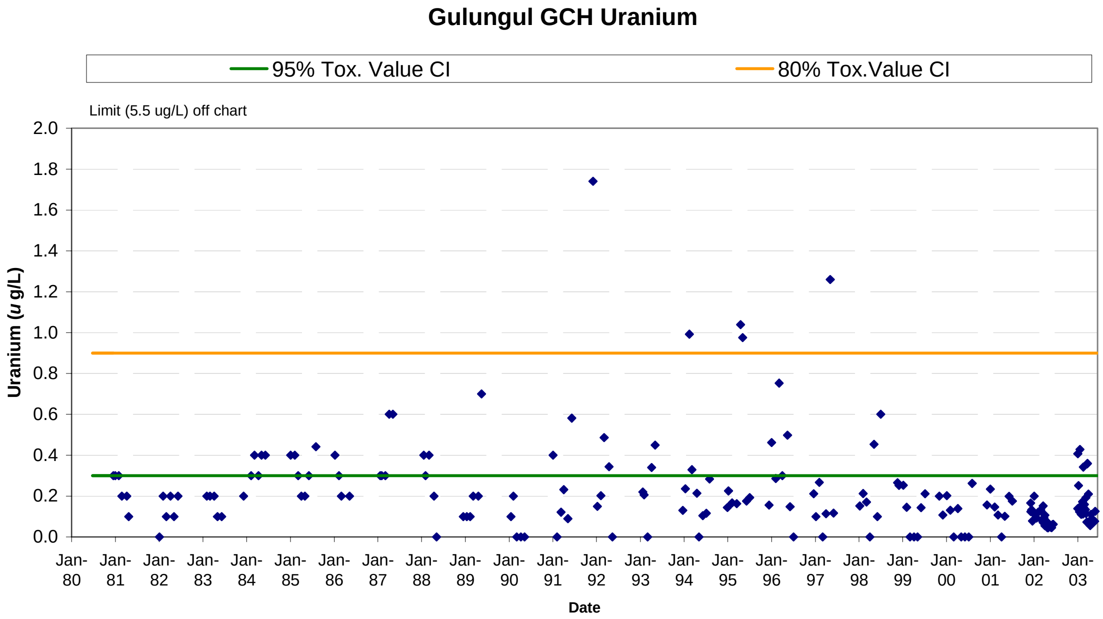

Figure 3.3.12 Control chart of Gulungul Creek downstream (GCH) historic uranium data showing recommended focus and action trigger values

Figure 3.3.12 illustrates that the lower 80% and 95% confidence levels of the toxicity value adopted as focus and action triggers would provide a useful tool for management of uranium concentrations in Gulungul Creek.

Recommendation: Once the revised ecotoxicological limit for Magela Creek (5.5 μg/L) has been reviewed and accepted by stakeholders it be adopted as the limit for Gulungul Creek The lower 80% and 90% confidence limits should be adopted as the focus and action triggers at that time.

3.3.5 Gulungul manganese

The Gulungul Creek reference site dataset has 46 manganese results. A box plot of GCUS/GCC manganese data with outliers identified is shown in figure 3.3.13. Details of outlier treatment are given in table 3.3.8.

Trigger values were derived using the 80th, 95th and 99.7th percentiles of the reference site data. These are shown, alongside current Magela Creek trigger values (for comparison), in table 3.3.9. A cumulative percent histogram of the GCUS/GCC manganese data is shown in figure 3.3.14. To illustrate the rate of expected exceedances of the derived trigger values, historic downstream manganese data are plotted on a control chart with the reference site percentiles (figure 3.3.15).

Table 3.3.8 Treatment of GCUS/GCC manganese outliers

Value	Date	Source	Detail	Decision
147	27/11/98	ERA	Suspected contamination of U & Mn	**REJECT**
8.05	7/03/01	ERA	Nothing in database to suggest data not reliable	RETAIN

Table 3.3.9 Current and revised Gulungul Creek manganese trigger values

Trigger	Percentile	Derived Gulungul Creek trigger values (µg/L)	Current Magela Creek trigger values (µg/L)
Focus	80^{th}	4.4	10
Action	95^{th}	6.3	18
Guideline/Limit	99.7^{th}	8.0	32

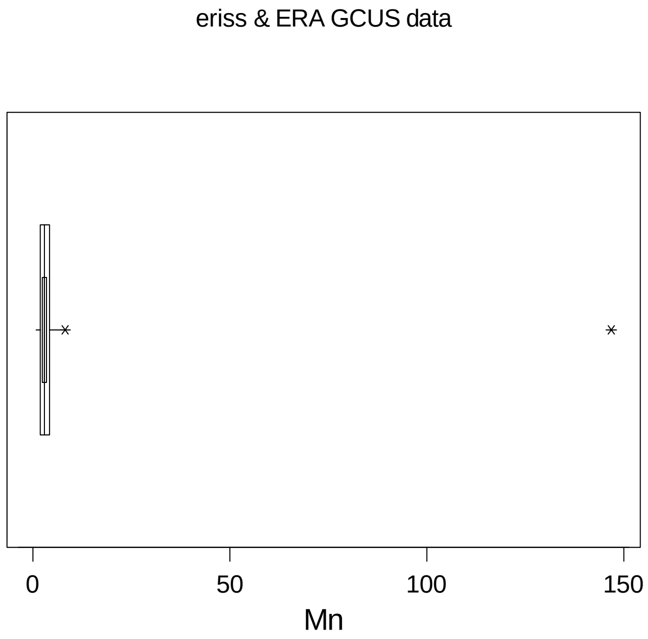

Figure 3.3.13 A box plot of GCUS/GCC manganese concentration (µg/L) data showing outliers

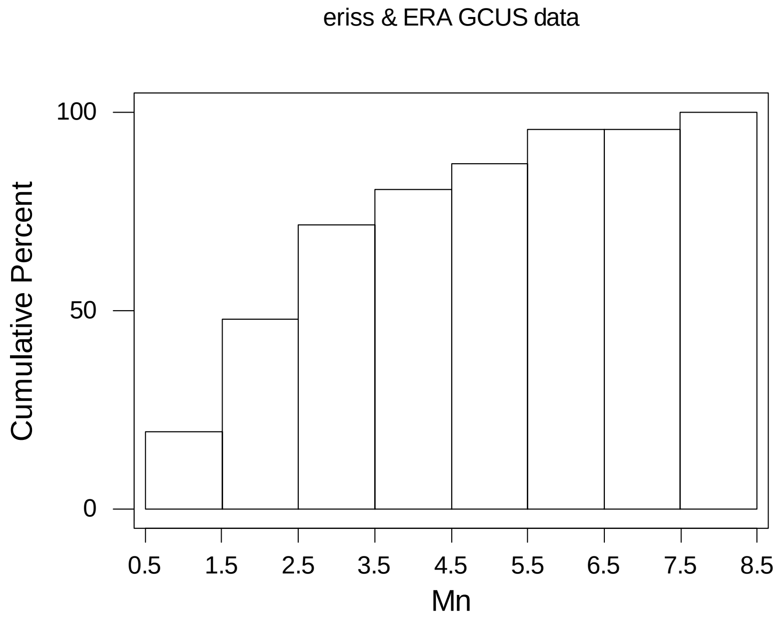

Figure 3.3.14 A cumulative percent histogram GCUS/GCC manganese concentration (µg/L) data

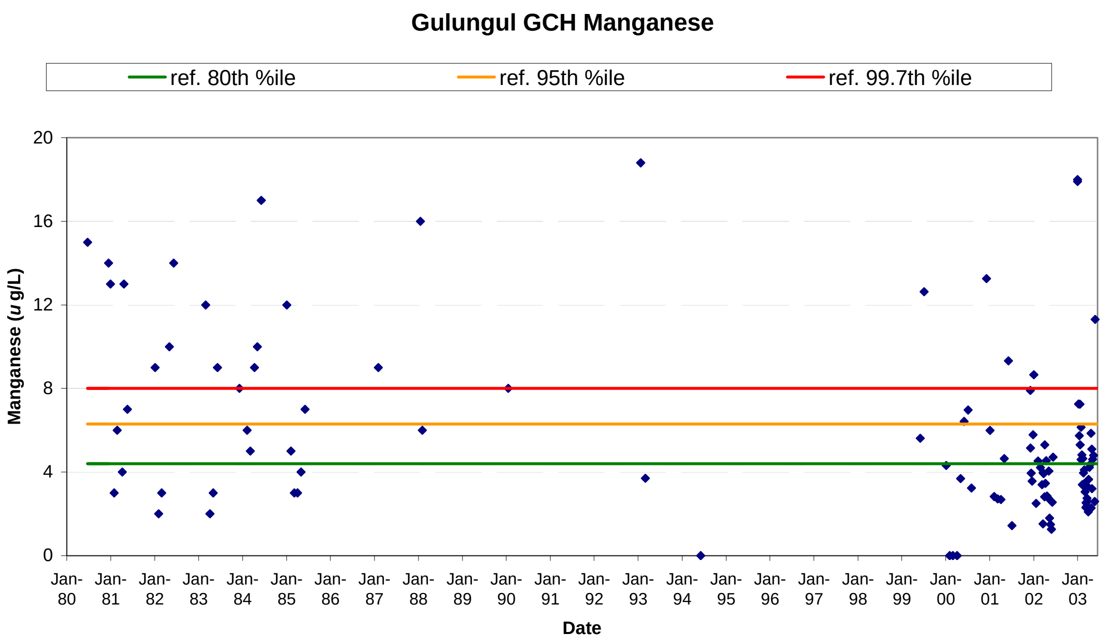

Figure 3.3.15 Control chart of Gulungul Creek downstream (GCH) historic manganese data showing reference site percentiles

Figure 3.3.15 shows that triggers set using reference site percentiles are not a good management tool. Even in the early 1980s, before any onsite practices would lead to mine impacts in Gulungul Creek, the triggers would have been exceeded too often.

Elevated concentrations with recessional flow can be seen in the GCH 2002/03 Wet season data (data for other years is not extensive enough to discern seasonal patterns). The upstream and downstream sites may have naturally different levels of manganese. Therefore, the upstream site may not be an ideal reference site for setting triggers for the downstream site. Supervising Scientist will investigate the toxicity of manganese in the 2003–04 research year. Information from that research can be used to set appropriate trigger values for the management of manganese in Gulungul Creek.

Recommendation: Wait for the outcome of the Supervising Scientist investigation into the toxicity of manganese before making any decision to change the current trigger values.

3.3.6 Gulungul magnesium

The Gulungul Creek reference site dataset has 47 magnesium results. A box plot of GCUS/GCC magnesium data with outliers identified is shown in figure 3.3.16. Details of outlier treatment are given in table 3.3.10.

Trigger values were derived using the 80th, 95th and 99.7th percentiles of the reference site data (table 3.3.11). A cumulative percent histogram of the GCUS/GCC magnesium data is shown in figure 3.3.17. To illustrate the rate of expected exceedances of the derived trigger values, historic downstream magnesium data are plotted on a control chart with the reference site percentiles (figure 3.3.18).

Table 3.3.10 Treatment of GCUS/GCC magnesium outliers

Value	Date	Source	Detail	Decision
3.23	2/07/01	ERA	EC also high – supports high Mg	RETAIN

Table 3.3.11 Derived Gulungul Creek magnesium trigger values

Trigger	Percentile	Derived trigger value (mg/L)
Focus	80th	1.3
Action	95th	1.7
Limit	99.7th	3.0

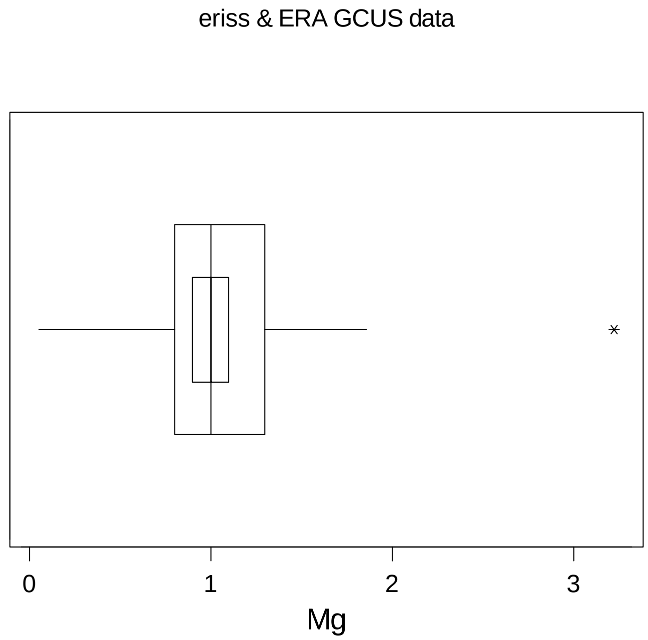

Figure 3.3.16 A box plot of GCUS/GCC magnesium concentration (mg/L) data showing outliers

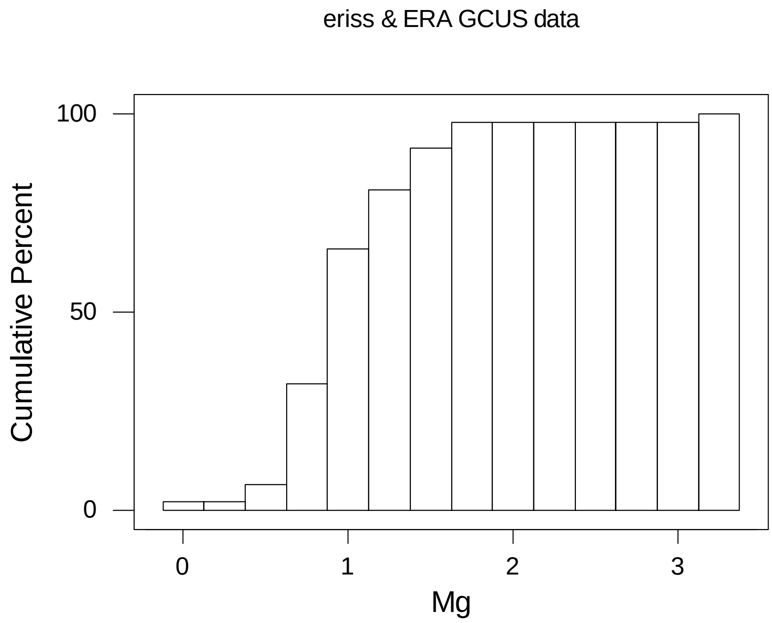

Figure 3.3.17 A cumulative percent histogram GCUS/GCC magnesium concentration (mg/L) data

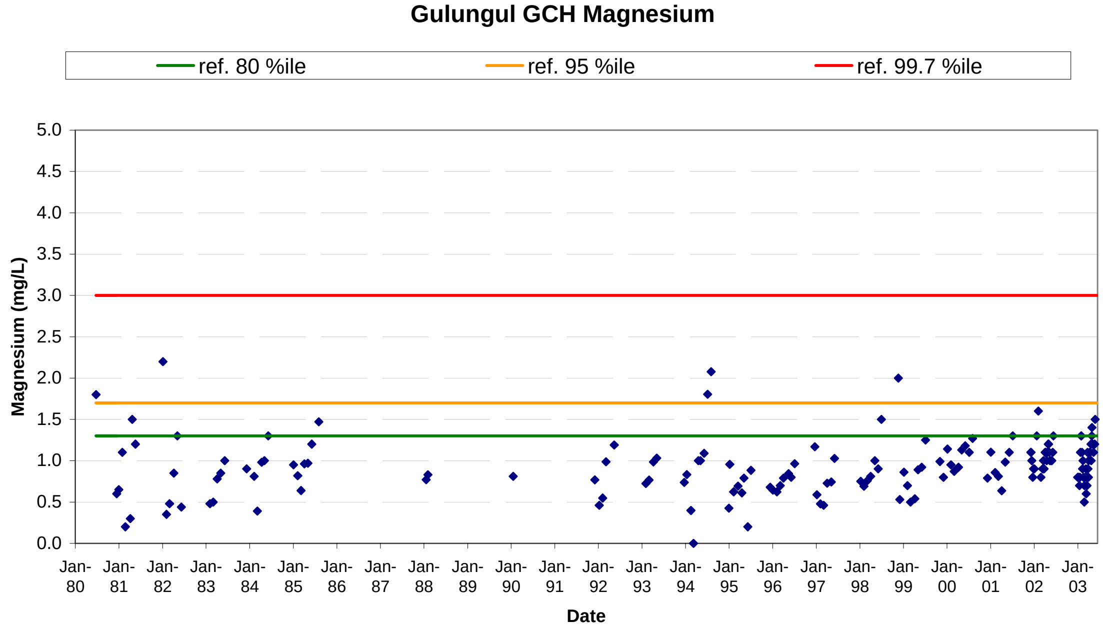

Figure 3.3.18 Control chart of Gulungul Creek downstream (GCH) historic magnesium data showing reference site percentiles

Figure 3.3.18 indicates that the downstream and upstream sites in Gulungul Creek have similar magnesium concentrations, and reference site percentiles as magnesium triggers would provide a good management tool. Figure 3.3.18 also shows that EC at the Gulungul Creek downstream site does not appear to be controlled by magnesium (cf figure 3.3.6). However, Supervising Scientist will publish an ecotoxicological value for magnesium (as a Mg:Ca ratio) soon so that value will be preferable to the statistically derived values derived here.

Recommendation: Once the ecotoxicological limit for magnesium has been published by Supervising Scientist and accepted by stakeholders it should be adopted as the limit for Gulungul Creek.

3.3.7 Gulungul sulfate

The Gulungul Creek reference site dataset has 46 sulfate results. A box plot of GCUS/GCC sulfate data shows that no outliers were identified (figure 3.3.19).

Trigger values were derived using the 80th, 95th and 99.7th percentiles of the reference site data (table 3.3.12). A cumulative percent histogram of the GCUS/GCC sulfate data is shown in figure 3.3.20. To illustrate the rate of expected exceedances of the derived trigger values, historic downstream sulfate data are plotted on a control chart with the reference site percentiles (figure 3.3.21).

Table 3.3.12 Derived GCUS sulfate trigger values

Trigger)	Percentile	Derived trigger values (mg/L)
Focus	80th	0.3
Action	95th	0.5
Limit	99.7th	0.6

It has been noted before that black soils between upstream and downstream sites on Gulungul Creek are believed to contribute to the sulfate signature at the downstream site (Supervising Scientist 2002a). Therefore, the upstream site (GCUS/GCC) is not an ideal reference site and the sulfate percentiles from that site are not expected to provide a good management tool for sulfate at the downstream site (GCH). The process of deriving trigger values for sulfate was carried out as an exercise to see how upstream percentiles compare to downstream measured results.

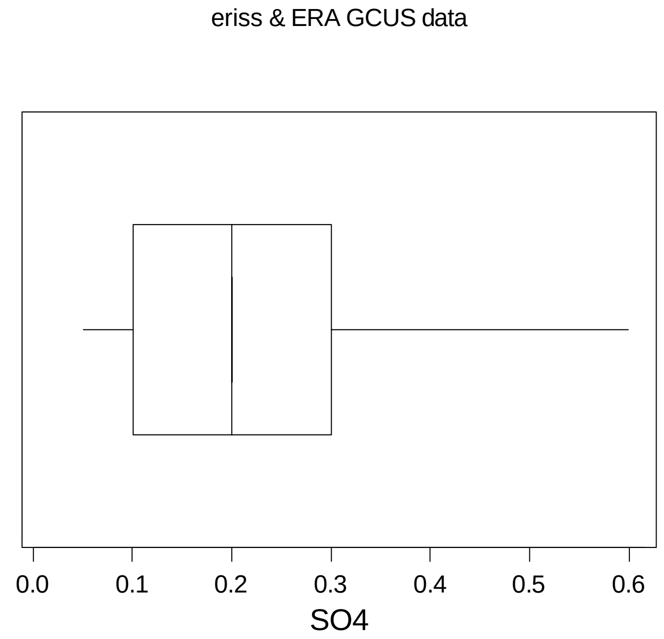

Figure 3.3.19 A box plot of GCUS/GCC sulfate concentration (mg/L) data

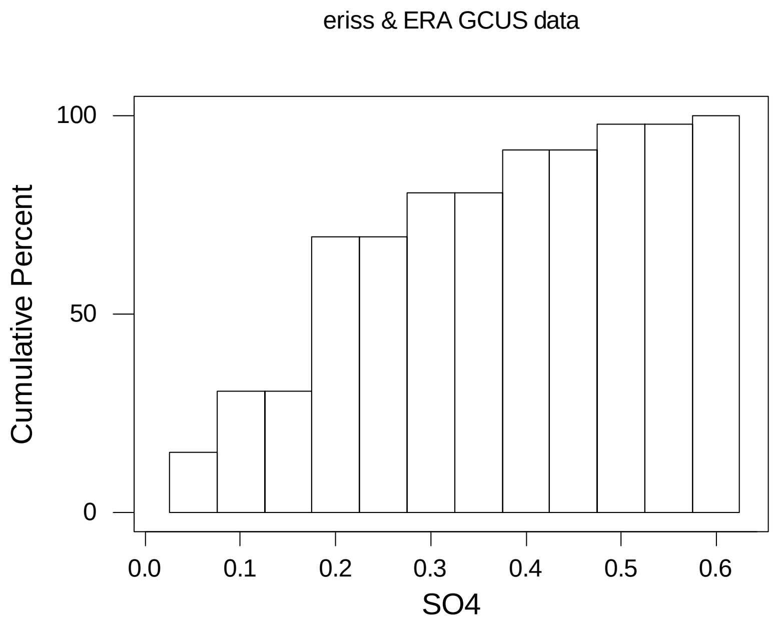

Figure 3.3.20 A cumulative percent histogram of GCUSGCC sulfate concentration (mg/L) data

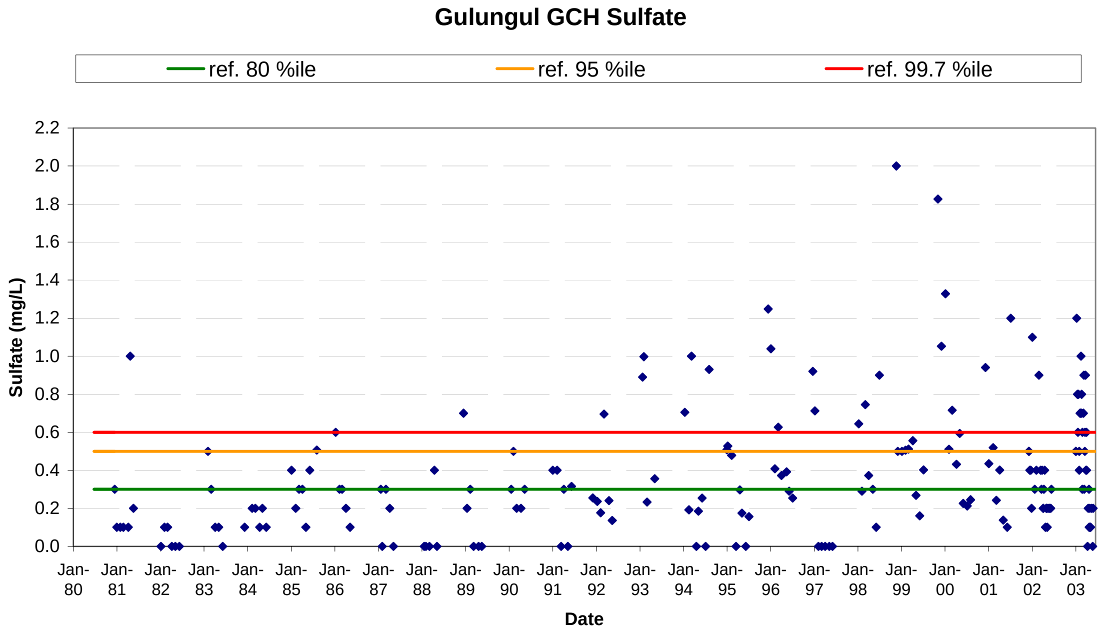

Figure 3.3.21 Control chart of Gulungul Creek downstream (GCH) historic sulfate data showing reference site percentiles

It is obvious from figure 3.3.21 that the downstream data sulfate data are very different from the upstream data. As expected the upstream reference site percentiles would not provide a useful management tool for sulfate in Gulungul Creek. However, Supervising Scientist will publish an ecotoxicological value for sulfate soon and that value can be adopted as the limit for GCH.

Recommendation: Once the ecotoxicological limit for sulfate has been published by Supervising Scientist and accepted by stakeholders it should be adopted as the limit for Gulungul Creek

4 Conclusions and recommendations

In summary the approach to deriving trigger values was to give preference to ecotoxicological effects data over reference site data and to only modify reference site data when it is known, from biological monitoring, that the ecological diversity will not be adversely affected. This approach is in line with the recommendations of the Water Quality Guidelines.

The process of setting trigger values for a downstream site on percentiles of an upstream reference site was found to be inappropriate for several constituents. This is especially true in the smaller catchments of Gulungul Creek and Ngarradj where inputs from tributaries or changing catchment chemistry alter the water chemistry between the upstream and downstream sites. This indicates the upstream sites on these creeks are not ideal reference sites for setting trigger values. However, they remain ideal control sites for routine monitoring purposes so trends at both sites can be compared.

The pH, turbidity, magnesium and sulfate are naturally different at the upstream and downstream sites at Ngarradj. Monitoring of Ngarradj has shown that the works on the Jabiluka lease have not caused an impact on the ecosystem downstream of the lease. Therefore, it is recommended that the 80th, 95th and 99.7th percentiles of downstream data collected to date be used to set focus, action and guideline trigger values for those parameters.

For uranium in Ngarradj it is recommended that, once published and accepted by the stakeholders, the revised ecotoxicological value and its lower confidence limits be adopted as trigger values for Ngarradj. Table 4.1 summarises the recommendations for Ngarradj.

Table 4.1 The recommendations for trigger values in Ngarradj

pH	Derive trigger values from the pH data collected from the downstream site (JSC) to date.
EC	The 80th, 95th and 99.7th percentiles of the JSCUS dataset be adopted as the EC focus, action and guideline trigger values for JSC when the trigger values are reset.
Turbidity	Derive trigger values from the turbidity data collected from the downstream site (JSC) to date.
Uranium	Once the revised ecotoxicological limit for Magela Creek (5.5 μg/L) has been reviewed and accepted by stakeholders it be adopted as the limit for Ngarradj. And the 95th and 99.7th percentiles of the reference dataset be adopted as focus and action triggers at the same time.
Manganese	The manganese reference site percentiles should be used internally to assist in data interpretation. There is no justification to adopt these as water quality objectives under the existing trigger values system, ie they should not become formal trigger values for Ngarradj.
Magnesium	Derive trigger values from the magnesium data collected from the downstream site (JSC) to date
Sulfate	Derive trigger values from the sulfate data collected from the downstream site (JSC) to date.

In Magela Creek excessive exceedances of EC, uranium, manganese, magnesium and sulfate would occur if trigger values were set on reference site percentiles only. For uranium the revised ecotoxicological value of 5.5 μg/L should be adopted as the limit once it has been published and accepted by the stakeholders. The lower 80th and 95th confidence limits of that value should be adopted as the focus and action triggers at that time. This meets the Guidelines recommendation to employ biological effects data, in preference to distributional properties of reference site data.

Site-specific high-reliability ecotoxicological values are currently being derived for sulfate and magnesium while the issue of manganese toxicity will be investigated in the Supervising Scientist 2003–04 Ecological Risk Assessment program. No change to the existing trigger values for these parameters is recommended before the results of those works is available. The ionic composition of Magela Creek waters and their effect on EC should be investigated with a view to adopting the magnesium/sulfate ecotoxicological value as a proxy for EC triggers.The following table summarises the recommendations for Magela Creek

Table 4.2 The recommendations for trigger values in Magela Creek

pH	The 80th, 95th and 99.7th percentiles of the MCUS pH dataset be adopted as the pH focus, action and guideline trigger values for MG009 when the trigger values are reset.
EC	Assess the environmental risk of ions controlling the EC in Magela Creek. If ions other than magnesium, calcium and sulfate are considered a low risk then adopt the ecotoxicological values for magnesium and sulfate as proxies for EC triggers at MG009.
Turbidity	The 80th, 95th and 99.7th percentiles of the MCUS turbidity dataset be adopted as the turbidity focus, action and guideline trigger values for MG009 when the trigger values are reset.
Uranium	Once the revised ecotoxicological limit for Magela Creek (5.5 μg/L) has been reviewed and accepted by stakeholders it be adopted as the limit for Magela Creek The lower 80% and 90% confidence limits should be adopted as the focus and action triggers at that time
Manganese	Wait for the outcome of the Supervising Scientist investigation into the toxicity of manganese before making any decision to change the current trigger values.

In Gulungul Creek trigger values based on upstream percentiles do not provide a good management tool for EC, turbidity, manganese and sulfate. Biological monitoring has shown no change in the macro invertebrate communities of Gulungul Creek. However, there has been some changes in fish communities but this has not been attributed to changes in water quality of Gulungul Creek. In light of the changes seen in the fish communities it is not proposed to adopt the same process as suggested for Ngarradj, ie triggers based on all available downstream data. Rather, the Gulungul Creek downstream data should be checked for changes since monitoring began in the 1980s. Data collected prior to any significant change could be used as the reference site dataset and triggers set based on the percentiles of that data. The changed detection limits for uranium in the older data will be an issue if this method is adopted. However, it is preferable to base uranium trigger values on the ecotoxicologically derived value and its confidence limits, so this problem will become superfluous. The following table summarises the recommendations for Gulungul Creek.

Table 4.3 The recommendations for trigger values in Gulungul Creek

pH	The 80th, 95th and 99.7th percentiles of the GCUS pH dataset be adopted as the pH focus, action and guideline trigger values for GCH when the trigger values are reset.
EC	As for Magela Creek.
Turbidity	Derive trigger values from the turbidity data collected from the downstream site (GCH) to date or prior to any significant change.
Uranium	Once the revised ecotoxicological limit for Magela Creek (5.5 µg/L) has been reviewed and accepted by stakeholders it be adopted as the limit for Gulungul Creek The lower 80% and 90% confidence limits should be adopted as the focus and action triggers at that time.
Manganese	Wait for the outcome of the Supervising Scientist investigation into the toxicity of manganese before setting triggers
Magnesium	Once the ecotoxicological limit for magnesium has been published by Supervising Scientist and accepted by stakeholders it should be adopted as the limit for Gulungul Creek
Sulfate	Once the ecotoxicological limit for sulfate has been published by Supervising Scientist and accepted by stakeholders it should be adopted as the limit for Gulungul Creek

Given the issues identified in this report, the trigger values in Magela and Ngarradj should remain unchanged for the 2003–04 Wet season. After the investigations recommended in this report are carried out, and ecotoxicological values are published and accepted by the stakeholders, new trigger values for Magela and Gulungul Creeks and Ngarradj can be adopted.

The Office of the Supervising Scientist aims to have the revised trigger values published in the Supervising Scientist 2003–2004 Annual Report.

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Appendix 1 Percentile sensitivity to inclusion of first flush data

This report documents the results of a comparison of percentiles of the JSCUS dataset with first flush data removed and first flush data retained.

Only those records identified as first flush by comments in the ERA and Supervising Scientist databases were not included in the first flush-removed dataset, which were only 4 records from approximately 200.

For each parameter the percentiles for the first flush-removed and -retained datasets are compared. Box plots identifying outliers and control charts of downstream data (JSC) against reference site percentiles are shown for first flush-removed and -retained datasets for each parameter.

As expected there was little change in the calculated percentiles between the dataset with and without the identified first flush data. Electrical conductivity and sulfate are the exceptions.

pH

Nothing in the ERA or Supervising Scientist database suggested the data points identified as outliers (figures A1 and A2) were unreliable. Therefore, no outliers were removed from either the first flush-removed or -retained datasets. With first flush data retained only the 0.3 percentile changed, and only by one tenth of a unit (table A1). No difference can be seen in the control charts for each dataset (figures A3 and A4).

Table A1 pH percentiles with first flush data removed and retained

Percentiles	pH percentiles with first flush data removed	pH percentiles with first flush data retained
20^{th} – 80^{th}	4.7–5.2	4.7–5.2
5^{th} – 95^{th}	4.5–5.4	4.5–5.4
0.3 – 99.7th	3.8–5.8	3.7–5.8

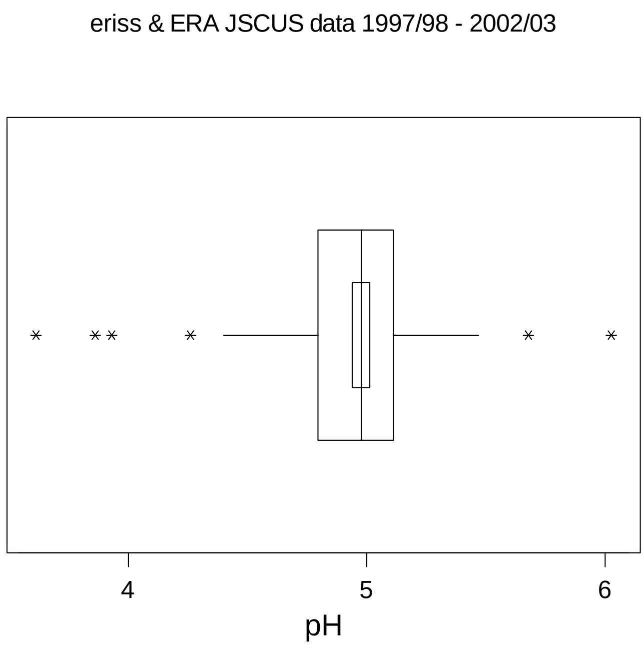

Figure A1 Box plot of JSCUS pH data showing outliers – first flush data **removed**

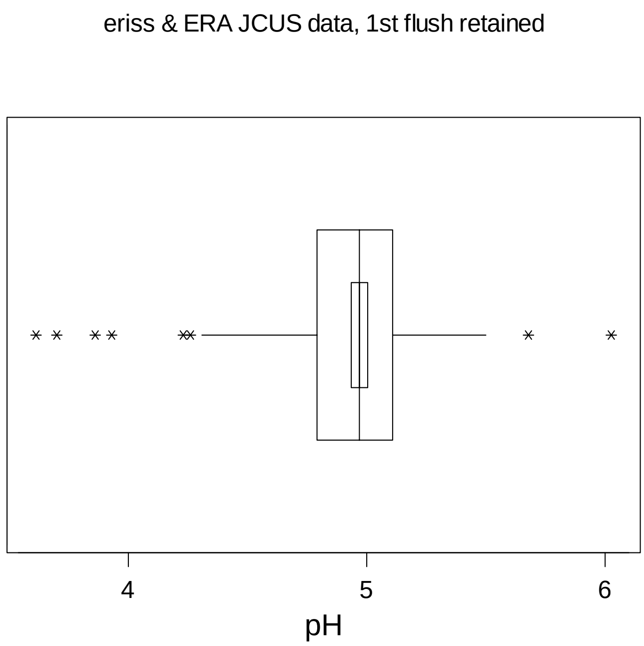

Figure A2 Box plot of JSCUS pH data showing outliers – first flush data **retained**

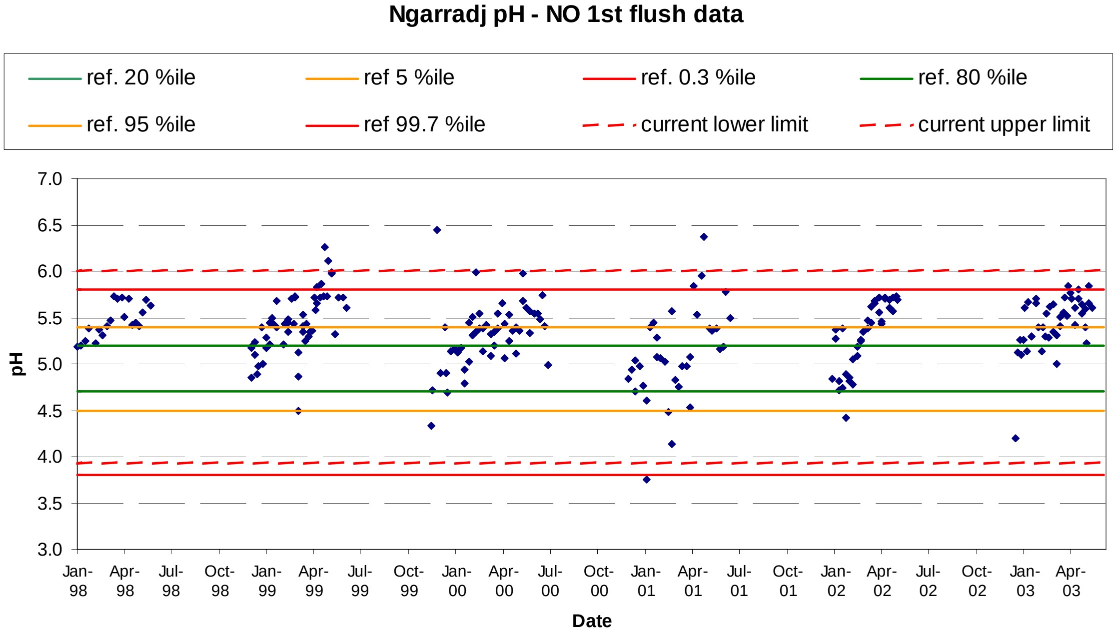

Figure A3 Control chart of all Ngarradj downstream (JSC) historic pH data showing revised and current trigger values – identified first flush data **removed**

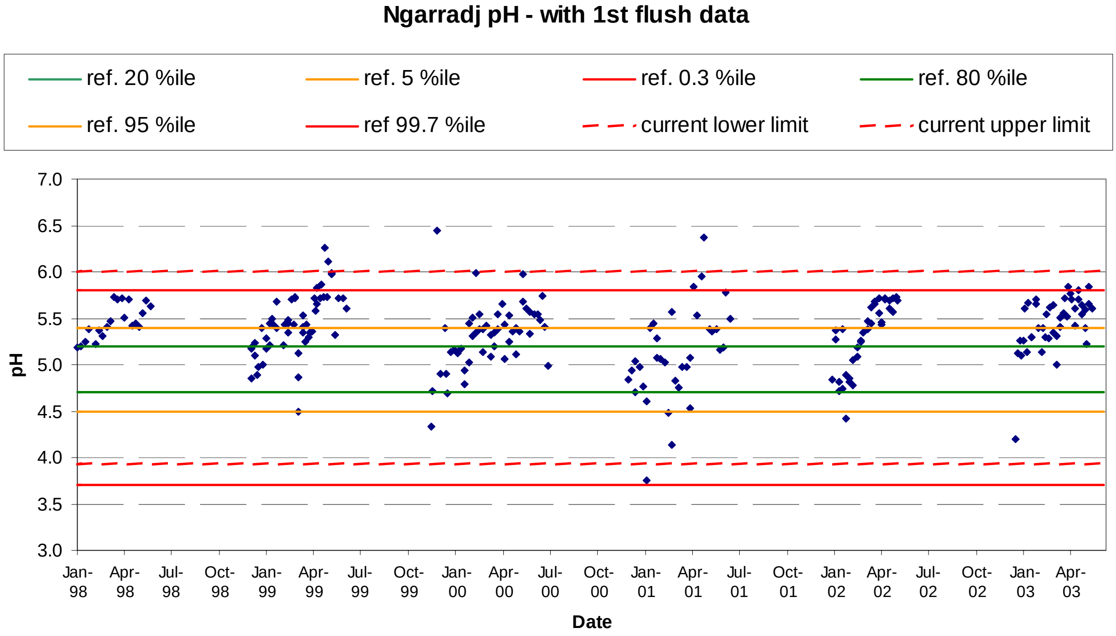

Figure A4 Control chart of all Ngarradj downstream (JSC) historic pH data showing revised and current trigger values – first flush data **retained**

EC

Outlier treatment was different for the first flush-retained and -removed datasets (cf tables A2 and A3 and figures A5 and A6). With first flush data retained the 95th and 99.7th EC percentiles increased by 2 and 7 units respectively (table A4).

Table A2 Treatment of EC outliers – first flush data removed

EC value (µS.cm^{-1})	Date	Source	Detail	Decision
23.6	2/1/03	Supervising Scientist	Nothing in database to clarify, reject as first flush	REJECT
88	6/2/01	ERA	ERA insitu value = 10	REJECT

Table A3 Treatment of EC outliers – first flush data retained

EC value (µS.cm^{-1})	Date	Source	Detail	Decision
23.6	2/1/03	Supervising Scientist	Within range of first flush data	RETAIN
88	6/2/01	ERA	ERA insitu value = 10	REJECT

Table A4 EC percentiles with first flush data removed and retained

Percentile	EC percentile (µS.cm^{-1}) first flush data out	EC percentile (µS.cm^{-1}) first flush data in
80th	14	14
95th	17	19
99.7th	19	26

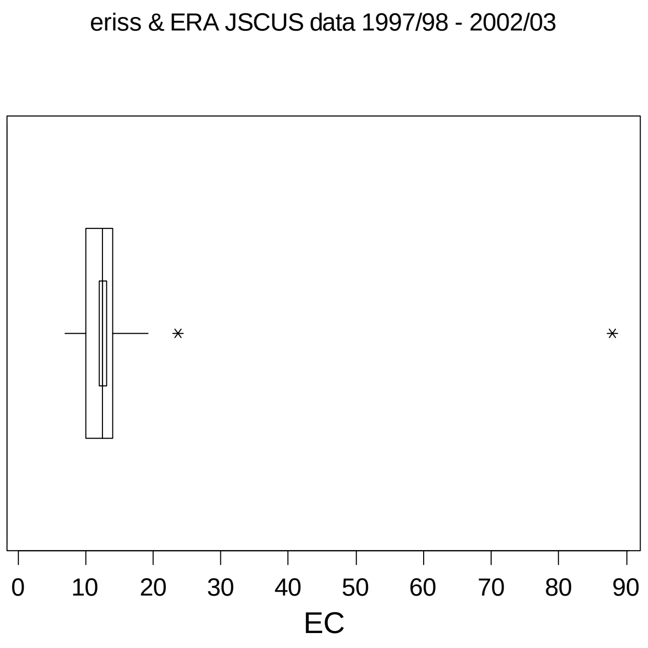

Figure A5 A box plot of JSCUS EC data showing outliers – first flush data **removed**

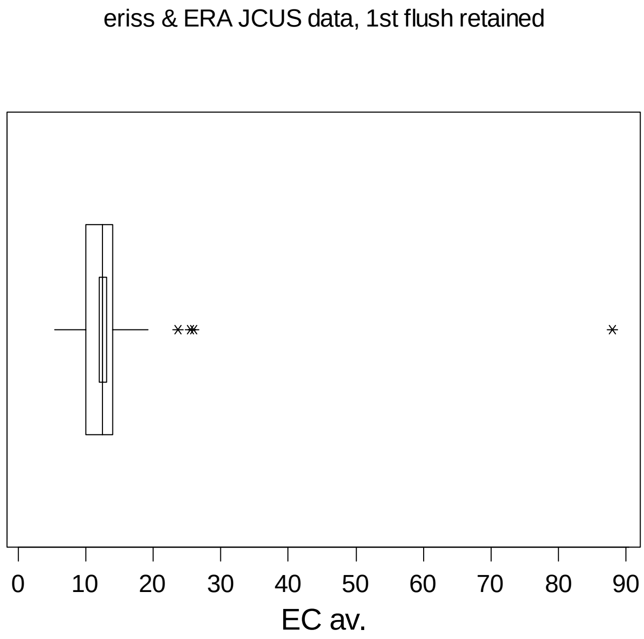

Figure A6 A box plot of JSCUS EC data showing outliers – first flush data **retained**

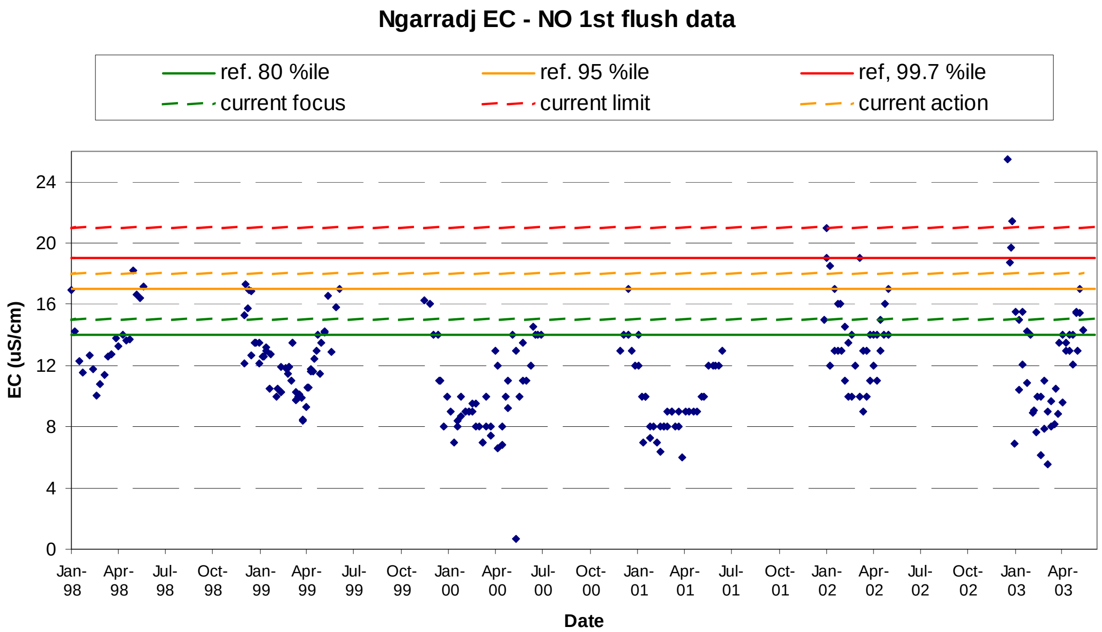

Figure A7 Control chart of all Ngarradj downstream (JSC) historic EC data showing revised and current trigger values – first flush data **removed**

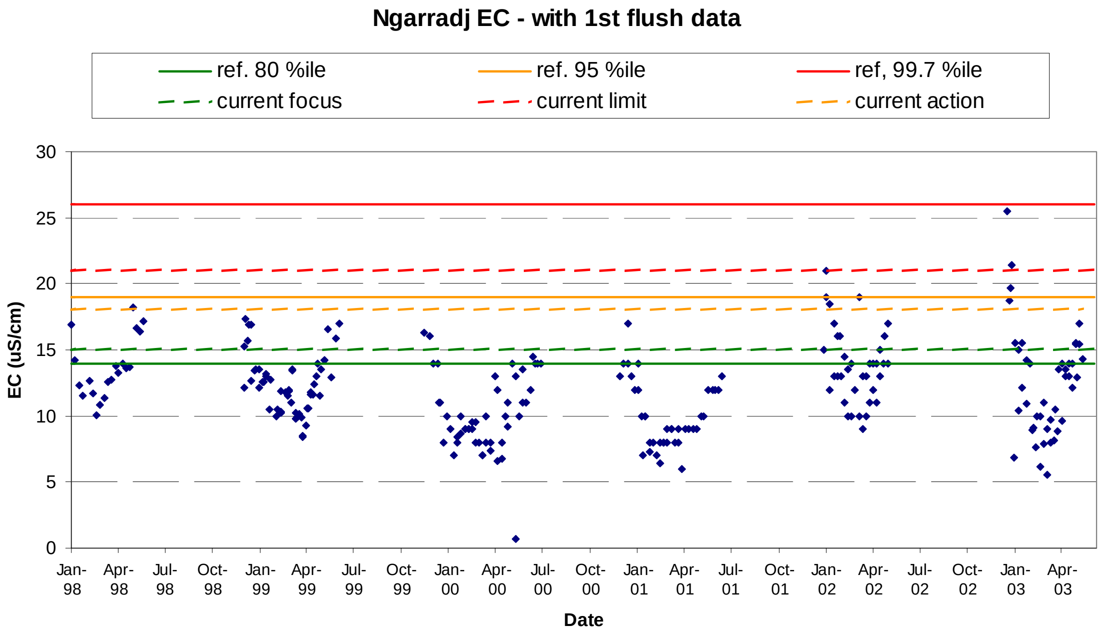

Figure A8 Control chart of all Ngarradj downstream (JSC) historic EC data showing revised and current trigger values – first flush data **retained**

Turbidity

Retaining the first flush data made little difference to the turbidity percentiles. Only the 99.7th percentile changed, and only by one unit (table A5). All identified outliers in both datasets (figures A9 and A10) were retained as they are within the range of values expected based on observation of the system (Prendergast & Evans 1998).

Table A5 Turbidity percentiles with first flush data removed and retained

Percentile	Turbidity percentile (NTU) – first flush data out	Turbidity percentile (NTU) – first flush data in
80th	2	2
95th	4	4
99.7th	11	12

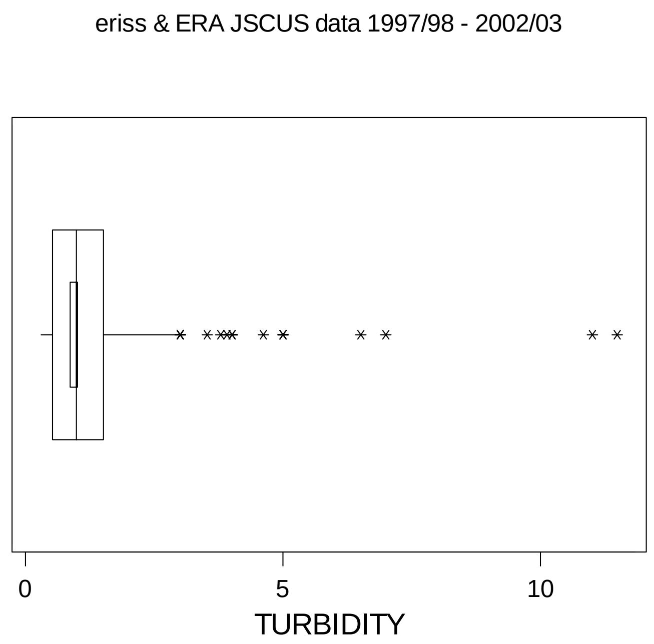

Figure A9 A box plot of turbidity data showing outliers – first flush data **removed**

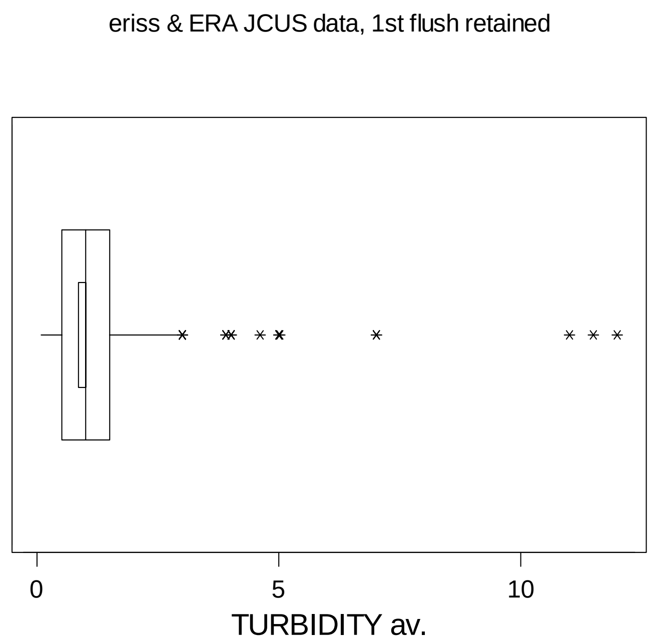

Figure A10 A box plot of turbidity data showing outliers – first flush data **retained**

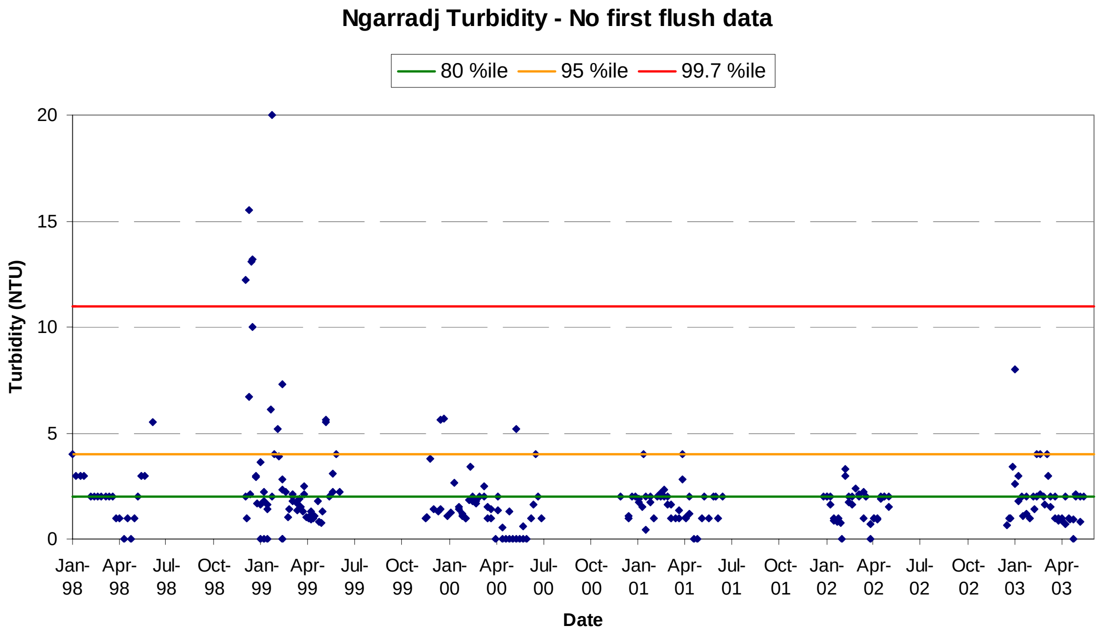

Figure A11 Control chart of all Ngarradj downstream (JSC) historic turbidity data showing recommended guideline values – first flush data **removed**

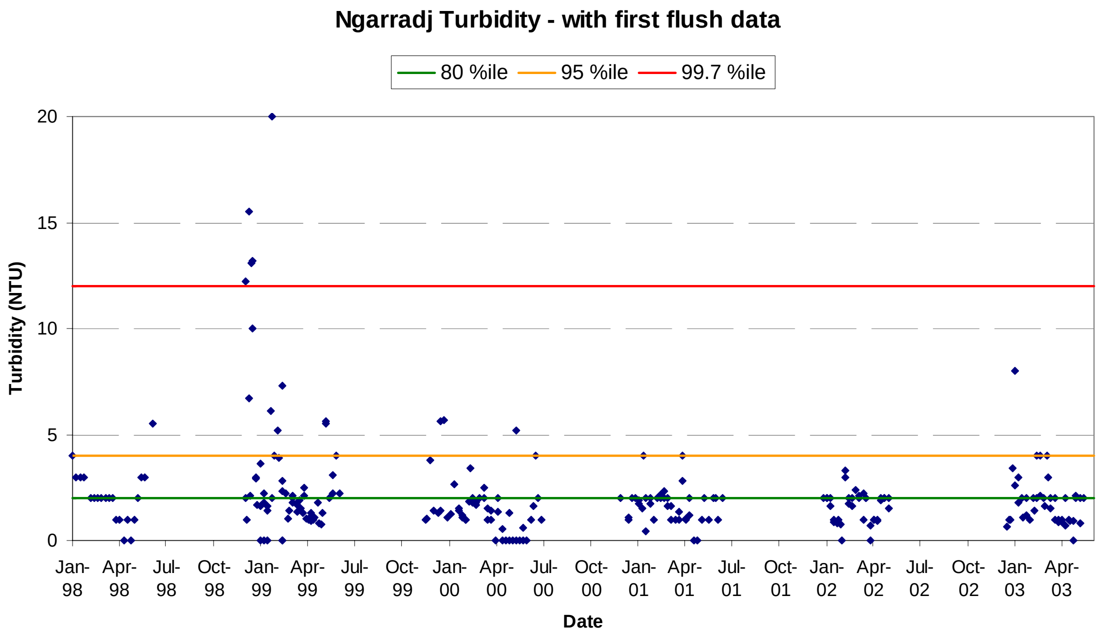

Figure A12 Control chart of all Ngarradj downstream (JSC) historic turbidity data showing recommended guideline values – first flush data **retained**

Uranium

Retention or removal of first flush data made no difference to the percentiles or identified outliers (figures A13 and A14). All data identified as outliers by Minitab have been retained in both the first flush -removed and -retained datasets.

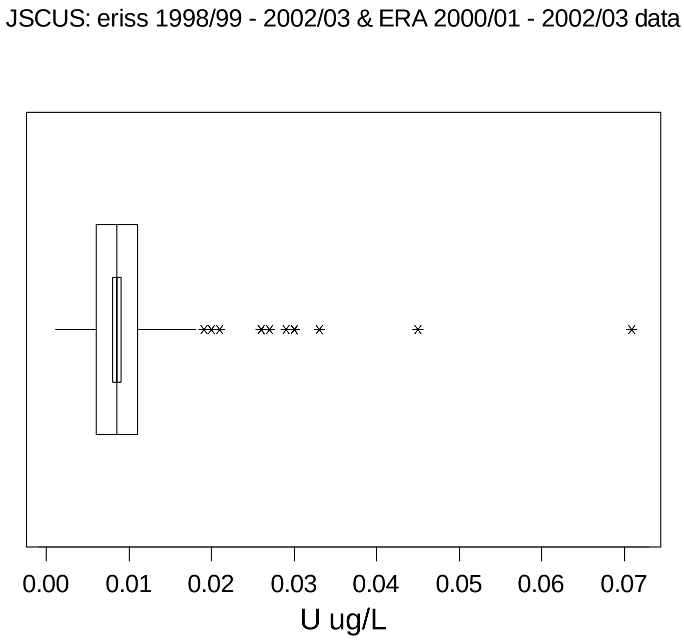

Figure A13 A box plot of JSCUS uranium data showing outliers – first flush data **removed**

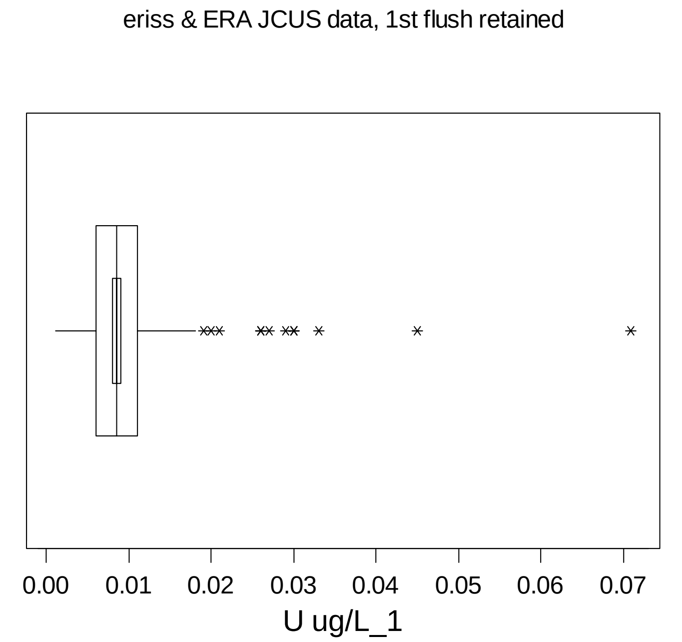

Figure A14 A box plot of JSCUS uranium data showing outliers – first flush data **retained**

Manganese

Retention of first flush data only altered the 99.7th percentile by one unit (table A6). All values identified as outliers in both the first flush–retained (figure A15) and –removed (figure A16) datasets were very low and considered to reflect natural variation, they have been retained.

Table A6 Manganese percentiles with first flush data removed and retained

Percentile	Manganese percentiles (µg/L) first flush data out	Manganese percentiles (µg/L) first flush data in
80th	6	6
95th	9	9
99.7th	14	15

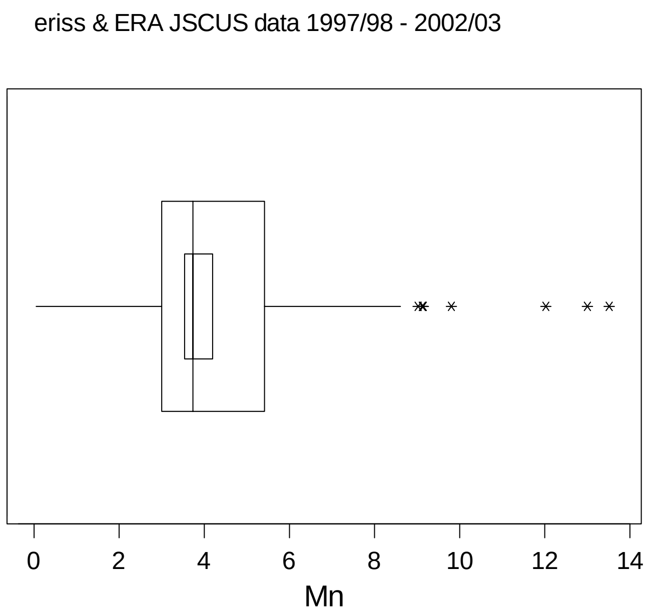

Figure A15 A box plot of JSCUS manganese data showing outliers – first flush data **removed**

eriss & ERA JCUS data, 1st flush retained

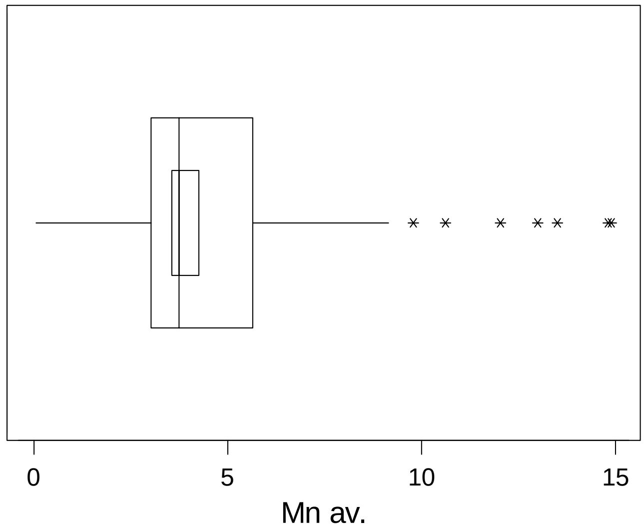

Figure A16 A box plot of JSCUS manganese data showing outliers – first flush data **retained**

Ngarradj Manganese - NO 1st flush data

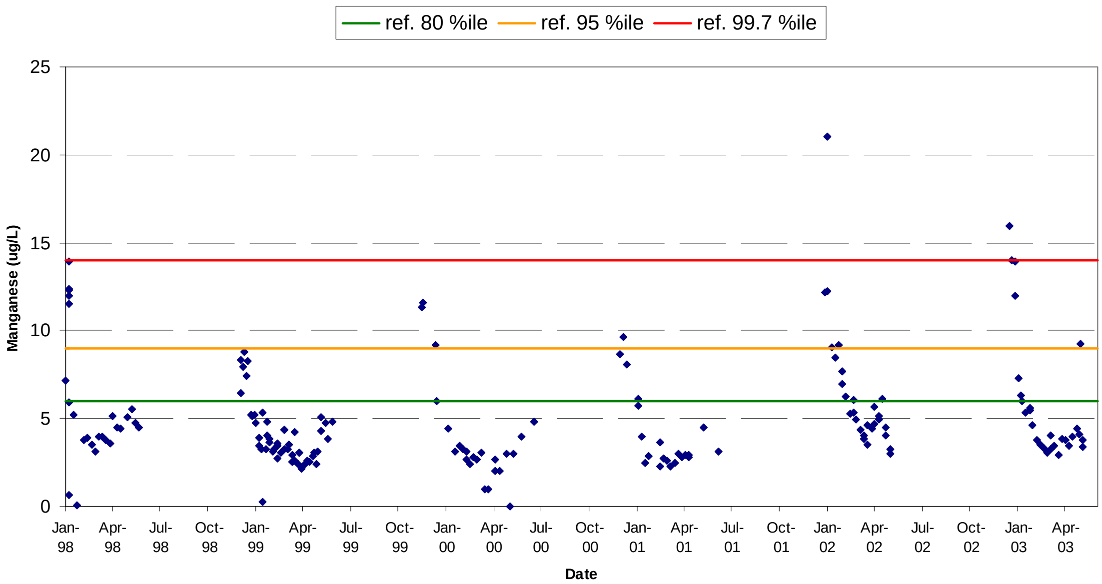

Figure A17 Control chart of all Ngarradj downstream (JSC) historic manganese data showing recommended guideline values – first flush data **removed**

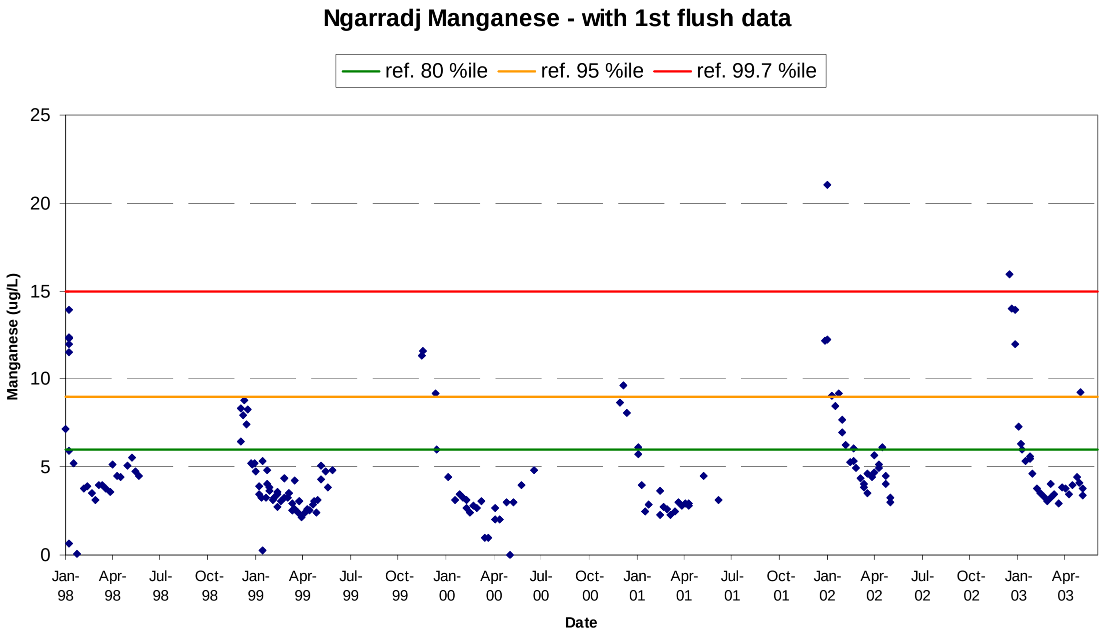

Figure A18 Control chart of all Ngarradj downstream (JSC) historic manganese data showing recommended guideline values – first flush data **retained**

Magnesium

Outlier treatment was the same for both datasets, ie rejection of the 14.2 value (table A7). Retaining the first flush data only resulted in a one-unit increase of both the 80th and 95th percentiles (table A8 and figures A21-22).

Table A7 Treatment of magnesium outliers–both datasets

Value	Date	Source	Detail	Decision
14.2	20/2/01	ERA	No Mg result was reported for this sample in the old ERA Minewater database	REJECT
0.50	Various	ERA & Supervising Scientist	Several results (n=6) through several years	RETAIN
0.60	27-30/12/02	ERA	Two results in close succession	RETAIN
0.75	25/07/00	ERA	Not atypical magnitude for recessional flow periods	RETAIN

Table A8 Magnesium percentiles with first flush data removed and retained

Percentile	Magnesium percentiles (µS.cm^{-1}) first flush data out	Magnesium percentiles (µS.cm^{-1}) first flush data in
80th	0.32	0.33
95th	0.49	0.50
99.7th	0.68	0.68

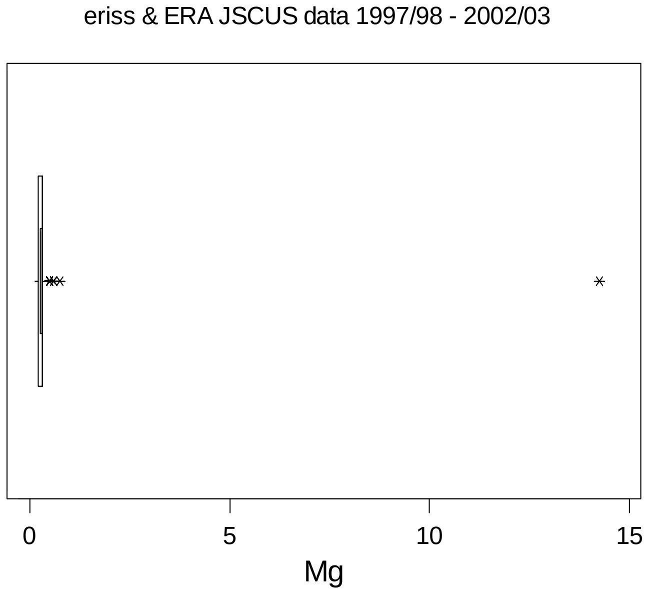

Figure A19 Box plot of JSCUS magnesium data showing outliers – first flush data **removed**

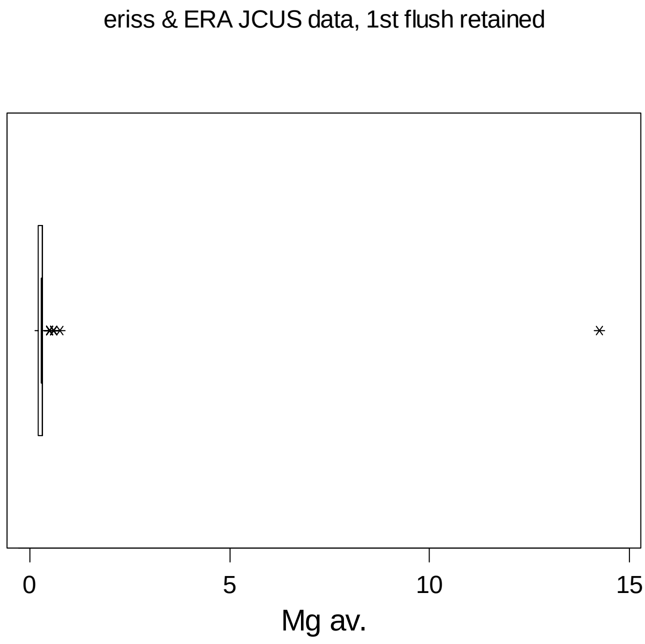

Figure A20 Box plot of JSCUS magnesium data showing outliers – first flush data **retained**

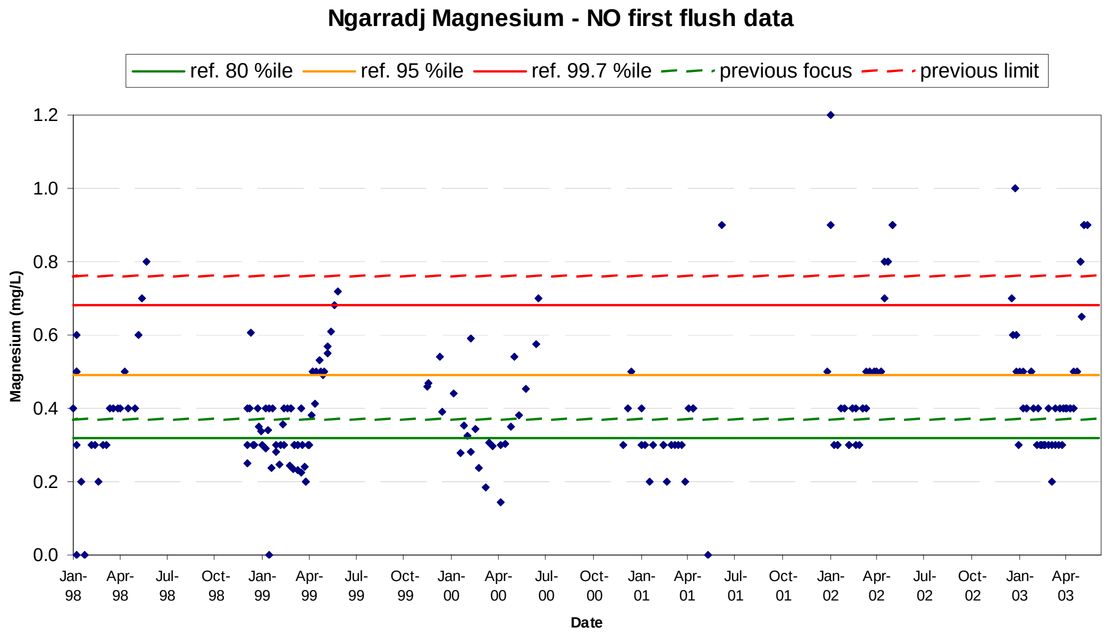

Figure A21 Control chart of all Ngarradj downstream (JSC) historic magnesium data showing revised and current guideline values – first flush data **removed**

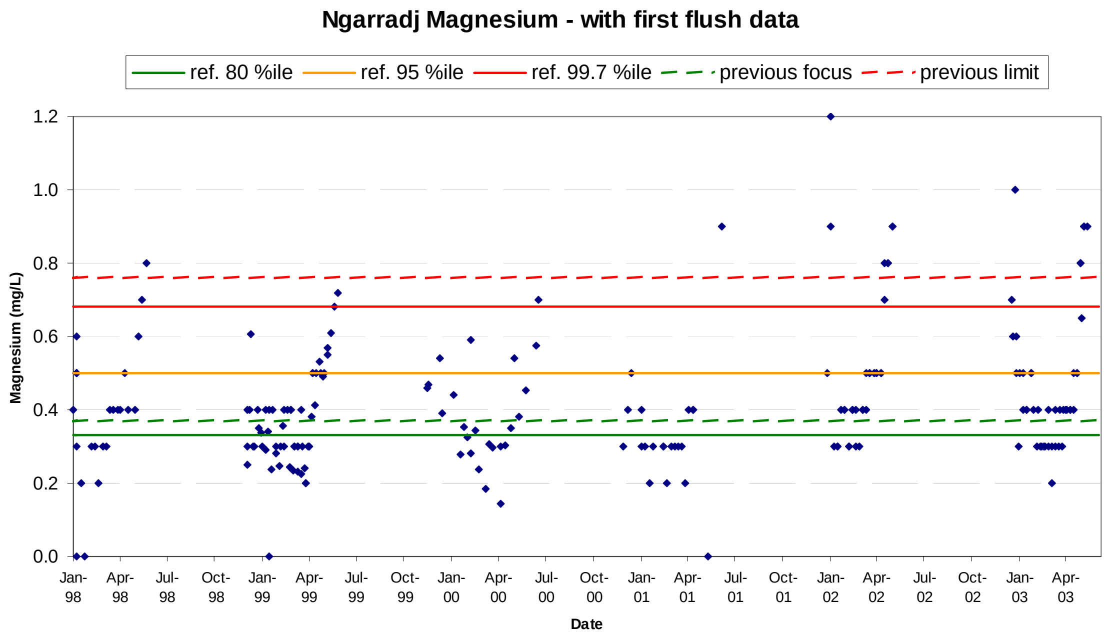

Figure A22 Control chart of all Ngarradj downstream (JSC) historic magnesium data showing revised and current guideline values – first flush data **retained**

Sulfate

Outlier treatment was the same for the first flush-removed and -retained datasets (table A9). Inclusion of the first flush data increased the 95th percentile by 0.01 and the 99.7th percentile by 0.39 mg/L (table A9 and figures A25–26).

Table A9 Treatment of sulfate outliers both datasets

Value	Date	Source	Detail	Decision
1.0 & 1.1	Several records	Both companies	Values not atypical of those expected in Ngarradj	RETAIN
1.20	15/12/98	ERA	Not identified as first flush sample	RETAIN
3.47	25/07/00	ERA	Very late sample - order of magnitude higher than previous data - ? evapoconcentration / stagnant water	REJECT

Table A10 Sulfate percentiles with first flush data removed and retained

Percentile	Sulfate percentiles (mg/L) first flush data out	Sulfate percentiles (mg/L) first flush data in
80th	0.60	0.60
95th	0.89	0.90
99.7th	1.15	1.54

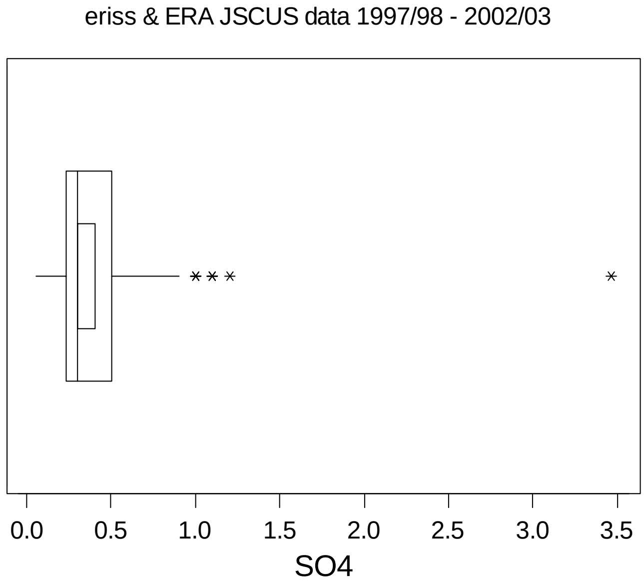

Figure A23 Box plot of JSCUS sulfate data showing outliers – first flush data **removed**

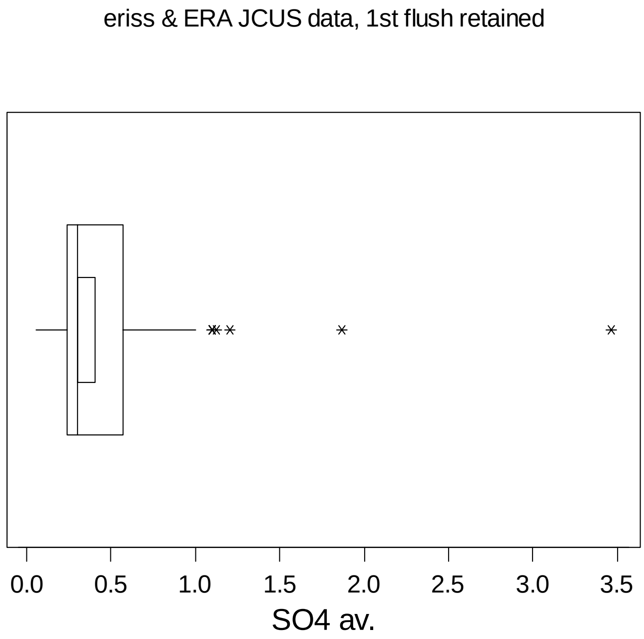

Figure A24 Box plot of JSCUS sulfate data showing outliers – first flush data **retained**

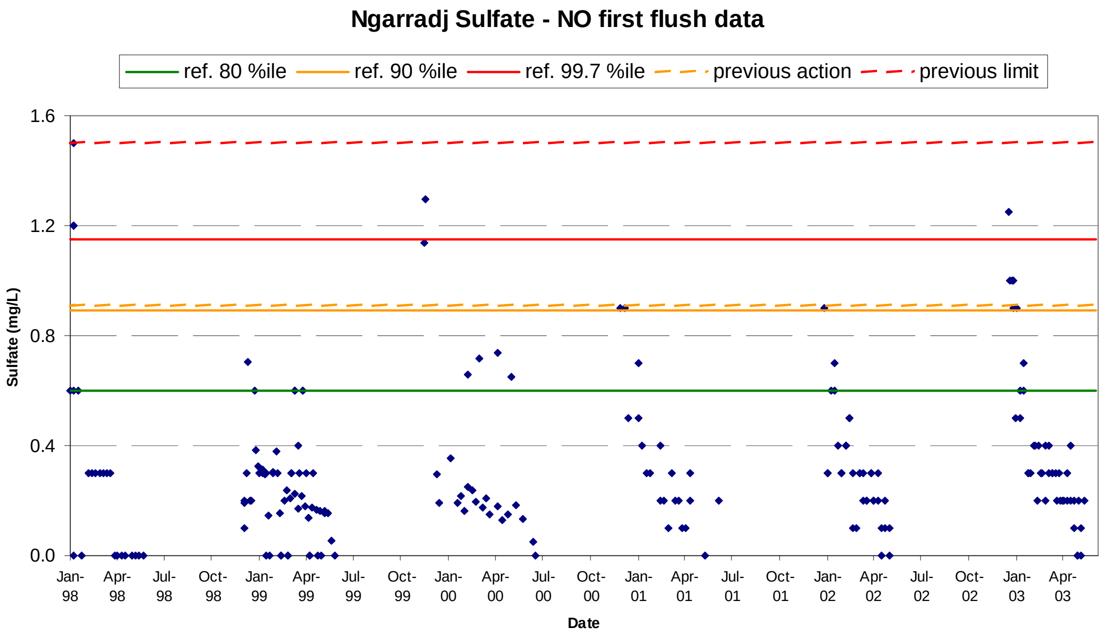

Figure A25 Control chart of all Ngarradj downstream (JSC) historic sulfate data showing revised and current trigger values – first flush data **removed**

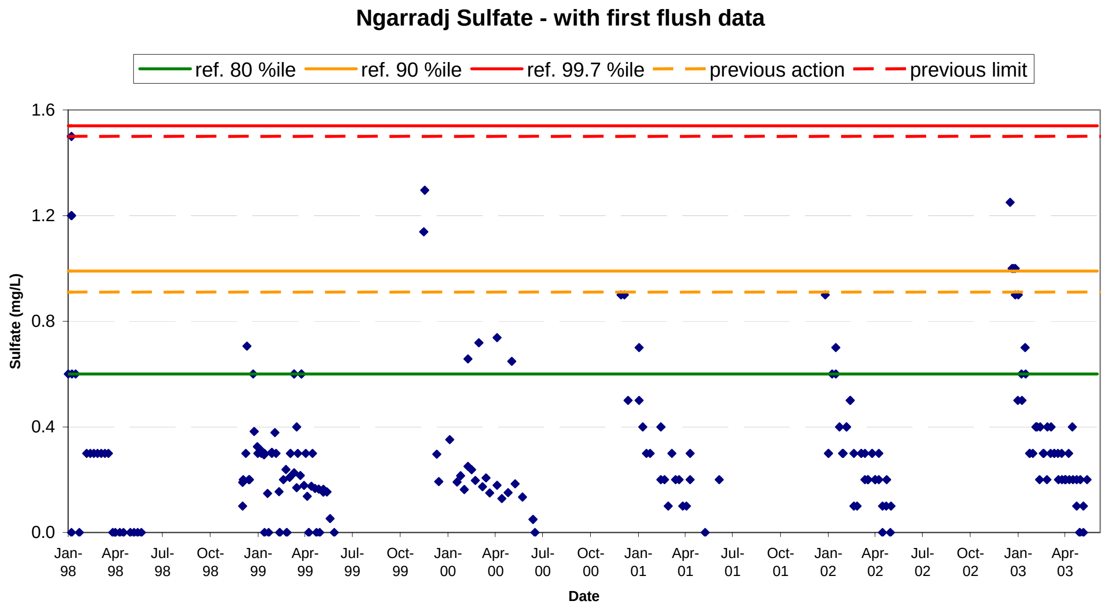

Figure A26 Control chart of all Ngarradj downstream (JSC) historic sulfate data showing revised and current trigger values – first flush data retained