# CANADA – BRITISH COLUMBIA
## WATER QUALITY MONITORING AGREEMENT

# WATER QUALITY ASSESSMENT OF Fraser River AT RED PASS (1984 – 2004)


Prepared by:

L. G. Swain, P. Eng.

B.C. Ministry of Environment


Prepared for:

B.C. Ministry of Environment

and

Environment Canada

March 2007

**Environment Canada** **Environnement Canada**

BRITISH COLUMBIA
The Best Place on Earth

Ministry of Environment

## EXECUTIVE SUMMARY

The Fraser River flows through a vast portion of the southern half of British Columbia, from the Rocky Mountains to the Pacific Ocean. The water quality monitoring site at Red Pass (located just below Moose Lake in the headwaters of the Fraser River) is the first of five long-term monitoring stations on the Fraser River. The remaining four monitoring sites are located at Hansard, Stoner, Marguerite, and Hope. This site represents a relatively pristine monitoring station, with no significant anthropogenic activity occurring upstream from this location. The primary purpose of the site is to provide an indication of ambient conditions that can be compared with water quality at downstream sites. The water quality trends identified below have not yet been confirmed by statistical analysis.

## CONCLUSIONS

- There was an increasing trend in nickel concentrations since about 1994, although it has been reduced in magnitude in recent years. The cause of this increase is unclear, but concentrations of total nickel remain well below guideline levels for aquatic life.
- There may be slight increases in cobalt, rubudium, and dissolved nitrogen and dissolved sulphate.
- There appears to be a decreasing trend in lead concentrations and a possible increase in manganese. These trends may be related to the elimination of leaded gas and the use of a manganese-based additive.
- Specific conductivity also appeared to be increasing over time, but the levels seem to have remained steady since about 1992. Similar patterns were noted for hardness.
- The Fraser River at Red Pass has a low sensitivity to acid inputs (has a high buffering capacity) based on its relatively high total alkalinity and calcium concentrations.
- Exceedances of water quality guidelines by metals such as total copper, total iron, and total silver, appear to be associated with elevated turbidity levels, indicating

that these metals were bound in particulate matter, and therefore not available to biota and not of concern. Many metals that appeared to have values that exceeded guidelines in the past, have been shown to meet guidelines since lower detection limits have been utilized, and confidence in results have coincidentally improved.

- As there are no major human activities upstream from the Red Pass site, the measured concentrations of all metals would appear to be due to natural erosion processes in the upper watershed. Occasional high turbidity values are also attributed to natural erosion processes.
- All fecal coliform values were very low, indicating little fecal contamination of the Fraser River was occurring upstream from Red Pass.
- True colour has only been measured at Red Pass since 1997, but all values since that time have been below the aesthetic guideline for drinking water quality.
- Another recent evaluation of water quality at the Red Pass site, using the Water Quality Index as an assessment tool, ranked the water quality as Good to Excellent. Benthic populations measured downstream from the site in 1996 also indicated excellent water quality, and the population itself was considered to be a "reference" (i.e. undisturbed) population.

## RECOMMENDATIONS

- Continue monitoring at this station for the present suite of water quality indicators, because the Red Pass site provides critical ambient water quality data necessary for interpreting data collected downstream in the Fraser River, as well as elsewhere in the province.
- Initiate monitoring of dissolved aluminum and hexavalent and trivalent chromium to enable the comparison of these metals to existing water quality guidelines.
- Continue to monitor extractable concentrations of all metals, including cadmium, to allow comparisons to total and dissolved concentrations of metals to be made (useful for determining potential impacts on aquatic life and/or drinking water).

## TABLE OF CONTENTS



## LIST OF FIGURES

## LIST OF FIGURES

## (CONTINUED)

# List of Figures

## (Continued)

## INTRODUCTION

Since 1985, B.C. Ministry of Environment and Environment Canada have been cooperatively measuring water quality at a number of locations in British Columbia. The express purposes of this joint monitoring program have been to define the quality of the water and to determine whether there are any trends in water quality.

Water quality measurements for the Fraser River at Rd Pass were plotted on a graph over time, along with the relevant water quality objectives or guidelines. The graphs were inspected for "environmentally significant" trends - where the measurements are increasing or decreasing over time and the levels are close to the objectives or guidelines, or are otherwise judged to represent an important change in water quality. These trends are further evaluated to ensure that they were not caused by measurement errors, to identify their causes, and to determine whether they are statistically significant. A confidence level of 95% or better is used to define statistical significance, unless noted otherwise.

The Fraser River basin is one of British Columbia's most valued ecosystems, draining fully one quarter of the province. Its headwaters are located in the Mount Robson Provincial Park near Moose Lake in the Rocky Mountains. The northern part of the river follows a northwest path before heading south, starting just north from Prince George. The Fraser River then flows 1,200 km before turning to the west, near Hope, and continues for about 150 km before entering the Pacific Ocean at Vancouver. The river has two very important tributaries which affect both flow and water quality. They are the Nechako River, which merges with the Fraser River at Prince George, and the Thompson River, which flows into the Fraser River at Lytton.

The Fraser River supports commercial and recreational fisheries of all five salmon species, and salmon runs on the Fraser River are among the largest in the world.

There are five long-term federal-provincial water quality monitoring sites on the Fraser River (Fraser River at Red Pass, Hansard, Stoner, Marguerite, and Hope). Also, there are long-term sites on both the Nechako and Thompson rivers. This report deals with the site on the Fraser River at Red Pass (Figure 1). Red Pass is located upstream from Hansard in a sparsely populated reach of the river. The drainage area for the site is 1,700 $km^2$, and is contained within the Mount Robson Provincial Park. There are no active water licences or permitted waste discharges between the headwaters of the Fraser River and Red Pass. The main potential human influences on water quality are the Yellowhead Highway and the Canadian National Railway, which run alongside the Fraser River and Moose Lake through Mt. Robson Park, recreational activities in the park, and atmospheric deposition of contaminants carried by rain and snow.

Data for the Fraser River at Red Pass have been collected on a frequency of about once every two weeks. As well, twice per year, two additional samples are collected in order to ensure that there are two periods when weekly samples are collected during five consecutive weeks to assess attainment of water quality objectives. In addition, quality assurance samples (blanks and replicates) are collected three times per year. The results for each variable were used in this assessment to identify potential outliers that should be removed form consideration of trends, and to "flag" questionable data in the database (www.waterquality.ec.gc.ca) as to possible or likely errors.

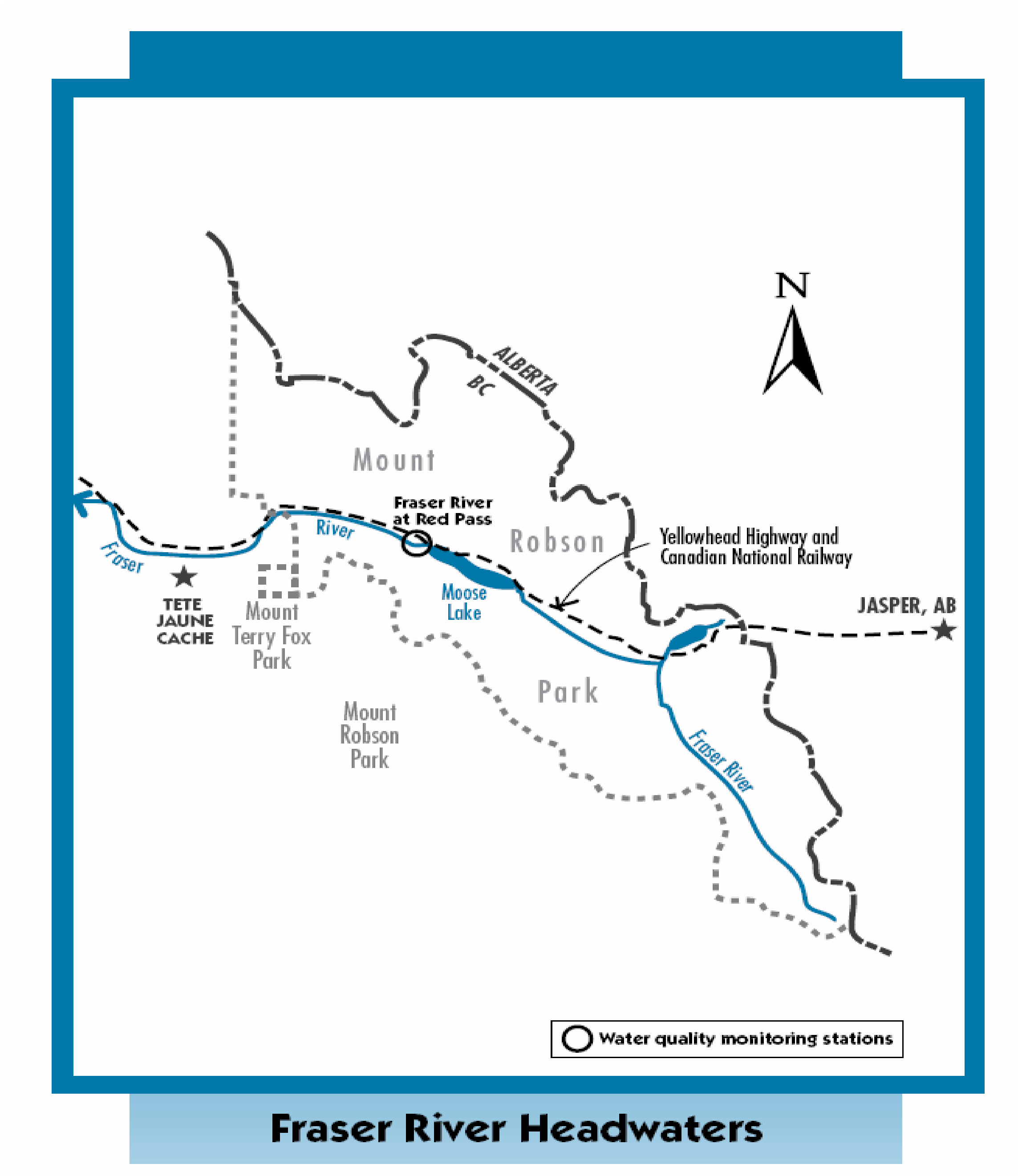



**Figure 1: Fraser River at Red Pass**

This report assesses twenty-one years (1984 – 2004) of water quality data collected by Environment Canada and B.C Environment. The data, from bi-weekly water samples, are stored in the Environment Canada database under ENVIRODAT station number BC08KA0007 and in the Ministry of Environment database under EMS number E236796. All of the data are available to the public on our web site, located at www.waterquality.ec.gc.ca. Flow data for the Fraser River at Red Pass (station no. BC08KA007), collected by the Water Survey of Canada, are plotted in Figure 2 for 1984-2004. Water quality data are plotted in Figures 3 to 54.

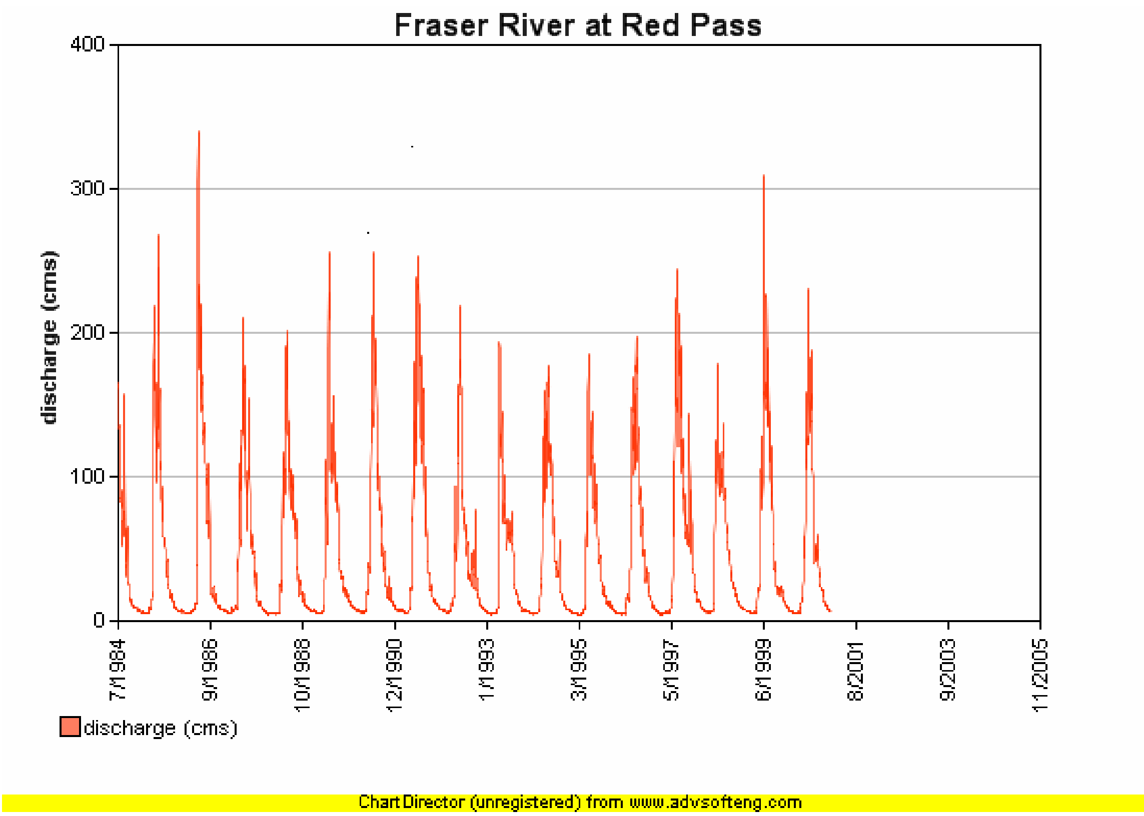



**Figure 2: Water Survey of Canada Flow Data for Fraser River at Red Pass**

## WATER QUALITY ASSESSMENT

The status and trends of various water quality indicators were assessed by plotting the indicators over time and comparing the values to the Province's approved and working water quality guidelines (Ministry of Environment, 2006a & 2006b). Any levels or changes of the indicators over time that may have been harmful to sensitive water uses, such as drinking water, aquatic life, wildlife, recreation, irrigation, and livestock watering, are described below in alphabetical order.

When concentrations of a substance cannot be detected, we have plotted the concentration at the level of detection. We believe this to be a conservative approach to assessing possible trends. As well, there are times when measurements were not taken for some reason. In these cases, straight lines will join the two consecutive points and may give the illusion on the graph of a trend that does not exist.

In cases where we have used statistical techniques such as linear regression analysis to estimate if a trend is possibly present, a more thorough statistical analysis of the trend is necessary for verification of the trend.

In some cases, testing for the presence of a variable has been terminated after a certain period. In general, this has been because a previous data assessment and review has indicated that collections of these data are not warranted for this station. For other variables, concerns about concentrations may have only arisen in recent years.

Water quality indicators were not discussed if they were in no danger of exceeding water quality guidelines values (if guidelines exist for the variable) and showed no harmful trends. These included: alkalinity, antimony, arsenic, barium, beryllium, bismuth, boron, calcium, carbon, chloride, gallium, lanthanum, lithium, magnesium, molybdenum, pH, phosphorus, selenium, sodium, strontium, solids, thallium, tin, uranium, and vanadium.

**Total aluminum** (Figure 4) exceeded the water quality guideline for the protection of wildlife, livestock and irrigation (5 mg/L) once. The highest values occurred in August and September of 1998, concurrent with high turbidity values (see Figure 4), which suggests that the majority of the aluminum was associated with particulate matter and not in the dissolved form. Aluminum is the most common metal on the planet, comprising 7-8% of the earth's crust, so it is not surprising to find that levels vary in proportion to the amount of sediment (turbidity) in the water. However, it is recommended that the concentration of dissolved aluminum be measured in the future to allow a useful comparison with the guidelines for aquatic life and drinking water. No change was noted in total aluminum concentrations over the duration of record.

**Cadmium** concentrations (Figure 11) have been hampered by high levels of detection that have made interpretation of results difficult. Detection limits have improved in 2003 and 2004 to 0.001 µg/L and values usually are less than the guidelines for the protection of aquatic life (0.008 µg/L) at minimum hardness of 20 mg/L and 0.024 µg/L at average hardness of 70 mg/L. No values have exceeded the guideline for the respective hardness since the detection limit has changed. In our analysis, we removed one suspected error/outlier from the data set: a value of 4 µg/L on September 16, 1985 when the level of detection was 1 µg/L.

**Total chromium** concentrations occasionally exceeded the aquatic life guidelines of 1 µg/L for hexavalent and 9 µg/L for trivalent chromium (Figure ). Irrigation guidelines are a maximum of 5 µg/L trivalent and 8 µg/L hexavalent chromium. Measurements of the trivalent and hexavalent forms of chromium with detection limits of 0.1 µg/L or lower should be made when the analytical methods become available.

**Total cobalt** has shown a slight increase during the period of record (Figure 16), although concentrations have not exceeded the B.C. guidelines for the protection of aquatic life (4 µg/L).

**Fecal coliform** concentrations have only been measured at Red Pass since early 2000 (Figure 17). All individual values were below the $90^{th}$ percentile guideline for the protection of drinking water that will receive only disinfection (10 CFU/100 mL). Two suspected errors were removed from the data set: <59 CFU on September 3, 2003 and <13 CFU on November 12, 2003.

**True colour** values (Figure 18) are below the aesthetic guideline for drinking water of 15 TCU. All apparent colour values were at or below that guideline.

**Specific conductivity** values (Figure 19) appear to be increasing; however, when the data before 1992 are excluded, there is no increase. All values are well below guidelines values, and this increase is not a cause for concern. Conductivity values generally increase with lower water levels (ions become more concentrated). In our analysis, we removed one suspected error/outlier: 408 µS/cm on April 25, 2001

**Total copper** (Figure 20). The aquatic life guidelines for copper are hardness-dependent. The guideline corresponding to the average hardness was exceeded on only a couple of occasions by individual samples; however, these were related to high suspended solids concentrations. This suggests that much of the copper present at these times was associated with particulate matter which decreases its availability to biota. There does not appear to be any change in total or extractable copper concentrations over time.

**Hardness** concentrations (Figure 23) appear to be increasing form the early 1980's; however, when the data before 1992 are excluded from our analysis as we did for specific conductivity, there is no apparent recent trend.

**Total iron** (Figure 24) concentrations exceeded the aesthetic drinking water and aquatic life guideline of 0.3 mg/L on occasion. These exceedances occurred almost invariably between July and September, when turbidity levels were relatively high. The occasional high concentrations of iron at Red Pass are due to natural sources, as there are no known human sources of iron upstream from this point. There was no apparent change in iron levels over time.

Guidelines for **total lead** (10 µg/L for drinking water and 30-day mean of 3.7 µg/L for aquatic life) were not exceeded by any samples collected between 1984 and 2004 (Figure 26). There appears (Figure 27) to be a trend of lower extractable lead concentrations during the 1991-2004 period. There seems to be some correlation between total lead concentrations and turbidity.

**Total manganese** concentrations seem to be showing a slight trend of increasing concentrations (Figure 29). This upward trend, in conjunction with the potentially decreasing trend for lead, suggests the possibility that these are related to the removal of leaded gas and the use of the fuel additive containing manganese. These concentrations seem to be correlated with turbidity to some degree. All values were less than the drinking water guideline of 50 µg/L.

**Total nickel** values measured at Red Pass during 1990-2004 were considerably below the guideline for the protection of aquatic life of 25 µg/L at a hardness of 0 to 60 mg/L. There appears to have been a gradually increasing trend in total nickel concentrations over time at this site (Figure 32), which has been reduced in scope in the period 1995 to 2004 (Figure 33). However, the levels were well below guidelines and are therefore not of environmental concern at this time. Total and extractable nickel values were similar and did not seem to be correlated with turbidity.

**Total dissolved nitrogen** seems to have increased slightly between 1984 and 2004 (Figure 35). **Nitrate** and **nitrite** concentrations generally were stable (Figure 34) but sampling for theses variables was suspended in the late 1990's.

**Extractable rubidium** (Figure 39) seems to be increasing slightly between 1997 and 2004. There appears to be a correlation between turbidity and rubidium concentrations. We could find no guidelines with which to assess this metal.

**Total silver** concentrations occasionally exceeded the 30-day average freshwater guideline of 0.05 µg/L but this only occurred when a high detection limit was in use (Figure 42). All values were less than the 1.5 µg/L guideline for maximum concentrations. All individual values have met the 0.05 µg/L guideline since detection limits have been lowered. No change was noted in total silver concentrations over the duration of the record.

**Dissolved sulphate** concentrations had a definite trend towards increasing values over time (Figure 47). However, all concentrations were well below guideline values (a maximum of 100 mg/L for the protection of aquatic life), and are therefore not a cause for concern at this time.

**Turbidity** values frequently exceeded both the drinking water guideline for health (1 NTU), and occasionally exceeded the aesthetic drinking water guideline (5 NTU) (Figure

51). This indicates that the water would require partial treatment (*e.g*., filtration) plus disinfection before use as drinking water.

The aquatic guidelines for **total zinc** are dependent on hardness and zinc concentrations appear to be correlated with turbidity events. The aquatic life guideline is a 30-day average of $\leq$7.5 µg/L. No individual zinc values have exceeded the this guideline over the period of record (Figure 54). It does not appear that zinc concentrations are changing over time at this site. Concentrations of extractable zinc were similar to those of total zinc. There are no known human sources of zinc in the upper Fraser River watershed.

## REFERENCES

Ministry of Environment. 2006a. British Columbia Approved Water Quality Guidelines (Criteria). , Ministry of Environment, Victoria, B.C.

Ministry of Environment. 2006b. A Compendium of Working Water Quality Guidelines for British Columbia. Ministry of Environment, Victoria, B.C.

Water Quality Branch. 1996. State of Water Quality of Fraser River at Red Pass (1984-1995). Water Quality Branch, Environmental Protection Department, Ministry of Environment, Lands and Parks, Victoria, B.C.

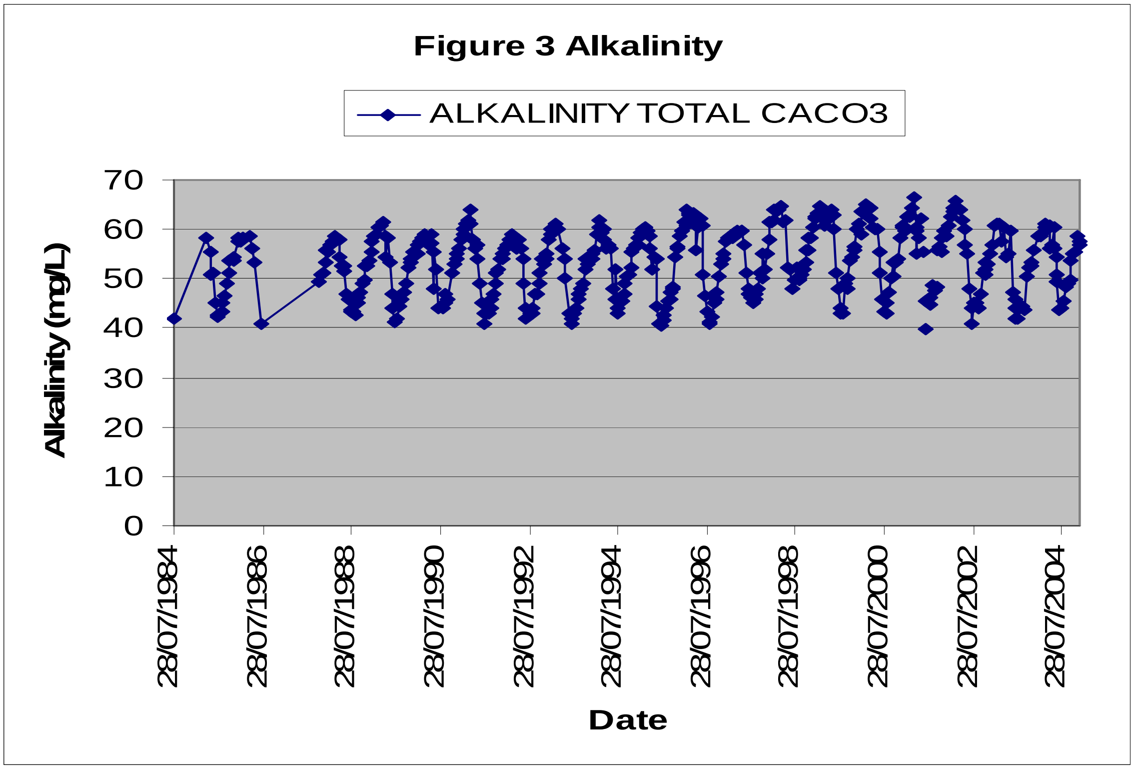


Figure 3 Alkalinity
ALKALINITY TOTAL CACO3
Alkalinity (mg/L)
70
60
50
40
30
20
10
0
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

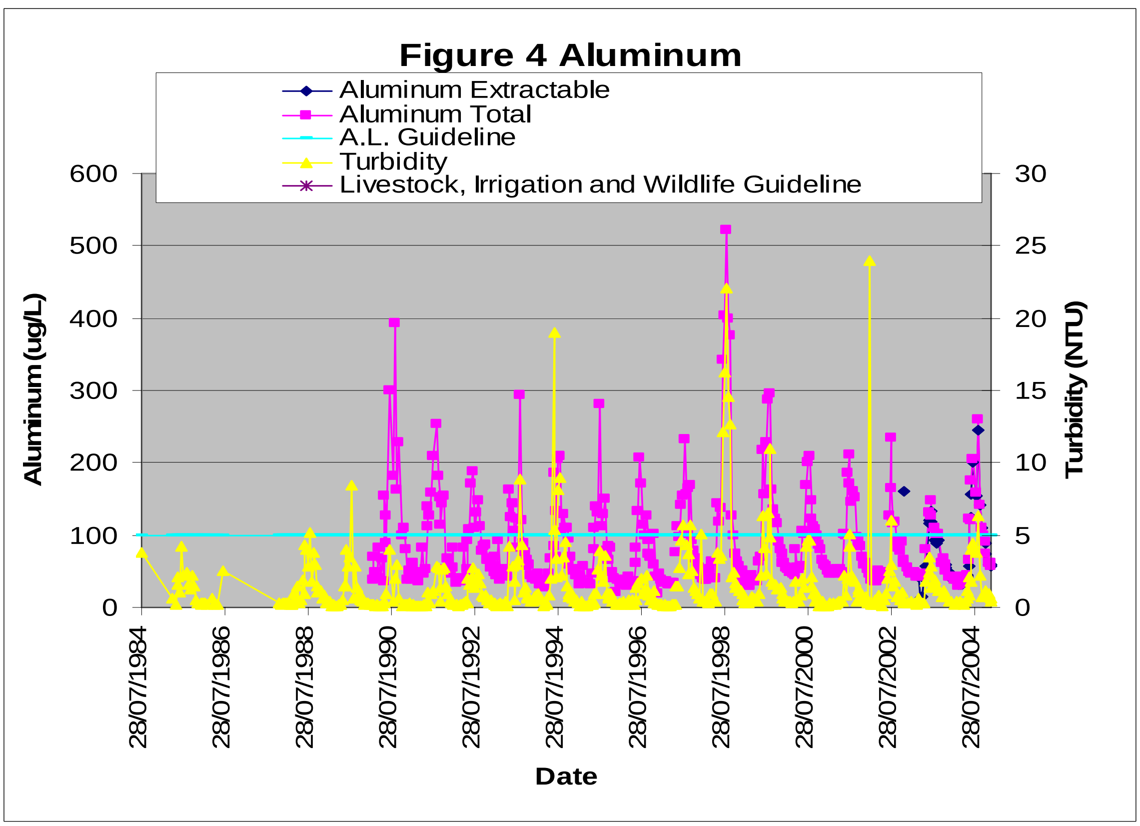


Figure 4 Aluminum
Aluminum Extractable
Aluminum Total
A.L. Guideline
Turbidity
Livestock, Irrigation and Wildlife Guideline
Aluminum (ug/L)
600
500
400
300
200
100
0
Turbidity (NTU)
30
25
20
15
10
5
0
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

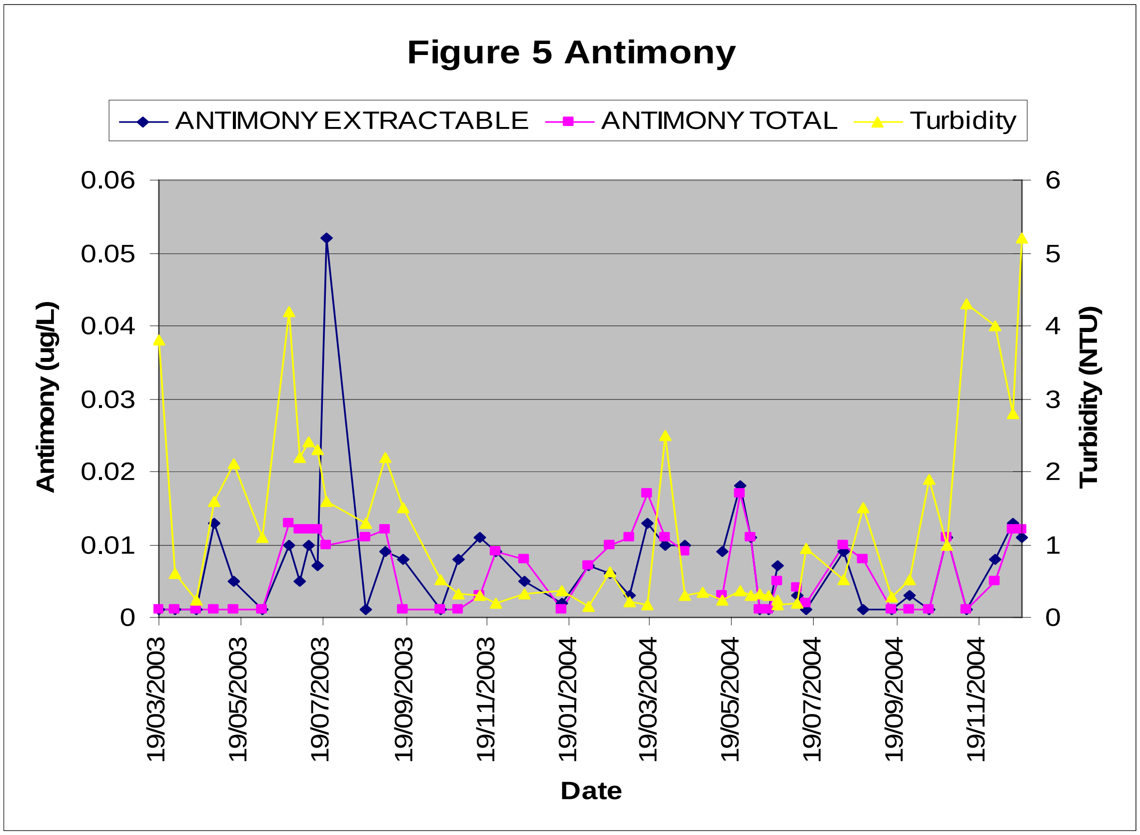


Figure 5 Antimony
ANTIMONY EXTRACTABLE
ANTIMONY TOTAL
Turbidity
Antimony (ug/L)
0
0.01
0.02
0.03
0.04
0.05
0.06
Turbidity (NTU)
0
1
2
3
4
5
6
19/03/2003
19/05/2003
19/07/2003
19/09/2003
19/11/2003
19/01/2004
19/03/2004
19/05/2004
19/07/2004
19/09/2004
19/11/2004
Date

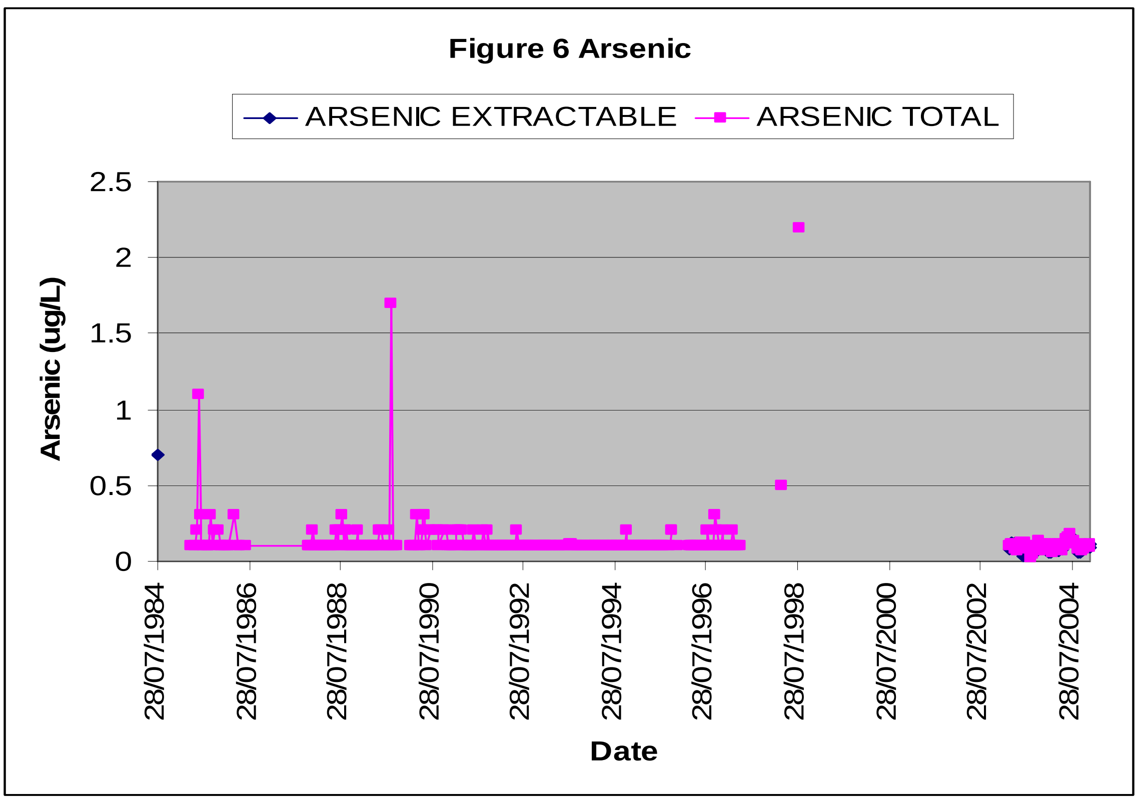


Figure 6 Arsenic
ARSENIC EXTRACTABLE
ARSENIC TOTAL
Arsenic (ug/L)
0
0.5
1
1.5
2
2.5
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

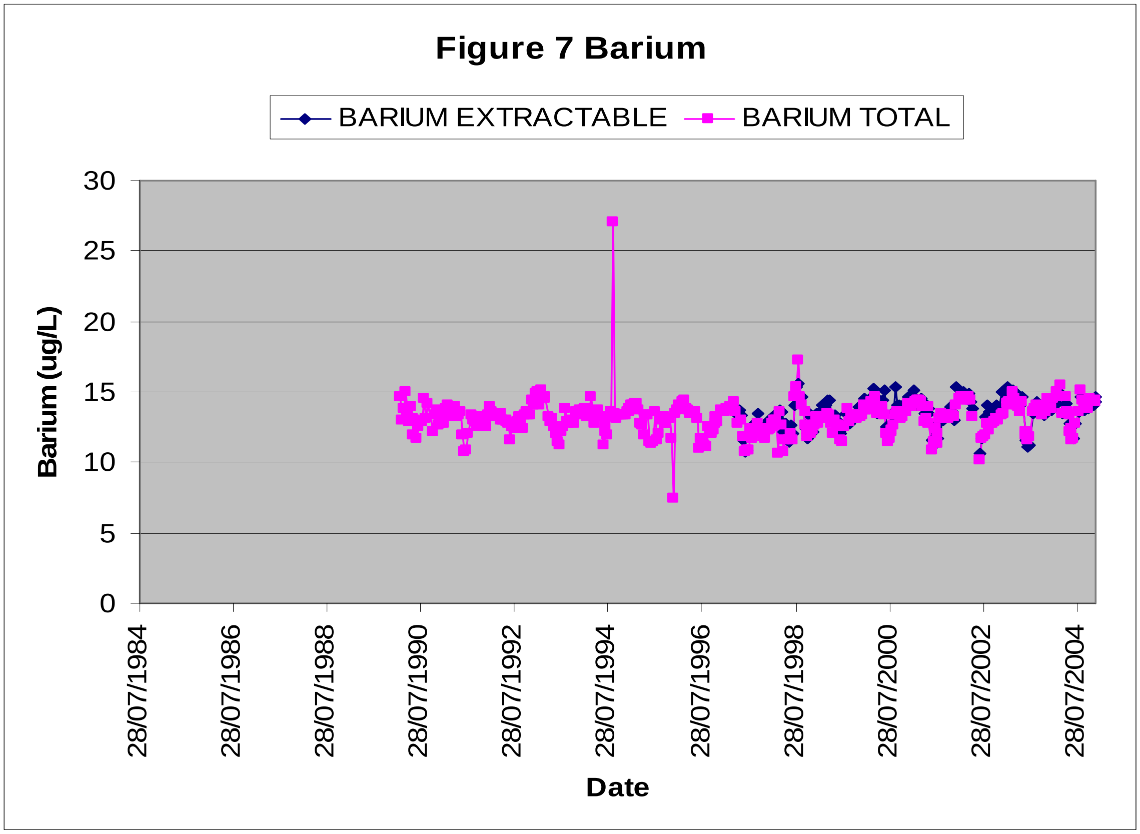


Figure 7 Barium
BARIUM EXTRACTABLE
BARIUM TOTAL
Barium (ug/L)
0
5
10
15
20
25
30
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

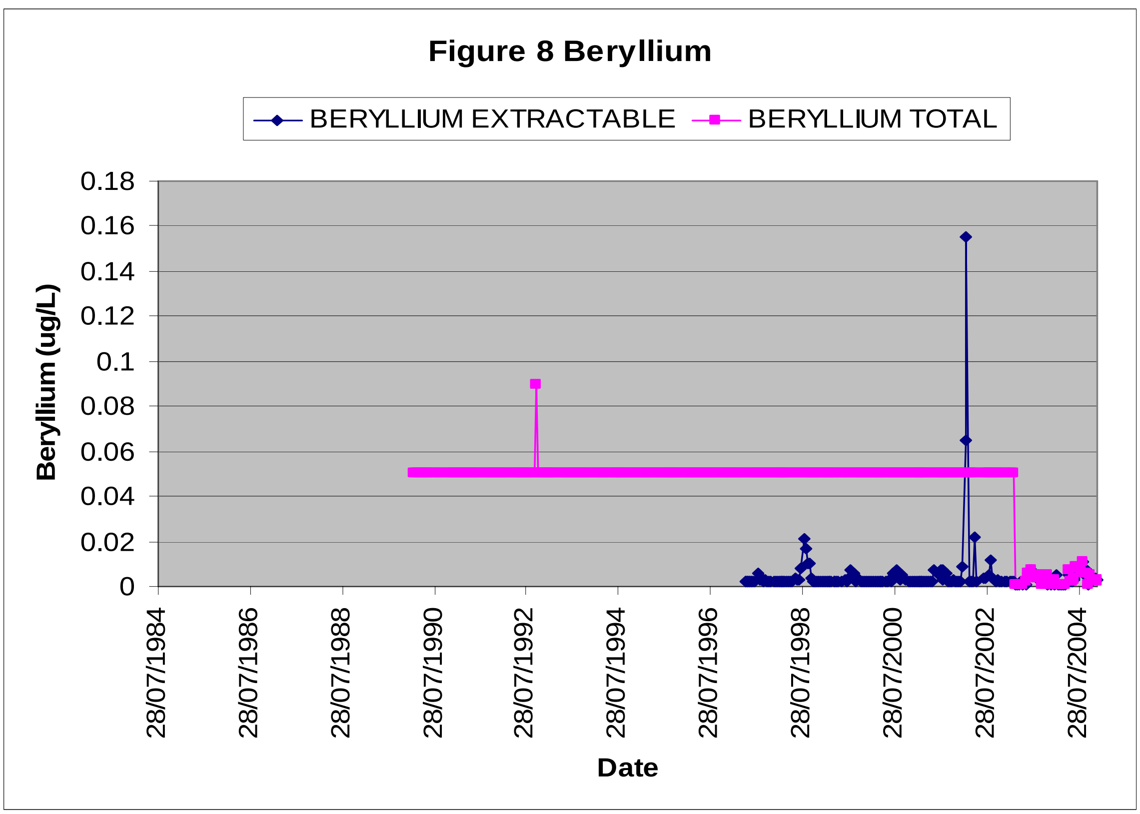


Figure 8 Beryllium
BERYLLIUM EXTRACTABLE
BERYLLIUM TOTAL
Beryllium (ug/L)
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

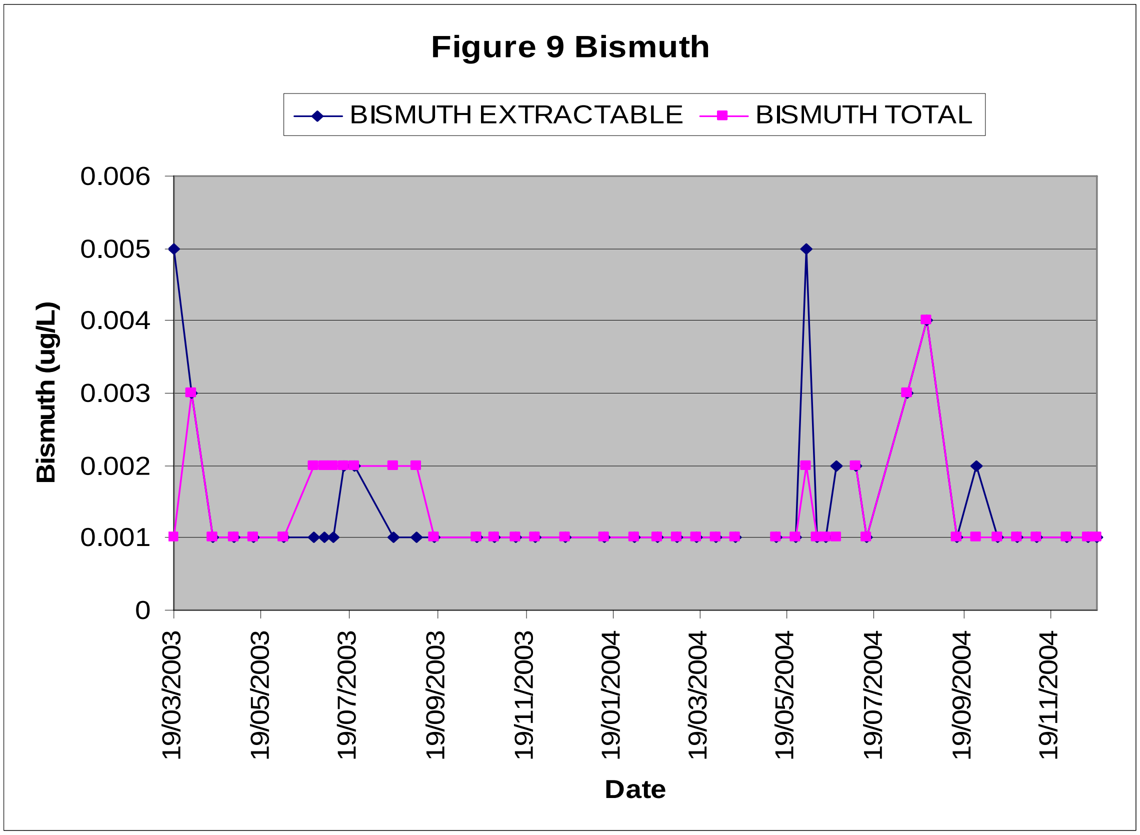


Figure 9 Bismuth
BISMUTH EXTRACTABLE
BISMUTH TOTAL
Bismuth (ug/L)
0.006
0.005
0.004
0.003
0.002
0.001
0
19/03/2003
19/05/2003
19/07/2003
19/09/2003
19/11/2003
19/01/2004
19/03/2004
19/05/2004
19/07/2004
19/09/2004
19/11/2004
Date

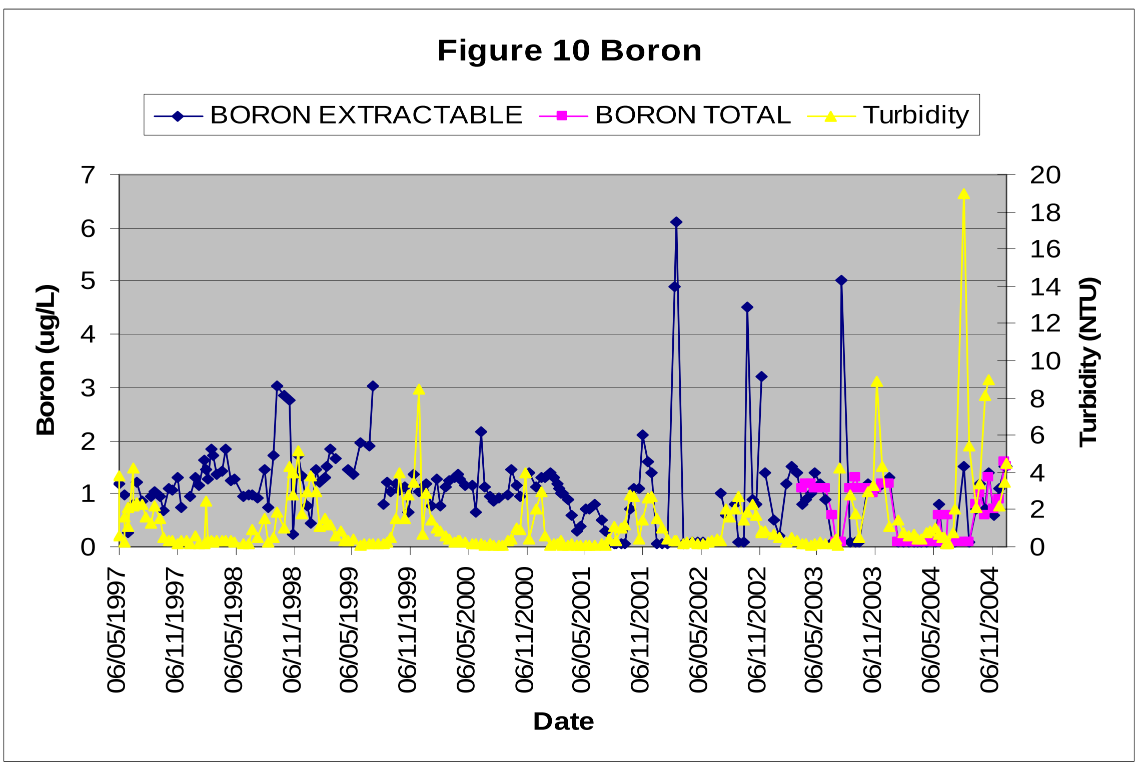


Figure 10 Boron
BORON EXTRACTABLE
BORON TOTAL
Turbidity
Boron (ug/L)
Turbidity (NTU)
7
6
5
4
3
2
1
0
20
18
16
14
12
10
8
6
4
2
0
06/05/1997
06/11/1997
06/05/1998
06/11/1998
06/05/1999
06/11/1999
06/05/2000
06/11/2000
06/05/2001
06/11/2001
06/05/2002
06/11/2002
06/05/2003
06/11/2003
06/05/2004
06/11/2004
Date

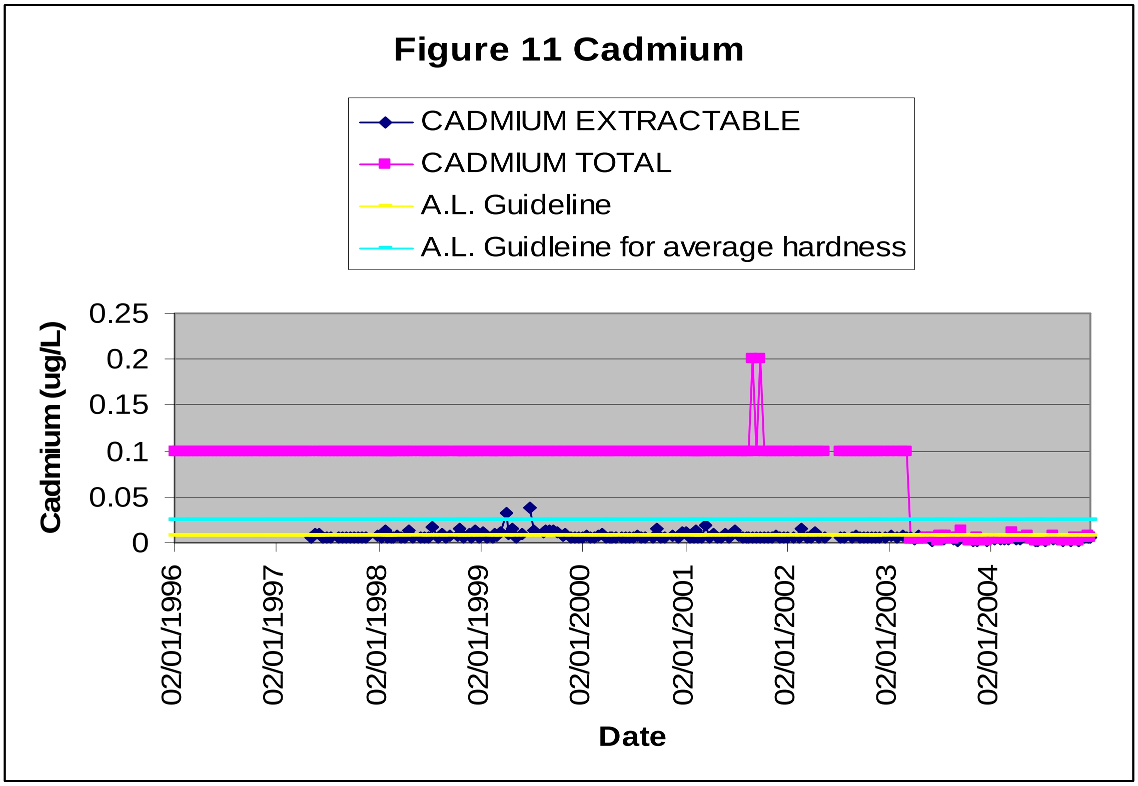


Figure 11 Cadmium
CADMIUM EXTRACTABLE
CADMIUM TOTAL
A.L. Guideline
A.L. Guidleine for average hardness
Cadmium (ug/L)
0.25
0.2
0.15
0.1
0.05
0
02/01/1996
02/01/1997
02/01/1998
02/01/1999
02/01/2000
02/01/2001
02/01/2002
02/01/2003
02/01/2004
Date

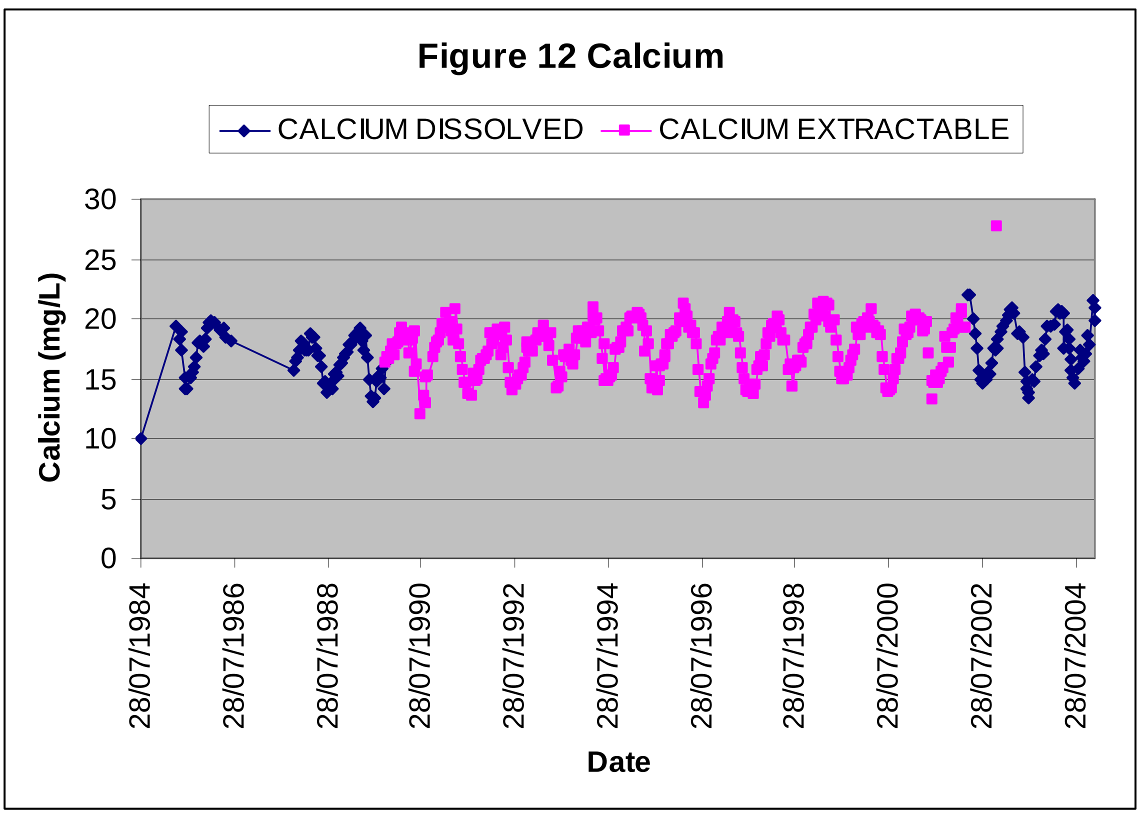



Figure 12 Calcium
CALCIUM DISSOLVED
CALCIUM EXTRACTABLE
Calcium (mg/L)
30
25
20
15
10
5
0
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

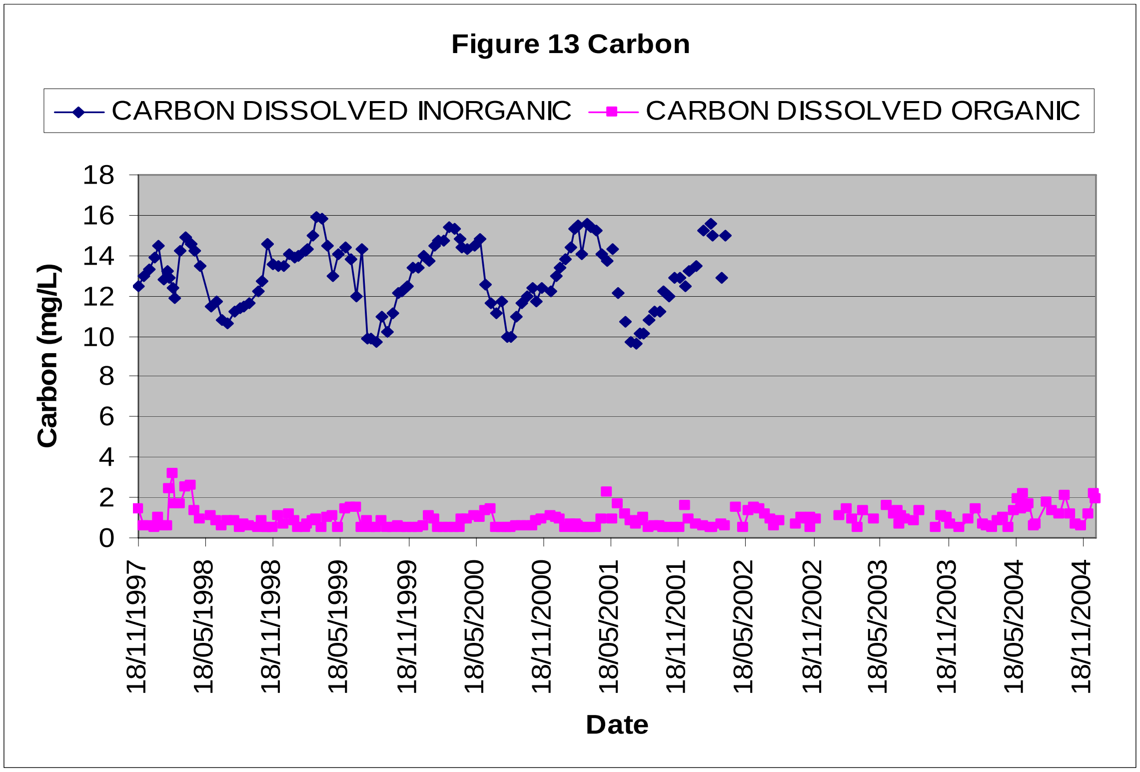


Figure 13 Carbon
CARBON DISSOLVED INORGANIC
CARBON DISSOLVED ORGANIC
Carbon (mg/L)
0
2
4
6
8
10
12
14
16
18
18/11/1997
18/05/1998
18/11/1998
18/05/1999
18/11/1999
18/05/2000
18/11/2000
18/05/2001
18/11/2001
18/05/2002
18/11/2002
18/05/2003
18/11/2003
18/05/2004
18/11/2004
Date

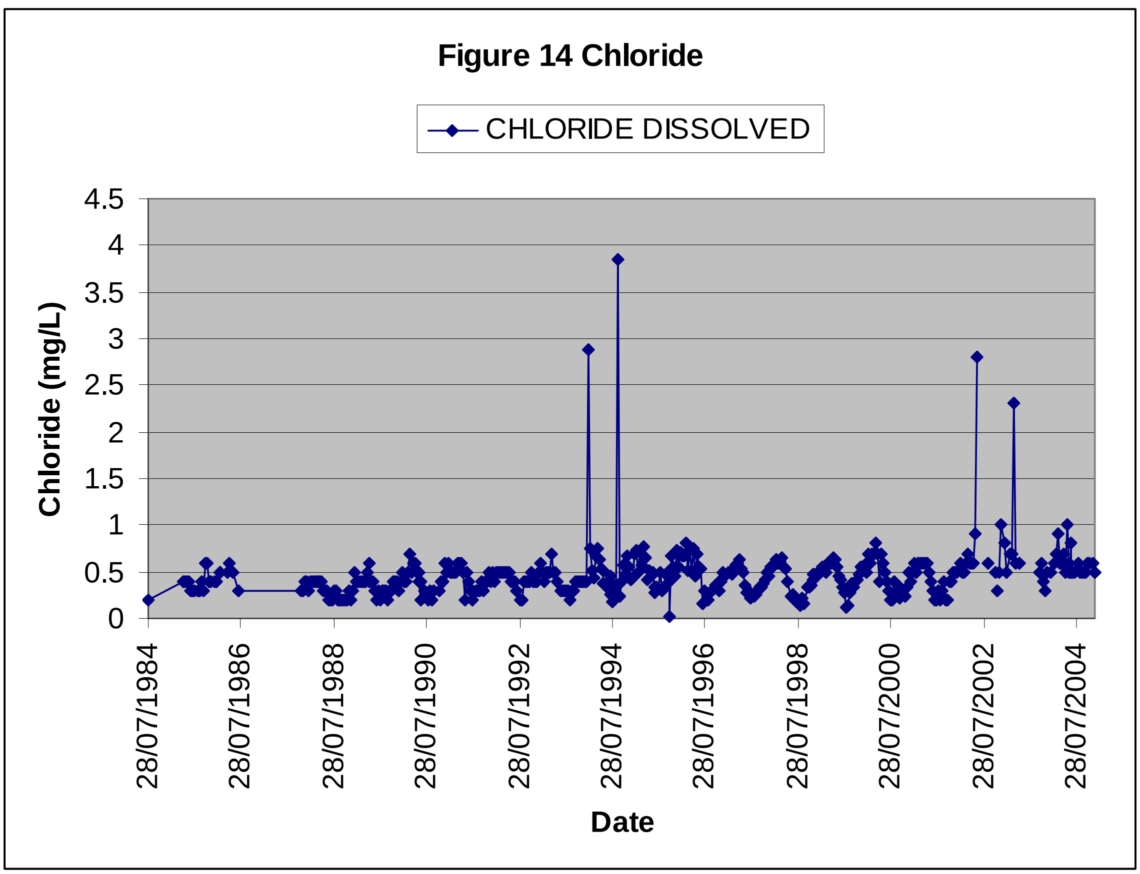


Figure 14 Chloride
CHLORIDE DISSOLVED
Chloride (mg/L)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

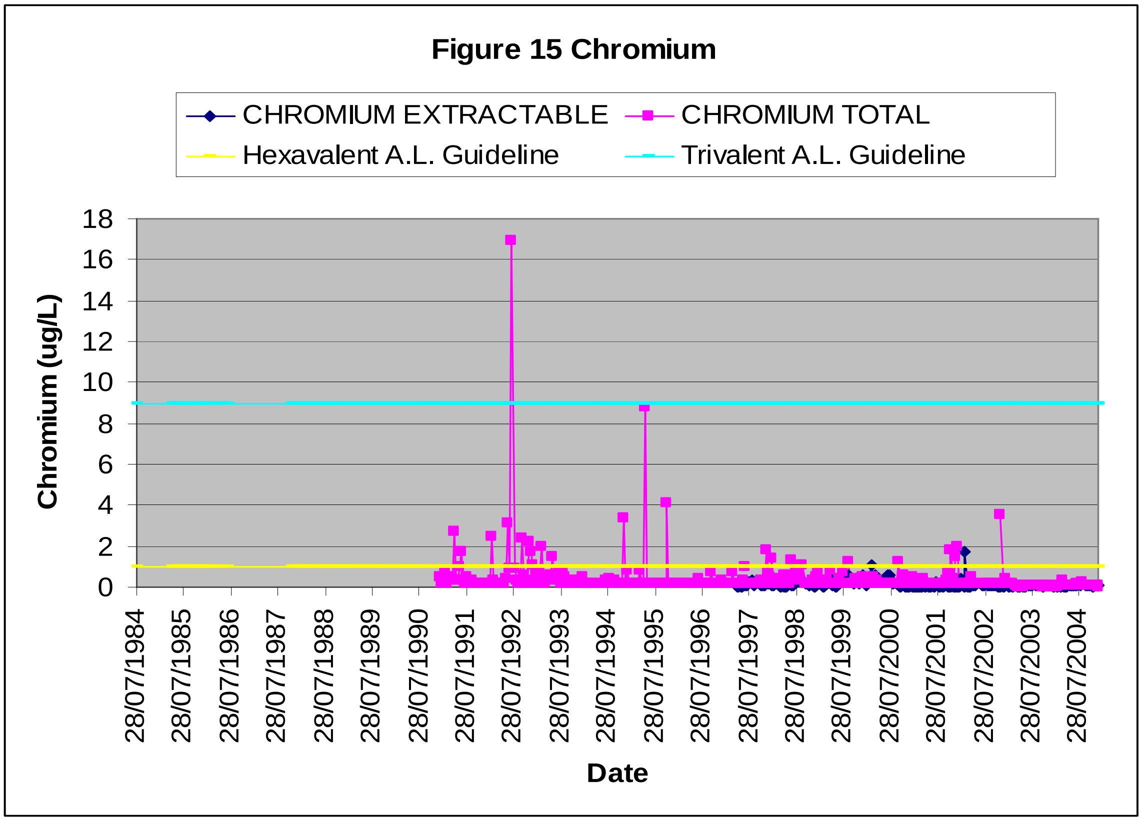


Figure 15 Chromium
CHROMIUM EXTRACTABLE
CHROMIUM TOTAL
Hexavalent A.L. Guideline
Trivalent A.L. Guideline
Chromium (ug/L)
0
2
4
6
8
10
12
14
16
18
28/07/1984
28/07/1985
28/07/1986
28/07/1987
28/07/1988
28/07/1989
28/07/1990
28/07/1991
28/07/1992
28/07/1993
28/07/1994
28/07/1995
28/07/1996
28/07/1997
28/07/1998
28/07/1999
28/07/2000
28/07/2001
28/07/2002
28/07/2003
28/07/2004
Date

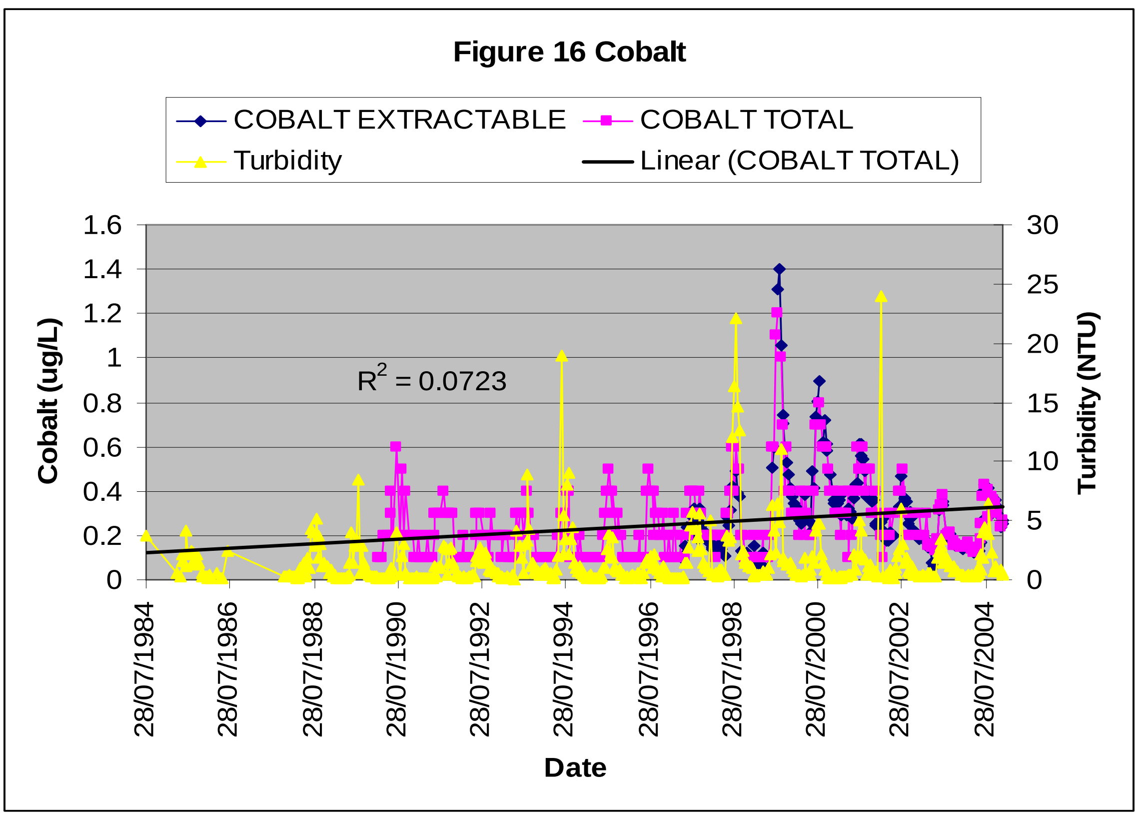


Figure 16 Cobalt
COBALT EXTRACTABLE
COBALT TOTAL
Turbidity
Linear (COBALT TOTAL)
$R^2 = 0.0723$
Cobalt (ug/L)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Turbidity (NTU)
0
5
10
15
20
25
30
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

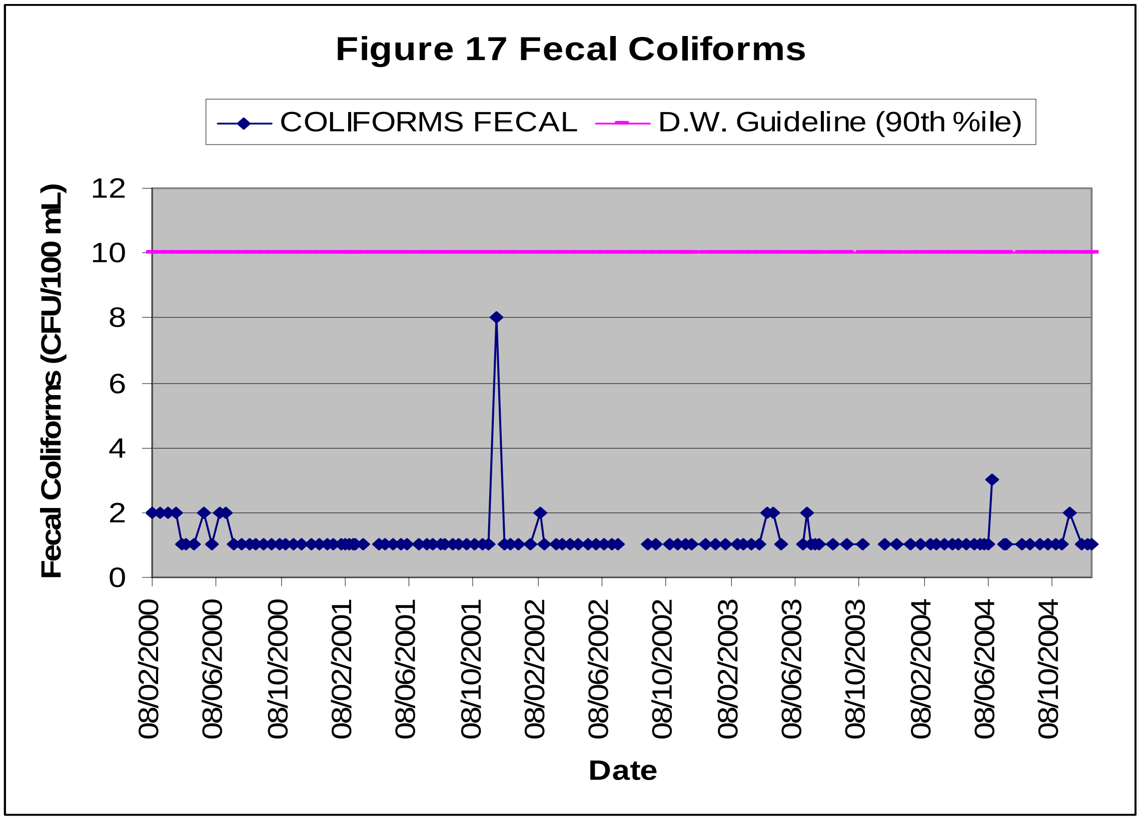


Figure 17 Fecal Coliforms
COLIFORMS FECAL
D.W. Guideline (90th %ile)
Fecal Coliforms (CFU/100 mL)
0
2
4
6
8
10
12
08/02/2000
08/06/2000
08/10/2000
08/02/2001
08/06/2001
08/10/2001
08/02/2002
08/06/2002
08/10/2002
08/02/2003
08/06/2003
08/10/2003
08/02/2004
08/06/2004
08/10/2004
Date

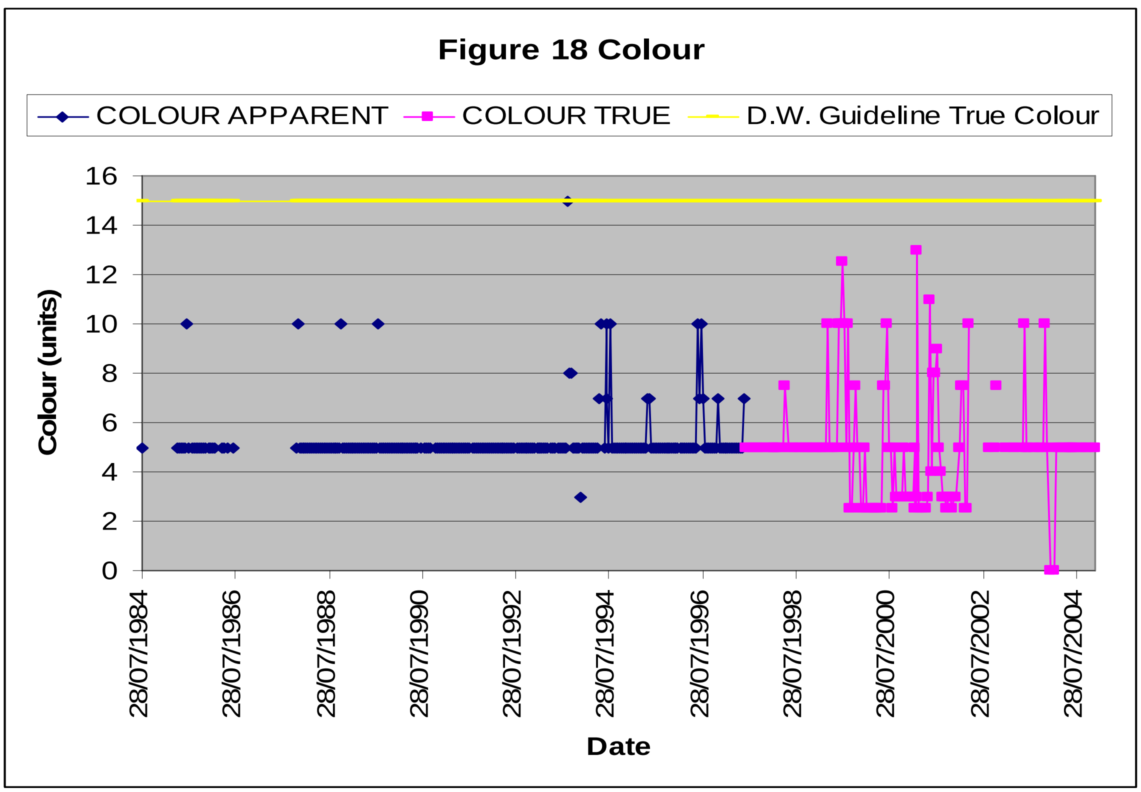


Figure 18 Colour
COLOUR APPARENT
COLOUR TRUE
D.W. Guideline True Colour
Colour (units)
0
2
4
6
8
10
12
14
16
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

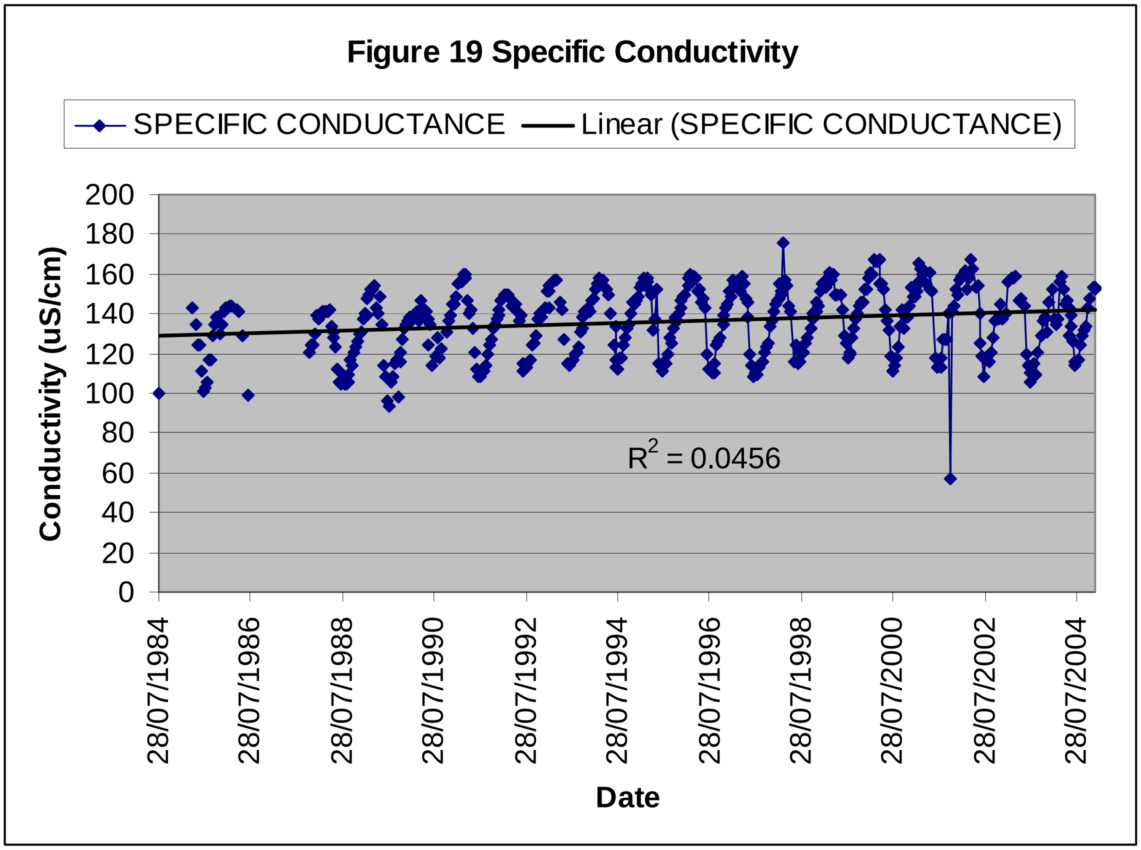


Figure 19 Specific Conductivity
SPECIFIC CONDUCTANCE
Linear (SPECIFIC CONDUCTANCE)
Conductivity (uS/cm)
200
180
160
140
120
100
80
60
40
20
0
$R^2 = 0.0456$
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

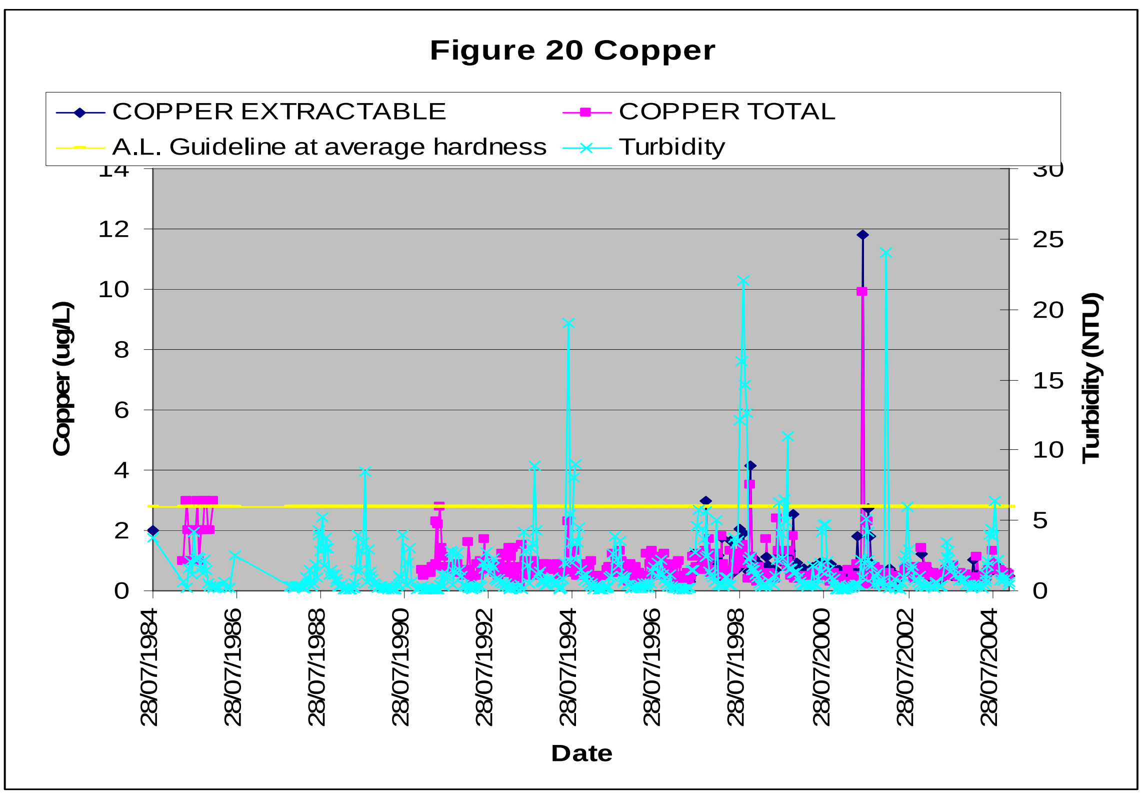


Figure 20 Copper
COPPER EXTRACTABLE
COPPER TOTAL
A.L. Guideline at average hardness
Turbidity
Copper (ug/L)
14
12
10
8
6
4
2
0
Turbidity (NTU)
30
25
20
15
10
5
0
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

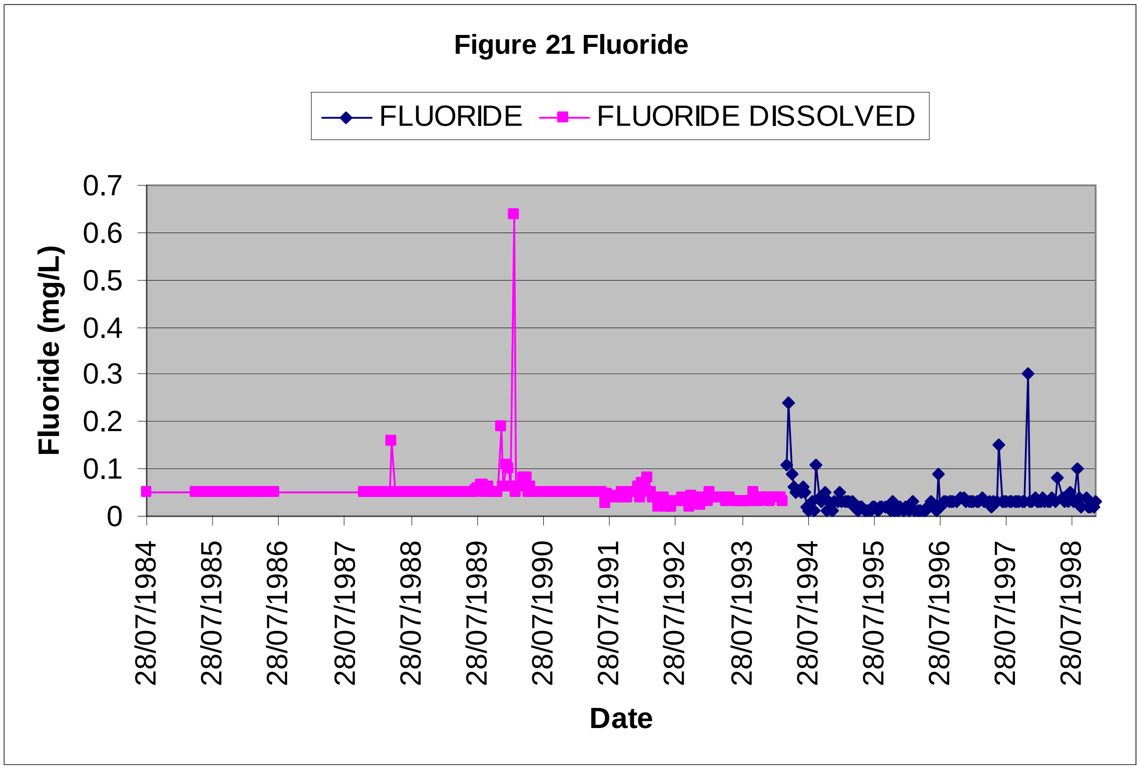


Figure 21 Fluoride
FLUORIDE
FLUORIDE DISSOLVED
Fluoride (mg/L)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
28/07/1984
28/07/1985
28/07/1986
28/07/1987
28/07/1988
28/07/1989
28/07/1990
28/07/1991
28/07/1992
28/07/1993
28/07/1994
28/07/1995
28/07/1996
28/07/1997
28/07/1998
Date

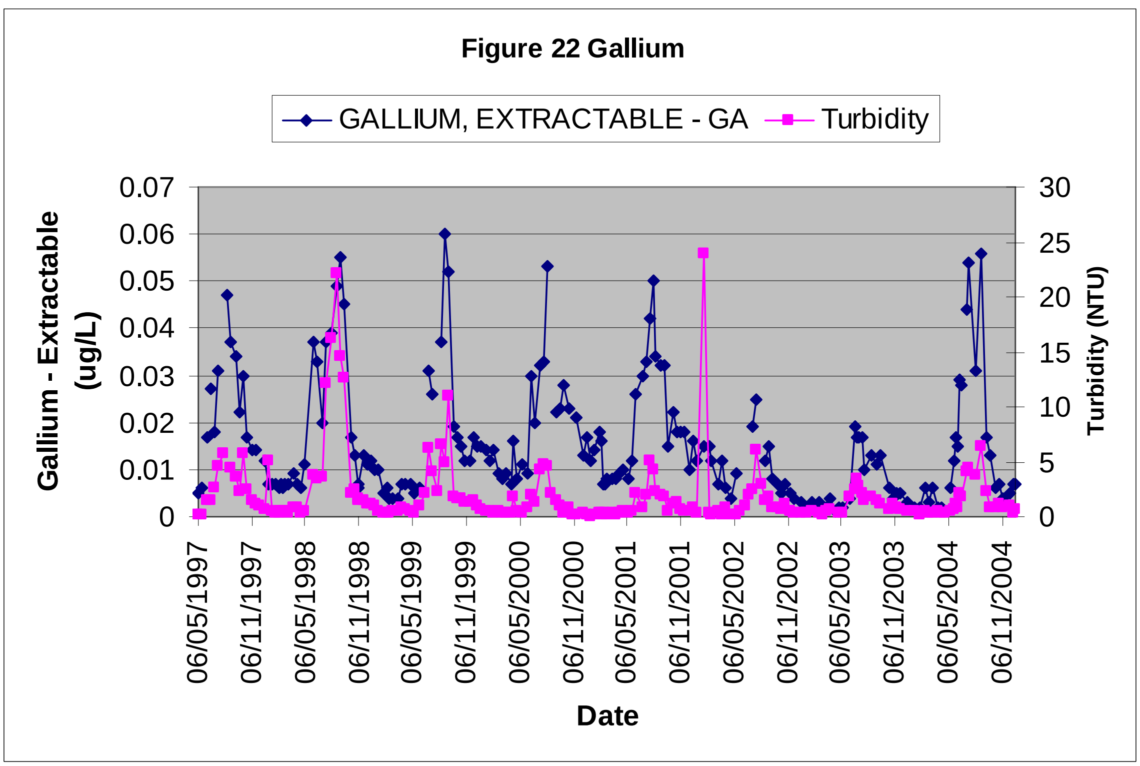


Figure 22 Gallium
GALLIUM, EXTRACTABLE - GA
Turbidity
Gallium - Extractable (ug/L)
Turbidity (NTU)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0
5
10
15
20
25
30
06/05/1997
06/11/1997
06/05/1998
06/11/1998
06/05/1999
06/11/1999
06/05/2000
06/11/2000
06/05/2001
06/11/2001
06/05/2002
06/11/2002
06/05/2003
06/11/2003
06/05/2004
06/11/2004
Date

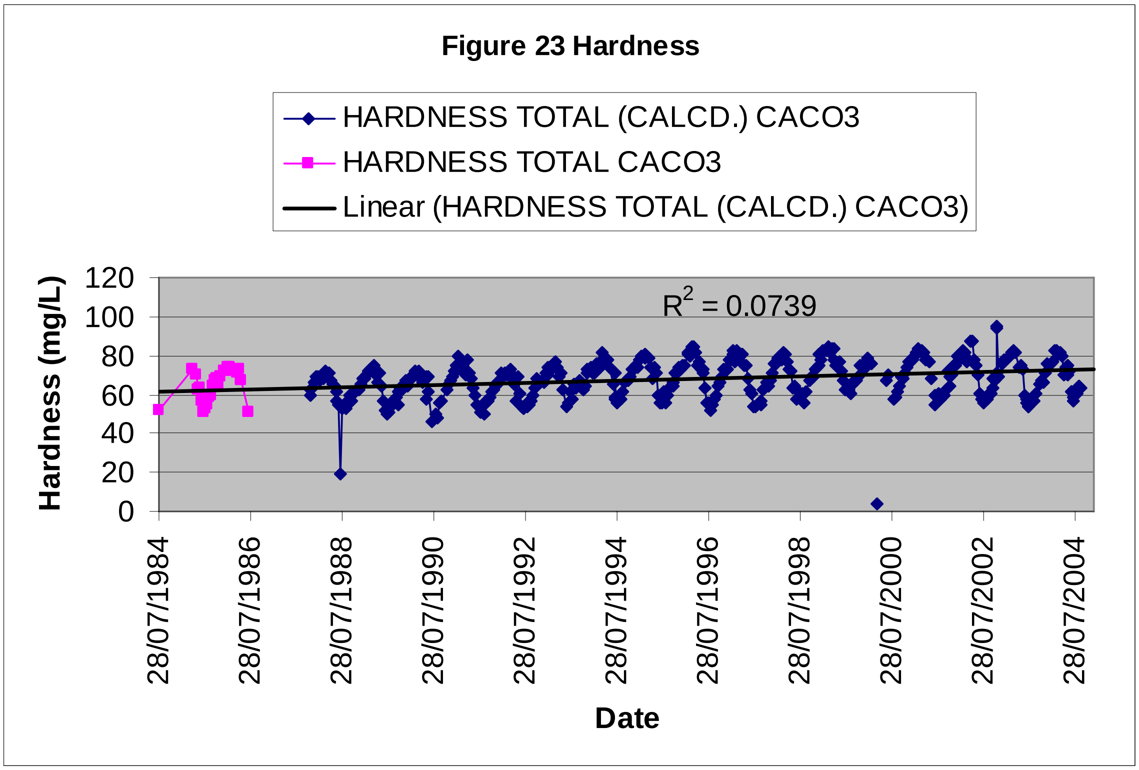


Figure 23 Hardness
HARDNESS TOTAL (CALCD.) CACO3
HARDNESS TOTAL CACO3
Linear (HARDNESS TOTAL (CALCD.) CACO3)
R2 = 0.0739
Hardness (mg/L)
120
100
80
60
40
20
0
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

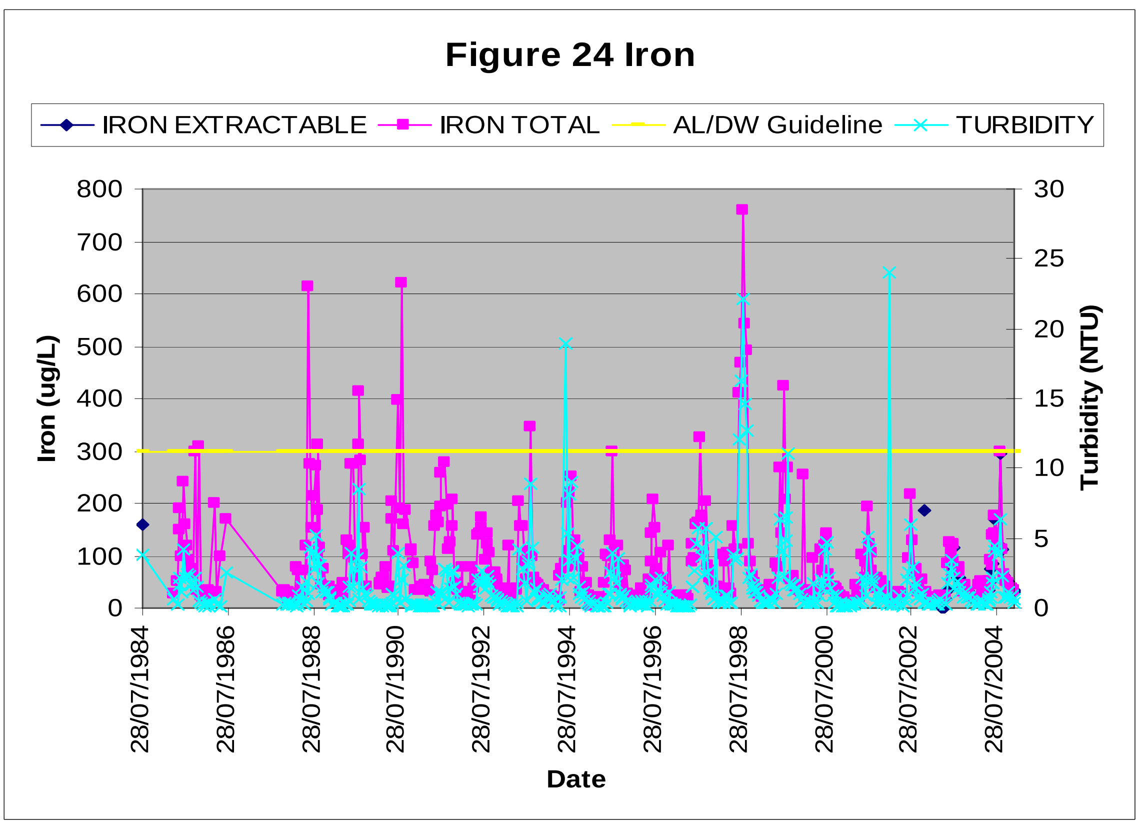


Figure 24 Iron
IRON EXTRACTABLE
IRON TOTAL
AL/DW Guideline
TURBIDITY
Iron (ug/L)
800
700
600
500
400
300
200
100
0
Turbidity (NTU)
30
25
20
15
10
5
0
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

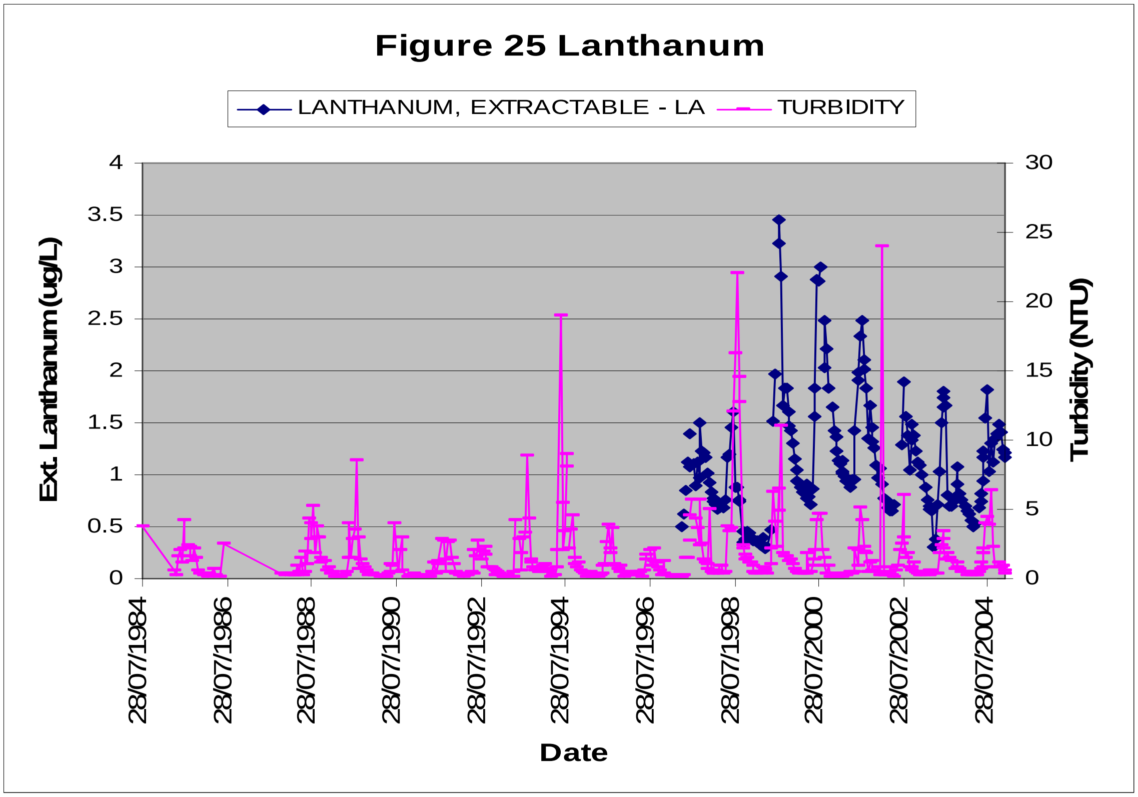


Figure 25 Lanthanum
LANTHANUM, EXTRACTABLE - LA
TURBIDITY
Ext. Lanthanum (ug/L)
Turbidity (NTU)
0
0.5
1
1.5
2
2.5
3
3.5
4
0
5
10
15
20
25
30
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

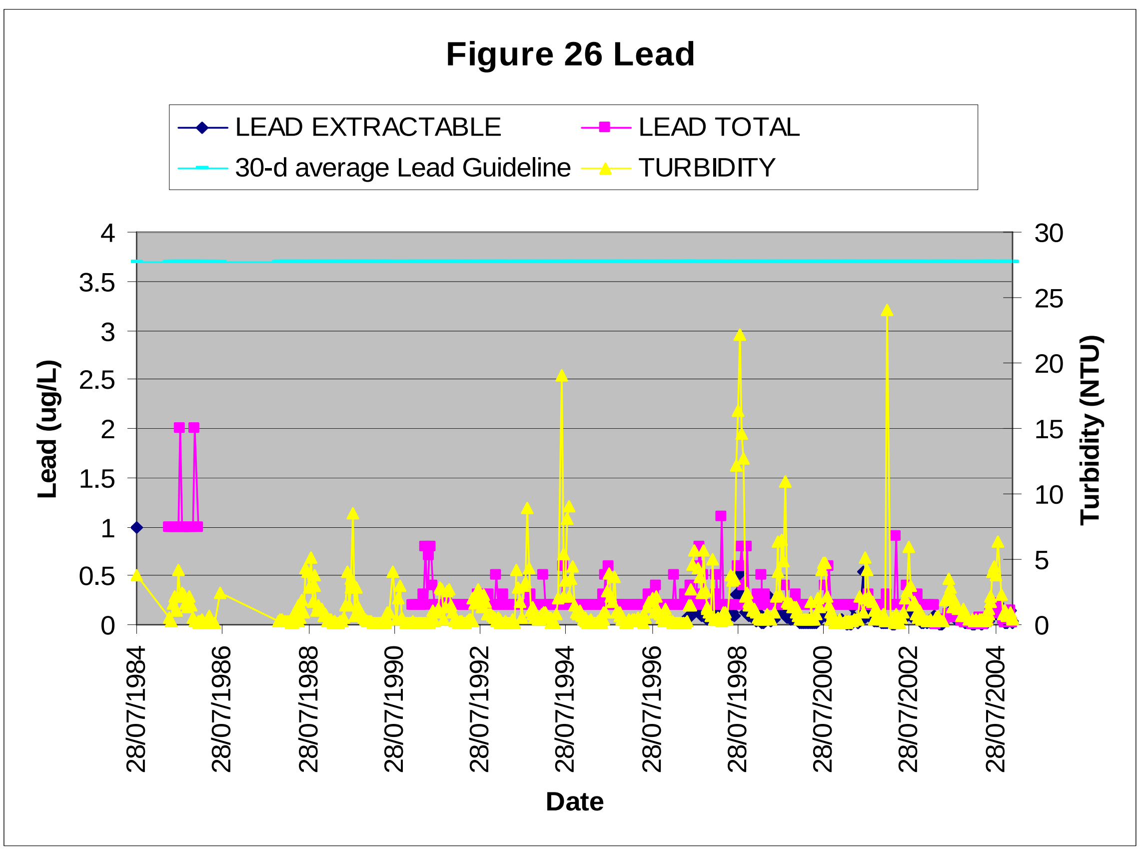


Figure 26 Lead
LEAD EXTRACTABLE
LEAD TOTAL
30-d average Lead Guideline
TURBIDITY
Lead (ug/L)
Turbidity (NTU)
0
0.5
1
1.5
2
2.5
3
3.5
4
0
5
10
15
20
25
30
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

**Figure 27 Lead (1991-2004)**

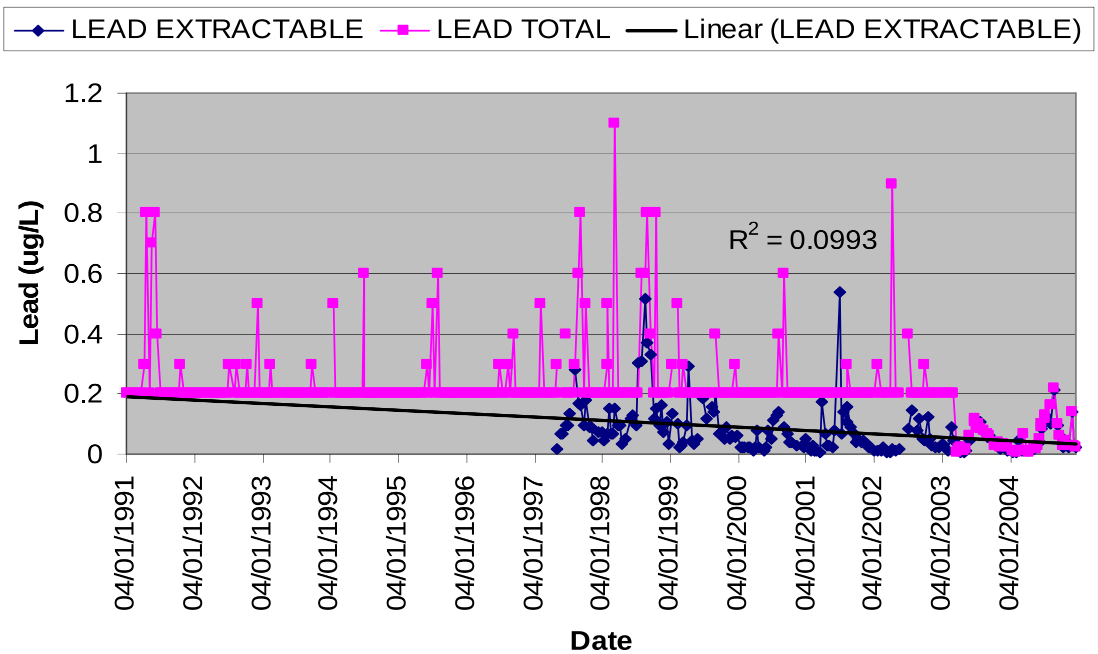
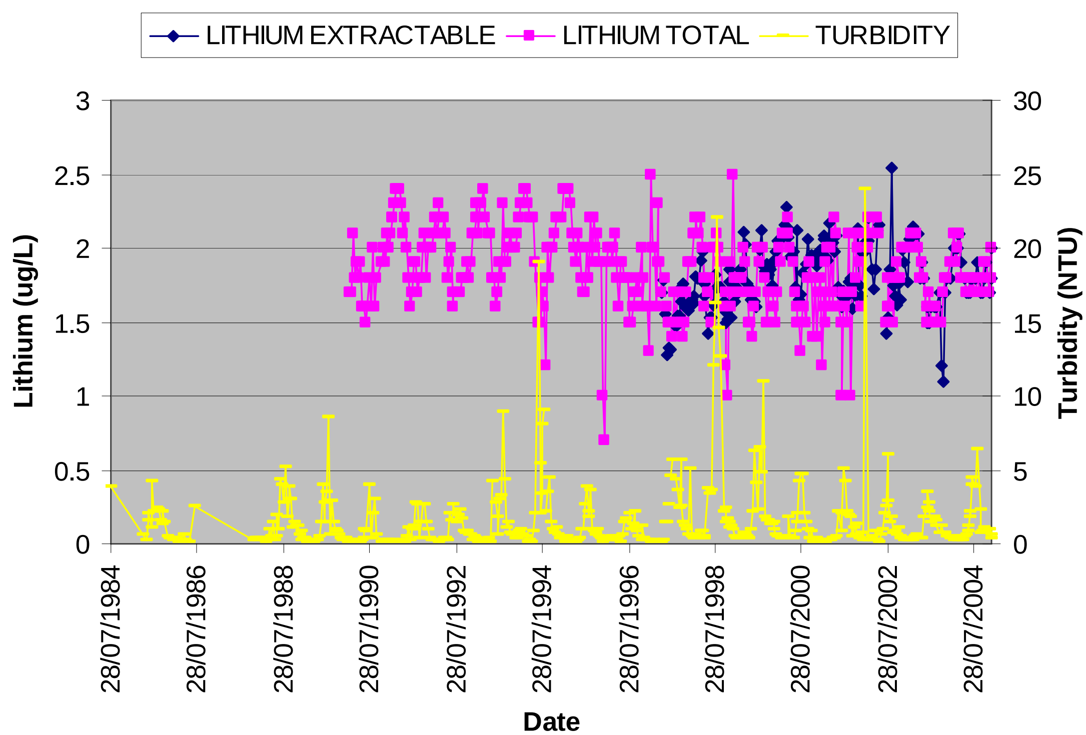



**Figure 28 Lithium**



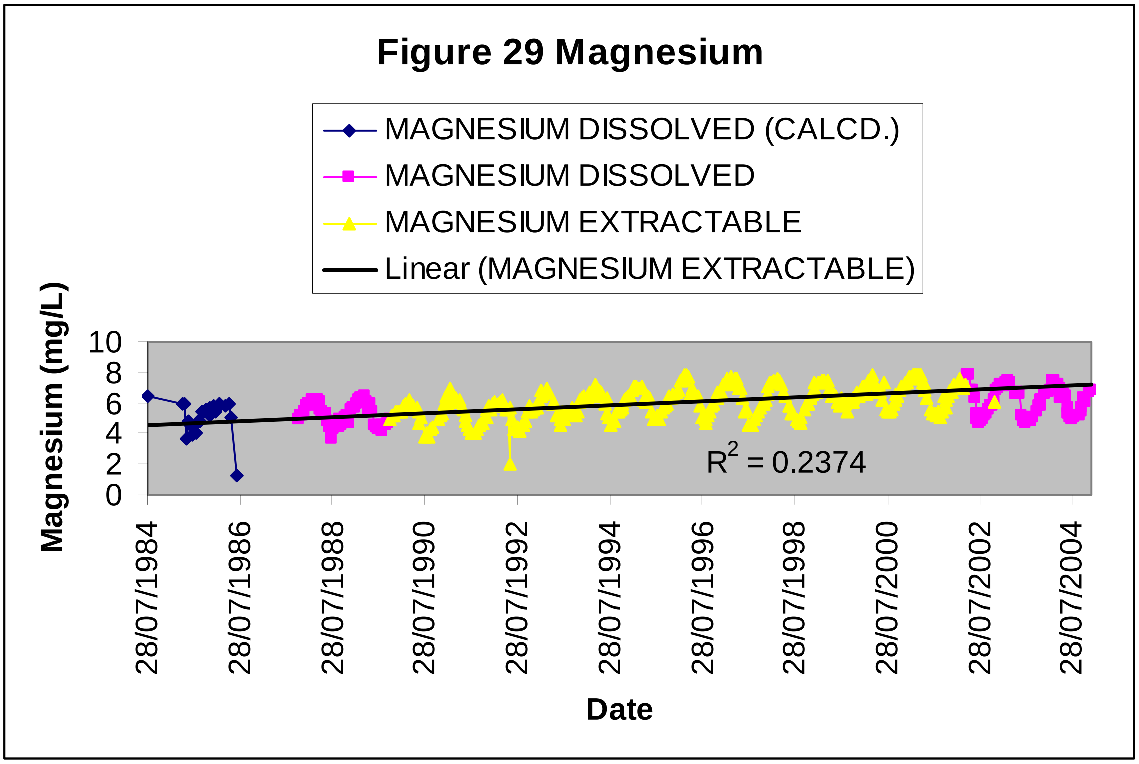


Figure 29 Magnesium
MAGNESIUM DISSOLVED (CALCD.)
MAGNESIUM DISSOLVED
MAGNESIUM EXTRACTABLE
Linear (MAGNESIUM EXTRACTABLE)
Magnesium (mg/L)
R2 = 0.2374
Date

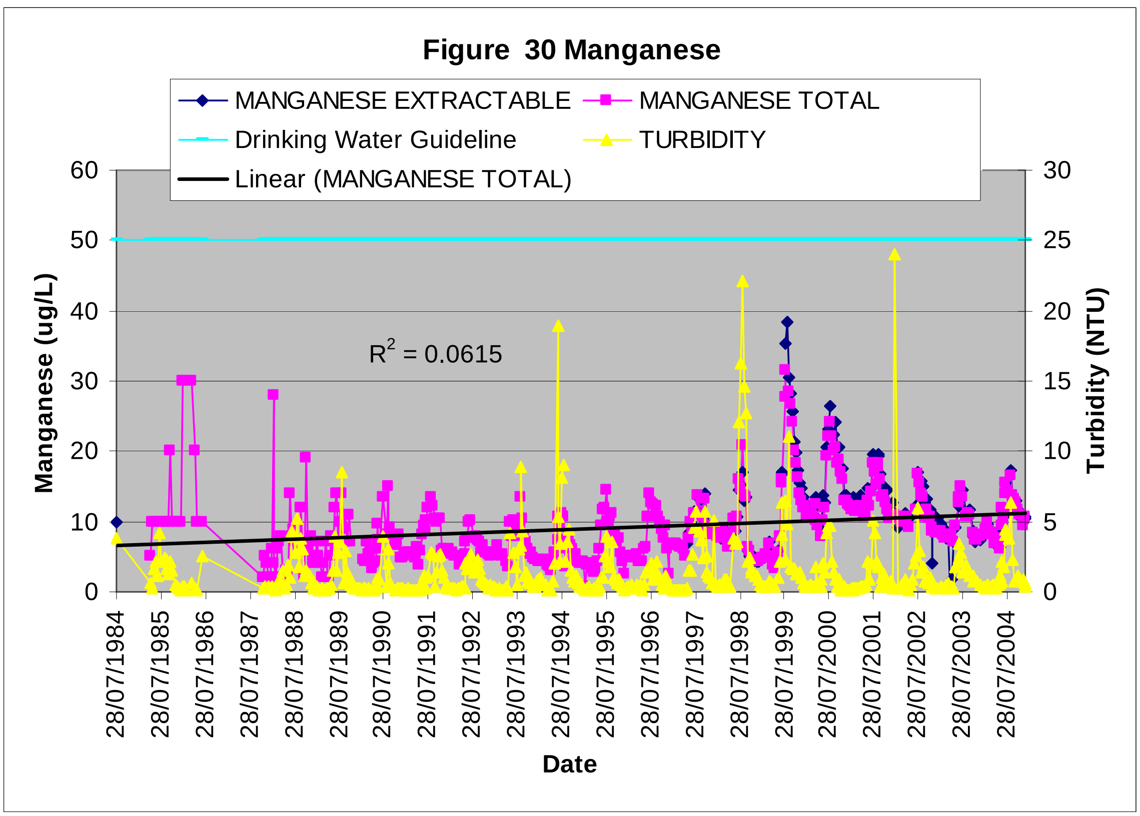


Figure 30 Manganese
MANGANESE EXTRACTABLE
MANGANESE TOTAL
Drinking Water Guideline
TURBIDITY
Linear (MANGANESE TOTAL)
Manganese (ug/L)
Turbidity (NTU)
R2 = 0.0615
Date

**Figure 31 Molybdenum**

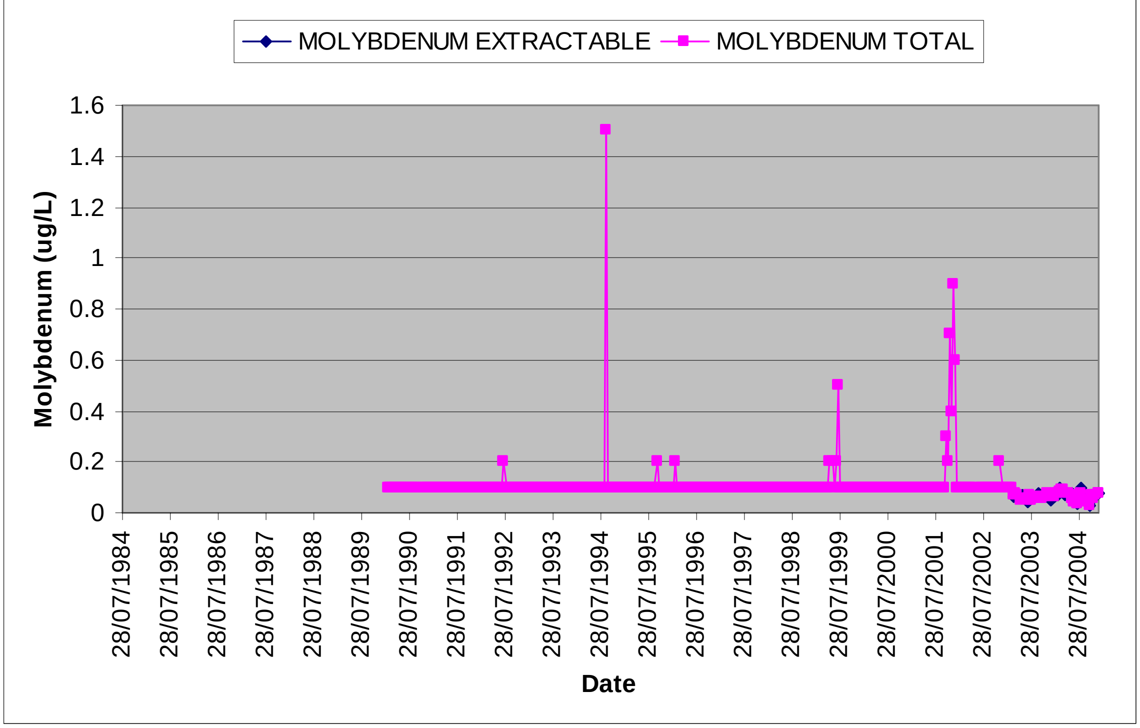
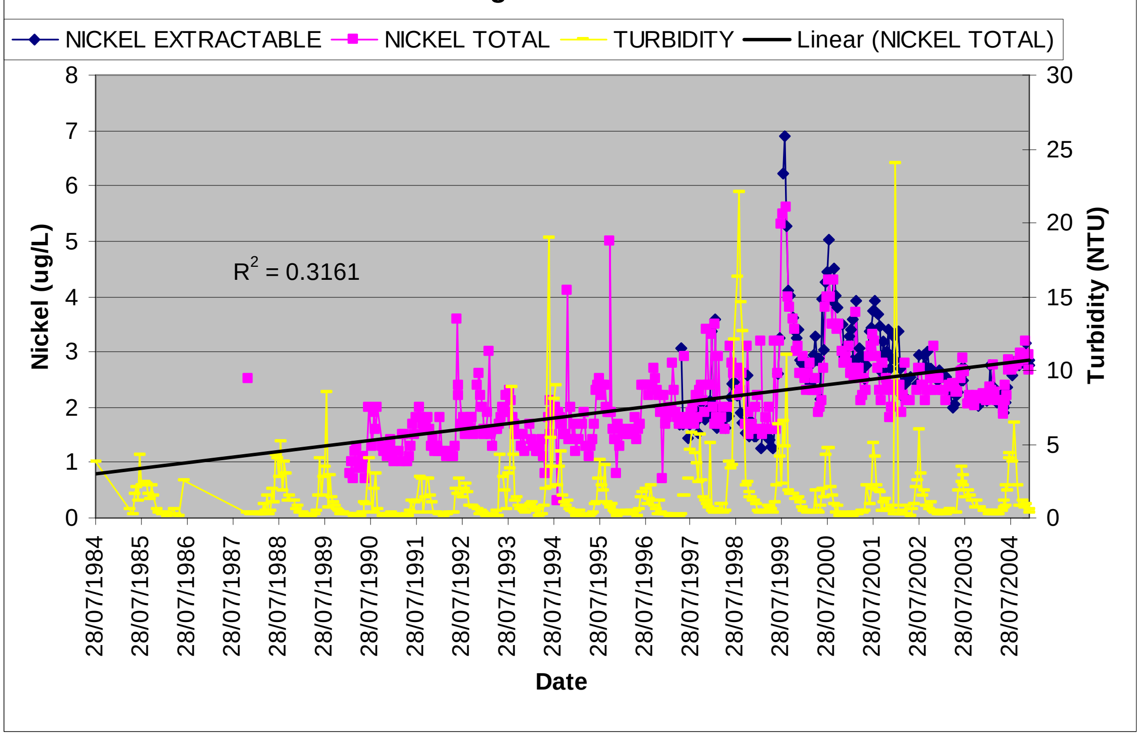



**Figure 32 Nickel**



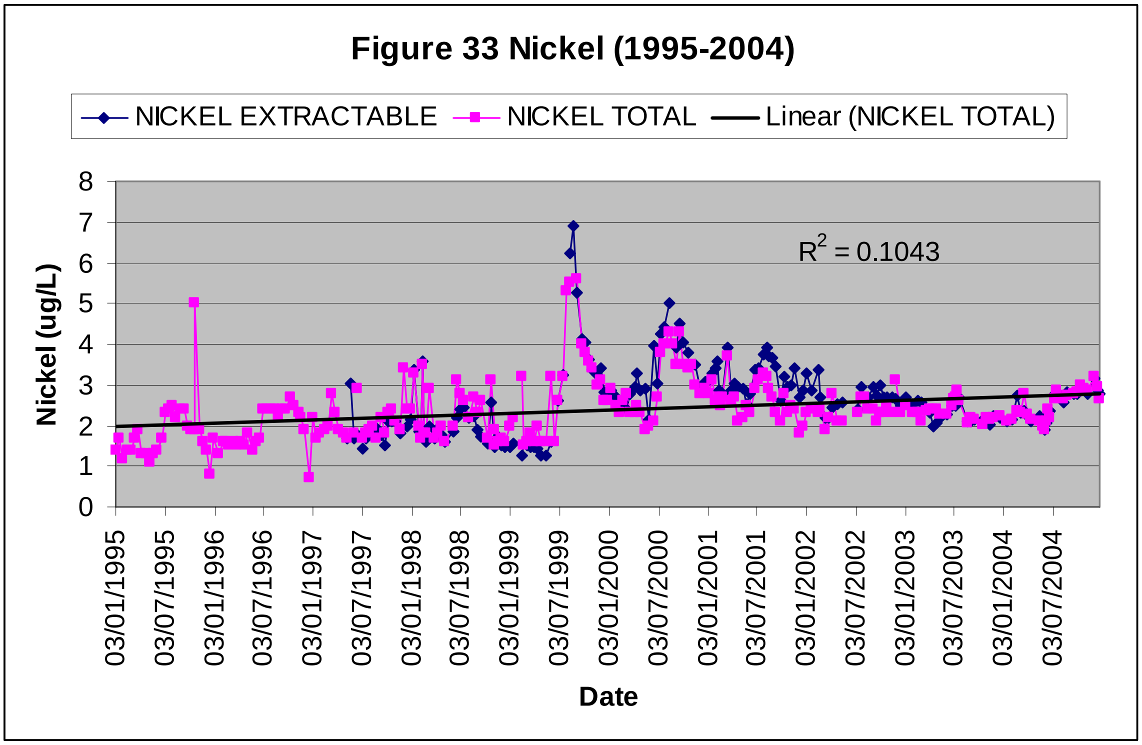


Figure 33 Nickel (1995-2004)
NICKEL EXTRACTABLE
NICKEL TOTAL
Linear (NICKEL TOTAL)
$R^2 = 0.1043$
Nickel (ug/L)
0
1
2
3
4
5
6
7
8
03/01/1995
03/07/1995
03/01/1996
03/07/1996
03/01/1997
03/07/1997
03/01/1998
03/07/1998
03/01/1999
03/07/1999
03/01/2000
03/07/2000
03/01/2001
03/07/2001
03/01/2002
03/07/2002
03/01/2003
03/07/2003
03/01/2004
03/07/2004
Date

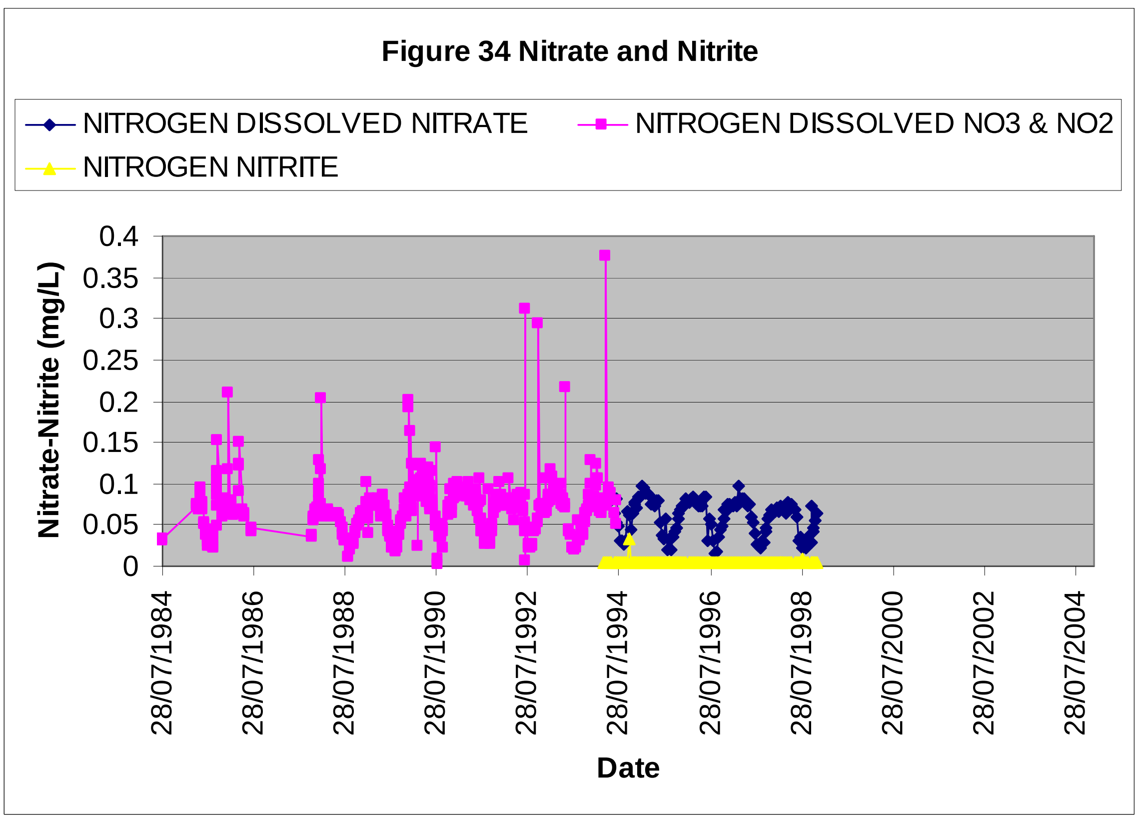


Figure 34 Nitrate and Nitrite
NITROGEN DISSOLVED NITRATE
NITROGEN DISSOLVED NO3 & NO2
NITROGEN NITRITE
Nitrate-Nitrite (mg/L)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

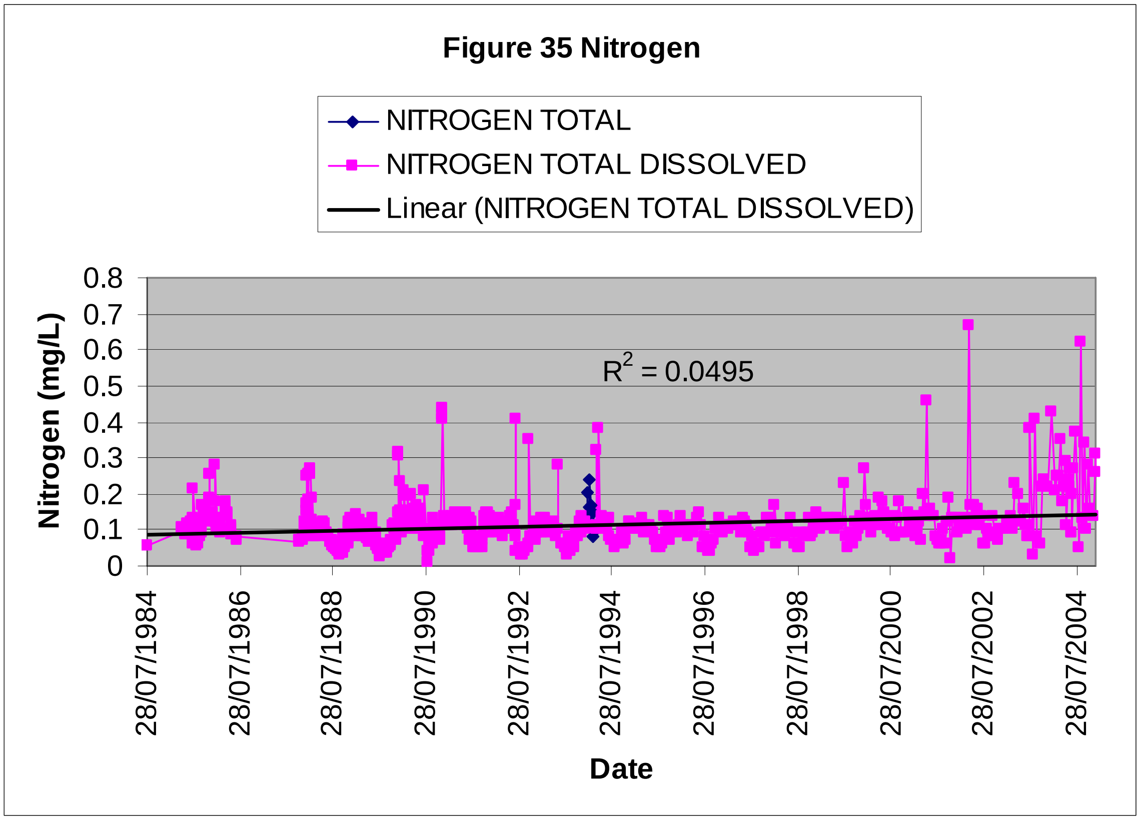


Figure 35 Nitrogen
NITROGEN TOTAL
NITROGEN TOTAL DISSOLVED
Linear (NITROGEN TOTAL DISSOLVED)
Nitrogen (mg/L)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
R2 = 0.0495
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

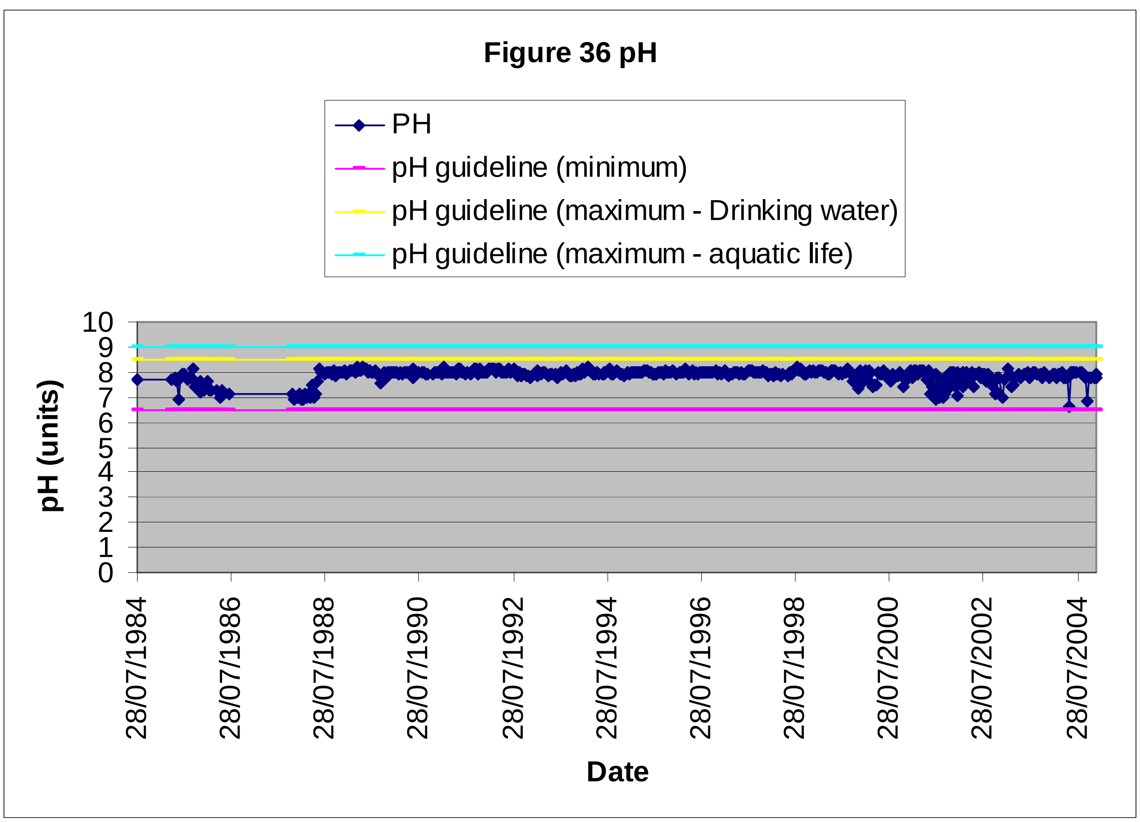


Figure 36 pH
PH
pH guideline (minimum)
pH guideline (maximum - Drinking water)
pH guideline (maximum - aquatic life)
pH (units)
10
9
8
7
6
5
4
3
2
1
0
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

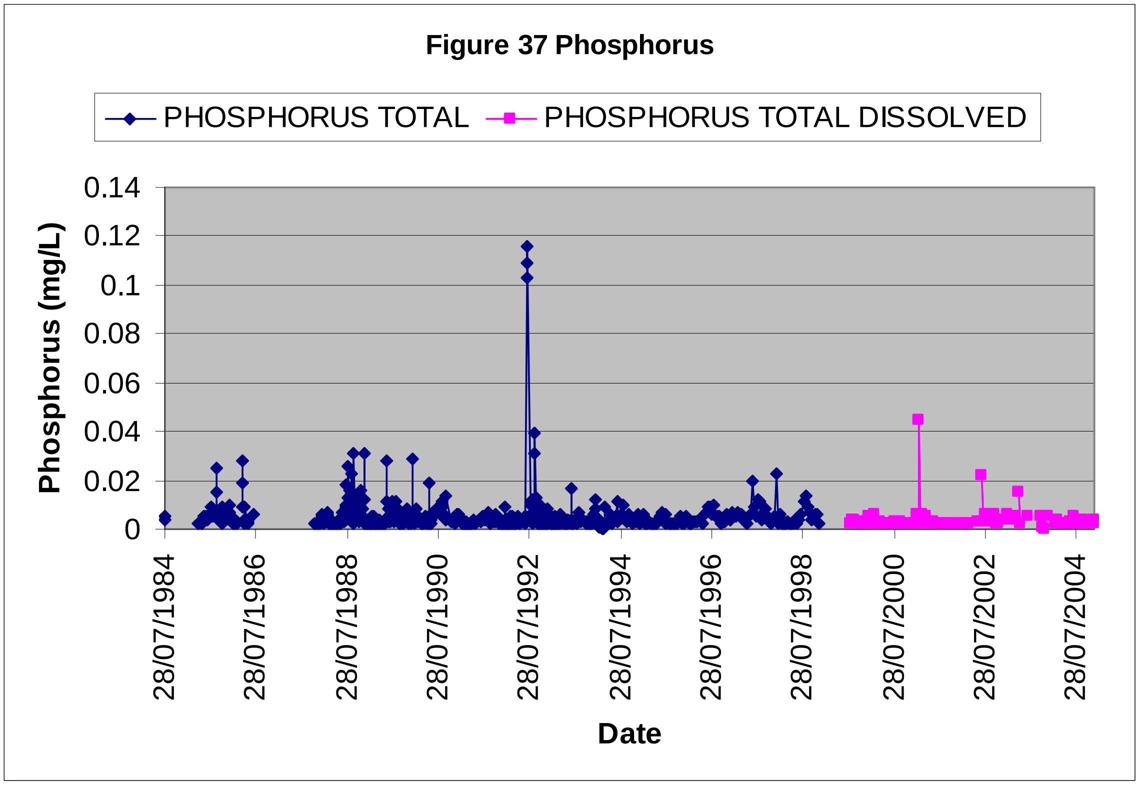


Figure 37 Phosphorus
PHOSPHORUS TOTAL
PHOSPHORUS TOTAL DISSOLVED
Phosphorus (mg/L)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

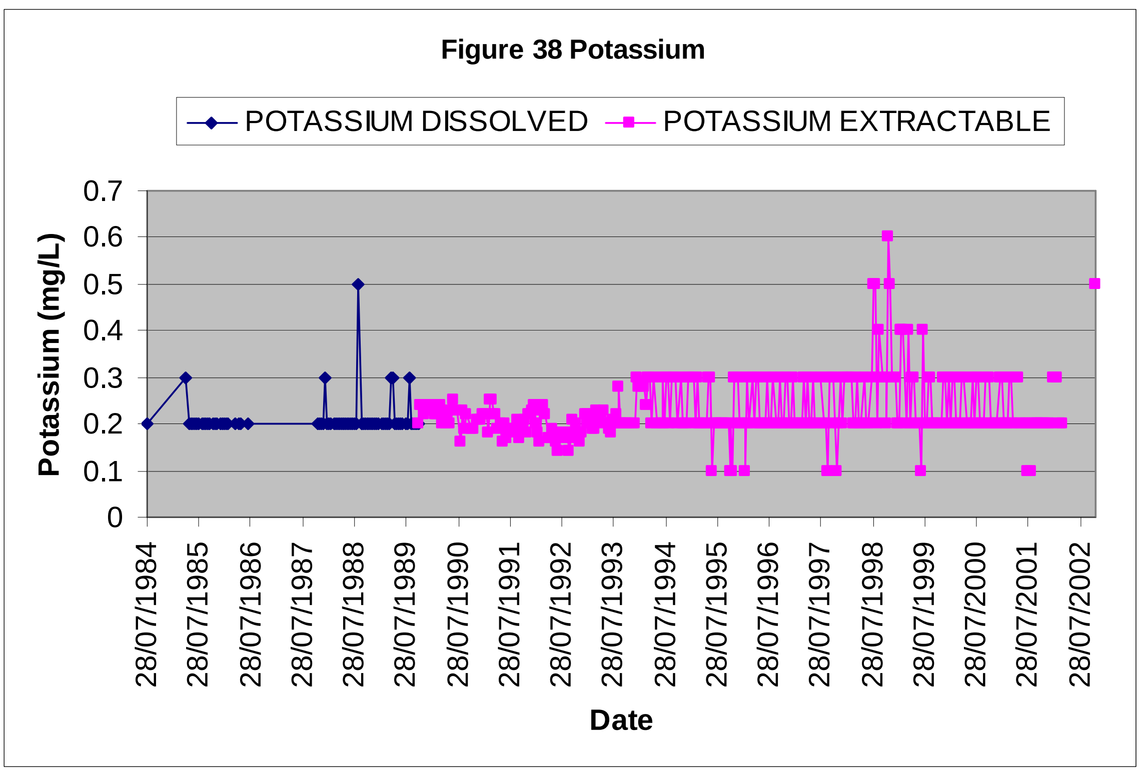


Figure 38 Potassium
POTASSIUM DISSOLVED
POTASSIUM EXTRACTABLE
Potassium (mg/L)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
28/07/1984
28/07/1985
28/07/1986
28/07/1987
28/07/1988
28/07/1989
28/07/1990
28/07/1991
28/07/1992
28/07/1993
28/07/1994
28/07/1995
28/07/1996
28/07/1997
28/07/1998
28/07/1999
28/07/2000
28/07/2001
28/07/2002
Date

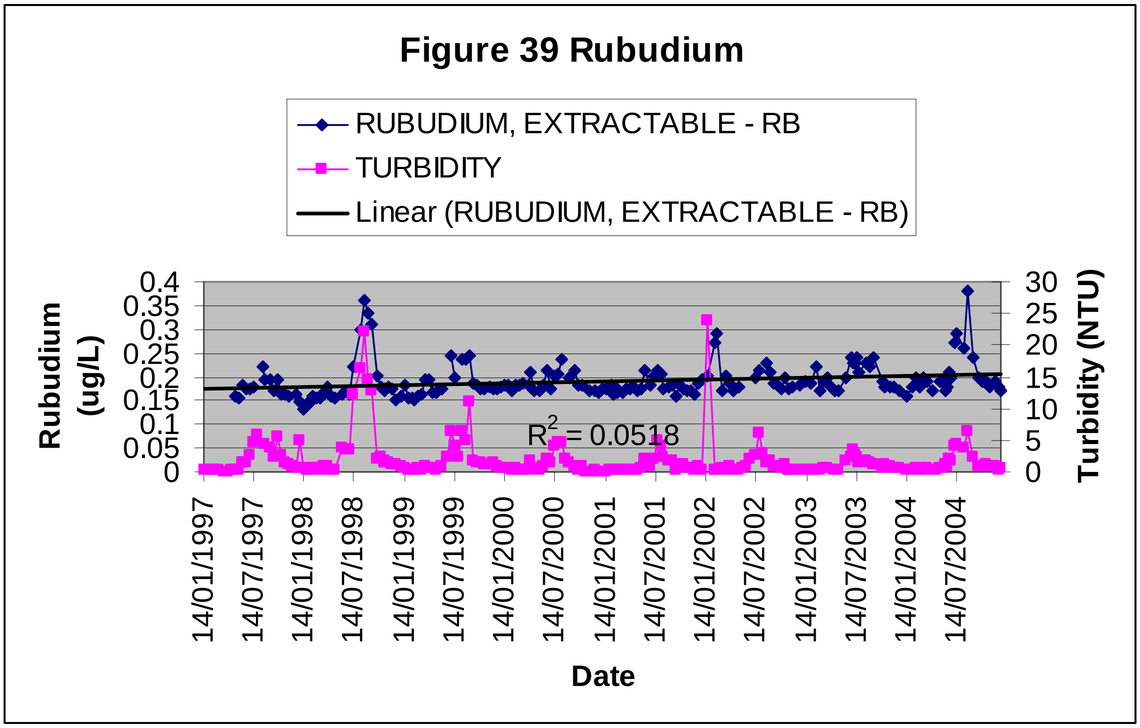


Figure 39 Rubudium
RUBUDIUM, EXTRACTABLE - RB
TURBIDITY
Linear (RUBUDIUM, EXTRACTABLE - RB)
Rubudium (ug/L)
Turbidity (NTU)
R2 = 0.0518
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
30
25
20
15
10
5
0
14/01/1997
14/07/1997
14/01/1998
14/07/1998
14/01/1999
14/07/1999
14/01/2000
14/07/2000
14/01/2001
14/07/2001
14/01/2002
14/07/2002
14/01/2003
14/07/2003
14/01/2004
14/07/2004
Date

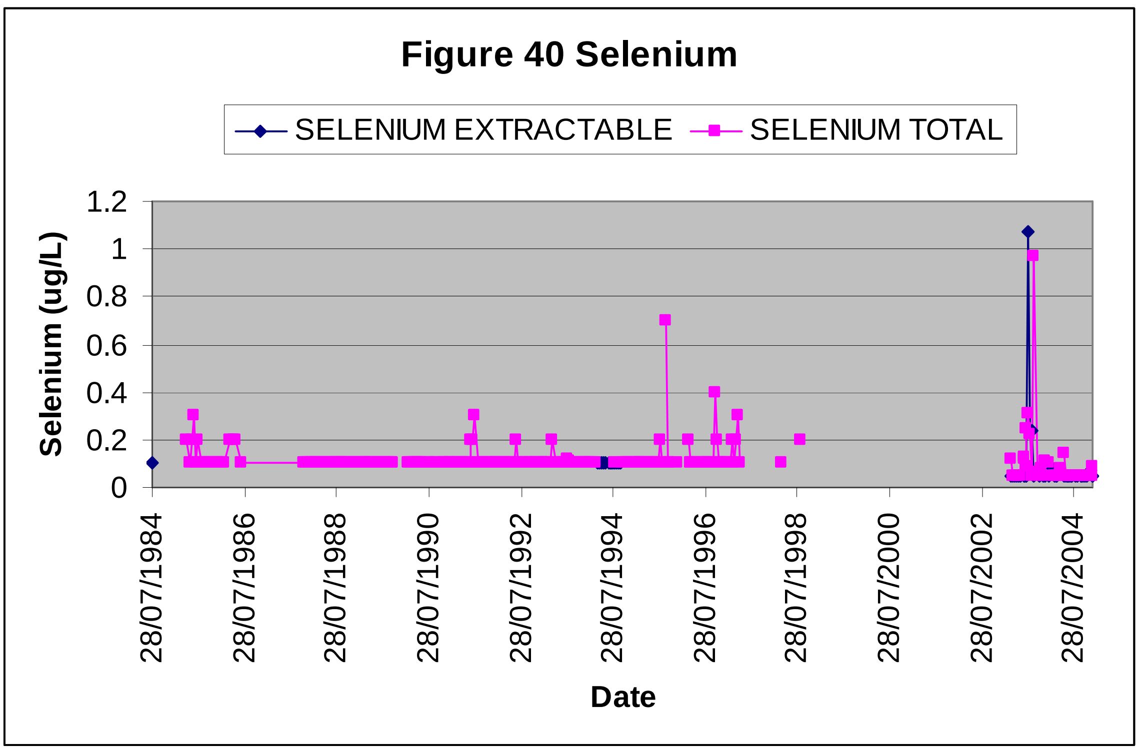


Figure 40 Selenium
SELENIUM EXTRACTABLE
SELENIUM TOTAL
Selenium (ug/L)
1.2
1
0.8
0.6
0.4
0.2
0
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

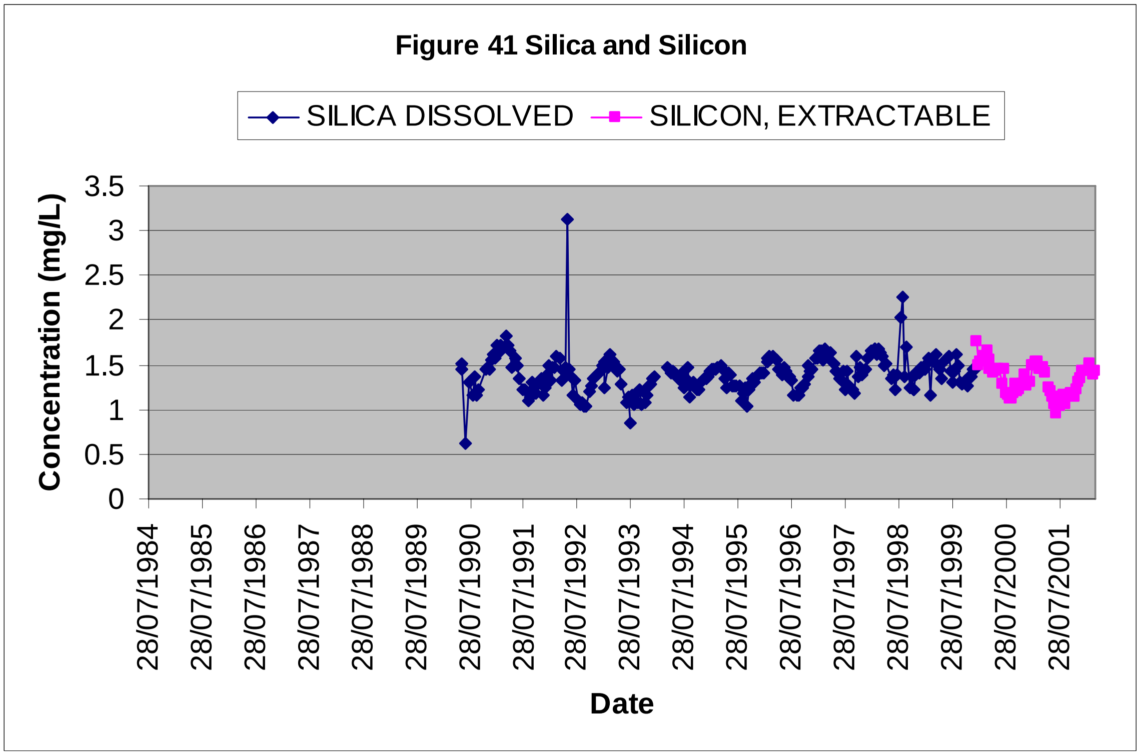


Figure 41 Silica and Silicon
SILICA DISSOLVED
SILICON, EXTRACTABLE
Concentration (mg/L)
3.5
3
2.5
2
1.5
1
0.5
0
28/07/1984
28/07/1985
28/07/1986
28/07/1987
28/07/1988
28/07/1989
28/07/1990
28/07/1991
28/07/1992
28/07/1993
28/07/1994
28/07/1995
28/07/1996
28/07/1997
28/07/1998
28/07/1999
28/07/2000
28/07/2001
Date

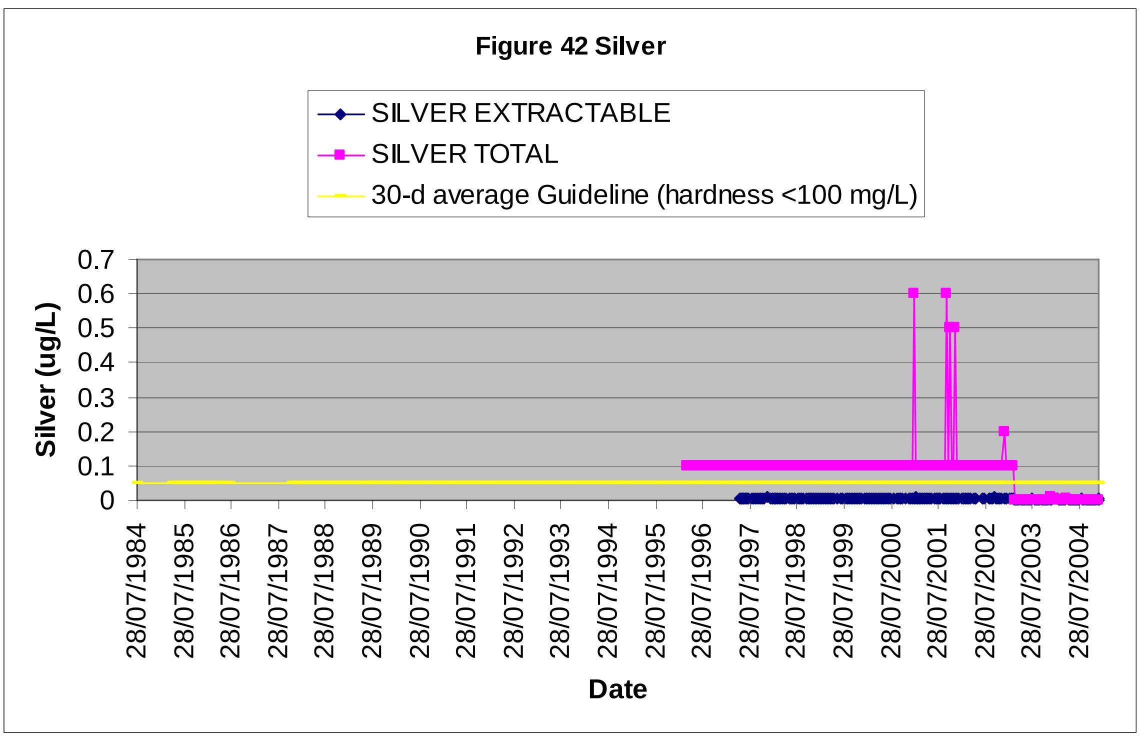


Figure 42 Silver
SILVER EXTRACTABLE
SILVER TOTAL
30-d average Guideline (hardness <100 mg/L)
Silver (ug/L)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
28/07/1984
28/07/1985
28/07/1986
28/07/1987
28/07/1988
28/07/1989
28/07/1990
28/07/1991
28/07/1992
28/07/1993
28/07/1994
28/07/1995
28/07/1996
28/07/1997
28/07/1998
28/07/1999
28/07/2000
28/07/2001
28/07/2002
28/07/2003
28/07/2004
Date

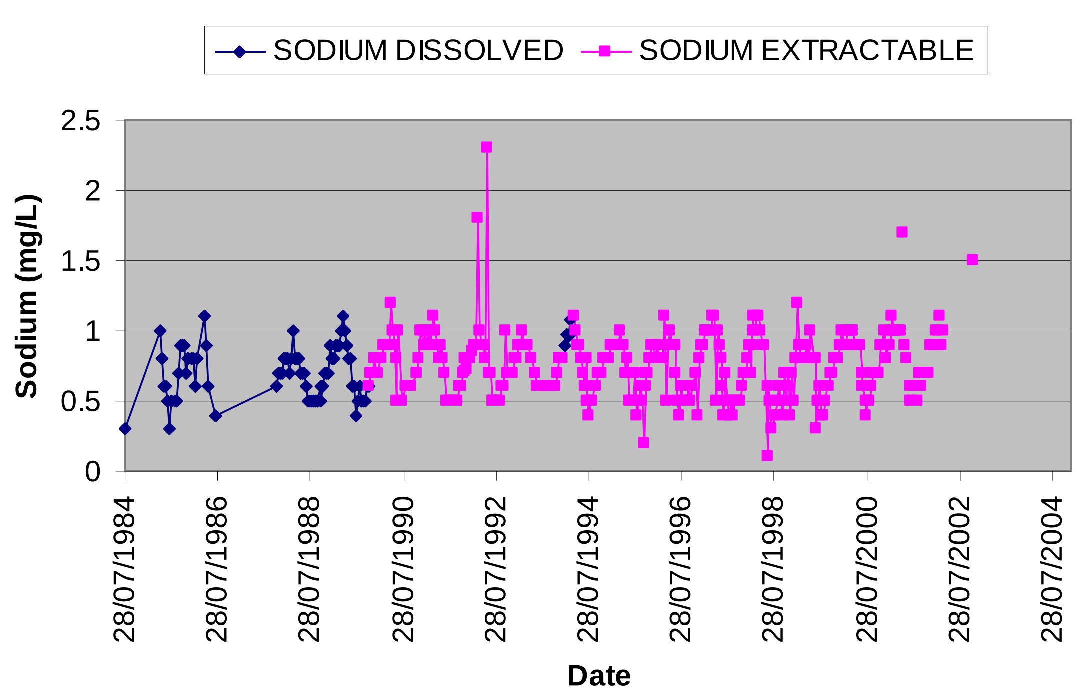



**Figure 43 Sodium**

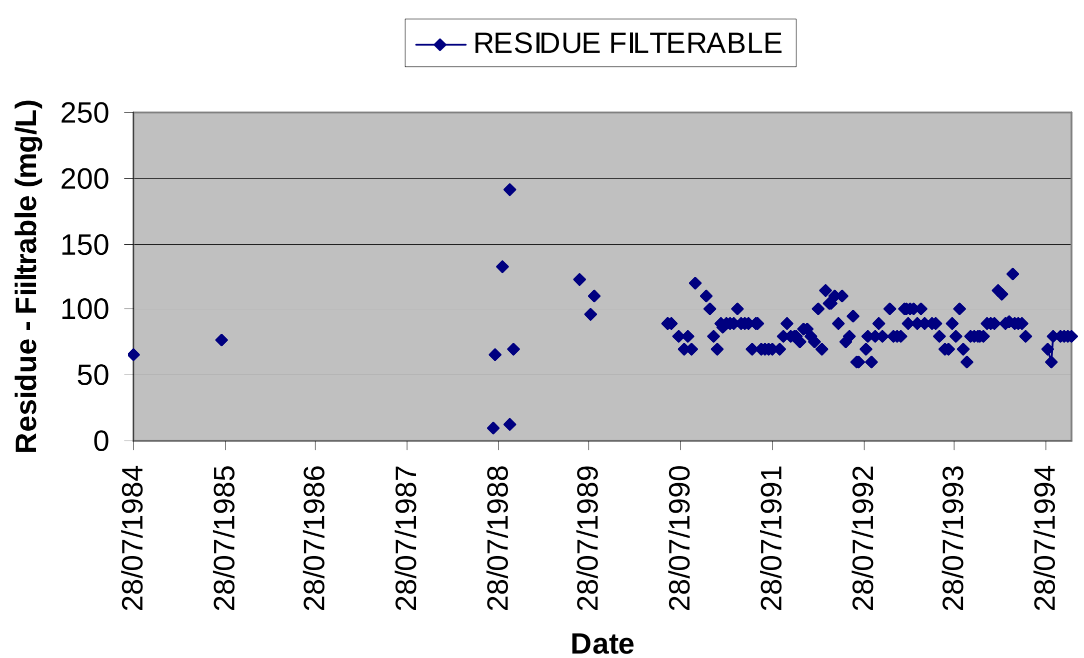



**Figure 44 Solids - Dissolved**

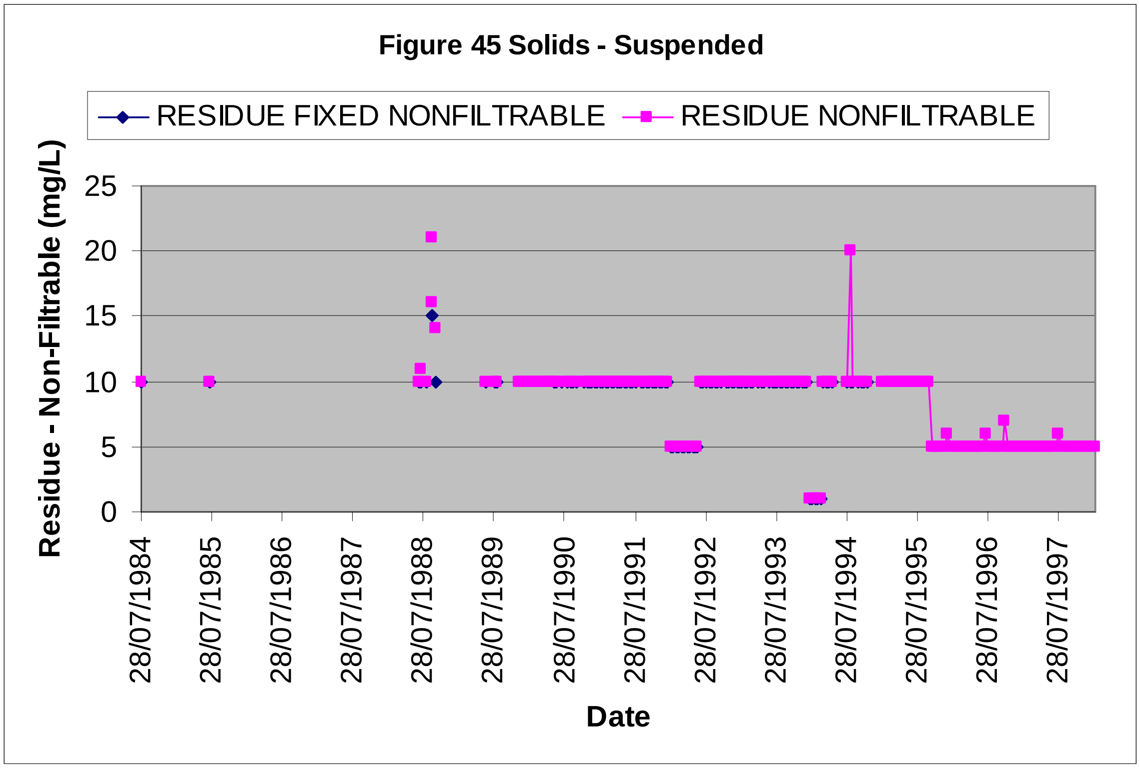


Figure 45 Solids - Suspended
RESIDUE FIXED NONFILTRABLE
RESIDUE NONFILTRABLE
Residue - Non-Filtrable (mg/L)
25
20
15
10
5
0
28/07/1984
28/07/1985
28/07/1986
28/07/1987
28/07/1988
28/07/1989
28/07/1990
28/07/1991
28/07/1992
28/07/1993
28/07/1994
28/07/1995
28/07/1996
28/07/1997
Date

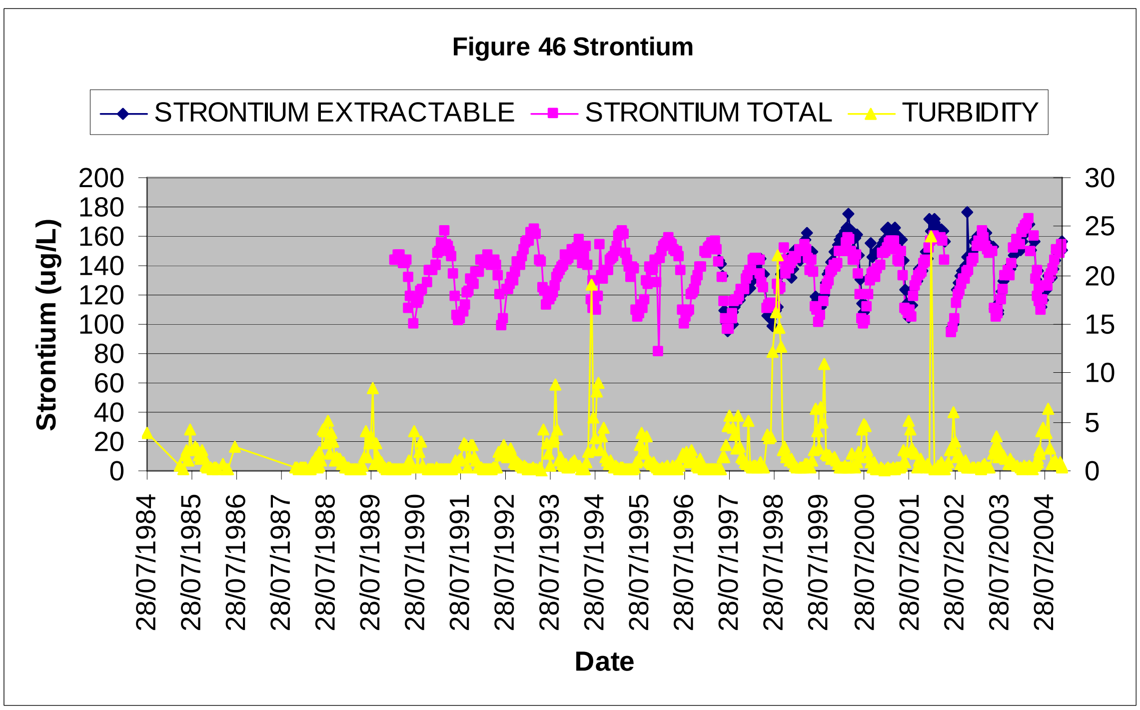


Figure 46 Strontium
STRONTIUM EXTRACTABLE
STRONTIUM TOTAL
TURBIDITY
Strontium (ug/L)
200
180
160
140
120
100
80
60
40
20
0
30
25
20
15
10
5
0
28/07/1984
28/07/1985
28/07/1986
28/07/1987
28/07/1988
28/07/1989
28/07/1990
28/07/1991
28/07/1992
28/07/1993
28/07/1994
28/07/1995
28/07/1996
28/07/1997
28/07/1998
28/07/1999
28/07/2000
28/07/2001
28/07/2002
28/07/2003
28/07/2004
Date

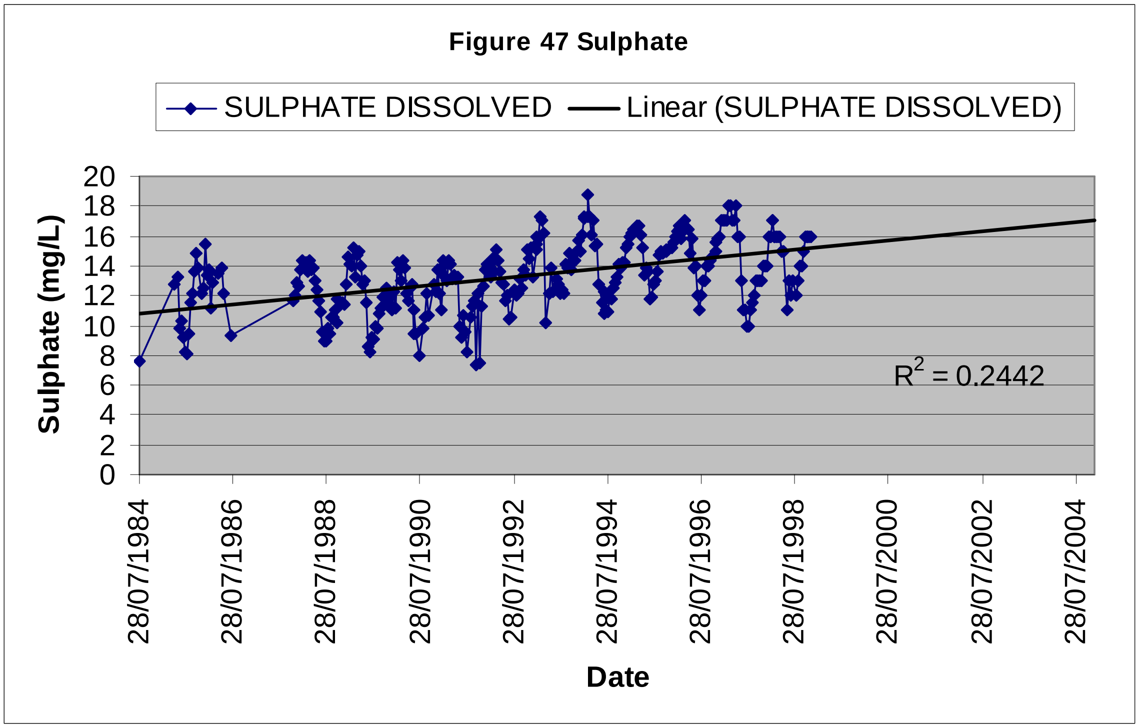


Figure 47 Sulphate
SULPHATE DISSOLVED
Linear (SULPHATE DISSOLVED)
Sulphate (mg/L)
20
18
16
14
12
10
8
6
4
2
0
$R^2 = 0.2442$
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

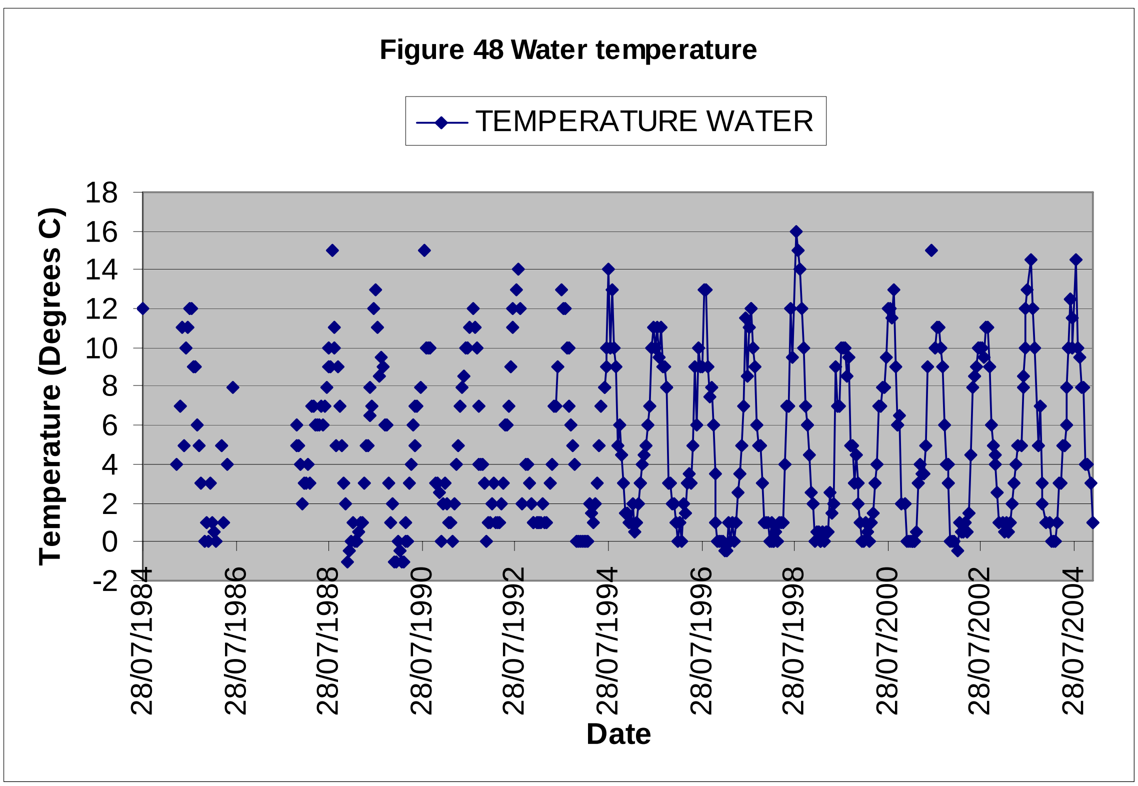


Figure 48 Water temperature
TEMPERATURE WATER
Temperature (Degrees C)
18
16
14
12
10
8
6
4
2
0
-2
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

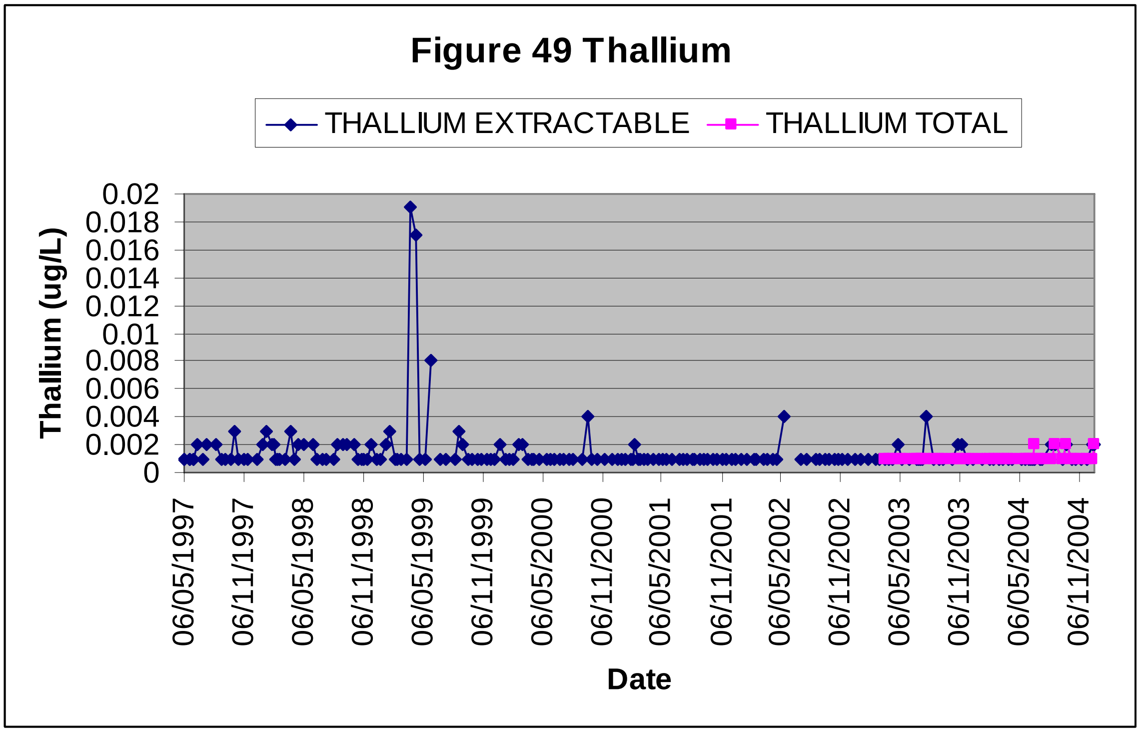


Figure 49 Thallium
THALLIUM EXTRACTABLE
THALLIUM TOTAL
Thallium (ug/L)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
06/05/1997
06/11/1997
06/05/1998
06/11/1998
06/05/1999
06/11/1999
06/05/2000
06/11/2000
06/05/2001
06/11/2001
06/05/2002
06/11/2002
06/05/2003
06/11/2003
06/05/2004
06/11/2004
Date

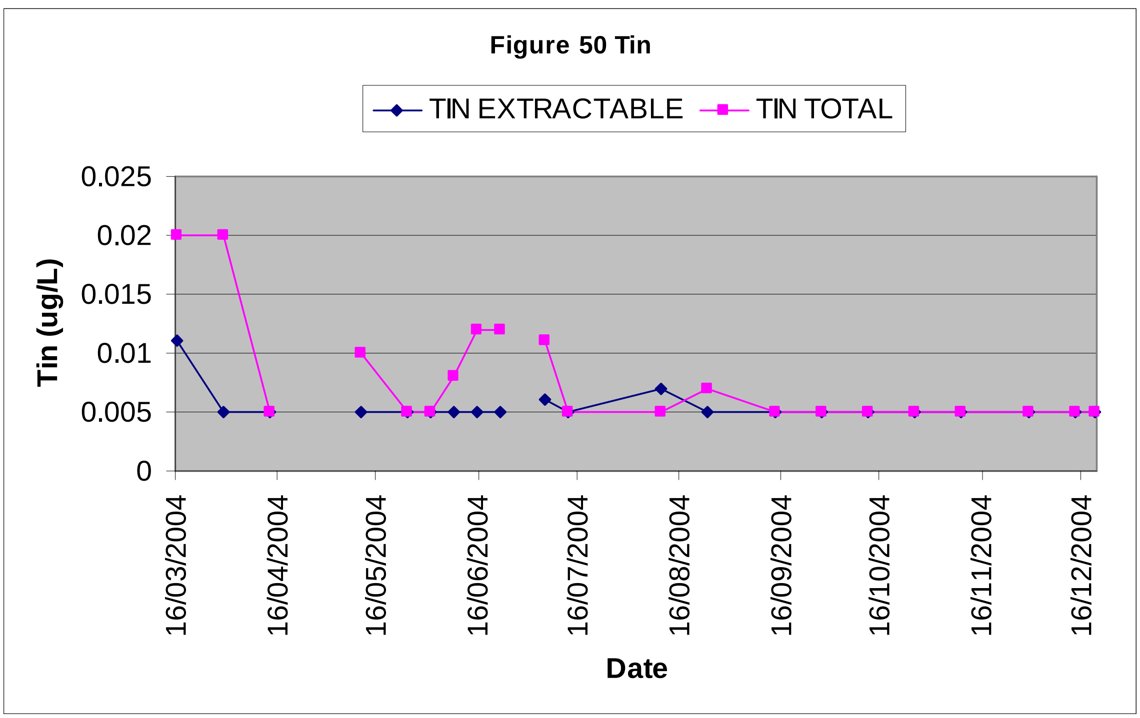


Figure 50 Tin
TIN EXTRACTABLE
TIN TOTAL
Tin (ug/L)
0.025
0.02
0.015
0.01
0.005
0
16/03/2004
16/04/2004
16/05/2004
16/06/2004
16/07/2004
16/08/2004
16/09/2004
16/10/2004
16/11/2004
16/12/2004
Date

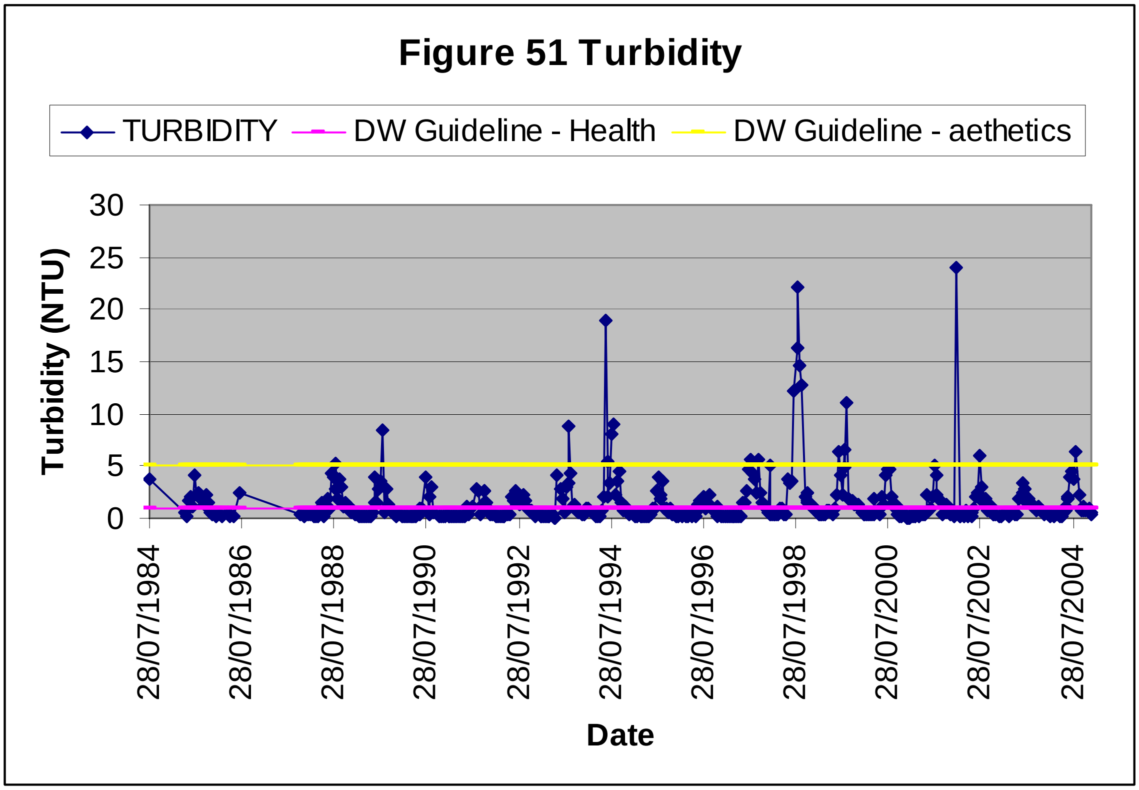


Figure 51 Turbidity
TURBIDITY
DW Guideline - Health
DW Guideline - aethetics
Turbidity (NTU)
30
25
20
15
10
5
0
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

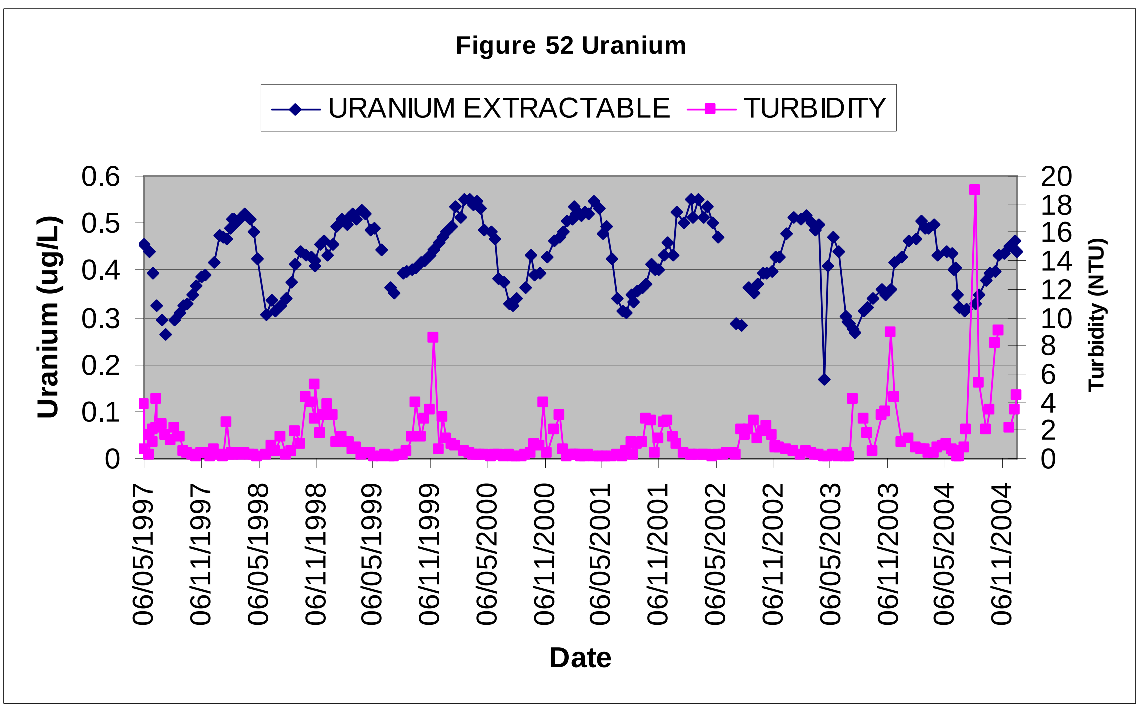


Figure 52 Uranium
URANIUM EXTRACTABLE
TURBIDITY
Uranium (ug/L)
0.6
0.5
0.4
0.3
0.2
0.1
0
Turbidity (NTU)
20
18
16
14
12
10
8
6
4
2
0
06/05/1997
06/11/1997
06/05/1998
06/11/1998
06/05/1999
06/11/1999
06/05/2000
06/11/2000
06/05/2001
06/11/2001
06/05/2002
06/11/2002
06/05/2003
06/11/2003
06/05/2004
06/11/2004
Date

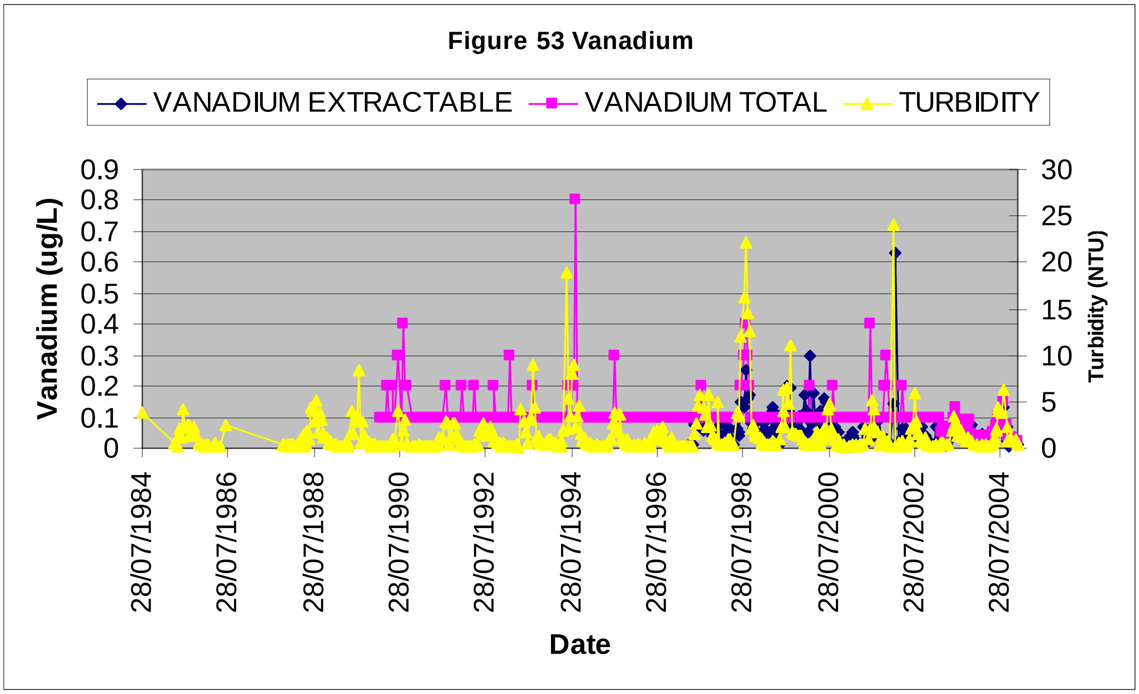


Figure 53 Vanadium
VANADIUM EXTRACTABLE
VANADIUM TOTAL
TURBIDITY
Vanadium (ug/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Turbidity (NTU)
30
25
20
15
10
5
0
28/07/1984
28/07/1986
28/07/1988
28/07/1990
28/07/1992
28/07/1994
28/07/1996
28/07/1998
28/07/2000
28/07/2002
28/07/2004
Date

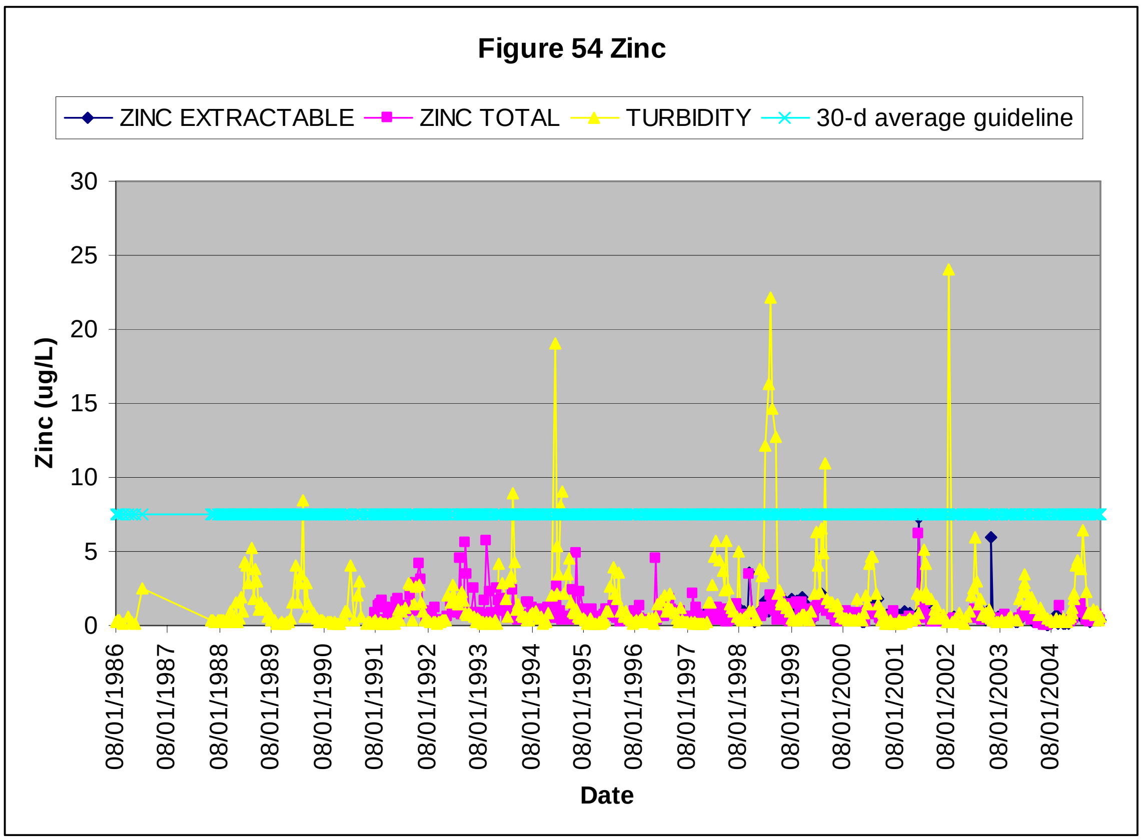


Figure 54 Zinc
ZINC EXTRACTABLE
ZINC TOTAL
TURBIDITY
30-d average guideline
Zinc (ug/L)
30
25
20
15
10
5
0
08/01/1986
08/01/1987
08/01/1988
08/01/1989
08/01/1990
08/01/1991
08/01/1992
08/01/1993
08/01/1994
08/01/1995
08/01/1996
08/01/1997
08/01/1998
08/01/1999
08/01/2000
08/01/2001
08/01/2002
08/01/2003
08/01/2004
Date