AN ANALYSIS OF NON-COMPLIANCE PATTERNS TO PRAIRIE PROVINCES WATER BOARD OBJECTIVES IN THE RED DEER RIVER AT THE ALBERTA/SASKATCHEWAN BOUNDARY

Prepared by:

Anne-Marie Anderson

Surface Water Assessment Branch
Technical Services and Monitoring Division
Alberta Environmental Protection

February 1996

rdrtext.ama
W9507

EXECUTIVE SUMMARY

This report is an initial attempt to understand why fecal coliforms, copper, zinc, lead and iron do not meet Prairie Provinces Water Board Objectives (PPWBO) on some occasions in the Red Deer River at Bindloss, Alberta, the PPWB long-term monitoring site.

Long-term and seasonal patterns in non-compliance with PPWBO were assessed at Bindloss and at two provincial long-term monitoring sites further upstream (i.e., Drumheller/Morrin Bridge, upstream of Drumheller and Hwy 2, upstream of Red Deer). This was done to delineate the river reach where the incidence of non-compliance increases and where the presence of contributing point and non-point sources could be suspected.

Dissimilarities in the patterns of non-compliance at Bindloss and at Drumheller/Morrin Bridge suggest that incidences of non-compliance at Bindloss are largely independent of sources upstream of Drumheller. There are a number of point and non-point sources which could elevate fecal coliform counts in the lower reach of the Red Deer River; they include municipal discharges, irrigation return flows, livestock and wildlife. There is insufficient current information about contributions from each of these sources to assess their relative importance with respect to non-compliance with PPWBO at Bindloss. The Surface Water Assessment Branch (AEP) will design a water quality program in 1996 to fill in these data gaps.

Non-compliance for copper, zinc and lead appears to occur mostly at Bindloss. There are no known point sources of copper, zinc or lead between Drumheller and Bindloss which could account for the observed increase in non-compliance. It is hypothesized that much of the trace elements in the lower Red Deer River are acquired during the passage of the river and its tributaries through the Bearpaw formation (a geological formation of marine origin containing deposits which are typically rich in trace elements) and through the 'badlands' (a highly erodible landscape). Approaches to test these hypotheses are outlined.

There is an insufficient number of non-compliances for iron to speculate on possible reasons for their occurrence.

ACKNOWLEDGEMENTS

G. Dunn, Prairie Provinces Water Board, supplied an electronic copy of PPWB water quality data at Bindloss.

R. Tchir downloaded water quality data from the provincial long-term monitoring sites.

B. Halbig provided support in data management and presentation and in the preparation of the manuscript.

D. Trew reviewed the manuscript.

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

The Prairie Provinces Water Board (PPWB) has monitored the Red Deer River at Bindloss, Alberta on a monthly basis since the mid-70's to assess and document the quality of Red Deer River water entering that province.

Comparisons of measured instream concentrations with Prairie Provinces Water Board Objectives (PPWBO) form the basis of annual water quality assessments. Over the period of record, there have been incidences of non-compliance for copper, zinc, iron, lead and fecal coliforms. To date, their cause has not been investigated.

An objective of this document is to make a first attempt to understand why some water quality attributes do not meet PPWBO on some occasions. PPWB and provincial long-term data are reviewed to try to delineate the river reach where instream concentrations increase. By doing so, it should be easier to identify sources (point or non-point) responsible for increases in instream concentrations. Furthermore, enough information may be acquired about patterns of non-compliance to determine whether a sampling program would have a reasonable chance of success at pinpointing possible sources.

2.0 DATA

Long-term water quality data at Bindloss were supplied by Mr. G. Dunn, Water Quality Specialist, Prairie Provinces Water Board. Data from the long-term stations which are maintained by the province of Alberta (i.e., Red Deer River at Hwy 2 upstream of Red Deer, at Drumheller and at Morrin Bridge) were downloaded from the provincial NAQUADAT system.

The provincial long-term site at Drumheller was monitored until 1986 when it was discontinued, and Morrin Bridge located approximately 50 river kilometres upstream became the long-term monitoring site. To simplify the presentation of data and facilitate comparisons among sites, data from the Red Deer River at Drumheller and at Morrin Bridge have been combined.

A variety of methods have been used by Alberta Environmental Protection (AEP) to analyze trace metals. As a result metals are reported as total, extractable, recoverable or dissolved. When PPWBO apply to total metals, AEP data for total and extractable metals are shown; when objectives apply to dissolved metals, AEP data for dissolved metals are shown.

Data are summarized in time series showing individual concentration records and monthly graphs showing monthly mean, maximum and minimum concentration records. Time series are used to determine if there has been a notable change in the timing or frequency of non-compliance. A sudden increase in non-compliance could be indicative of a new point source or a change in effluent quality. Monthly graphs help identify seasonal patterns in non-compliance. Such patterns could be indicative of natural chemical (e.g., oxidation/reduction) or physical (e.g., flow dependency) influences or of intermittent anthropogenic effects (e.g., intermittent wastewater discharges).

In this analysis, PPWBO are applied to data from Bindloss and from provincial long-term sites so that there is a common basis to compare sites. Ordinarily, Alberta Ambient Surface Water Quality Interim Guidelines (Alberta Environmental Protection (1993) or Canadian Water Quality Guidelines (CCME 1987) would be used to evaluate provincial water quality data.

3.0 FECAL COLIFORMS

3.1 RESULTS

PPWB objectives for irrigation water specify that fecal coliform counts should not exceed 100 organisms/100 mL. This objective has not been met from time to time at all long-term sites (Figures 1 to 3). The incidence of non-compliance does not exhibit a trend at Hwy 2, but it does at the two other sites. At Drumheller/Morrin Bridge, the time-series graph generally shows higher peak concentrations in each year since 1987. This change coincides with the relocation of the long-term site at Drumheller to a site further upstream at Morrin Bridge. At Bindloss, higher peak concentrations have been recorded since 1980; possible causes are discussed below.

Seasonal patterns are similar at the three sites, with higher counts and a higher frequency of non-compliance occurring in the summer months. Counts peak in successive months for the three sites (i.e., June for Hwy 2; July for Drumheller/Morrin Bridge and August for Bindloss). Non-compliance under ice is not uncommon at Drumheller/Morrin Bridge, but does not occur in general at the other two sites.

3.2 DISCUSSION

According to CCME (1987), fecal coliform counts are useful indicators of fecal contamination from warm-blooded animals in general, not from humans specifically. However, not all coliforms counted as fecal coliforms are of fecal origin (e.g., *Klebsiella* is common in certain types of industrial effluents). *Escherichia coli* counts are considered to be more accurate indicators of fecal contamination.

In the Red Deer River, municipal effluent discharges, agricultural runoff, and wildlife (mammals and birds) are all potential sources of fecal coliforms.

- There are a few municipal discharges upstream of Hwy 2, but agricultural runoff and wildlife are likely the largest contributors of fecal coliforms. Overall, counts are low at that site and likely representative of background conditions.

- The Red Deer River at Drumheller and Morrin Bridge is influenced by municipal discharges from a number of smaller centres, and by those from the City of Red Deer. It is probable that there is a link between these municipal discharges and the high numbers which are occasionally recorded at the long-term monitoring site. The higher counts recorded when the site was moved further upstream (i.e., closer to Red Deer) and the occurrence of high counts under ice suggest that a continuous point source is involved. High fecal coliform counts in City of Red Deer treated sewage (e.g., 56,000/100 mL on July 6, 1992) suggest that this effluent may be that point source. However, critical information is lacking to be certain of cause and effect relationships. More specifically, there is no information about the distance that fecal coliforms can travel in the Red Deer River under different combinations of river discharge and temperature. A mixing zone study currently planned for the City of Red Deer wastewater effluent during periods of low flow (early fall, late winter) will provide initial data, but further information will have to be acquired to describe patterns during the summer months.

- The dissimilarity in the pattern of non-compliance at Drumheller/Morrin Bridge and Bindloss suggest that incidences of non-compliance at Bindloss are to a large extent independent of sources upstream of Drumheller. It is worth noting that the relationship between river discharge and high fecal coliform counts is inconsistent at Bindloss: high fecal coliform counts may coincide with high or low river flows (compare Figure 1 and 16). There are a number of potential point and non-point sources downstream of Drumheller.

    - Point sources include continuous discharges to the river from Drumheller, East Coulee and Rosedale and a number of intermittent (spring/fall) discharges to tributaries of the Red Deer River from smaller municipalities such as Delia, Hanna, Duchess, Rosemary and Patricia. The Drumheller plant was upgraded in the early 1980's and East Coulee and Rosedale chlorinate their effluent. Recently, Brooks has changed its biannual discharges to One Tree Creek, a tributary of the Red Deer River, to effluent irrigation (pers.comm., A. Kennedy, Regional Engineer, Red Deer, AEP).

- Other point sources include irrigation returns, the major ones being Rosebud Creek and Matzihiwin Creek (pers. comm., S. Figliuzzi, Hydrologist, Surface Water Assessment Branch, AEP). Irrigation returns could have high fecal coliform counts if they drain pastures or land that has received manure or sewage applications (e.g., Kirchmann 1994). Irrigation ditches also provide habitat for wildlife which could further elevate counts. There are no current data on the bacterial content of irrigation return flows to the Red Deer River, but high bacterial counts were reported at Jenner downstream of irrigation return flows in 1983 (Cross 1991).

- Non-point sources include grazing land along the river or areas where livestock have free access to the river for drinking. The lower portion of the Red Deer River also offers habitat to abundant waterfowl populations which are another potential source of fecal coliforms.

Although several potential point and non-point sources of fecal coliforms can be identified in the lower reaches of the Red Deer River there is insufficient information available to determine the relative importance of these sources with regard to non-compliance with PPWBO at Bindloss.

To develop a better understanding of the origin and fate of fecal coliforms in the Red Deer River at Bindloss, there is a need to:

a.) Provide current information on municipal wastewater quality and extent of the impact zone at different times of year.

b.) Document bacterial levels in tributaries and irrigation return flows to the Red Deer River, especially during periods of runoff (spring, summer), but also during periods of low flow.

c.) Obtain information on livestock density and distribution of livestock along the Red Deer River, particularly to locate high animal density operations. (Agricultural data summarized by CAESA could be helpful in this respect, but a higher spatial resolution than currently available (i.e., municipal district) may be required.)

d.) Obtain information on the distribution and density of waterfowl in the lower Red Deer River (contact Fish and Wildlife Division) and document effects of waterfowl populations on instream fecal coliform levels.

e.) Assess the value of using the ratio of E. coli/fecal coliforms as an indicator of fecal contamination (CCME 1987) rather than fecal coliforms only.

4.0 COPPER, ZINC AND LEAD

4.1 RESULTS

It is important to note again that metals have been reported in a variety of forms by AEP. Only data for extractable and total metals are shown here. All PPWB data for copper, zinc and lead are for total metals. The differences in which metals have been reported weakens the validity of comparisons between PPWB and provincial data.

4.1.1 Copper

PPWBO for the protection of fisheries recommend that total copper levels not exceed 0.004 mg/L.

Copper data for long-term sites are shown in Figures 4 to 6.

There are frequent records of non-compliance with PPWBO for copper at Bindloss; these incidences are most frequent during the open-water season (March to September) and appear to be bimodal (first peak in April, second peak in July). Similar seasonal patterns are visible in NFR and flow data (Figures 16 and 17). There have been occasional incidences of non-compliance at Drumheller/Morrin Bridge for total and extractable copper and only four cases of non-compliance for total copper at Hwy 2.

4.1.2 Zinc

PPWBO for the protection of fisheries recommend that total zinc concentrations not exceed 0.03 mg/L.

Although there have been numerous incidences of non-compliance for total zinc at Bindloss, data indicate that most of these occurred in the 1980's and that peak concentrations have declined over time (Figure 7). As for copper, the incidence of non-compliance is restricted to the open-water season (April to September). There have been four incidences of non-compliance for extractable zinc at Drumheller/Morrin Bridge (Figure 8) and one at Hwy 2 (Figure 9).

4.1.3 Lead

PPWBO for the protection of fisheries recommend that total lead concentrations not exceed 0.007 mg/L.

There have been several cases of non-compliance at Bindloss in the 1980's, but so far all samples taken in the 90's have complied (Figure 11). All non-compliances have occurred from March to September. There have been four non-compliance records for extractable lead at Drumheller/Morrin Bridge (Figure 11) and none at Hwy 2 (Figure 12).

4.2 DISCUSSION

The differences in frequency of non-compliance for trace metals among the three sites suggests that non-compliance at Bindloss is primarily related to sources between Drumheller/Morrin Bridge and Bindloss. The seasonal pattern of the trace metal concentrations at Bindloss matches that for NFR and flow quite well and correlation analysis (Appendix 1) confirms that there are significant correlations among flow, NFR and metals. This suggests that most of these trace metals are associated with NFR - or particles - and are transported during periods of higher river flows. The most probable source of copper, zinc and lead is sediment carried with runoff from the drainage basin or re-suspended from the river bottom when river flows increase.

The layout and transition of geological formations relative to the channel of the Red Deer River seems to support the idea that there is a relation between the geology of the drainage basin and stream water quality. Most of the Red Deer River upstream of Drumheller flows through the Paskapoo formation (Alberta Research Council 1982). Downstream of Drumheller there is a rapid transition from the Paskapoo over the Horseshoe Canyon to the Bearpaw formation. The lower Red Deer River in Alberta flows through the Oldman formation. Of these formations, the Bearpaw is the only one of marine origin. It is typified by dark grey blocky shale and silty shale. Dark shales from marine origin typically have a higher trace element content than light coloured shales or than sandstone (pers. comm., Dr. C. Holmden, Dept. of Geology, University of Alberta; Singh and Steines 1994). It is hypothesized that much of the trace elements in the lower Red Deer River are acquired during the passage of the river and its tributaries through the Bearpaw formation. Furthermore, a substantial portion of the Red Deer River downstream of Drumheller flows through 'badlands'. This highly erodible landscape undoubtedly contributes to the suspended sediment and trace metal content of the river during runoff episodes.

To test these hypotheses two approaches could be taken:

- Undertake a comparison of trace element (especially Cu, Zn and Pb) concentrations -and loads- of tributaries which flow over the Bearpaw formation (e.g., Bullpound, Berry and Blood Indian creeks) with those from tributaries which flow over other formations (e.g., Rosebud and Threehills creeks).

- Compare Cu, Zn, Pb and NFR concentrations -and loads- in the Red Deer River upstream and downstream of badlands, during runoff episodes.

5.0 IRON

PPWBO for the protection of drinking water quality specify that dissolved iron levels should not exceed 0.3 mg/L.

Dissolved iron data for the three long-term data sets are shown in Figures 13 to 15. There have been four incidences of non-compliance at Bindloss; three at Drumheller/Morrin Bridge and none at Hwy 2. There are too few cases of non-compliance to comment on their seasonality or to speculate on possible reasons for their occurrence.

6.0 LITERATURE CITED

Alberta Environmental Protection. 1993. Alberta ambient surface water quality interim guidelines.

Alberta Research Council. 1992. Geological map of Alberta. National Resources Division. Alberta Geological Survey.

Aroner, E.R. 1994. WQHYDRO - Water quality/hydrology/graphics/analysis system. P.O. Box 18149, Portland, OR 97218.

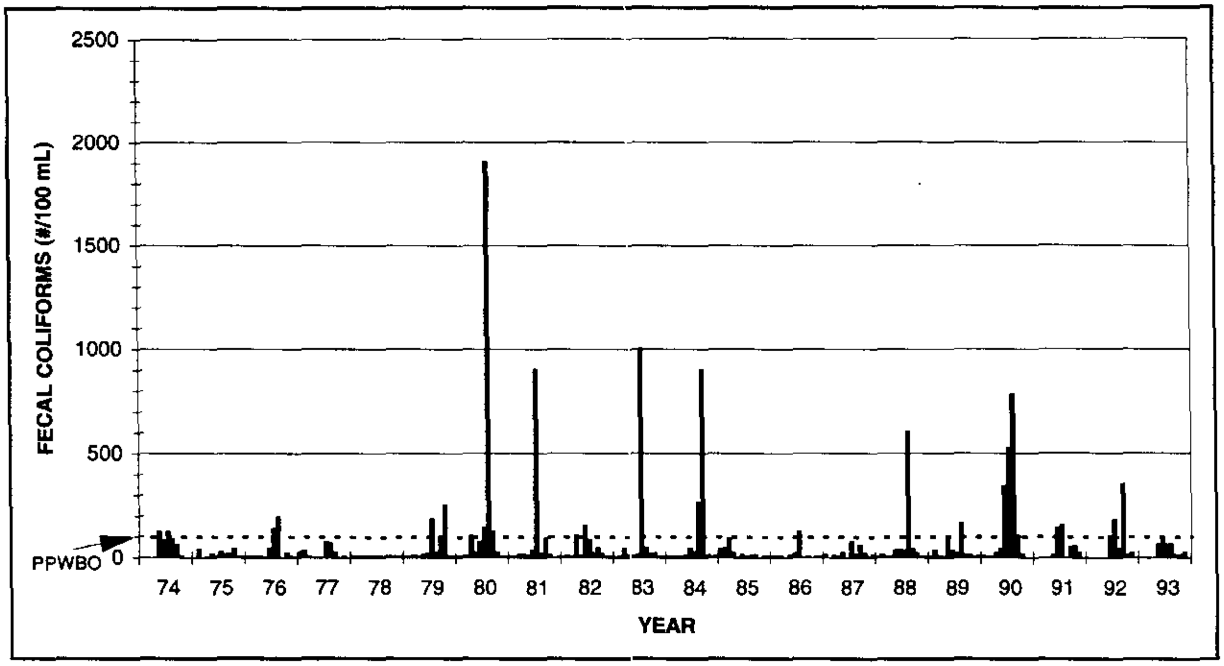
CCME (Canadian Council of Ministers of the Environment). 1987. Canadian water quality guidelines. Environmental Quality Guidelines Division, Ottawa.

Cross, P.M. 1991. An overview of water quality in the Red Deer River Basin (1983-1984). Alberta Environmental Protection, Surface Water Assessment Branch. 84 p.

Kirchmann, H. 1994. Animal and municipal organic wastes and water quality. In: Lal, R. and B.A. Stewart (Eds). Advances in soil science soil processes and water quality. Lewis Publishers, London.

Singh, B.R. and E. Steinnes. 1994. Soil and water contamination by heavy metals. In: Lal, R. and B.A. Stewart (Eds.). Advances in soil science soil processes and water quality. Lewis Publishers, London. p. 233-270.

Figure 1. Fecal coliforms in the Red Deer River at Bindloss.



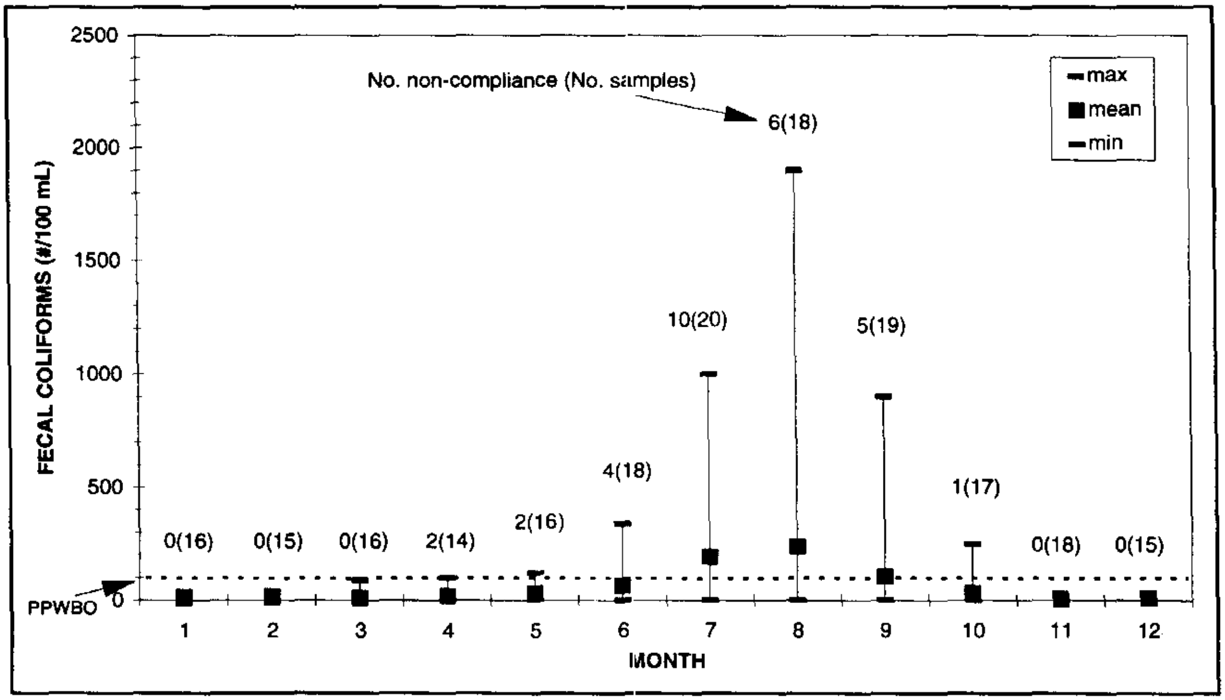
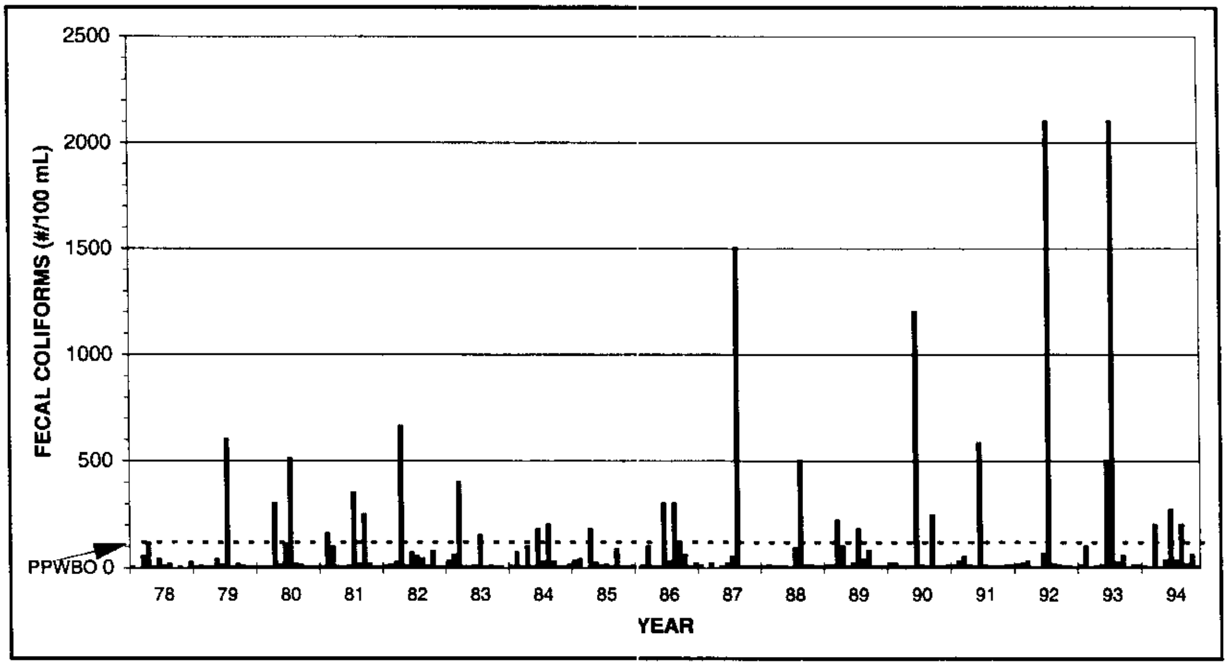


Figure 2. Fecal coliforms in the Red Deer River at Drumheller (1978-1986) and Morrin Bridge (1987-1994).



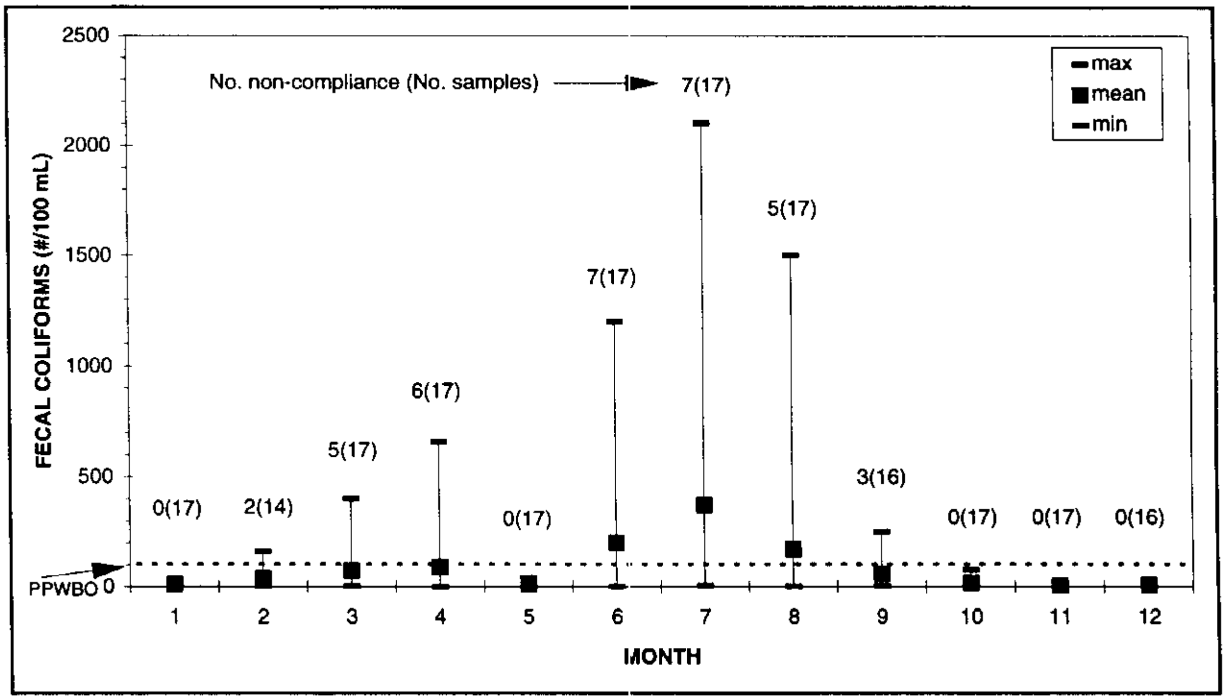
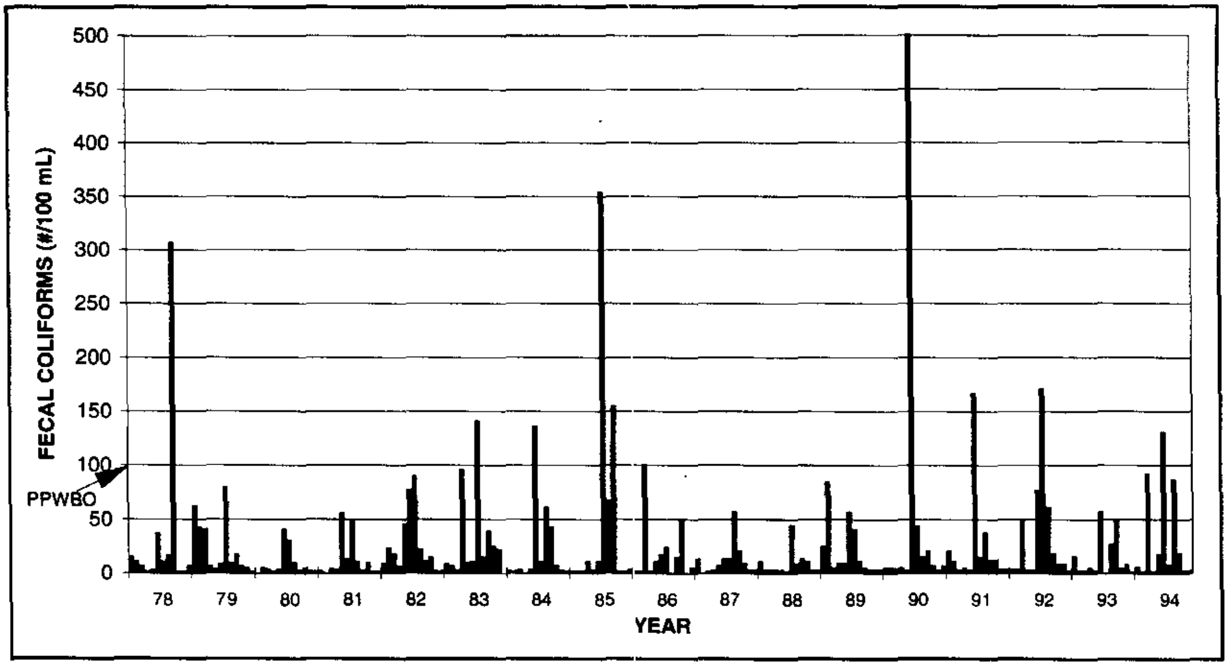


Figure 3. Fecal coliforms in the Red Deer River at Hwy 2.



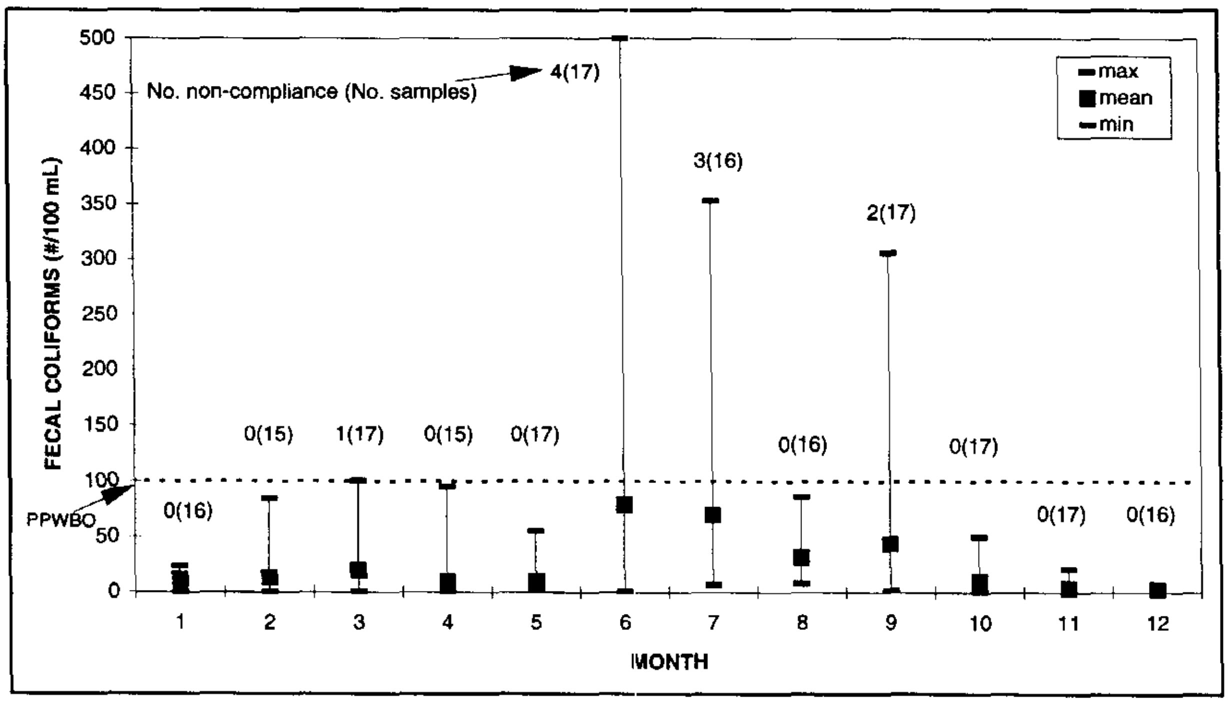
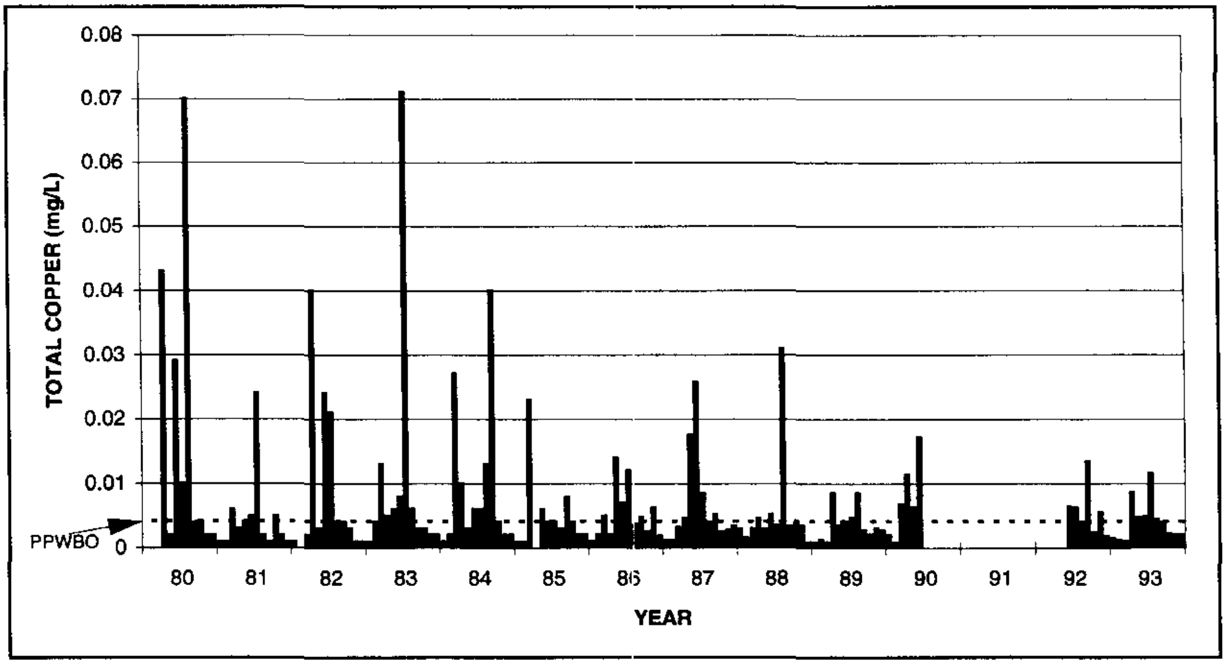


Figure 4. Copper in the Red Deer River at Bindloss.



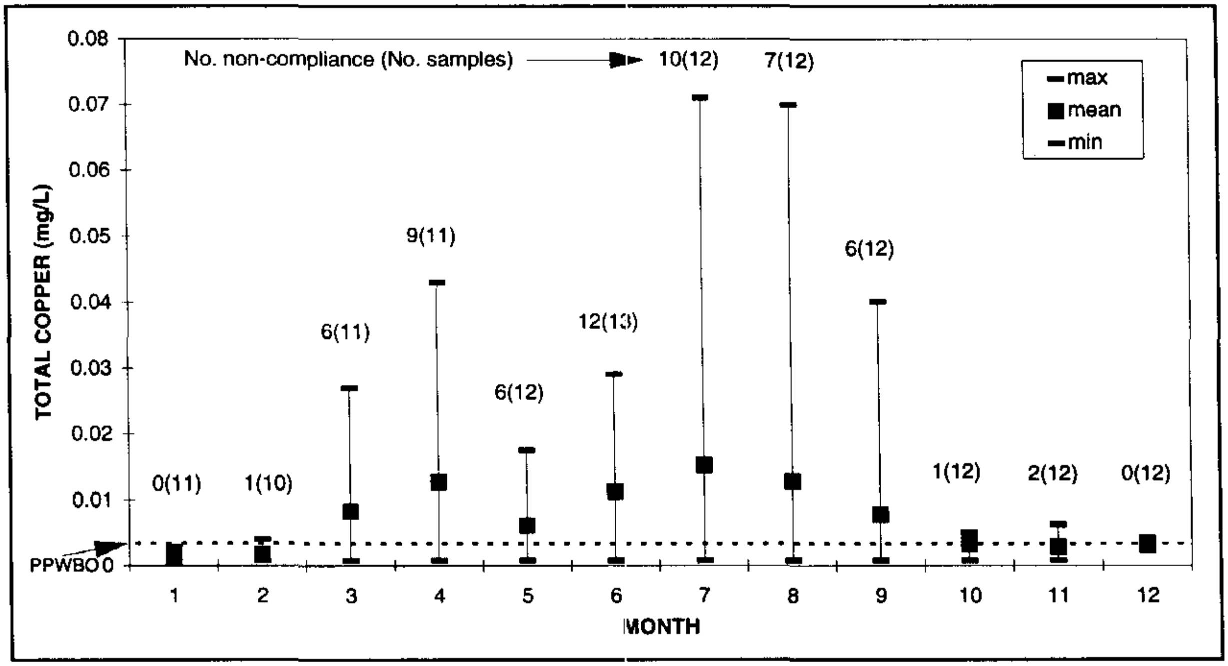
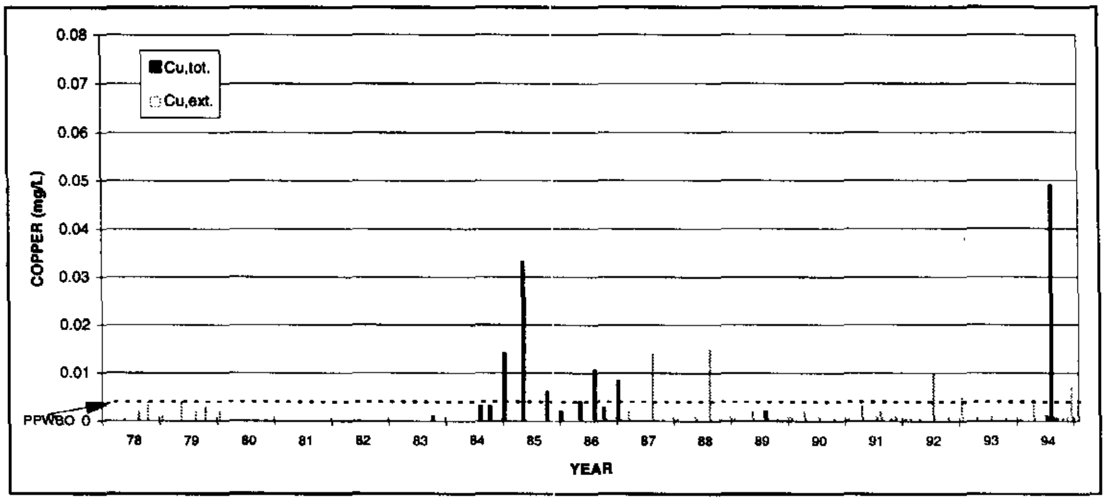
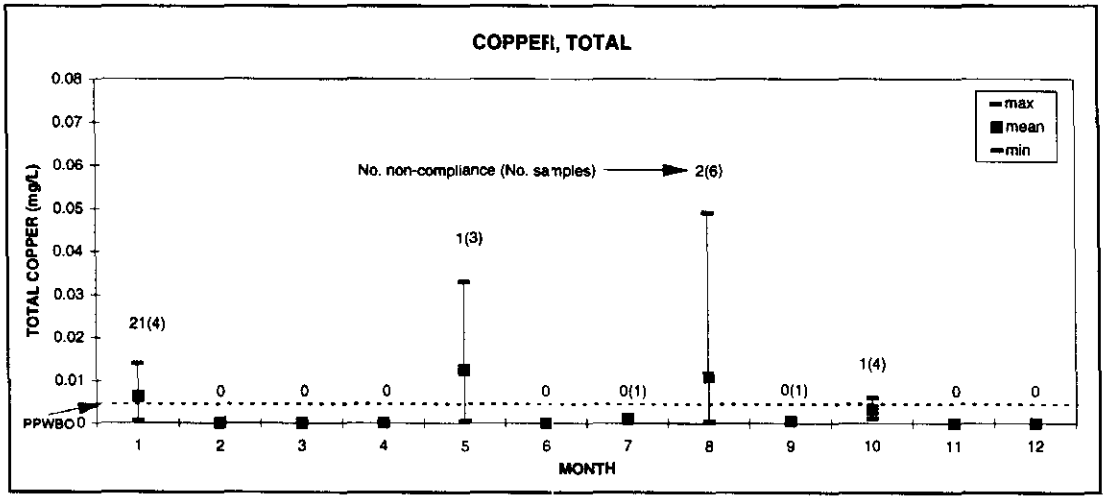


Figure 5. Copper in the Red Deer River at Drumheller (1978-1986) and Morrin Bridge (1987-1994).





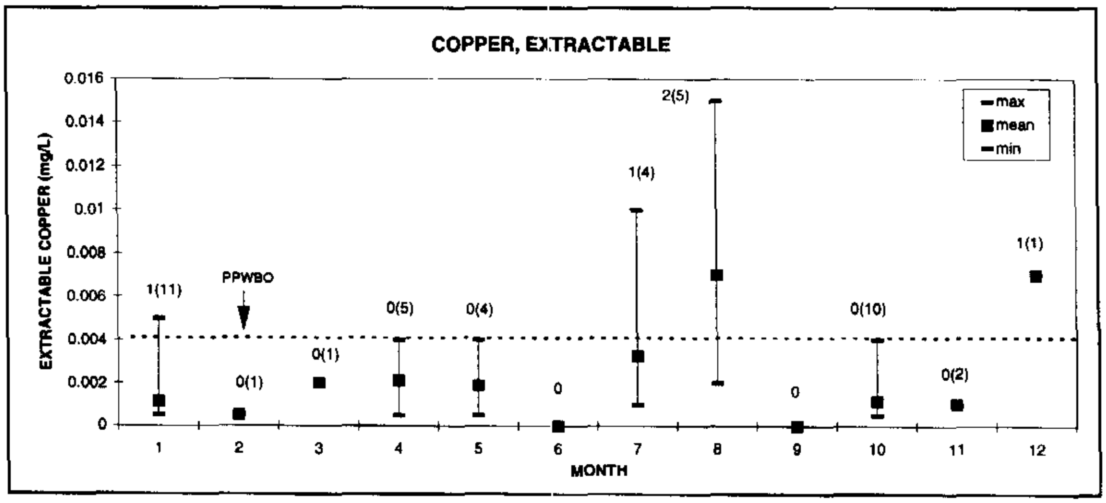


Figure 6. Copper in the Red Deer River at Hwy 2.

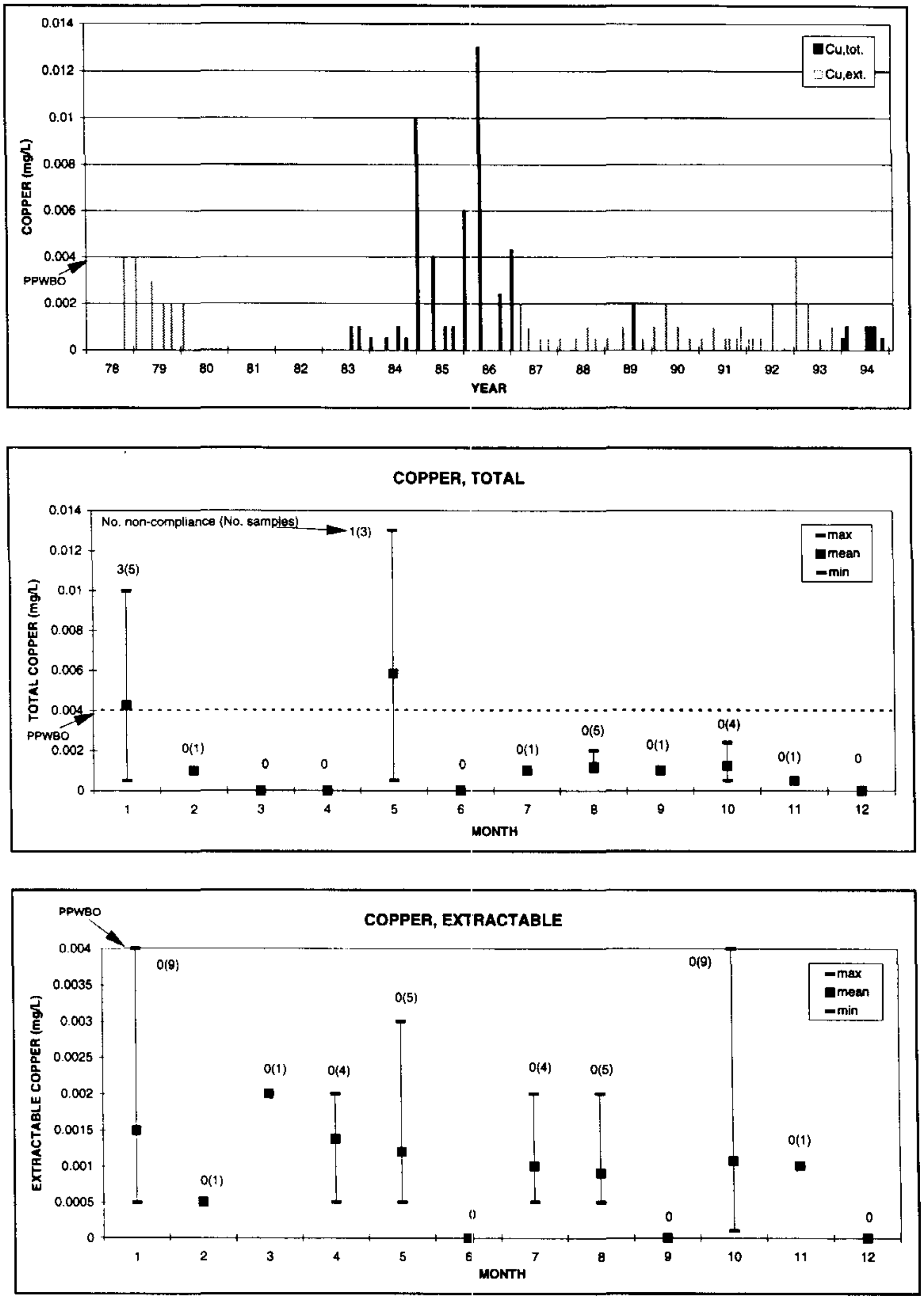
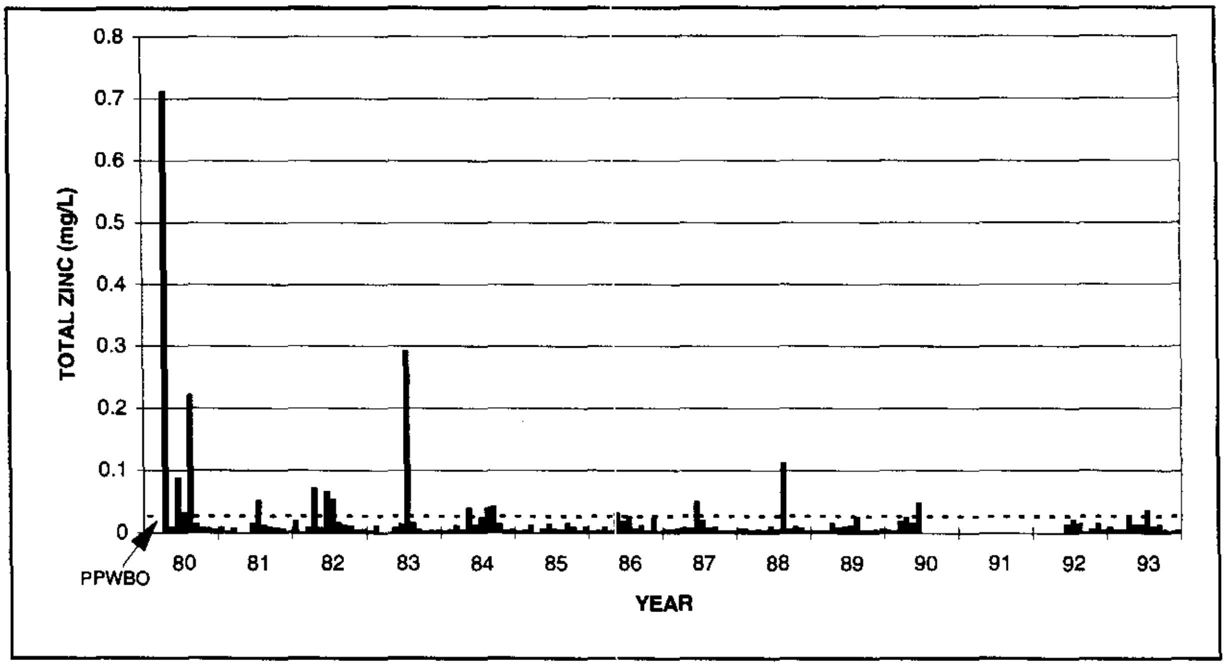


Figure 7. Zinc in the Red Deer River at Bindloss.



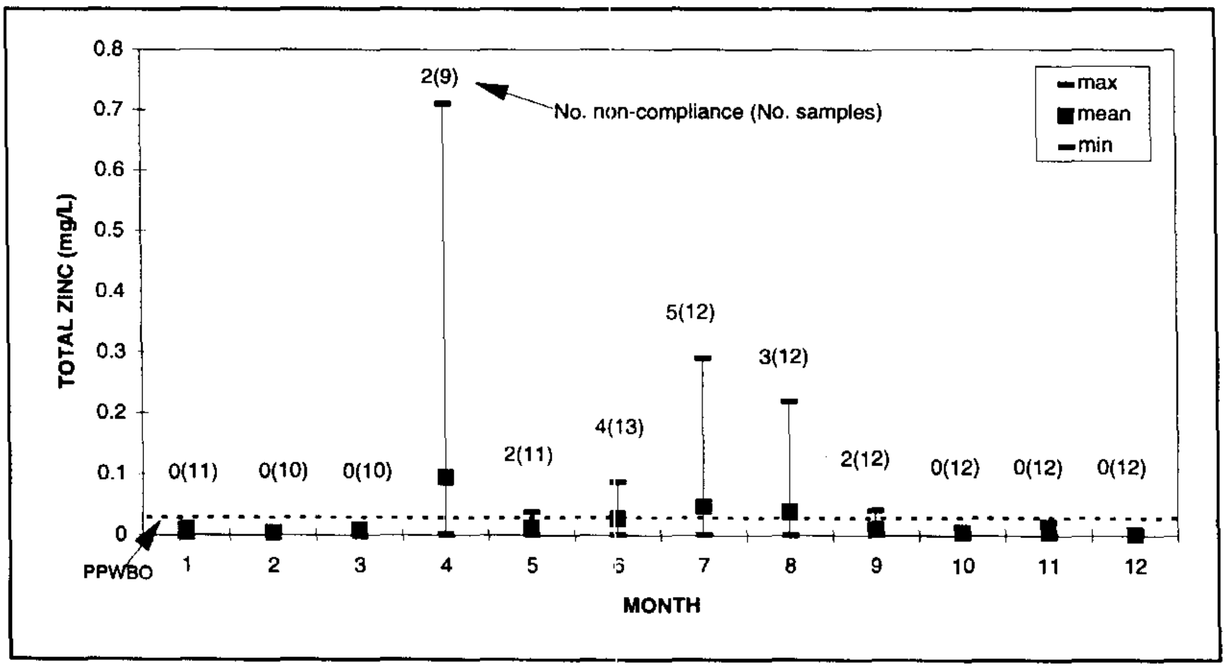
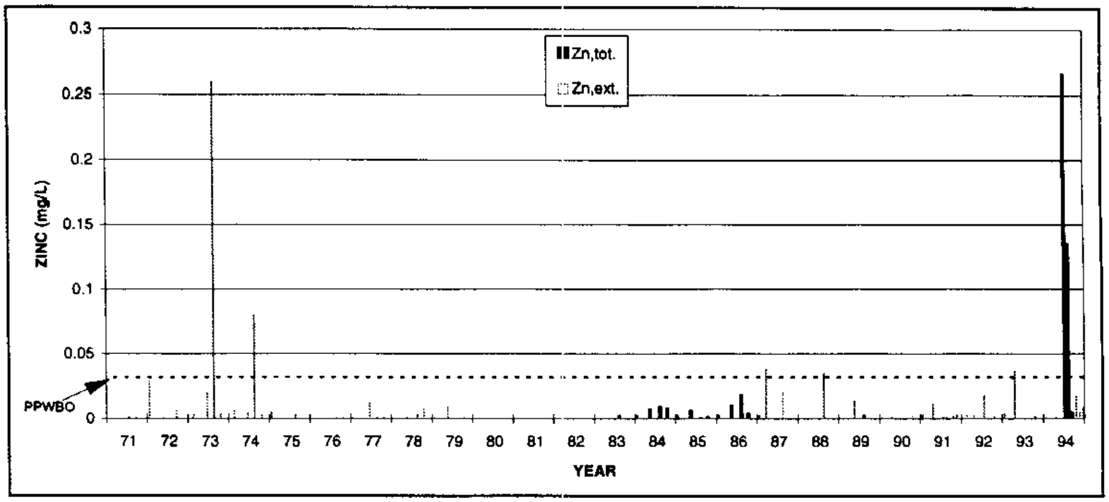
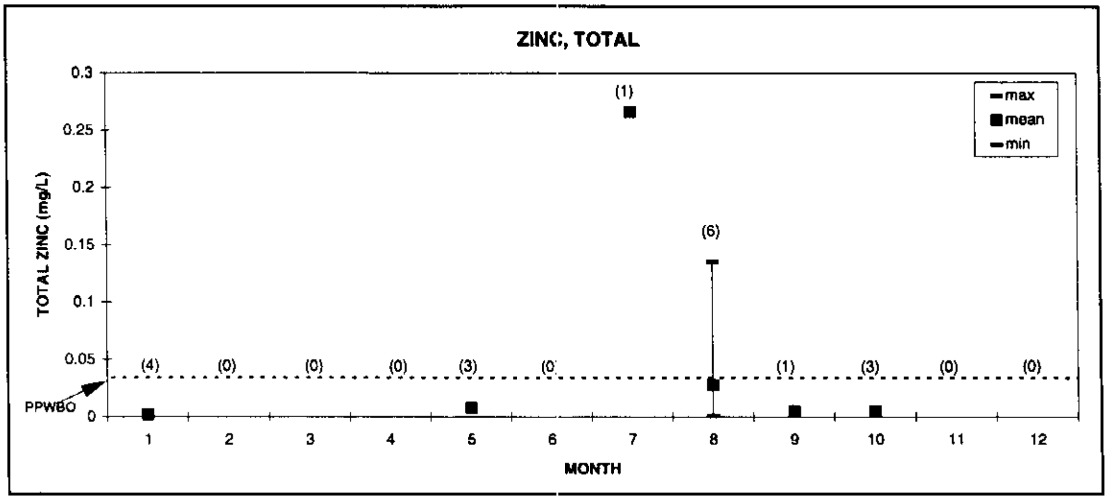


Figure 8. Zinc in the Red Deer River at Drumheller (1971-1986) and Morrin Bridge (1987-1994).





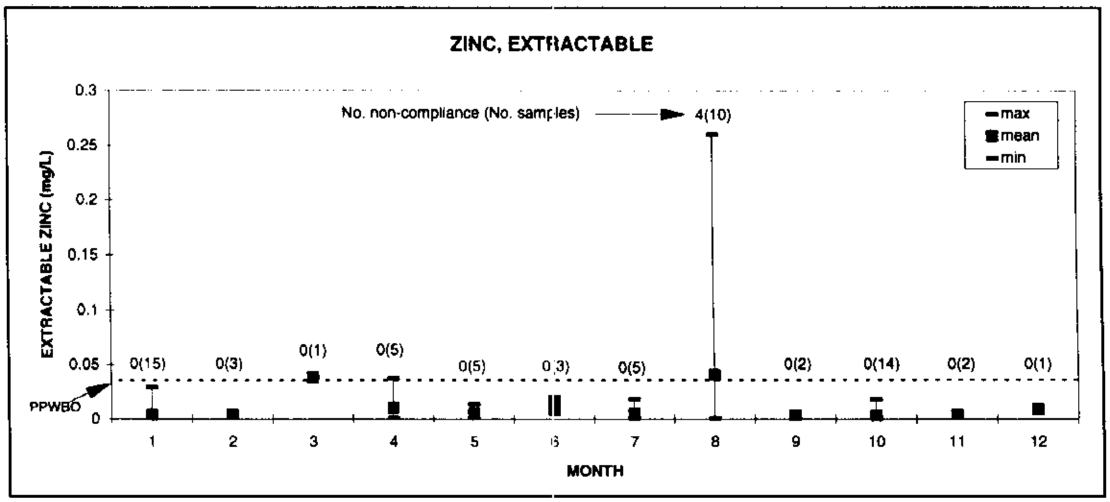
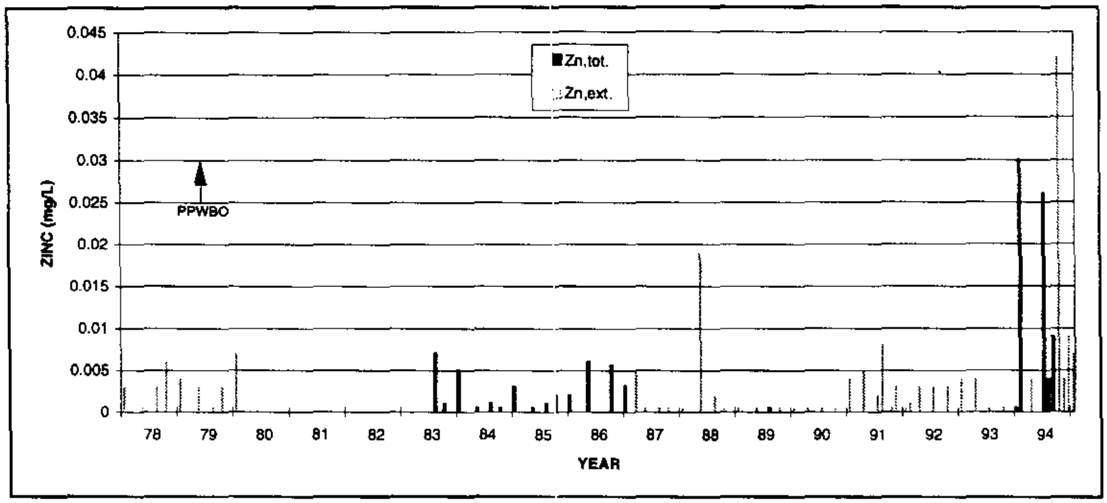
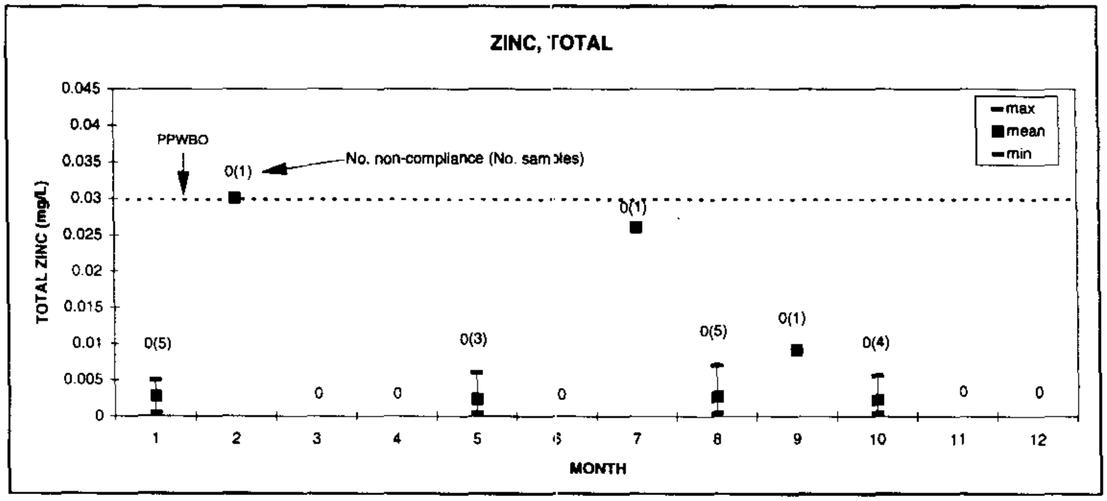


Figure 9. Zinc in the Red Deer River at Hwy 2.





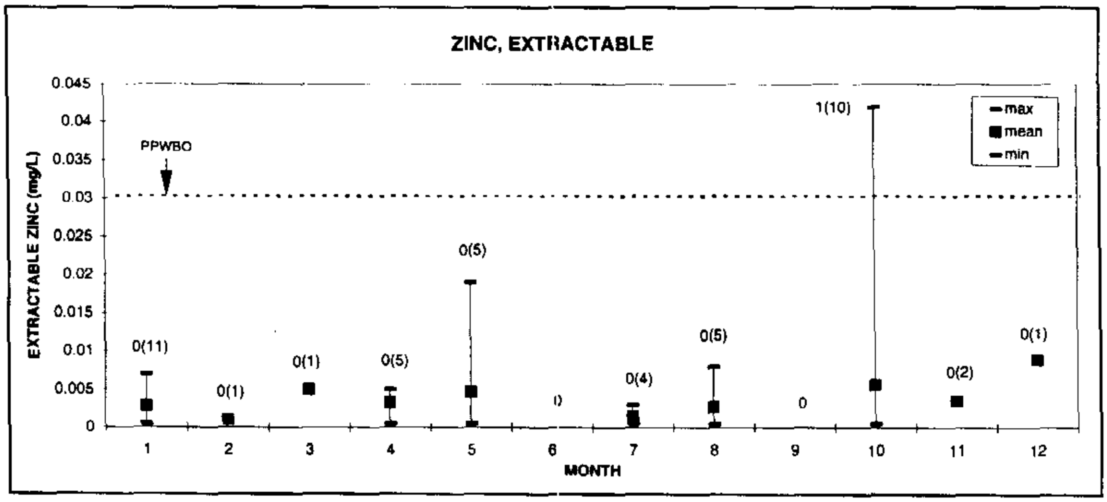
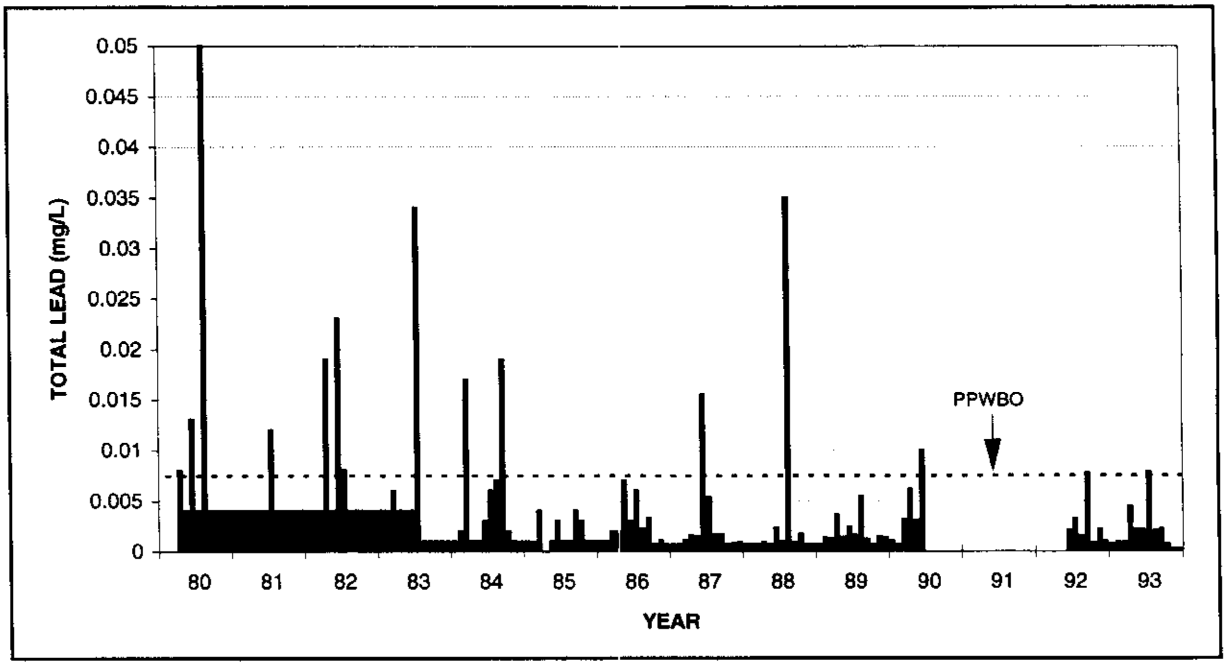


Figure 10. Lead in the Red Deer River at Bindloss.



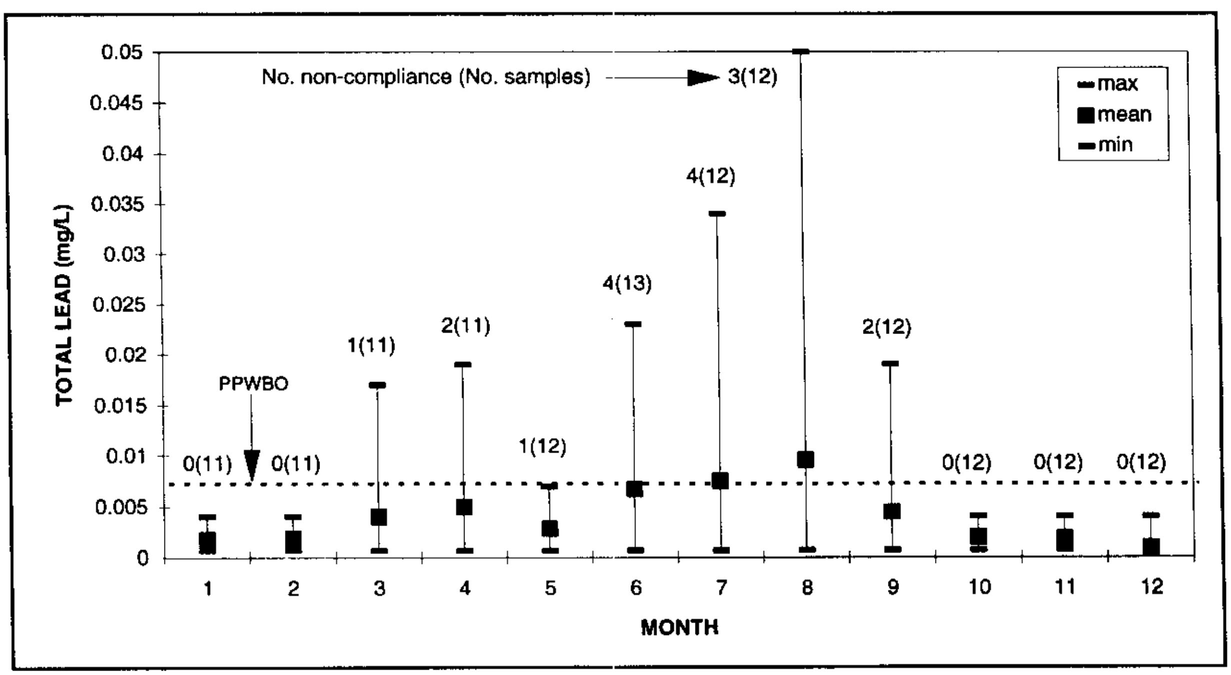
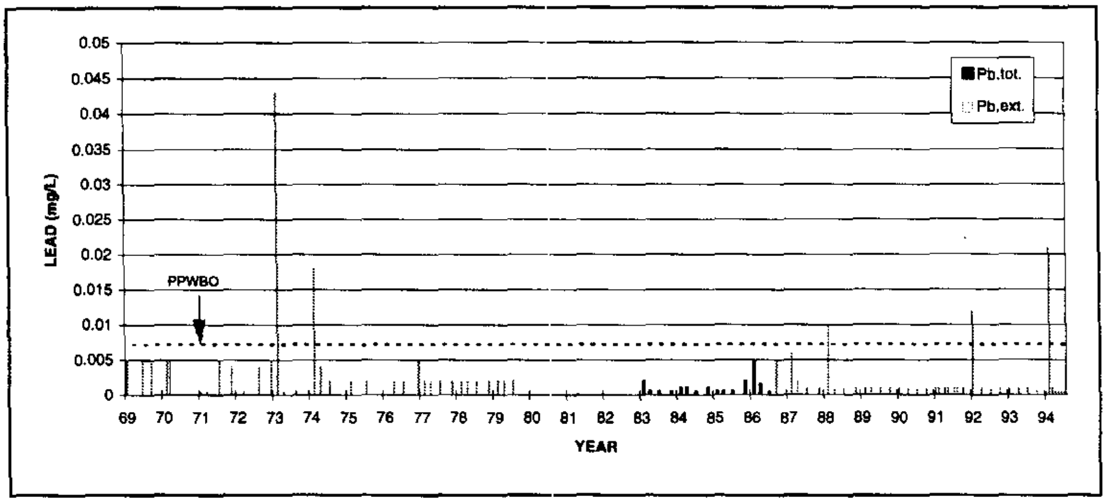
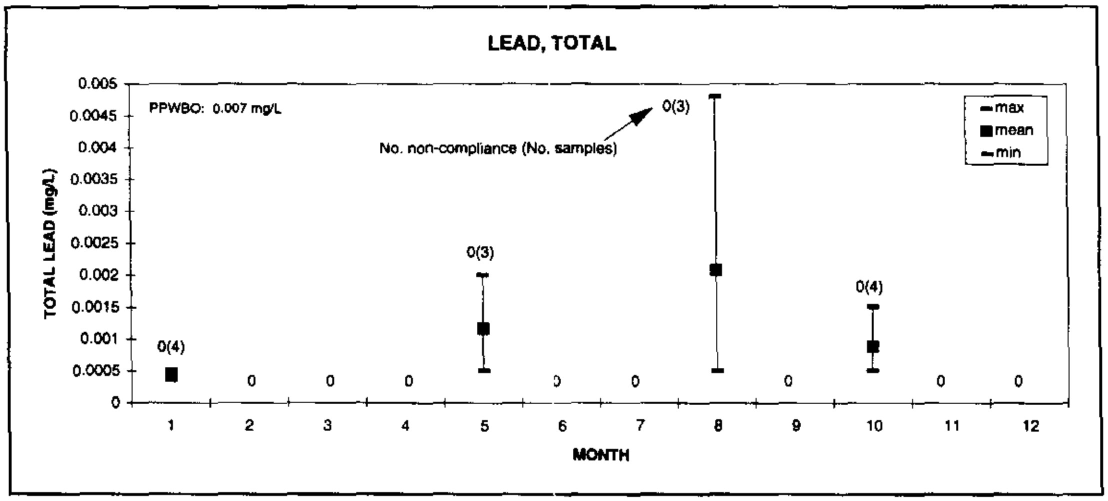


Figure 11. Lead in the Red Deer River at Drumheller (1969-1986) and Morrin Bridge (1987-1994).





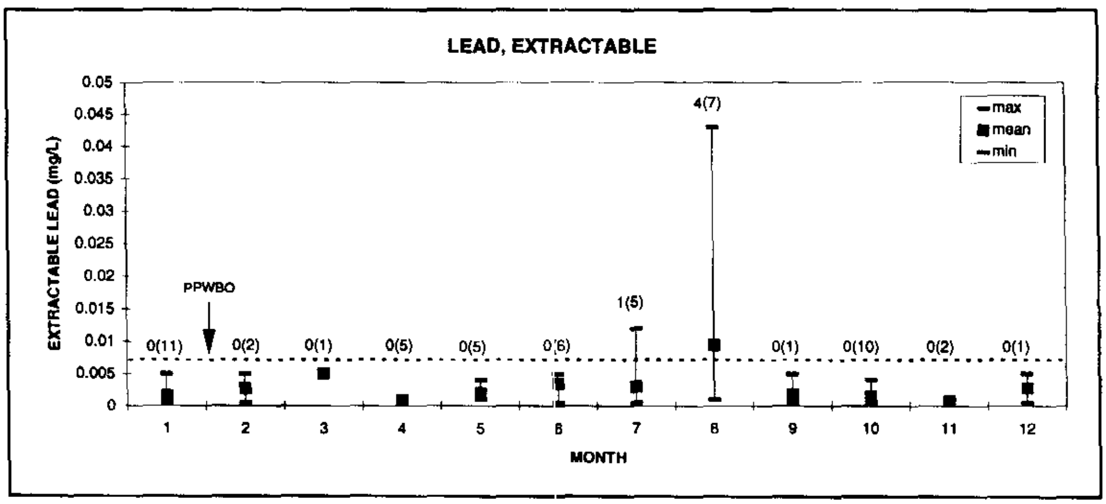


Figure 12. Lead in the Red Deer River at Hwy 2.

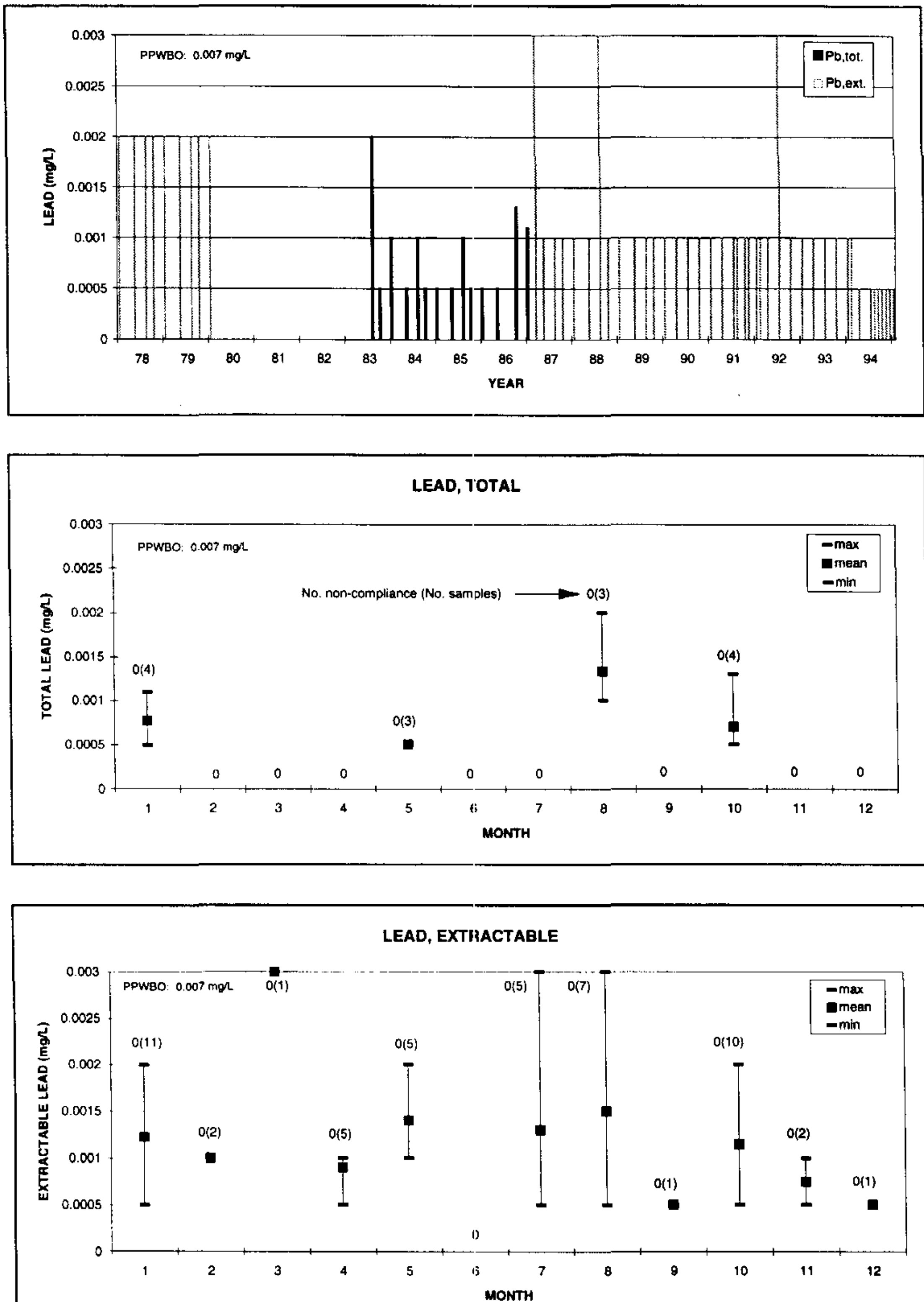
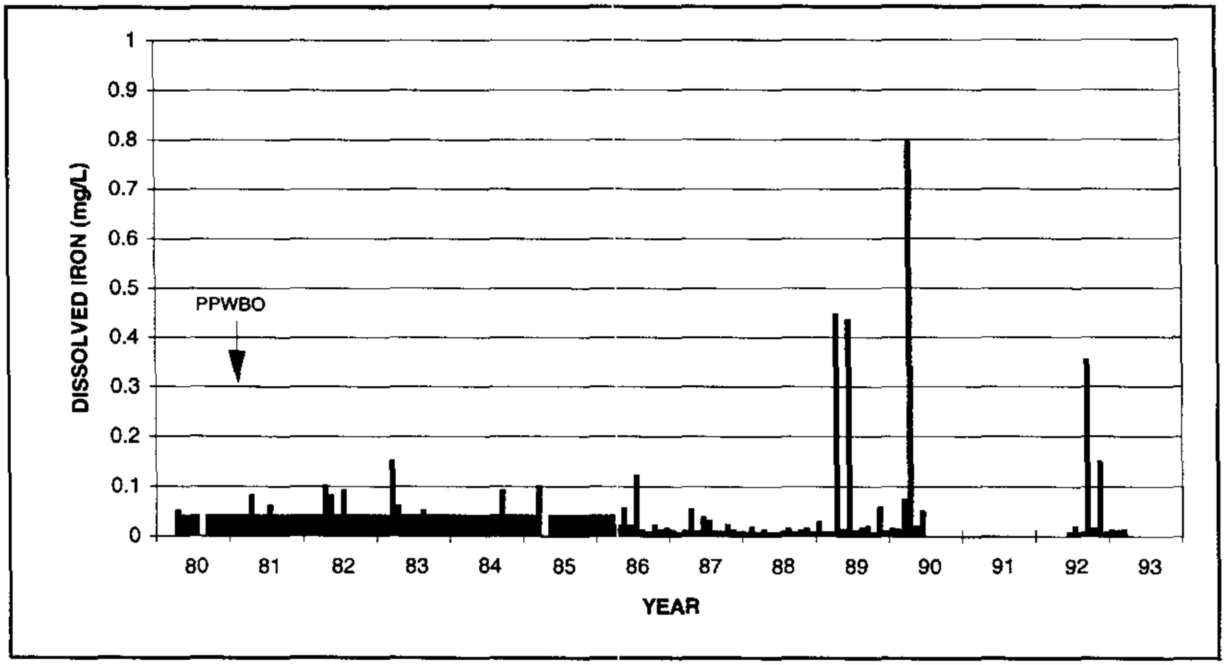


Figure 13. Iron in the Red Deer River at Bindloss.



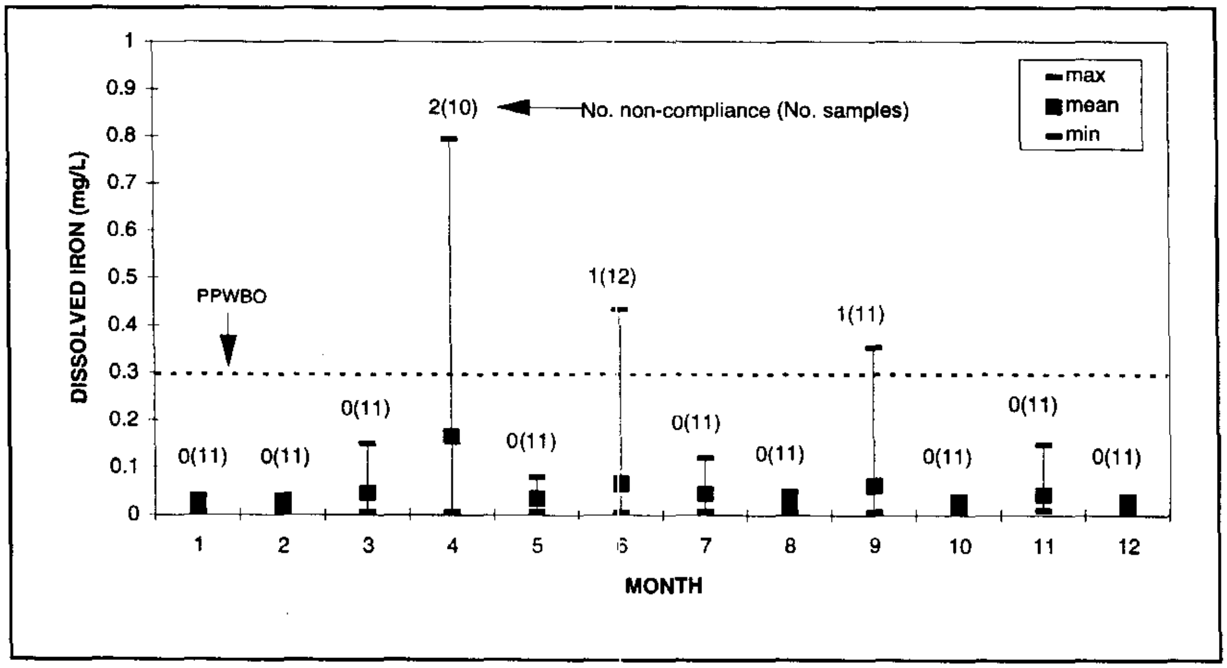
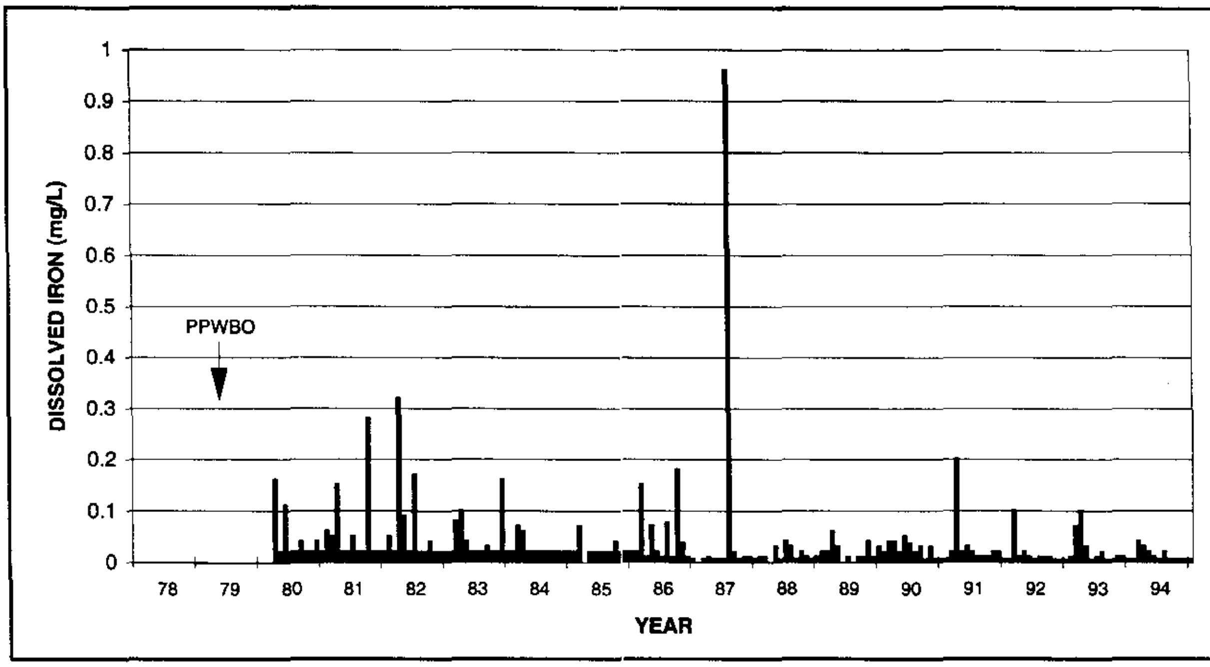


Figure 14. Iron in the Red Deer River at Drumheller (1978-1986) and Morrin Bridge (1987-1994).



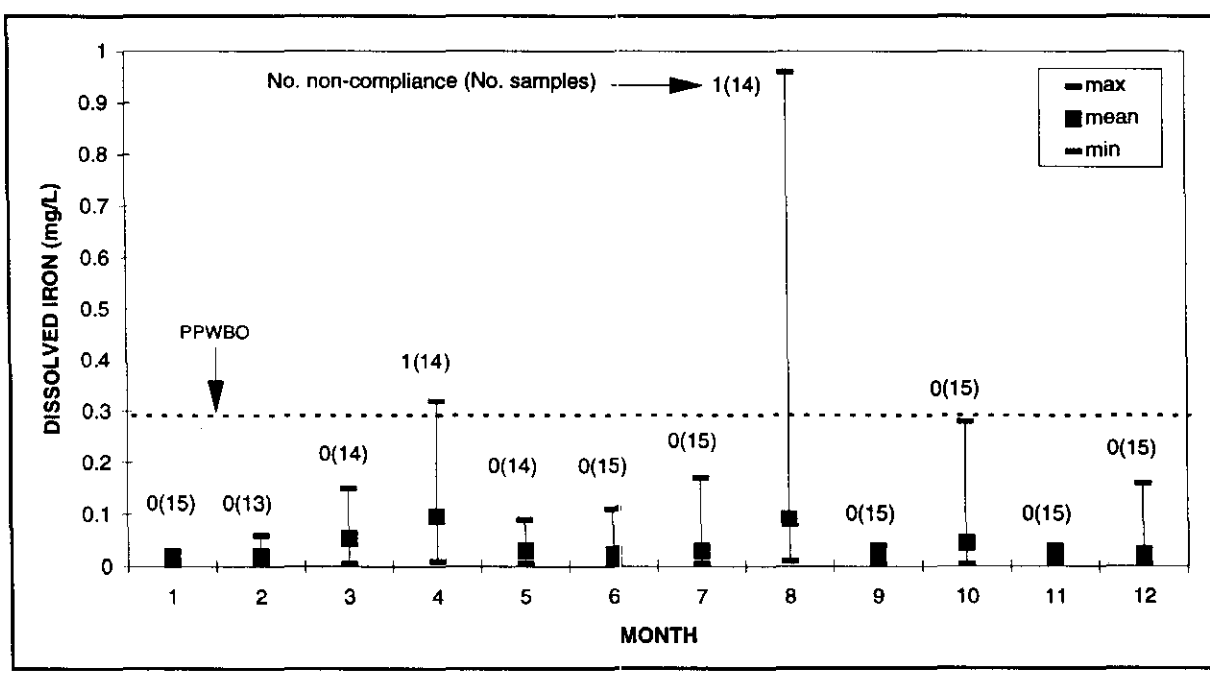
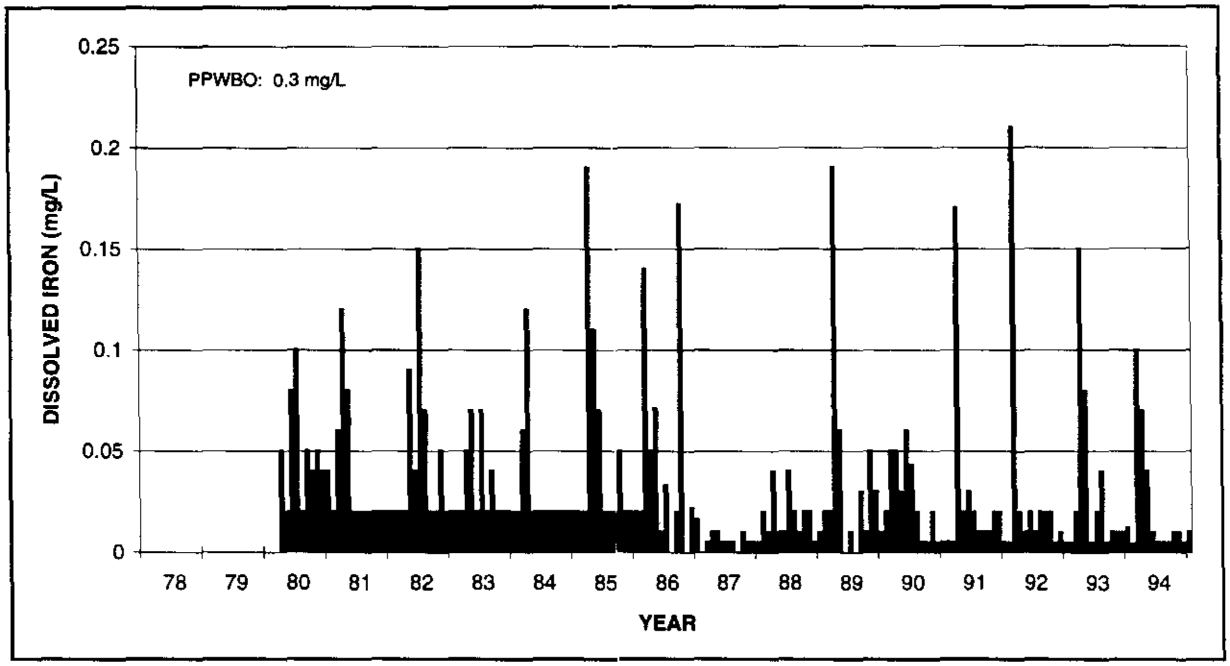


Figure 15. Iron in the Red Deer River at Hwy 2.



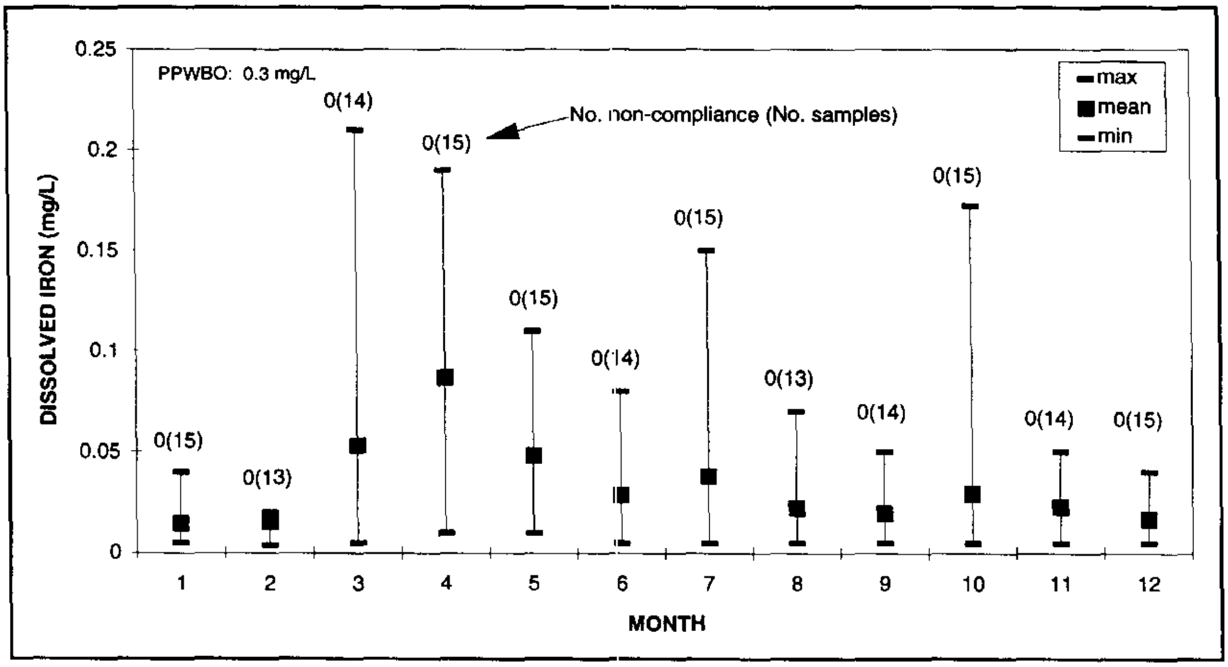
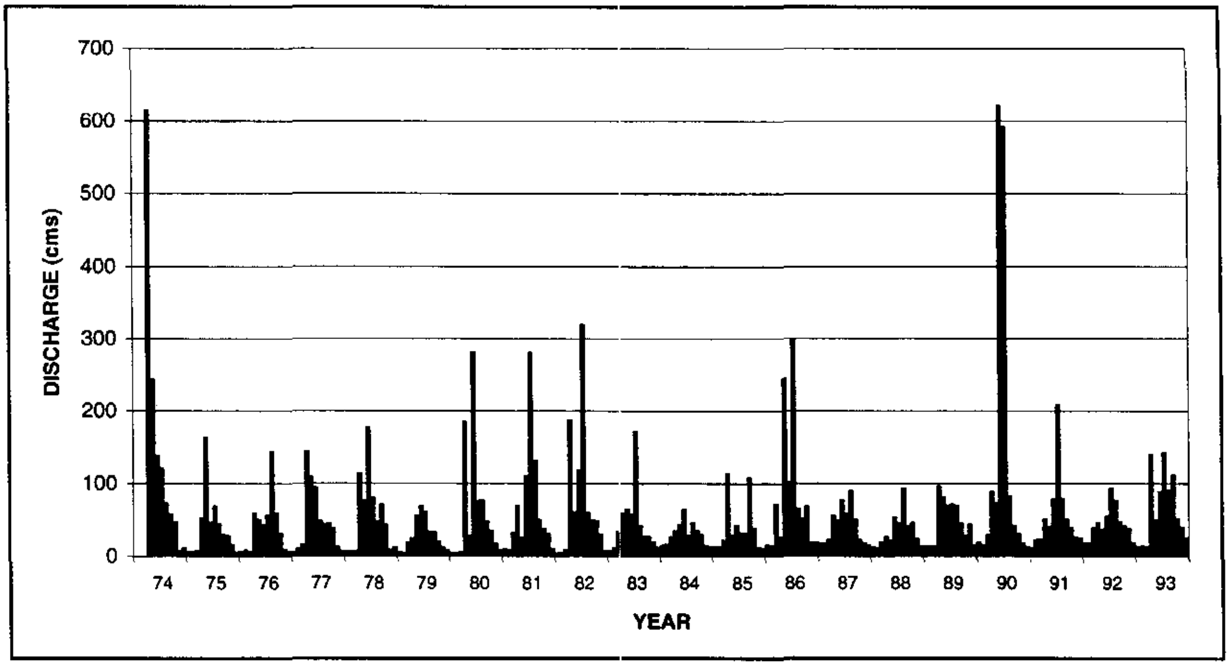


Figure 16. Discharge in the Red Deer River at Bindloss.



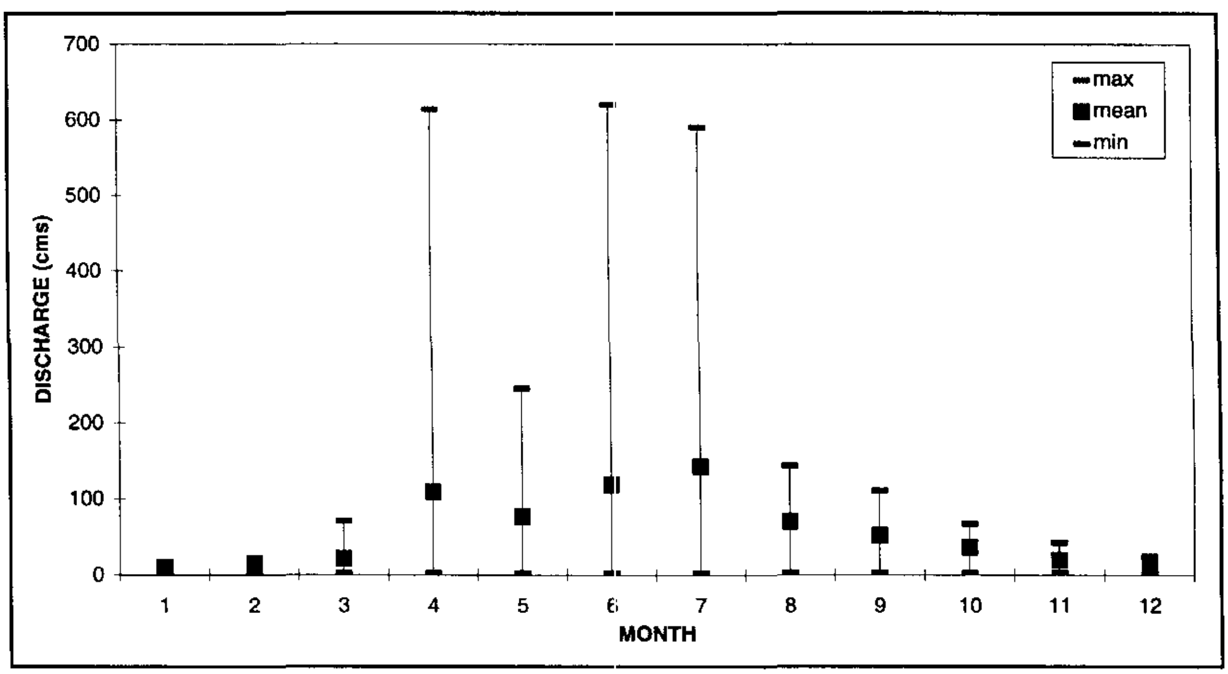
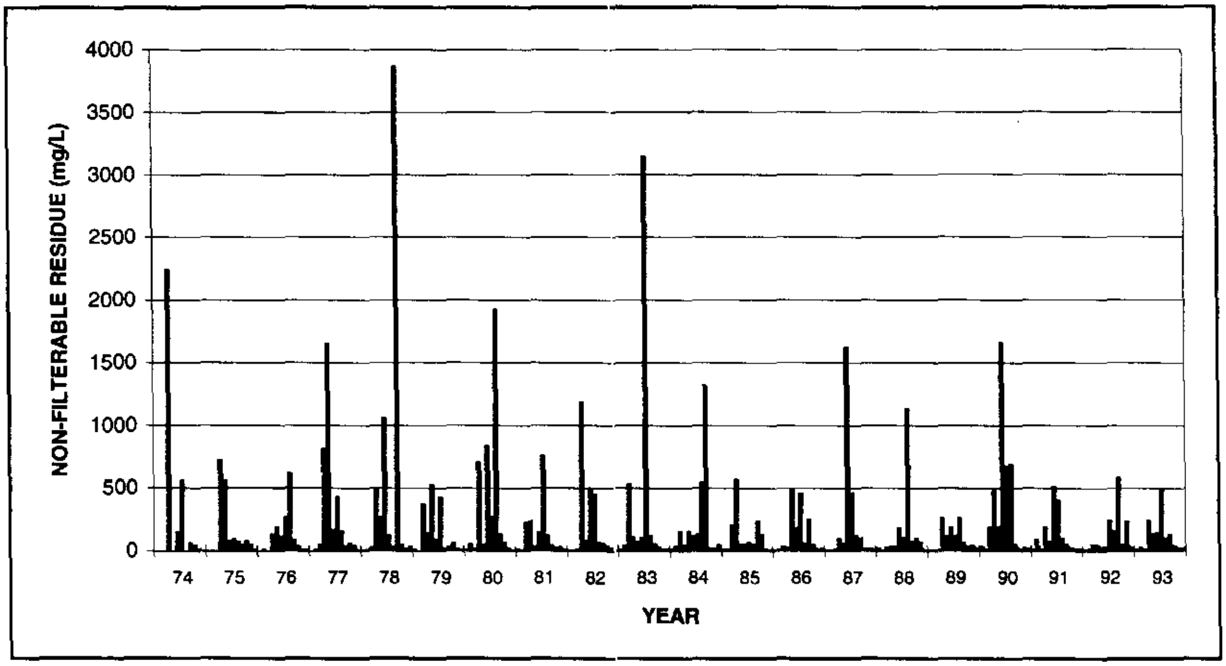
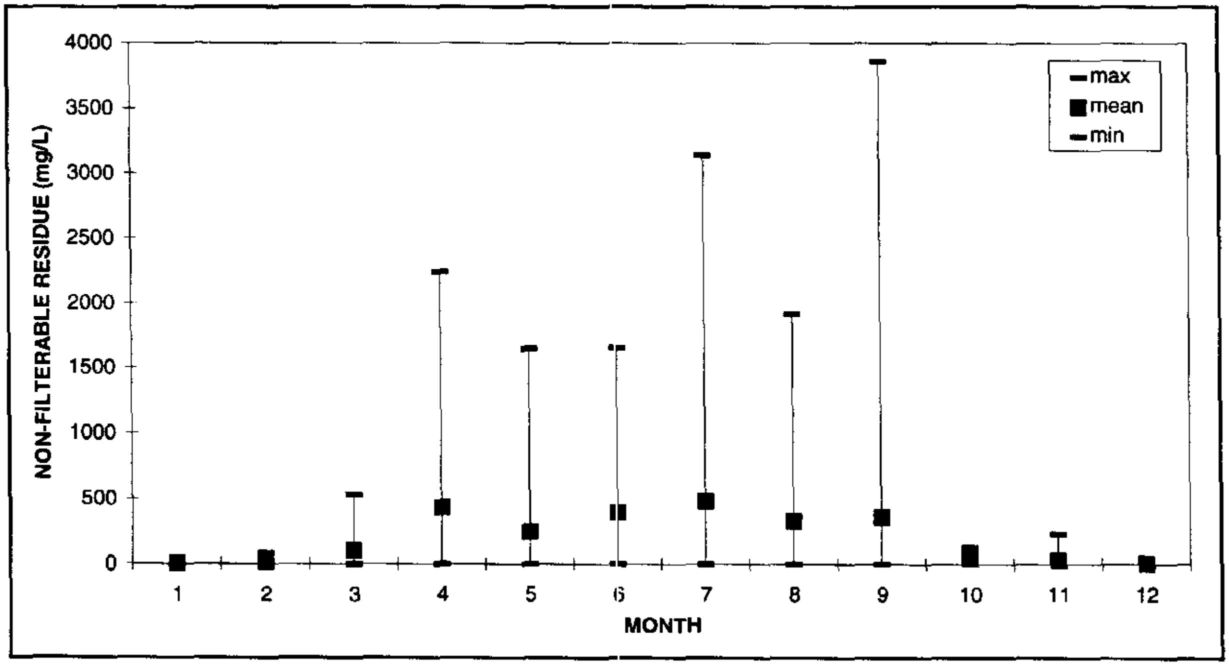


Figure 17. Non-filterable residue in the Red Deer River at Bindloss.





Appendix 1. Red Deer River at Bindloss - correlation and regression analysis of water quality data.

	NON-PARAMETRIC RANK CORRELATION COEFFICIENTS		PARAMETRIC LINEAR REGRESSION COEFFICIENT	
	Kendall Zau	**Spearman Rho**	**r**	**Data Transformation**
Flow and NFR	0.67	0.86	0.84	log - log
Flow and Cu	0.56	0.75	0.72	log - log
Flow and Zn	0.50	0.68	0.66	log - log
NFR and Cu	0.71	0.87	0.89	linear - linear
NFR and Zn	0.62	0.77	0.73	log - log

Analysis were performed using WQHYDRO Software (Aroner 1994)