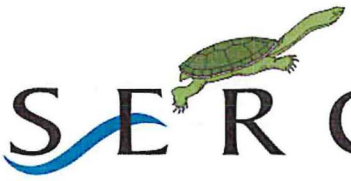
Water and sediment quality in the Bennett Springs Catchment

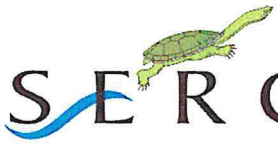
2002 – 2010 Analysis

Prepared by



South East Regional Centre for Urban Landcare

(September 2011)



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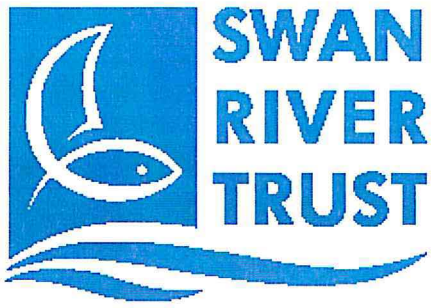

Caring for the Swan Canning Riverpark

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Executive Summary

This assessment of the water and sediment quality within the Bennett Springs sites was undertaken in September 2011 and is part of a trend analysis for the water and sediment quality at Bennett Brook catchment, which is under preparation. Initiated in 2002, the program aims to provide baseline data on the water and sediment quality within the catchment, identifying any contaminant 'hotspots' and emergent trends.

This analysis is based on an analysis from the water and sediment data collected from 2002 to 2010. The effect of seasonal and flow variations on the water and sediment quality in the Bennett Springs catchment were therefore not a part of this analysis. Consequently, the results represent the condition of the water in the catchment at the time of sampling only.

It is important to consider that there is not sufficient data for a thorough statistical analysis and all the snapshot data that have been collected come with the disclaimer that this is the data at a series of points at a single point in time and should not be taken as trends or being indicative of wider water quality even though this is the inference that is made. It is required to have 30 to 60 data points per site for decent statistics.

However, the periodicity of one sampling event per year is not enough to provide sufficient data about the condition of the catchment and to interpret trends and changes that are happening over time. Snapshots only provide information regarding a specific point in time and space and greater temporal coverage of the catchment would result in more data and therefore, a more detailed picture of the water quality in the catchment. For this reason, increasing the annual frequency has been paramount to be able to collect more information in order to analyse and discuss better the results and understand better the dynamics in the catchment.

The data was collected usually in spring on: October 16th 2002, December 16th 2003, December 14th 2004, September 13th 2005, October 12th 2006, November 5th 2007, October 22nd 2008, September 24th 2009 and October 6th 2010. Water and sediment samples were collected and analysed from two sites within the Bennett Springs catchment area located along the Emu Swamp Drain which discharges into the Bennett Brook.

The laboratory results were compared to trigger values provided in the ANZECC guidelines. Results that exceed the referenced trigger values are an indication that further investigation should be considered, as there is the potential for an environmental impact. The key findings of the 2002 - 2010 analysis are outlined below.

Background

Bennett Brook is located in the north east of the Perth metropolitan area and was once a natural creek system. However, its tributaries to the west have been significantly modified into deeply incised drains to allow the surrounding land to be utilised for development. The Brook is a slow flowing stream 17 km in length, with headwaters in Whiteman Park. The Brook is fed primarily from groundwater seepage from the Gnangara mound and discharges into the Swan River at Success Hill in Bassendean.

The Emu Swamp Main Drain has three sample sites 8, 9 and 10 which run though the Bennett Springs Estate. The catchment area of the Emu Swamp Main Drain has been, and continues to be, subjected to high levels of residential development. These sites were selected to determine the water quality entering the Brook from this major drainage line, and to assess the impact urban development has upon the water quality.

Each year, Site 10 (Emu Swamp drain – Bennett Springs estate) has recorded consistently elevated TN concentrations (1.9mg/L), suggesting an ongoing source of TN to the system localised around this vicinity. 50% of the TN recorded at this site was in the form of total oxidised nitrogen (TON), 45% of the TN present as organic-nitrogen and ammonia (5%). TON includes nitrate and nitrite, which are commonly found in fertilisers. Site 10 is downstream of a heavily urbanised area and the over-use of fertiliser on gardens or previous historical land uses may be the source.

The Bennett Springes Estate has been chosen as a case study site as it has a number of years of data that consistently shows an increase in nutrient levels from the water entering the estate to when it leaves the estate. Previous land use for turf farming has been identified as a possible source to elevated nitrogen levels in this catchment. All catchments are likely to be subject to historical land-use that may impact surface and groundwater. Known historical land use includes: a home green turf farm; sporting club; palm nursery and a mini-feedlot which all still operating in this area and would all be contributing nutrient loads.

Prior to April 2008, the north metropolitan conservation group was very active in the area of Bennett Springs with annual water and sediment quality monitoring and fish stock monitoring.

Sampling Procedures

Site Location

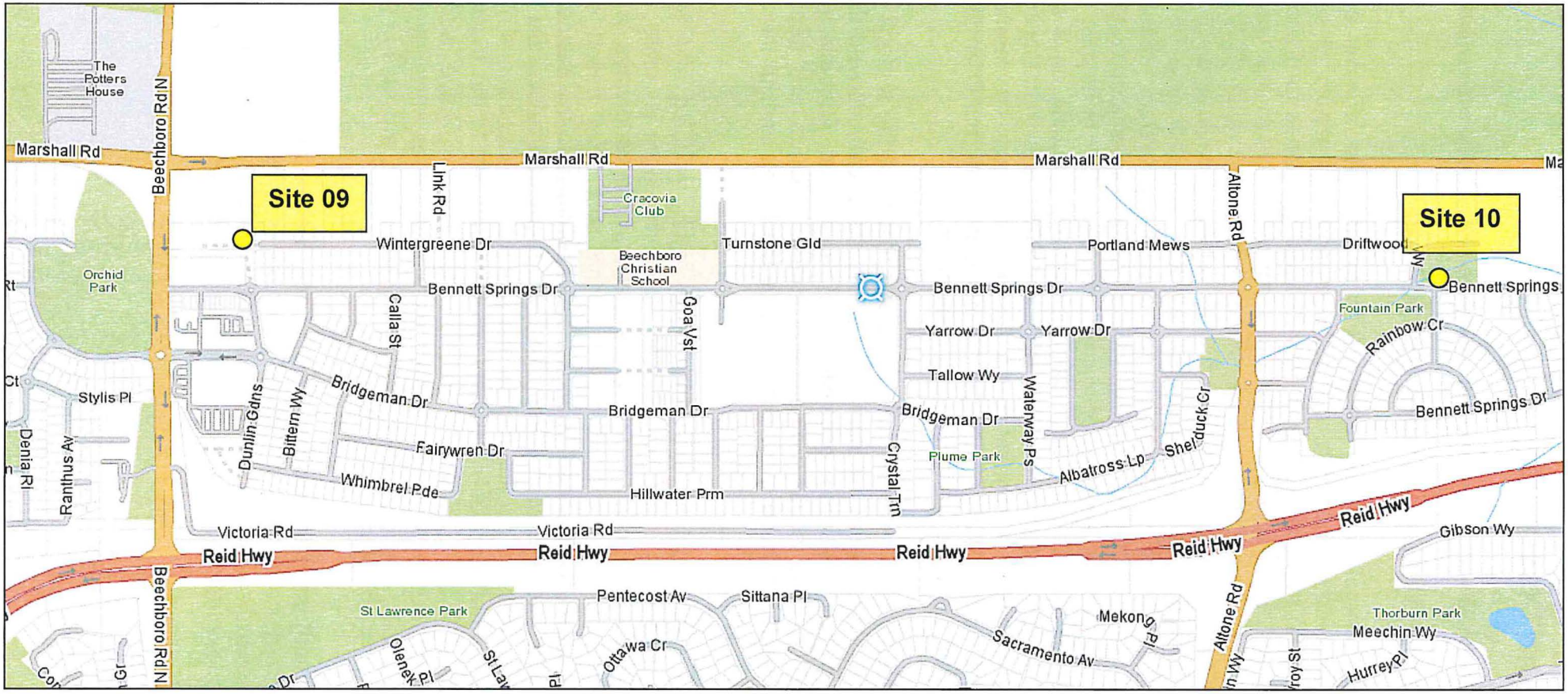
Due to the low rainfall levels during the period of sampling site 9 could not be sampled; therefore comparison between the two sites was not always possible. Figure 1 and table 1 show the location of the two sites: BBCSN 09 and BBCSN 10.

The catchment area of the Emu Swamp Main Drain has been, and continues to be, subjected to high levels of residential development, such as Ballajura Estates and Bennett Springs Estate. These sites were selected to determine the water quality entering the Brook from this major drainage line, and to assess the impact urban development has upon the water quality.

Table 1: List and description of sampling sites in the Bennett Springs catchment

Site No.	Drain section/component	Location	Easting	Northing
BBCSN09	Emu Swamp Drain	Open drain adjacent to Uniweld Coast Road Beechboro	398446	6474883
BBCSN10	Emu Swamp Drain	Compensation Basin, Bennett Springs Estate, Beechboro	400550	6474832

Figure 1: Sampling sites in the Bennett Springs catchment



Results and Discussion

Comparison of results with guidelines

To provide a general frame of reference as to the state of water quality in the Bennett Springs catchment, this analysis compares the results of sampling with trigger levels from the Australian and New Zealand guidelines for fresh and marine water quality ANZECC guidelines that are most applicable to this water body. To select which set of guidelines to use, the environmental value (EV) and level of protection of any water resource (including its receiving environment), needs to be determined and agreed upon between all key stakeholders. The guidelines recognise three levels of protection for aquatic ecosystem; those with high conservation value, slightly to moderately disturbed ecosystems and highly disturbed ecosystems. To assess the level of toxicant contamination in aquatic ecosystems, trigger values were developed from data using toxicity testing on a range of test species. The trigger values (99%, 95%, 90% and 80%) approximately correspond to the levels of protection described above. An exceedence of the referenced trigger level does not indicate that "standards" are not being met, but is an indication that further consideration should be given to the situation.

Nutrient concentrations and physical parameter results of the surface water of the Bennett Springs catchment are compared to the statistically derived default trigger values for slightly disturbed ecosystems of southwest Australia (ANZECC & ARMCANZ 2000). The results are compared to the 'lowlands river' ecosystem type, as this is considered to be most applicable to the brook and its tributaries (open drains).

Urban and industrial catchments tend to be highly modified and often artificial ecosystems where the risk of toxicant contamination is high and current environmental value is low. On that basis many of the waterways in the Bennett Springs catchment would be compared to the 80% level based on ANZECC guidance. However, the Bennett Springs Catchment flows to the Bennett Brook and this one directly into the Swan River where environmental values are high and for this reason, the toxicant results, metals and metalloid concentrations of the surface water of the Bennett Springs catchment will be compared to the trigger values for 95% protection levels, applicable to high conservation value and slightly to moderately disturbed ecosystems. Where no trigger values currently exist, results will be compared to interim or low-reliability trigger values, provided in the ANZECC guidelines (ANZECC & ARMCANZ 2000).

From a human-use perspective, the surface waters of the Bennett Springs catchment are not a source of drinking water but may be accessed by the public, either as unfenced sections or as water bodies in parks. It is therefore reasonable to compare the toxicant results to recreational guidelines that take into account risks to public health.

The concentrations of metals in the sediments of the Bennett Springs catchment are compared to the interim sediment quality guidelines where both low and high trigger values are reported (ANZECC & ARMCANZ 2000). Where metal concentrations exceed the low trigger value further consideration should be given to the situation and a further assessment of the bioavailability of the metal may be required.

The results of the chemical analysis of sediment samples collected from the Bennett Springs catchment will be compared to the ANZECC guidelines for fresh and marine water quality (ANZECC 2000), specifically the Interim Sediment Quality Guidelines. These guidelines provide both low and high trigger values. Where concentrations are between the low and high values background concentrations should be investigated. If the results exceed the high guidelines or are above the background concentrations a further assessment for the bioavailability of the metal is required.

Appendix 2 displays the ANZECC trigger values and other guidelines used in the data analysis.

Physical Properties

pH

A pH between 6.5 and 8.0 is required to sustain aquatic life in lowland rivers (ANZECC & ARMCANZ 2000). The pH of the surface water of the two sampled sites at Bennett Springs catchment were within the acceptable ANZECC range, except for three samples that were below 6.5. Site 9 recorded a pH below 6.0 in the 2002 sampling event and both sites recorded pHs <6.0 in the 2005 sampling event.

The highest value (7.82) was recorded at site 10 in 2009 and the lowest at site 9 (5.91) in 2005. Site 10 always recorded pHs higher than site 9, with the exception of the 2008 sampling event.

Dissolved Oxygen

A dissolved oxygen concentration of between 80 and 120 % is required to sustain aquatic life in freshwater lowland rivers (ANZECC 2000). Dissolved oxygen can fluctuate greatly over a diurnal cycle and it is preferable to measure it over a full diurnal cycle for a few days (ANZECC & ARMCANZ 2000). This type of DO monitoring was not conducted as part of this monitoring program.

The DO concentration of the surface waters of the Bennett Springs catchment was varied. Half (7 out of 14 samples) of the DO concentrations were below the acceptable DO range and 4 of them were above it.

The highest and lowest DO concentrations were recorded at site 9 in 2008 (128.3%) and 2002 (64.5%) respectively. Whilst the DO concentrations have usually been higher at site 9 (with the exception of records in 2002 and 2006); site 10 has always been between the acceptable range.

Electrical Conductivity

The ANZECC acceptable range for lowland rivers is 0.12 to 0.3 mS/cm.

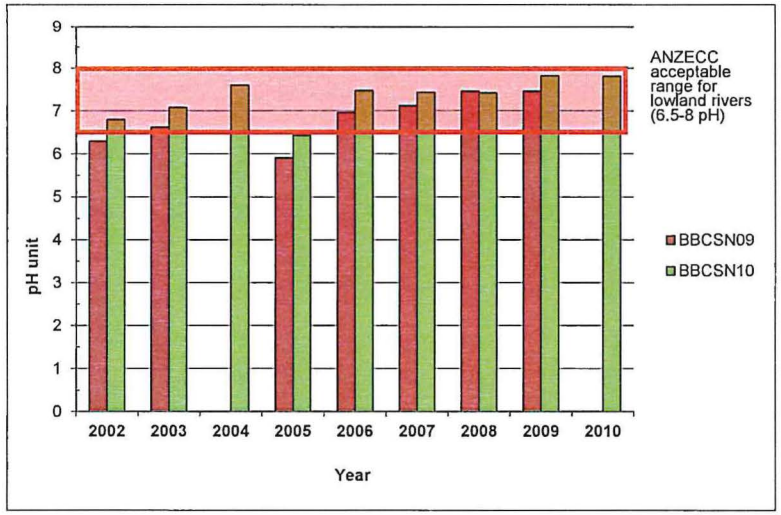
The EC levels at both sites have usually been above the acceptable range with the exception of 2006 when both sites recorded levels below 0.12 mS/cm. The only level within the acceptable range was recorded at site 9 in 2006 (0.272 mS/cm).

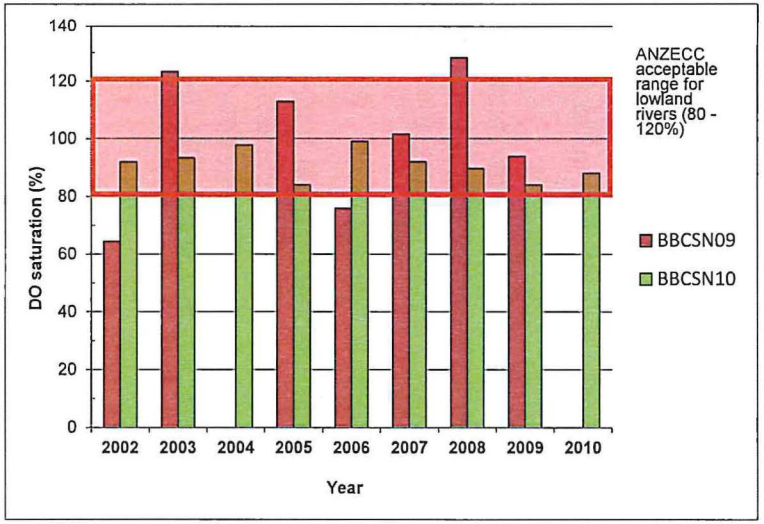
The highest and lowest EC levels were recorded at site 10 in 2009 (1.401 mS/cm) and 2008 (0.051 mS/cm) respectively. Site 10 has always recorded higher levels than site 9, with the exception of the record in 2008.

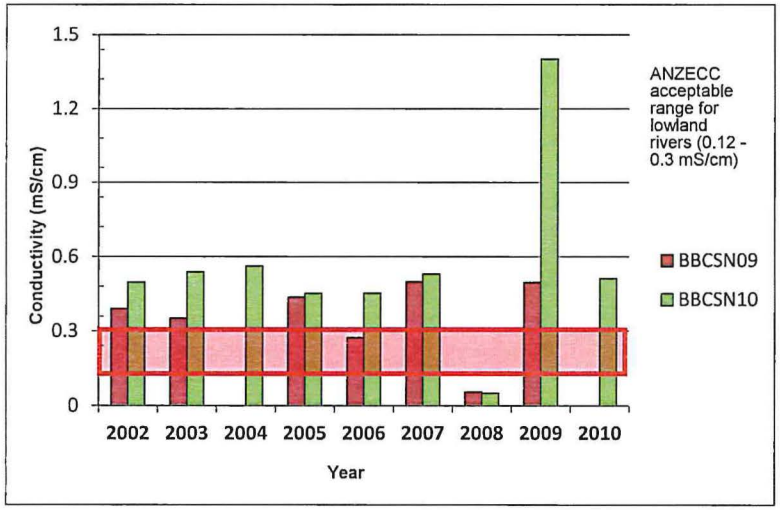
Total Suspended Solids

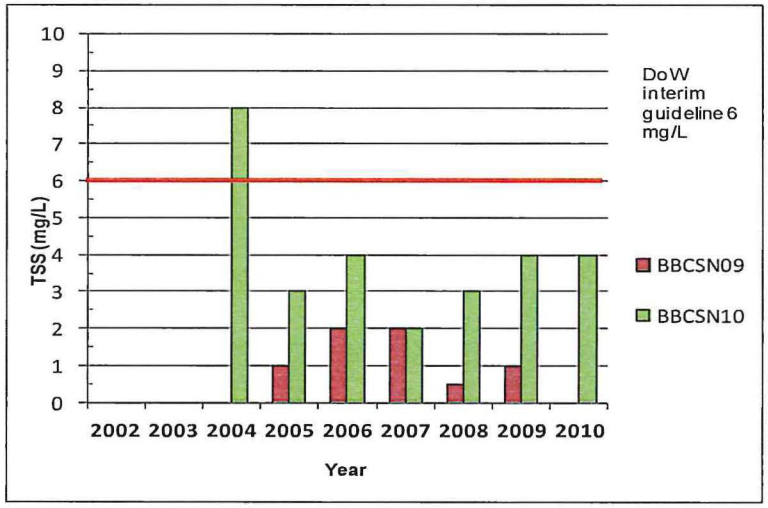
The TSS concentrations were low and below the DoW interim guideline of 6 mg/L at all sites with the only exception of site 10 in 2004 (8 mg/L); however site 10 has always recorded higher concentrations than site 9, with the exception of 2007 when both sites recorded the same concentration (2 mg/L).

Figure 2: Physical parameters in the surface waters of Bennett Springs catchment (pH, DO, EC and TSS)









Nutrient concentrations in water

Nitrogen

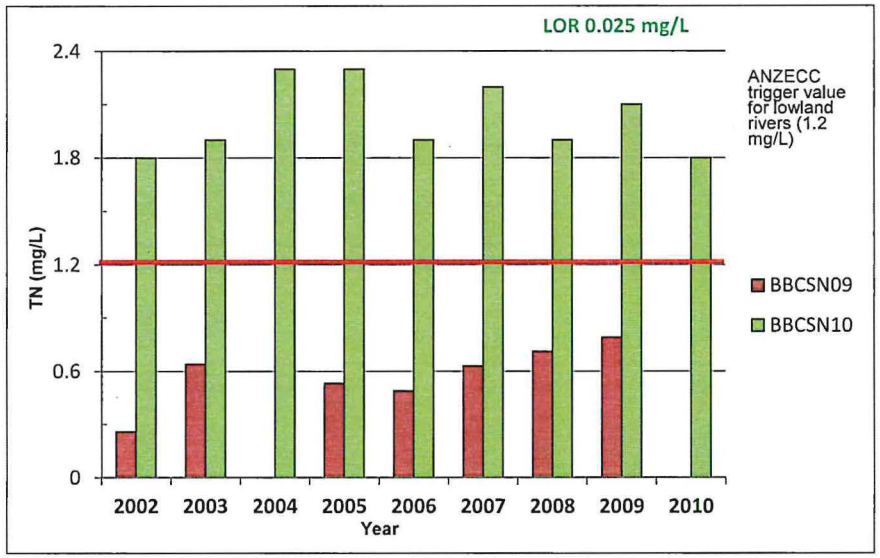
The total nitrogen (TN) concentrations at site 10 have always been above the ANZECC trigger value of 1.2 mg/L for lowland rivers and have always been below it at site 9. The highest concentration was recorded in 2010 (1.8 mg/L) at site 10 and the lowest in 2002 (0.26 mg/L) at site 9.

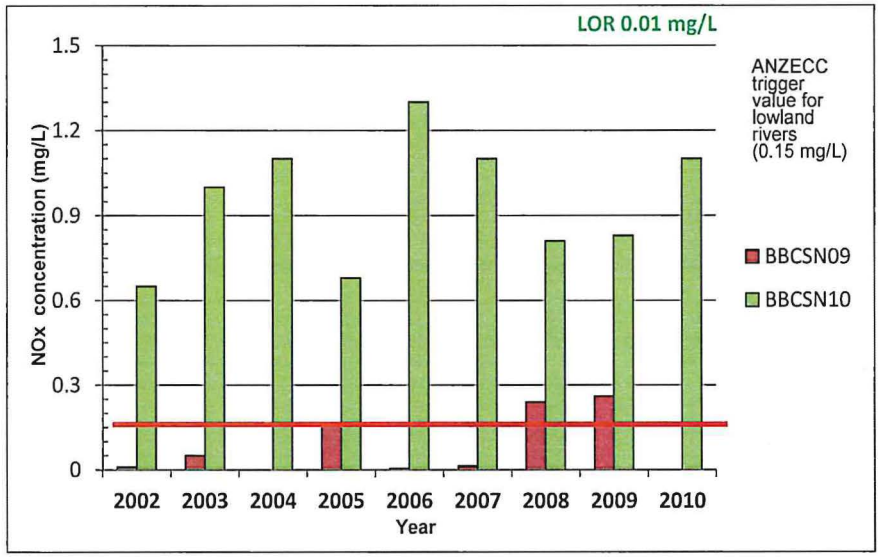
Total oxidised nitrogen (NO_x) has been the main component of TN over the nine years of monitoring for both sites, but the major concern is at site 10 since all the concentrations of NO_x have exceeded the ANZECC trigger value for lowland rivers of 0.15 mg/L. This site is downstream of a heavily urbanised area and the over-use of fertiliser on gardens or previous historical land uses may be possible sources.

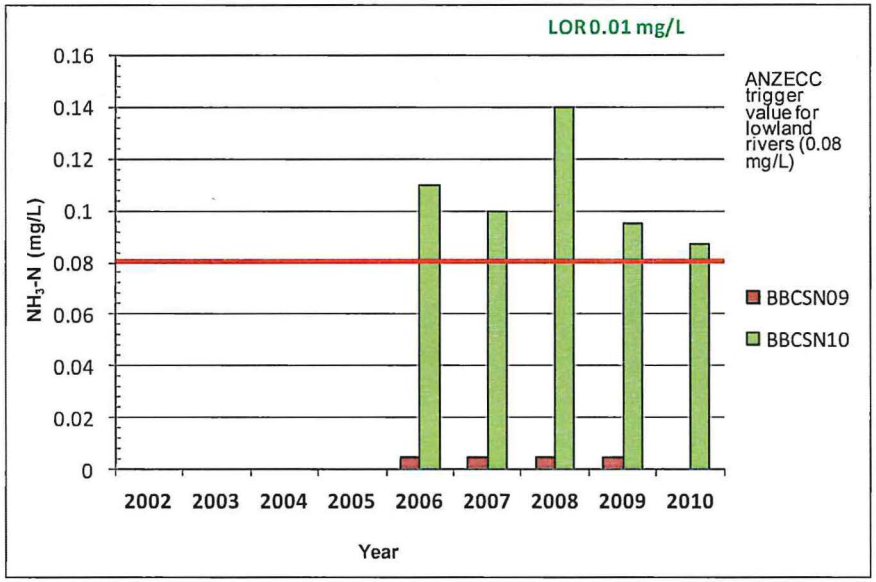
The nitrogen as ammonia/ammonium (NH_3-N/NH_4-N) concentrations exceeded the ANZECC trigger value of 0.08 mg/L at site 10 since 2006 when this parameter was added to the monitoring program. At site 9 the concentrations have always been below the limit of reporting of 0.01 mg/L.

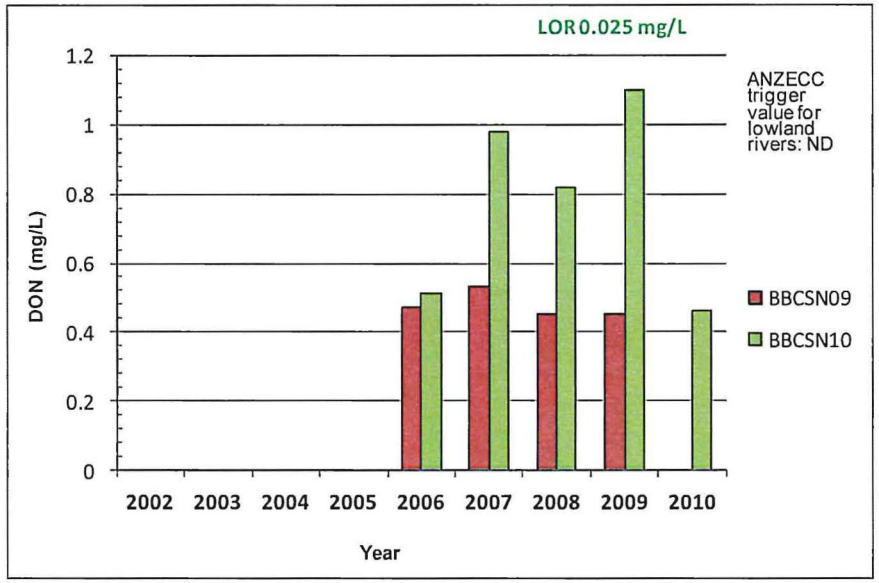
As no guideline currently exists for dissolved organic nitrogen (DON) it is difficult to assess this concentration in terms of threats to ecosystem and/or human health. However, samples at both sites have always exceeded the limit of reporting value (0.025 mg/L) since 2006 when this parameter was added. DON has been more significant component of the TN at site 9 than at site 10.

Figure 3: Nitrogen concentrations in the surface waters of Bennett Springs catchment (TN, NO_x, NH_3-N and DON)







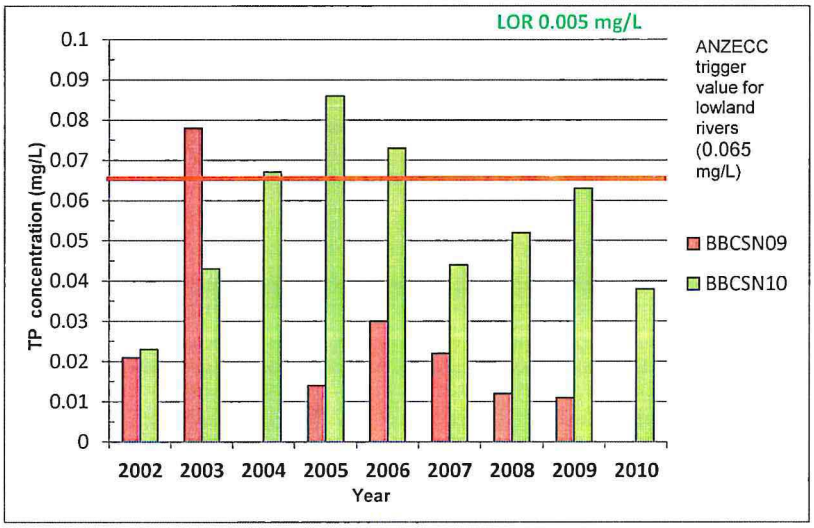


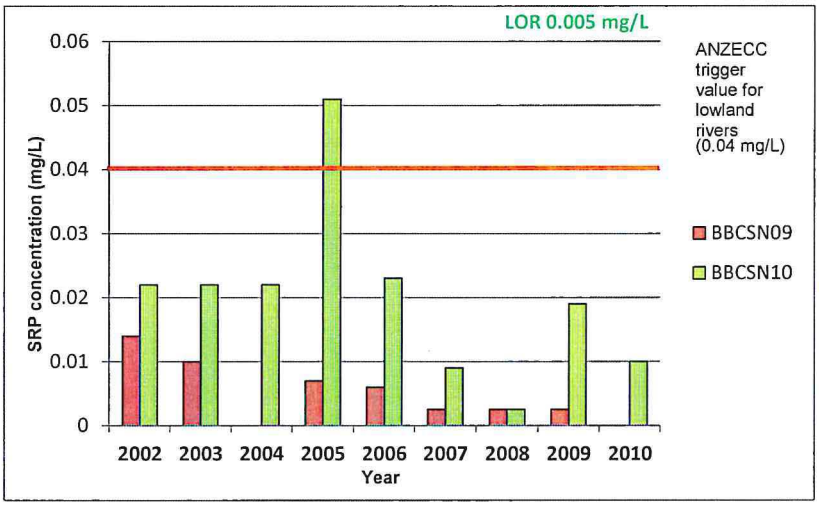
Phosphorus

The concentrations of total phosphorus (TP) have varied over the nine year monitoring program at Bennett Springs and the majority of the samples (11 out of 15) have recorded concentrations below the ANZECC trigger value for lowland rivers of 0.065 mg/L. However, site 10 has usually recorded higher concentrations than site 9, with the exception of 2003 when site 9 recorded 0.078 mg/L and site 10 recorded 0.043 mg/L.

Soluble Reactive Phosphorus (SRP) provides a measure of the immediately available phosphate for plant uptake and as such, is attributed to algal blooms of rapid growth in aquatic flora. Over the nine year period of monitoring, samples at both sites have recorded SRP concentrations below the ANZECC trigger value for lowland rivers (0.04 mg/L) with the exception on 2004 when site 10 recorded 0.051 mg/L.

Figure 4: Phosphorus concentrations in the surface water of the Bennett Springs catchment (TP and SRP)



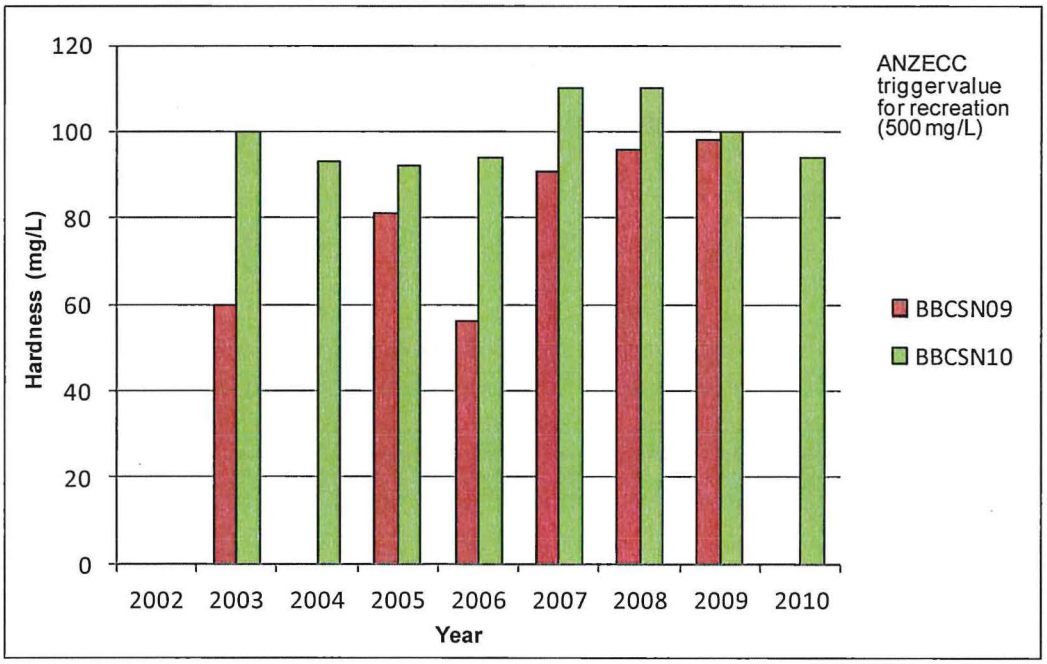


Water hardness

Water hardness can have an effect on trigger values for particular metals concentrations such as copper, cadmium, zinc, lead, nickel and chromium. Water samples with higher concentrations of water hardness need to have the trigger values for these metals amended by a certain multiplication factor, as recommended in ANZECC (2000) guidelines. As water hardness is variable between sites, the trigger values for these particular heavy metals can be different for each site. Trigger values for these metals have been corrected based on the concentration of water hardness for each site, using the hardness-dependant algorithm provided in ANZECC and ARMCANZ (2000).

There is no ANZECC guideline regarding water hardness and ecosystem health, however all sites were below the ANZECC recreational guideline of 500 mg/L. Water hardness in the surface waters of the Bennett Springs catchment have always been within the moderate range (60 to 119 mg/L), with the only exception of site 9 in 2005 when the concentration was in the soft range (0-59 mg/L). Site 10 has always recorded hardness concentrations higher than site 9.

Figure 5: Water hardness concentrations in the surface water of Bennett Springs catchment



Metals in water

Aluminium

The ANZECC trigger value for aluminium is 0.055 mg/L but is only applicable when the pH is greater than 6.5. The aluminium concentration in the surface waters of the Bennett Springs catchment were elevated, with all nine samples exceeding the ANZECC trigger value of 0.055 mg/L. All recorded aluminium concentrations are valid as all samples recorded pH readings greater than 6.5.

The cause(s) of the elevated aluminium concentrations is currently unknown, but may be attributed to an accumulation of the natural release of aluminium from sediment, as well as possible contaminants flowing in from industrial areas and historical land uses. These possible sources vary between sites throughout the catchment.

Site 10 has always recorded higher aluminium concentrations than site 9. The highest and lowest concentrations were recorded in 2007 at site 10 (0.33 mg/L) and at site 9 (0.087 mg/L).

Arsenic

The ANZECC recreational trigger value of 0.05 mg/L and the trigger value of 0.024 mg/L for freshwater lowland rivers should not be exceeded. Arsenic concentrations at both sites have always been below the ANZECC trigger values and the majority of the samples have been below the limit of reporting. Site 10 has recorded concentrations above the limit of reporting in 2007, 2008 and 2009 (0.002, 0.001 and 0.001 mg/L respectively).

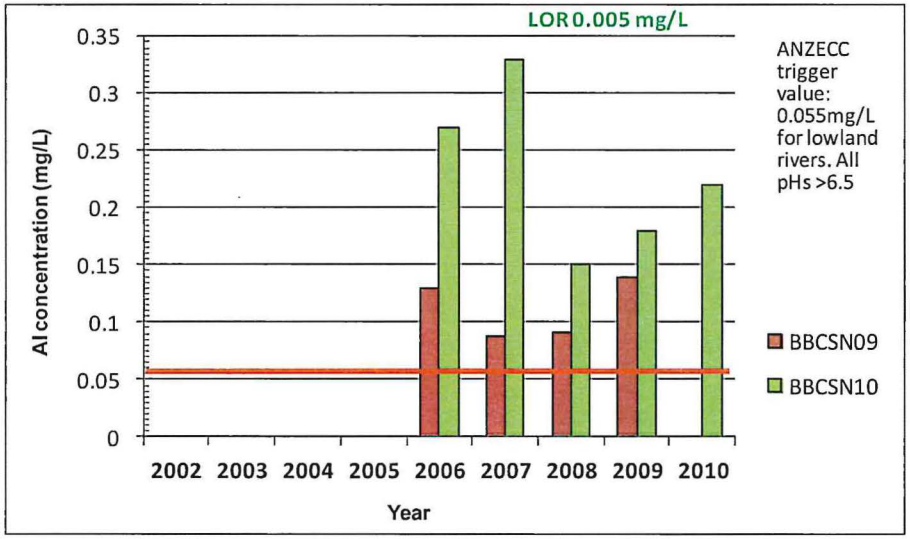
Cobalt

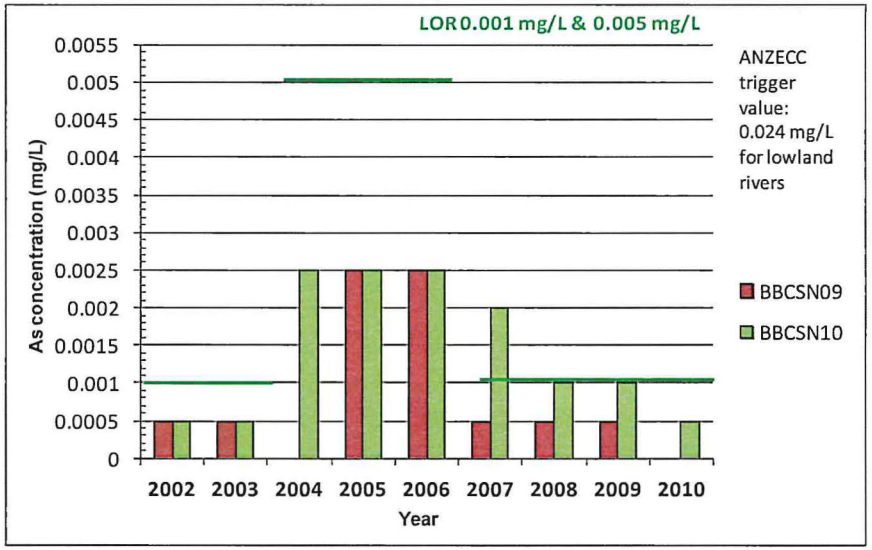
Currently no recreational trigger value or guideline exists for cobalt in surface waters, however the ANZECC trigger values for freshwater lowland rivers is 0.0028 mg/L. Both sites have always recorded concentrations below the limit of reporting (0.001 mg/L) and therefore, the ANZECC trigger value (0.0028 mg/L).

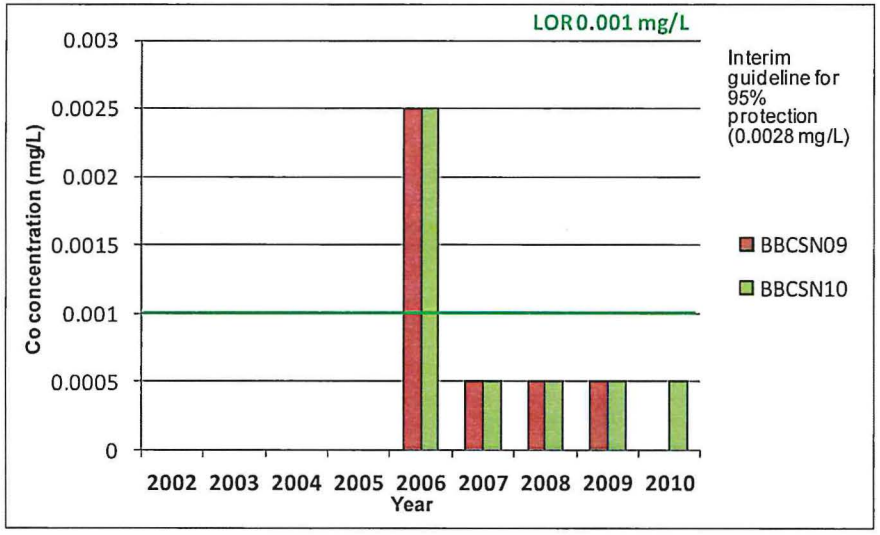
Iron

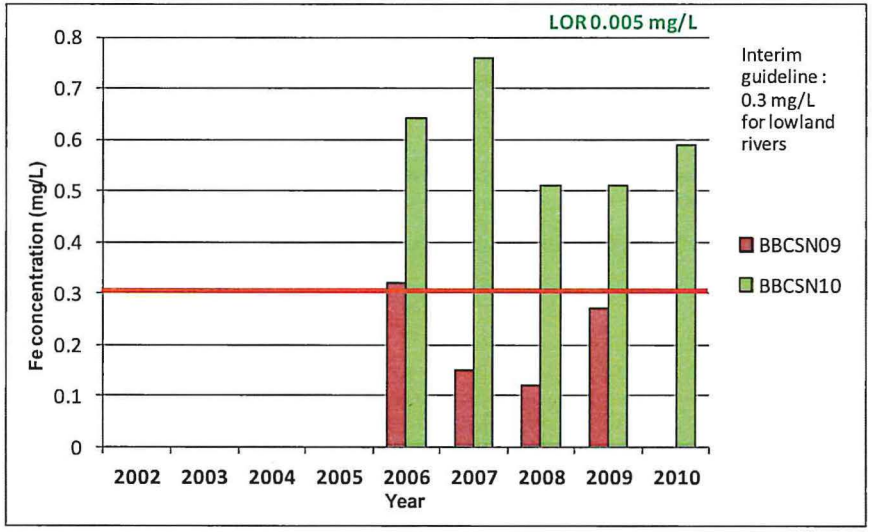
The interim guideline value for lowland rivers and recreational value (both 0.3 mg/L) should not be exceeded. The total and soluble iron concentrations in the surface waters of the Bennett Springs catchment have always been above the interim guideline at site 10. Only one sample in 2006 exceeded the guideline at site 9. The highest concentration of 0.76 mg/L was recorded at site 10 in 2007 and the lowest concentration of 0.12 mg/L at site 9 in 2008.

Figure 6: Aluminium, Arsenic, Cobalt and Iron concentrations in the surface waters of the Bennett Springs catchment









Mercury

The ANZECC trigger value for 95% protection of 0.0006 mg/L and recreational value of 0.001 mg/L should not be exceeded. Both sites have always recorded concentrations below the trigger values and the majority of the times below the limit of reporting (0.0001 mg/L); the only exception was in 2005 when both sites recorded concentrations of 0.0001 mg/L.

Manganese

The ANZECC recreational trigger value of 0.1 mg/L and the trigger value of 1.9 mg/L for freshwater lowland rivers should not be exceeded. Manganese concentrations throughout the surface waters of the Bennett Springs catchment have been low and below the trigger values. However, site 10 has always recorded higher concentrations than site 9.

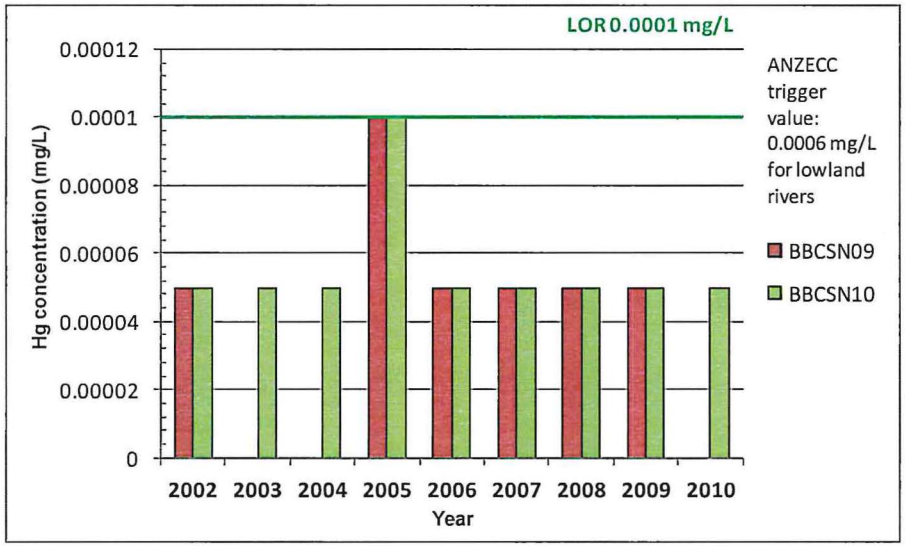
Molybdenum

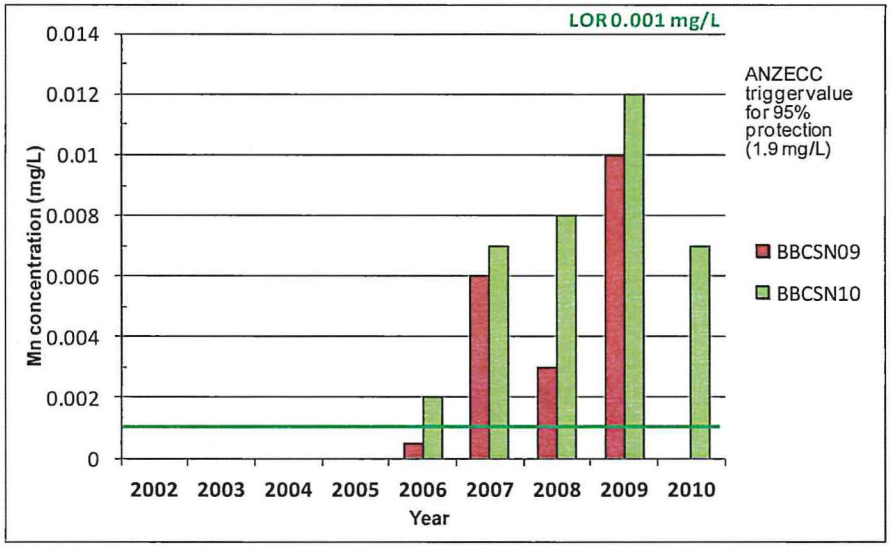
Currently no recreational trigger value or guideline exists for molybdenum in surface waters, however the ANZECC trigger values for freshwater lowland rivers is 0.034 mg/L. Molybdenum concentrations in the surface waters of the Bennett Springs catchment have always been below the limit of reporting (0.001 and 0.005 mg/L) at both sites and therefore, the ANZECC trigger value.

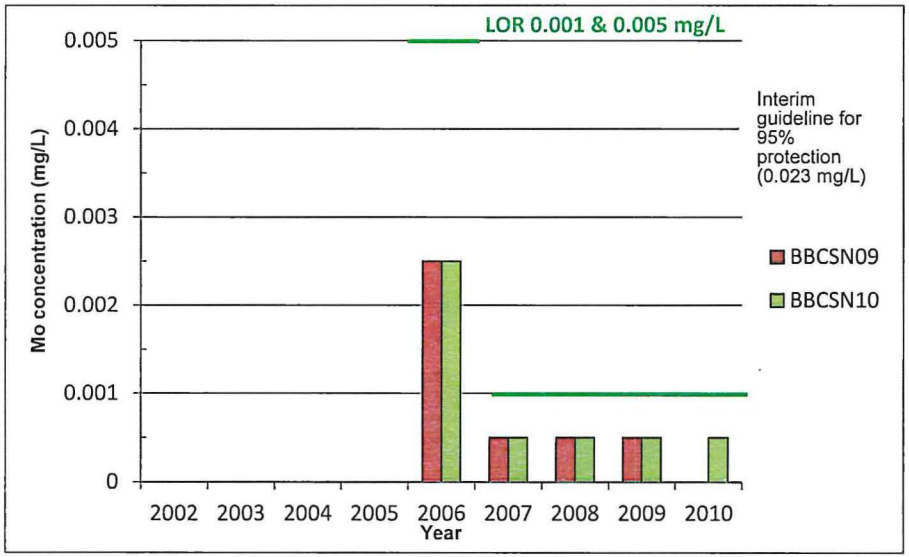
Selenium

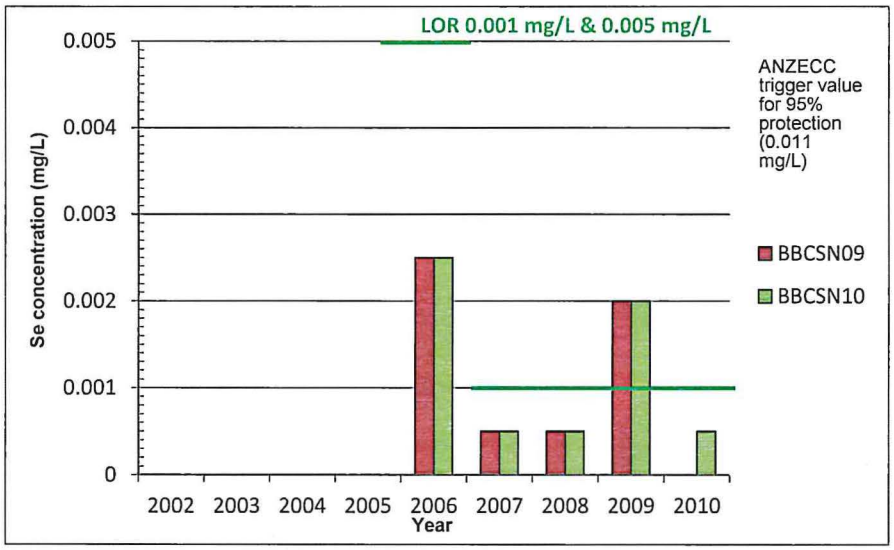
The ANZECC recreational trigger value of 0.01 mg/L and the trigger value of 0.011 mg/L for freshwater lowland rivers should not be exceeded. Selenium concentrations in the surface waters of the Bennett Springs catchment have been below the limits of reporting (0.005 and 0.001 mg/L) and therefore, the ANZECC trigger value. The only exception was in 2009 when both sites recorded 0.002 mg/L.

Figure 7: Mercury, Manganese, Molybdenum and Selenium concentrations in the surface waters of the Bennett Springs catchment









Cadmium

The ANZECC recreational trigger value of 0.005 mg/L and the trigger value of 0.0002 mg/L for freshwater lowland rivers should not be exceeded. The trigger values for cadmium are affected by water hardness and consequently the trigger value has to be adjusted for each sample.

Cadmium concentrations have always been below to the limits of reporting (0.001, 0.002 and 0.0001 mg/L) in the surface waters of Bennett Springs catchment. However it was not possible to adjust the trigger values in 2002 because water hardness was not included in the analysis and therefore it is not possible to conclude if the cadmium concentrations could exceed the modified trigger values. Moreover, considering that in 2002, 2004, 2005 and 2006 the limit of reporting (0.002 mg/L) was above the specific trigger value (0.0001 mg/L), it is not possible to conclude if the cadmium concentrations could exceed the water hardness modified trigger value.

Chromium

The ANZECC hardness-modified trigger value of 0.0033 mg/L for chromium (III), for freshwater ecosystem protection should not be exceeded. As the trigger values are affected by water hardness, the trigger values shown on the graph vary depending on the water hardness recorded at each site.

Chromium concentrations have always been below or equal to the limits of reporting (0.001, and 0.005 mg/L) in the surface waters of Bennett Springs catchment; with the exception of a concentration of 0.002 mg/L recorded in 2007 at site 10. However, it was not possible to adjust the trigger values in 2002 because water hardness was not included in the analysis and therefore it is not possible to conclude if the chromium concentrations could exceed the modified trigger values. Moreover, considering that in 2004, 2005 and 2006 the limit of reporting (0.005 mg/L) was above the specific trigger value (0.0033 mg/L), it is not possible to conclude if the chromium concentrations could exceed the water hardness modified trigger value.

Copper

Currently no recreational trigger value or guideline exists for copper in surface waters, however the ANZECC trigger values for freshwater lowland rivers is 0.0014 mg/L. The trigger values for copper are affected by water hardness. Therefore the trigger values vary, dependant on the water hardness concentration recorded at each site.

Copper concentrations have always been below or equal to the limits of reporting (0.001 and 0.005 mg/L) in the surface waters of Bennett Springs catchment; with the exception of 2009 when both sites recorded 0.002 mg/L. However it was not possible to adjust the trigger values in 2002 because water hardness was not included in the analysis and therefore it is not possible to conclude if the copper concentrations could exceed the modified trigger values. Moreover, considering that in 2004, 2005 and 2006 the limit of reporting (0.005 mg/L) was above the specific trigger value (0.0014 mg/L), it is not possible to conclude if the copper concentrations could exceed the water hardness modified trigger value.

Lead

The ANZECC recreational trigger value of 0.05 mg/L and the 95% level of protection trigger value of 0.0034 mg/L for freshwater lowland rivers should not be exceeded. The trigger values for lead are affected by water hardness. Therefore the trigger values are variable, dependent on the water hardness concentration recorded at each site.

Lead concentrations have always been below to the limits of reporting (0.01 and 0.001 mg/L) in the surface waters of Bennett Springs catchment. However it was not possible to adjust the trigger values in 2002 because water hardness was not included in the analysis and therefore it is not possible to conclude if the lead concentrations could exceed the modified trigger values. Moreover, considering that in 2004, 2005 and 2006 the limit of reporting (0.01 mg/L) was above the specific trigger value (0.0034 mg/L), it is not possible to conclude if the lead concentrations could exceed the water hardness modified trigger value.

Nickel

The ANZECC recreational trigger value of 0.01 mg/L and the trigger value of 0.011 mg/L for freshwater lowland rivers should not be exceeded. The trigger values for nickel are affected by water hardness. Therefore the trigger values are variable, dependent on the water hardness concentration recorded at each site.

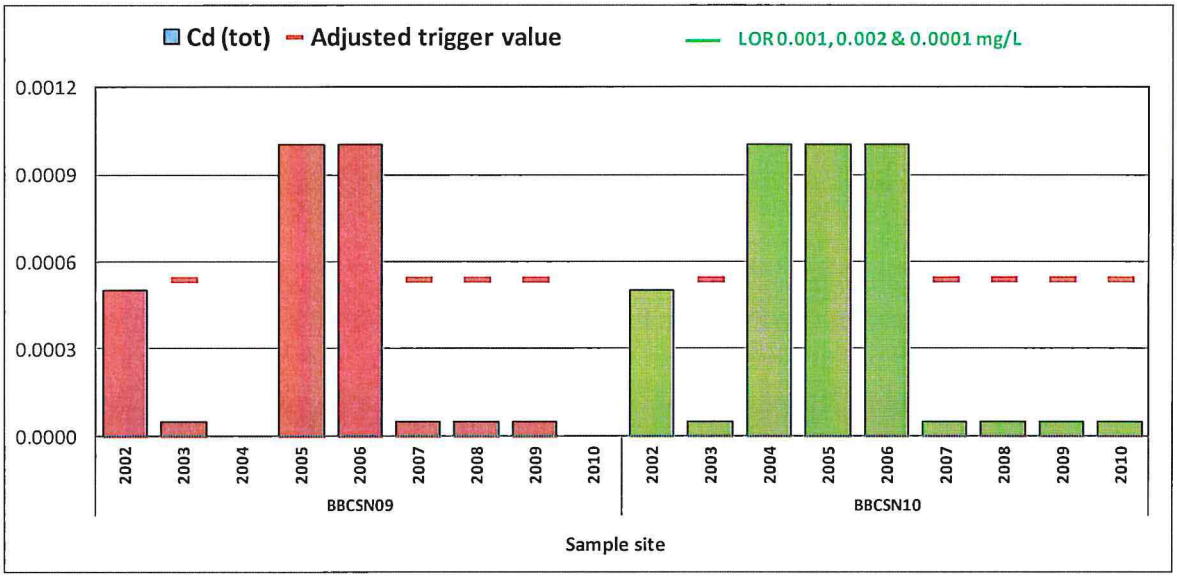
Nickel concentrations have always been below to the limits of reporting (0.001 and 0.005 mg/L) and the hardness modified trigger value in the surface waters of the Bennett Springs catchment. The only exception was a concentration of 0.002 mg/L recorded at site 10 in 2003. However it was not possible to adjust the trigger values in 2002 because water hardness was not included in the analysis and therefore it is not possible to conclude if the nickel concentrations could exceed the modified trigger values.

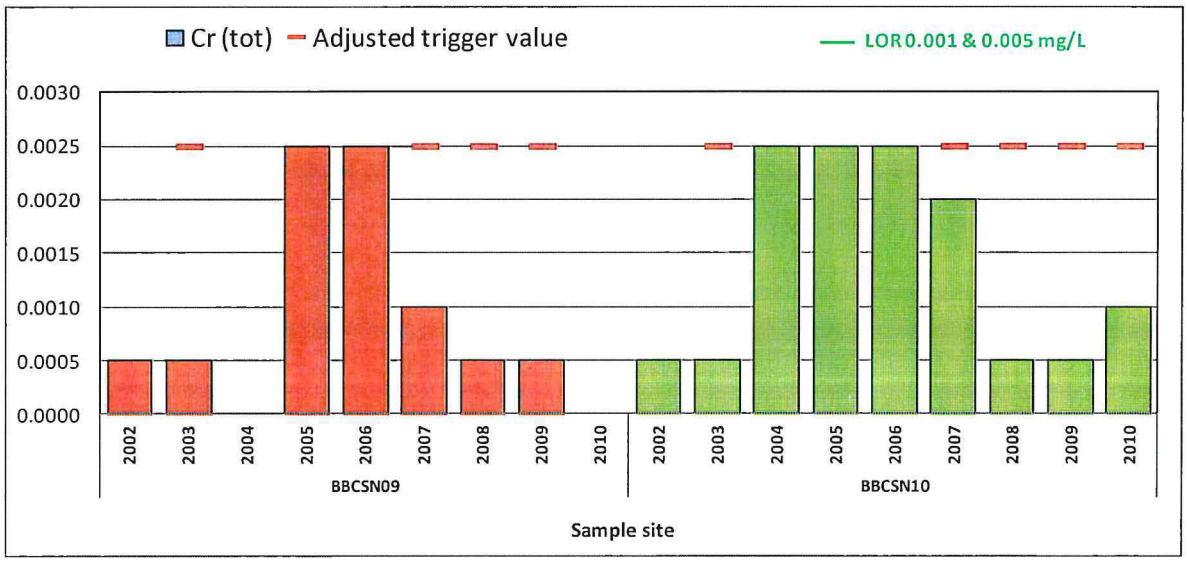
Zinc

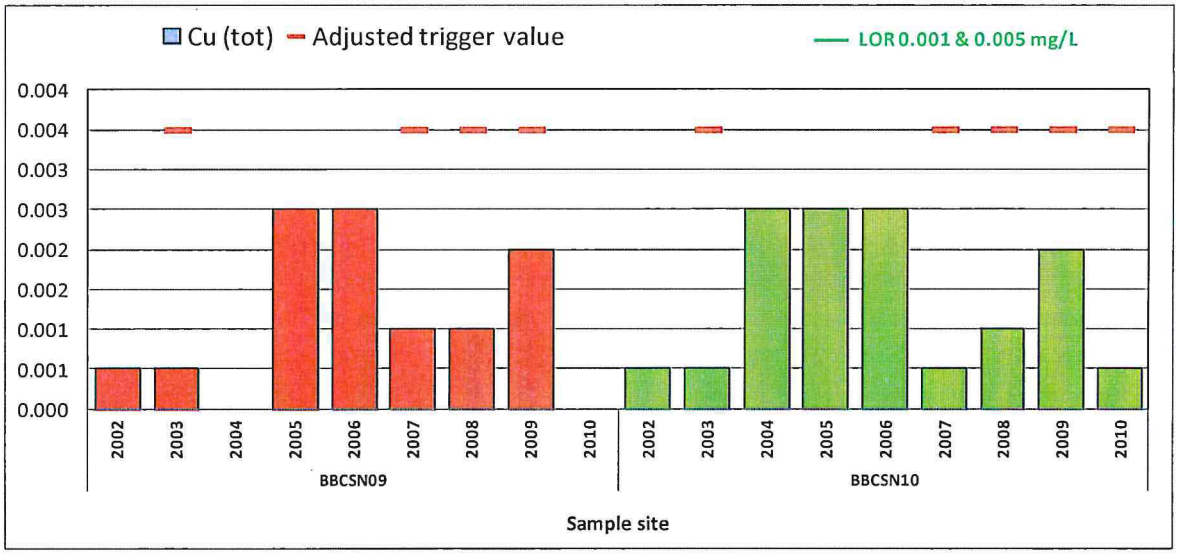
The ANZECC recreational trigger value of 5.0 mg/L and the trigger value of 0.008 mg/L for freshwater lowland rivers should not be exceeded. The trigger values for zinc are affected by water hardness. Therefore the trigger values shown on the graph are variable, dependant on the water hardness concentration recorded at each site.

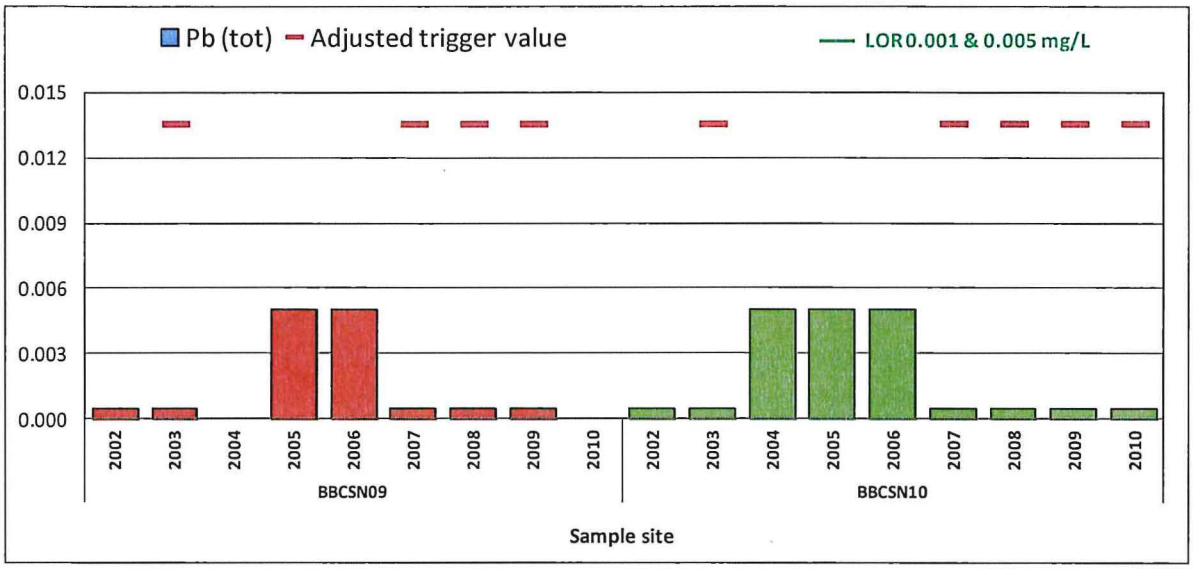
A total of five out of 14 samples recorded concentrations exceeding the hardness adjusted 95% level of protection trigger value. No sample has exceeded the recreational trigger value of 5 mg/L. Site 9 recorded concentrations exceeding the modified trigger value in 2006, 2007 and 2008 (0.02, 0.08 and 0.06 mg/L respectively) and site 10 in 2007 and 2008 (0.06 mg/L in both years). Site 9 has always recorded higher zinc concentrations than site 10; with the exception of 2002 when site 10 recorded a bigger value (0.026 mg/L in site 9 and 0.029 mg/L in site 10) and 2008 when both sites recorded the same concentration (0.06 mg/L).

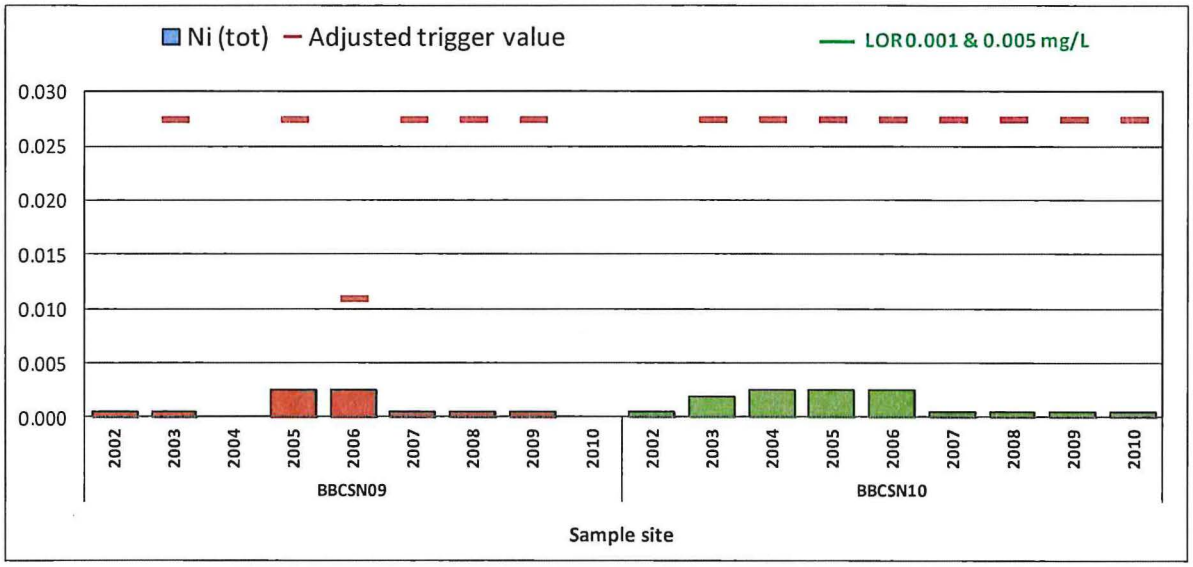
Figure 8: Cadmium, Chromium, Copper, Nickel and Zinc concentrations in the surface waters of Bennett Springs catchment

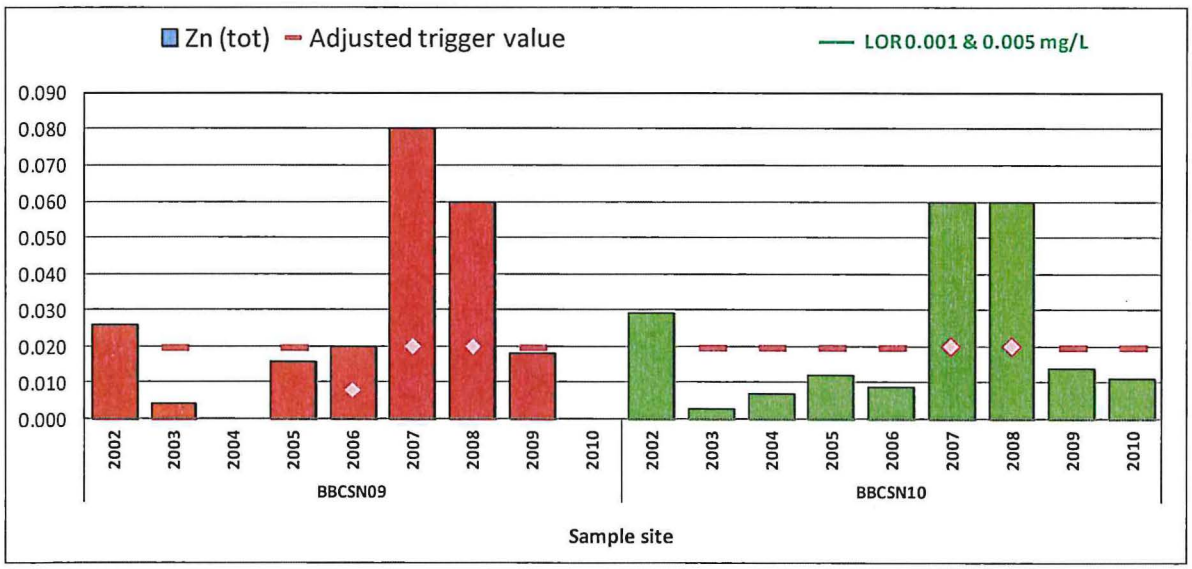







Pb (tot)
Adjusted trigger value
LOR 0.001 & 0.005 mg/L
0.015
0.012
0.009
0.006
0.003
0.000
2002
2003
2004
2005
2006
2007
2008
2009
2010
BBCSN09
BBCSN10
Sample site


Ni (tot)
Adjusted trigger value
LOR 0.001 & 0.005 mg/L
0.030
0.025
0.020
0.015
0.010
0.005
0.000
2002
2003
2004
2005
2006
2007
2008
2009
2010
BBCSN09
BBCSN10
Sample site


Zn (tot)
Adjusted trigger value
LOR 0.001 & 0.005 mg/L
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
2002
2003
2004
2005
2006
2007
2008
2009
2010
BBCSN09
BBCSN10
Sample site

Metals in sediments

Aluminium

No guideline currently exists for aluminium concentrations in sediments; therefore, it is difficult to gauge the severity of any potential impact arising from the concentrations recorded in the sediments of the Bennett Springs catchment, in terms of human and ecosystem health.

The lowest concentration of 270 mg/Kg was recorded at site 9 in 2008 and the highest concentration of 9,120 mg/Kg at site 10 in 2009. Further monitoring is recommended, especially given the elevated concentrations of aluminium found in the surface water samples.

Arsenic

Arsenic concentrations in the sediments of the Bennett Springs catchment have always been below the low trigger value of 20 mg/Kg. The highest concentration of 7.2 mg/Kg was recorded at site 10 in 2009 and the lowest (below the limit of reporting of 0.5 mg/Kg) in site 9 in 2003, 2005, 2008 and 2009. Site 10 has always recorded higher concentrations than site 9.

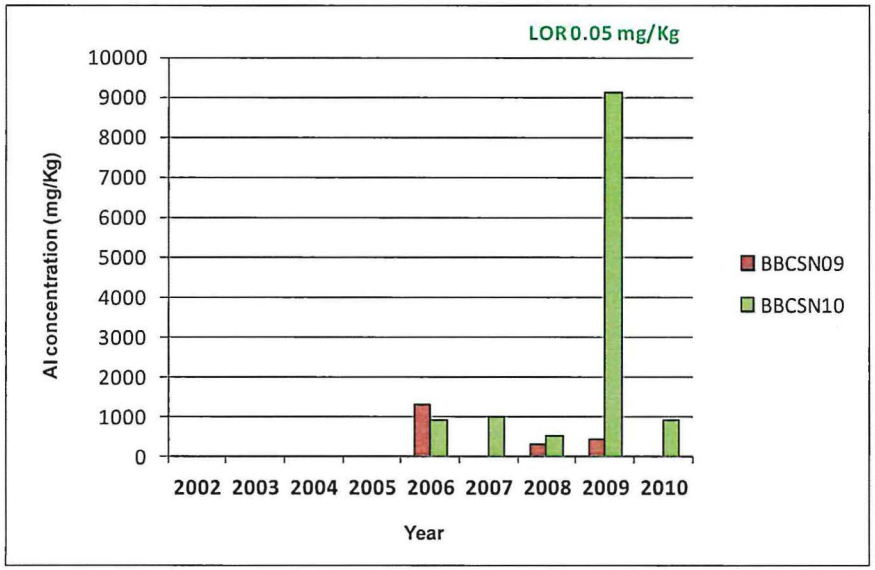
Cobalt

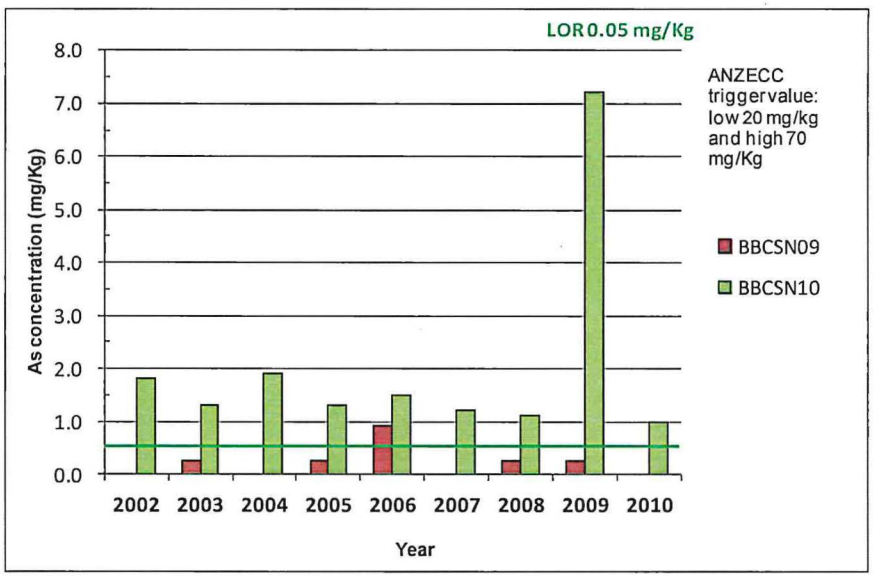
No trigger value or guideline currently exists for cobalt concentrations in sediments; therefore it is difficult to assess the concentrations in terms of threats to human health and the ecosystem. The cobalt concentrations of the sediments of the Bennett Spring catchment have generally been below the limit of reporting of 0.5 and 1.0 mg/Kg with the exception of site 10 in 2009 that recorded 1.1 mg/Kg.

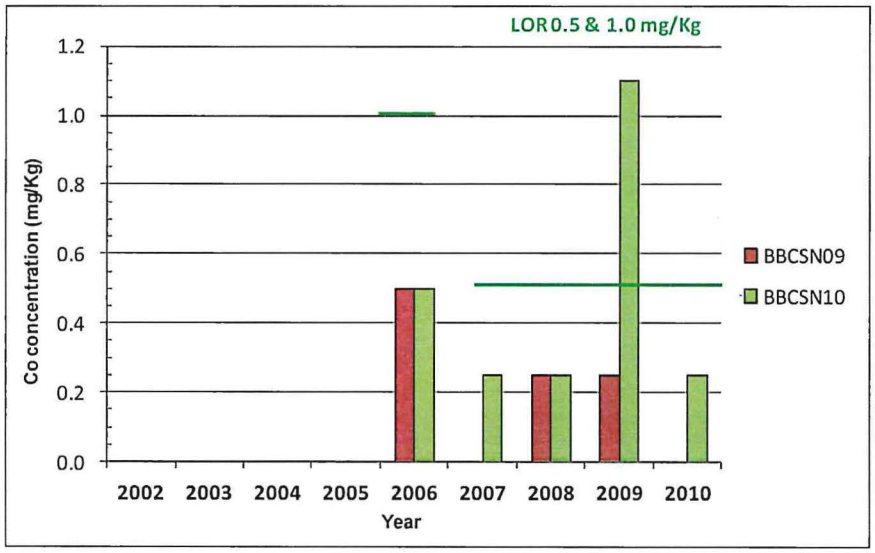
Iron

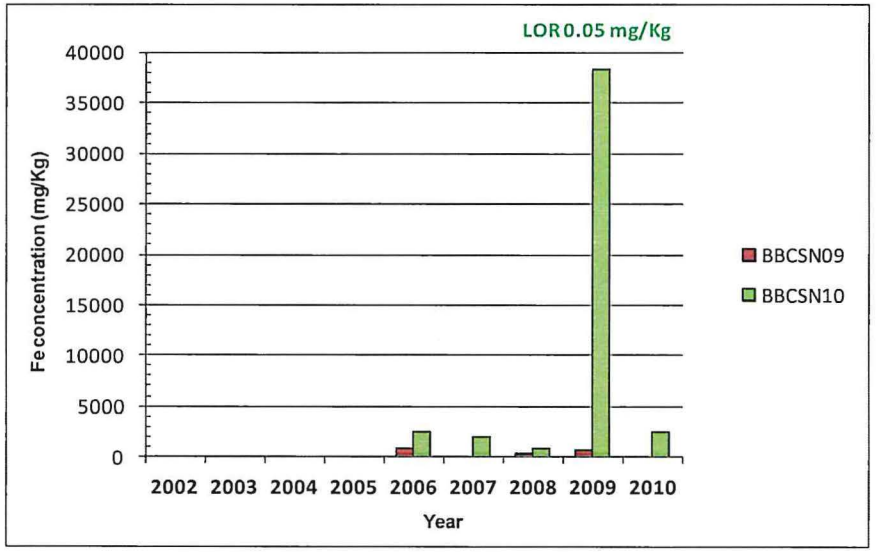
As no guidelines currently exist for iron in sediment it is difficult to assess the concentration in terms of threats to ecosystem and/or human health. The highest concentration of 38,400mg/Kg was recorded at site 10 in 2009 and the lowest of 400 mg/Kg at site 9 in 2008. Site 10 has always recorded higher iron concentrations than site 9. It is currently not known if the large variability in iron concentrations is due to contamination of some kind or the local geology.

Figure 9: Aluminium, Arsenic, Cobalt and Iron in sediments of Bennett Springs catchment.









Mercury

Mercury concentrations in the sediments of the Bennett Springs catchment have always been below limits of reporting of 0.1 and 0.2 mg/Kg with the exception of site 9 that recorded 0.23 mg/Kg in 2002; exceeding also the low trigger value of 0.15 mg/Kg. However, because the limit of reporting of 0.2 mg/Kg in 2002 was higher than the low trigger value, it is not possible to conclude that site 10 recorded a concentration below the low trigger value of 0.15 mg/Kg.

Manganese

As no guidelines currently exist for manganese in sediment it is difficult to assess the concentration in terms of threats to ecosystem and/or human health. The manganese concentrations in the sediments of the Bennett Springs catchment have always been above the limit of reporting of 0.5 mg/Kg. The highest and lowest concentrations have been recorded at site 10, 24 mg/Kg in 2009 and 0.74 mg/Kg in 2008.

Molybdenum

As no guidelines currently exist for molybdenum in sediment it is difficult to assess the concentration in terms of threats to ecosystem and/or human health. The molybdenum concentrations for the sediments of the Bennett Springs catchment have always been below the limits of reporting of 0.5 and 1.0 mg/Kg; with the exception of site 10 that recorded 0.6 mg/Kg in 2009.

Selenium

As no guidelines currently exist for selenium in sediment it is difficult to assess the concentration in terms of threats to ecosystem and/or human health. The selenium concentrations for the sediments of the Bennett Springs catchment have always been below the limits of reporting of 0.5 mg/Kg; with the exception of 2009 when both sites recorded concentrations above it, 4 mg/Kg at site 9 and 72 mg/Kg at site 10.

Cadmium

Cadmium concentrations in the sediments of the Bennett Springs catchment have always been below limits of reporting of 0.2, 0.5 and 1.0 mg/Kg; therefore concentrations have always been below the low trigger value of 1.5 mg/Kg.

Chromium

Chromium concentrations in the sediments of the Bennett Springs catchment have always been above the limit of reporting of 0.5 mg/Kg but below the low trigger value of 80 mg/Kg. The highest concentration of 14 mg/kg was recorded at site 10 in 2009 and the lowest of 0.64 mg/Kg at site 9 in 2008.

Copper

Copper concentrations in the sediments of the Bennett Springs catchment have always been below the low trigger value of 65 mg/Kg. The highest concentration of 11 mg/kg was recorded at site 10 in 2009 and concentrations below the limits of reporting of 0.5 mg/Kg and 1.0 mg/Kg were recorded at sites 10 from 2002 to 2008. Site 9 has only recorded a concentration below the limit of reporting of 0.5 mg/Kg once in 2008.

Lead

Lead concentrations in the sediments of the Bennett Springs catchment have always been below the low trigger value of 50 mg/Kg but usually above the limit of reporting of 1.0 mg/Kg. The highest concentration of 28 mg/kg was recorded at site 9 in 2002 and concentrations below the limit of reporting have only been recorded at site 10 in 2004, 2005 and 2006. Site 9 has always recorded lead concentrations higher than site 10; with the exception of 2009 when site 10 recorded 19 mg/Kg and site 9 recorded 1.3 mg/Kg.

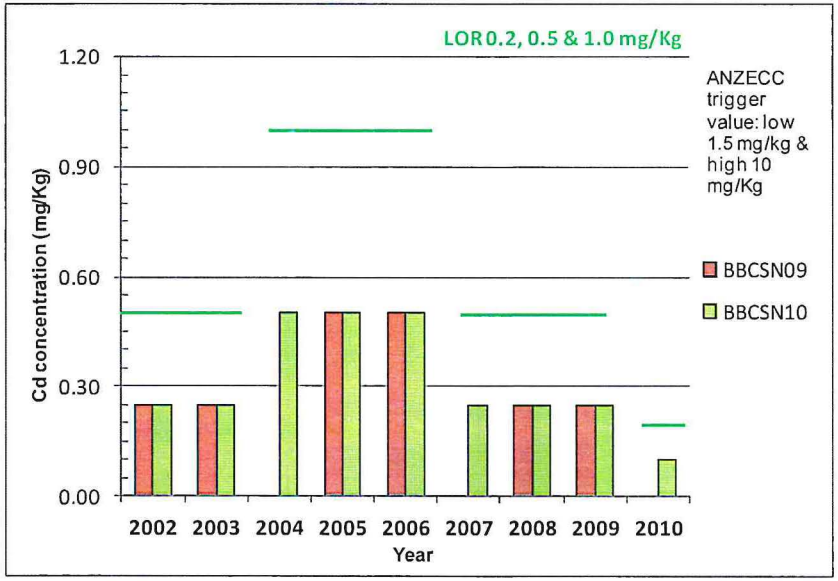
Nickel

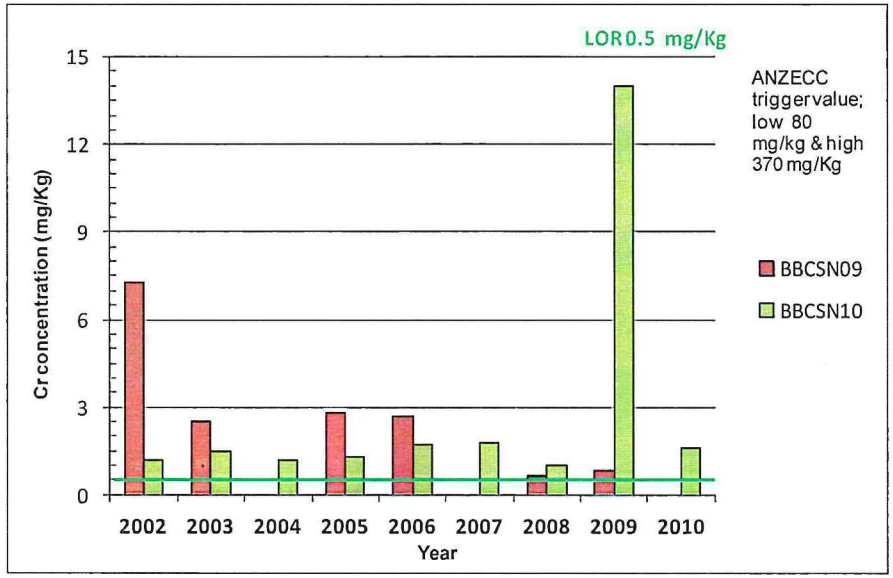
Nickel concentrations in the sediments of the Bennett Springs catchment have usually been below the limits of reporting of 0.5 and 1.0 mg/Kg with only three exceptions, but always below the low trigger value of 21 mg/Kg. Site 9 recorded 0.63 mg/Kg in 2003 and site 10 recorded 0.54 and 3.5 mg/Kg in 2007 and 2009 respectively.

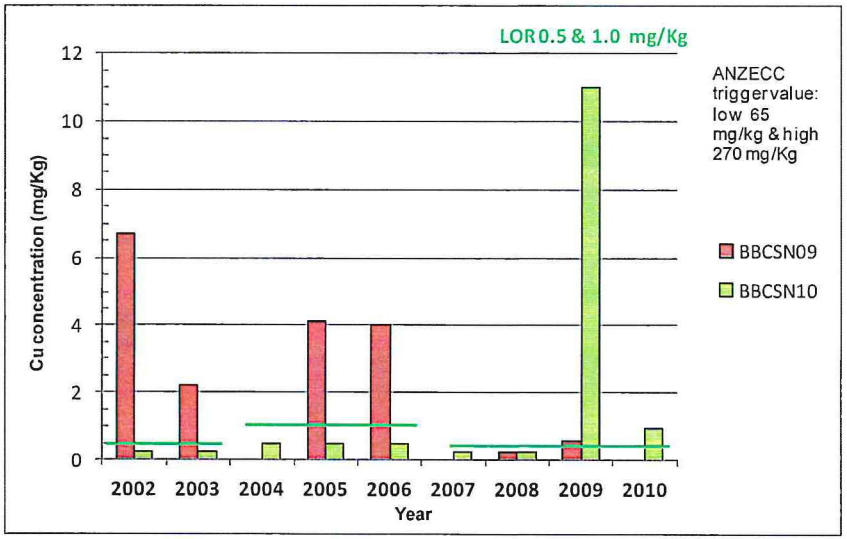
Zinc

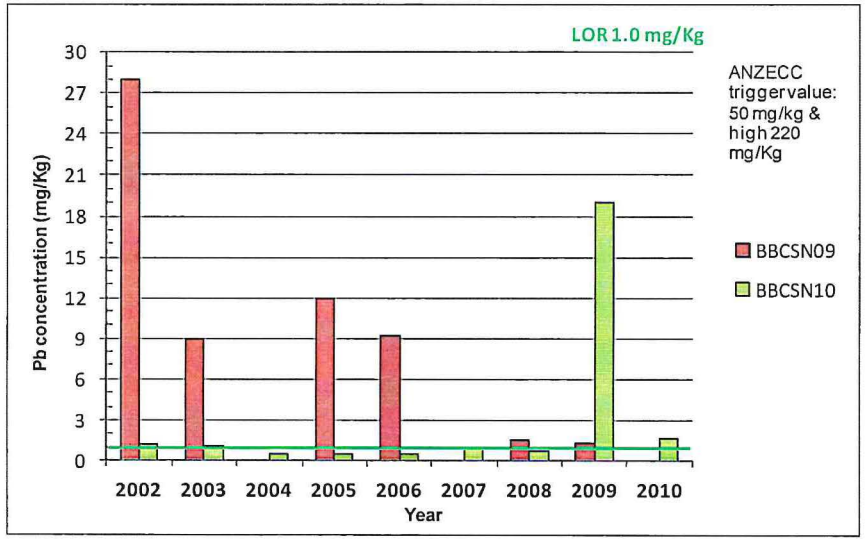
Zinc concentrations in the sediments of the Bennett Springs catchment have usually been above the limit of reporting of 0.5 mg/Kg, but always below the low trigger value of 200 mg/Kg. The highest concentration of 39 mg/Kg was recorded at site in 2005. Ste 9 has always recorded zinc concentrations higher than site 10; the only exception was in 2009 when both sites recorded a concentration below the limit of reporting.

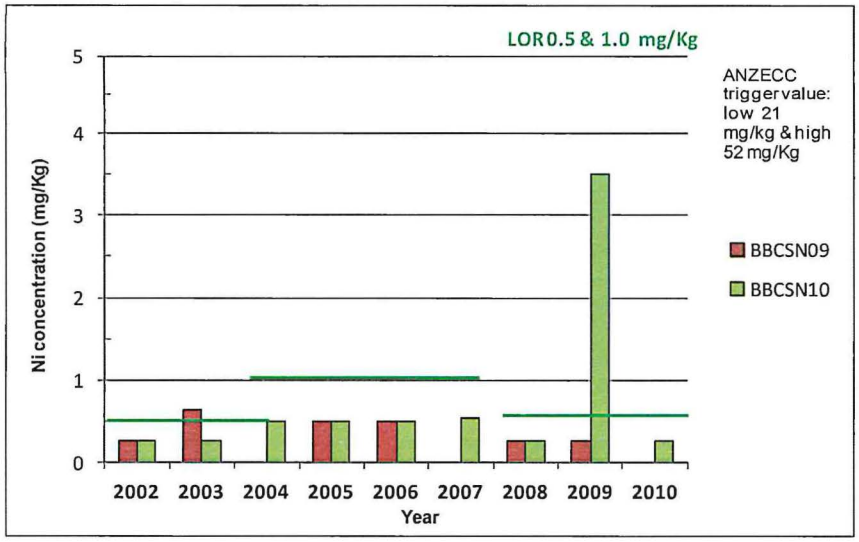
Figure 10: Cadmium, Chromium, Copper, Lead, Nickel and Zinc in sediments of Bennett Springs catchment

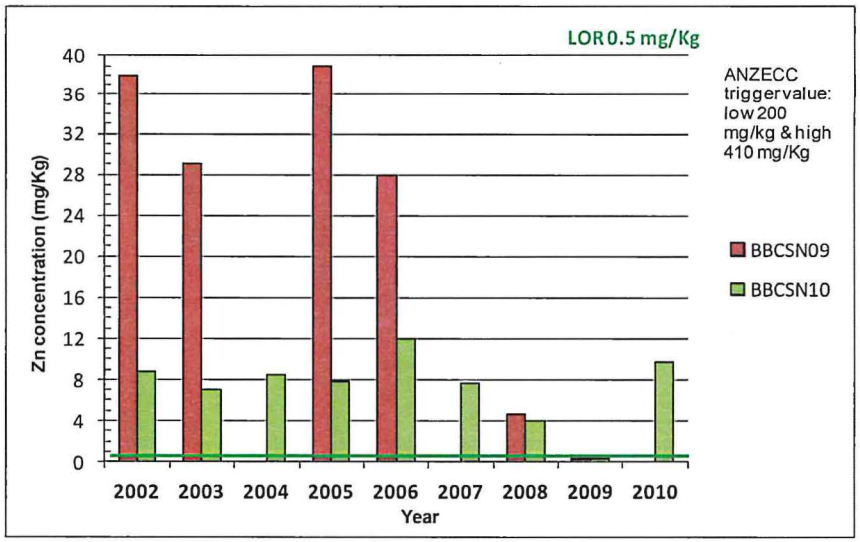









LOR 0.5 & 1.0 mg/Kg
Ni concentration (mg/Kg)
0
1
2
3
4
5
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year
ANZECC trigger value: low 21 mg/kg & high 52 mg/Kg
BBCSN09
BBCSN10


LOR 0.5 mg/Kg
Zn concentration (mg/Kg)
0
4
8
12
16
20
24
28
32
36
40
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year
ANZECC trigger value: low 200 mg/kg & high 410 mg/Kg
BBCSN09
BBCSN10

Conclusions

- Due to the lack of water at site 9, it was not possible to take water and sediment samples in 2004 and 2010 and also sediments in 2007. Therefore, the comparison between both sites could not be done effectively.
- Due to the periodicity of one sampling event per year it is important to keep in mind that the findings are not significative to provide sufficient data for the analysis and conclusions and therefore, to know the condition of the catchment and interpret trends and changes that are happening over time. Snapshots only provide information regarding a specific point in time and space.
- Site 10 usually recorded higher concentrations than site 9 for the following parameters in water: electrical conductivity, total nitrogen, nitrogen as ammonia/ ammonium, total oxidised nitrogen, dissolved organic nitrogen, total phosphorus, soluble reactive phosphorus, aluminium, iron and manganese.
- Site 9 usually recorded higher concentrations than site 10 for dissolved oxygen and zinc in water.
- There is something contributing nitrogen and fractions of nitrogen between sites 9 and 10 but due to insufficient data points it is not possible to prove it statistically.

WATER

Physical

- pHs readings were usually within the ANZECC acceptable range.
- Dissolved oxygen concentrations were usually within the ANZECC acceptable range.
- Electrical conductivity levels were of concern; almost all samples were above the upper limit of the ANZECC acceptable range.
- Total suspended solids were usually below the DoW interim guideline.

Nutrients

- Site 10 has always recorded total nitrogen concentrations above the ANZECC trigger value and site 9 has always recorded concentrations below it.
- Total oxidised nitrogen was the most significant component of the total nitrogen at site 10 and dissolved organic nitrogen at site 9.
- Total phosphorus concentrations have usually been below the ANZECC trigger value. Soluble reactive phosphorus has been a more significant component of total phosphorus in site 10 than site 9.

Metals

- Concentrations of mercury, cobalt, molybdenum, selenium, lead and nickel were always below to or equal to limits of reporting at both sites.
- Aluminium concentrations exceeded the trigger value at both sites.
- Iron concentrations have been above the interim guideline since 2006 at site 10 when this parameter was included and only in 2006 at site 9.

- Manganese concentrations have usually been above the limit of reporting, but below the trigger value.
- Zinc concentrations have always been above the limit of reporting and five out of 14 samples have exceeded the modified trigger value.
- Cadmium, chromium and copper concentrations have always recorded concentrations below the different limits of reporting. However in 2004, 2005 and 2006, the limits of reporting selected were higher than the trigger value and therefore it was not possible to conclude if the concentrations could or could not exceed the specific modified trigger values. Additionally, in 2002 water hardness was not included and therefore it was not possible to adjust the specific trigger values for these three metals.

SEDIMENTS same as above

- Site 10 recorded in 2009 the highest concentrations for the majority of: aluminium, arsenic, iron, cobalt, manganese, molybdenum, selenium, chromium, copper, lead and nickel.
- Aluminium concentrations were always above the limit of reporting and site 10 has always recorded higher concentrations than site 9. However, as no guideline currently exists for aluminium in sediment it is difficult to assess this concentration in terms of threats to ecosystem and/or human health.
- Arsenic concentrations were always above the limit of reporting at site 10, but at site 9 only in 2006. However, all samples have been below the low trigger value.
- Iron concentrations have always been above the limit of reporting and site 10 has usually recorded higher concentrations than site 9. However, as no guideline currently exists for iron in sediment it is difficult to assess this concentration in terms of threats to ecosystem and/or human health.
- Mercury concentrations have always been below limits of reporting with the only exception of one sample at site 9 in 2002, which exceeded the low trigger value.
- Cobalt concentrations have always been below the limit of reporting with the exception of one sample at site 10 in 2009. However, as no guideline currently exists for cobalt in sediment it is difficult to assess this concentration in terms of threats to ecosystem and/or human health.
- Manganese concentrations have always been above the limit of reporting. However, as no guideline currently exists for manganese in sediment it is difficult to assess this concentration in terms of threats to ecosystem and/or human health.
- Molybdenum concentrations have always been below the limit of reporting with the exception of one sample at site 10 in 2009. However, as no guideline currently exists for molybdenum in sediment it is difficult to assess this concentration in terms of threats to ecosystem and/or human health.
- Selenium concentrations have always been below the limit of reporting with the exception of 2009 when both sites recorded concentrations higher than it. However, as no guideline currently exists for selenium in sediment it is difficult to assess this concentration in terms of threats to ecosystem and/or human health.

- Cadmium concentrations have always been below the limit of reporting and therefore, below the low trigger value.
- Chromium concentrations have always been above the limit of reporting but below the low trigger value. Site 9 has usually recorded higher concentrations than site 10.
- Copper concentrations have always been below the low trigger value. Site 9 has always recorded higher concentrations than site 10, with the exception of 2009.
- Lead concentrations have usually been above the limit of reporting, but always below the low trigger value. Site 9 has always recorded higher concentrations than site 10, with the exception of 2009.
- Nickel concentrations have usually been below the limit of reporting and always below the low trigger value.
- Zinc concentrations have always been above the limits of reporting with the exception of 2009 when both sites recorded concentrations below it. Site 9 has always recorded higher concentrations than site 10, but always below the low trigger value.

Table 2: Summary of key findings

Parameter		Site 9		Site 10	
		# samples exceeding TV	# of samples	# samples exceeding TV	# of samples
Water					
Physical	pH	2	7	1	9
	DO	4	7	0	9
	EC	5	7	8	9
	TSS	0	5	1	7
Nutrients	TN	0	7	9	9
	NO_x	2	7	9	9
	NH_3-N	0	4	5	5
	TP	1	7	3	9
	SRP	0	7	1	9
Metals	Al	4	4	5	5
	As	0	7	0	9
	Cd	0	4	0	5
	Co	0	4	0	5
	Cr	0	4	0	5
	Cu	0	4	0	5
	Fe	1	4	5	5
	Hg	0	6	0	9
	Mn	0	4	0	5
	Mo	0	4	0	5
	Ni	0	6	0	8
	Pb	0	4	0	5
	Se	0	4	0	5
	Zn	3	6	2	8
Sediment					
Metals	Al	No TV set	3	No TV set	5
	As	0	6	0	9
	Cd	0	6	0	9
	Co	No TV set	3	No TV set	5
	Cr	0	6	0	9
	Cu	0	6	0	9
	Fe	No TV set	3	No TV set	5
	Hg	0	6	0	9
	Mn	No TV set	3	No TV set	5
	Mo	No TV set	3	No TV set	5
	Ni	0	6	0	9
	Pb	0	6	0	9
	Se	No TV set	3	No TV set	5
	Zn	0	6	0	9

Appendix 1 – Bennett Springs Catchment Water and Sediment Quality Results

pH

ANZECC trigger value for lowland rivers of SW Australia 6.5 - 8.0 Max (red) 7.82 Min (blue) 5.91

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	6.3	6.62		5.91	6.96	7.12	7.46	7.46	
BENNETT BROOK - EMU SWAMP DRAIN EXIT	BBCSN10	6.8	7.08	7.6	6.43	7.47	7.43	7.42	7.82	7.81

Dissolved oxygen (DO)

ANZECC trigger value 80-120% saturation Max (red) 128.3 Min (blue) 64.5

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	64.5	123.4		113.0	76	101.6	128.3	94	
BENNETT BROOK - EMU SWAMP DRAIN EXIT	BBCSN10	91.9	93.3	97.8	84.0	99.1	92	89.7	84	88.1

Electrical Conductivity (EC)

ANZECC trigger value 0.12-0.3 mS/cm Max (red) 1.401 Min (blue) 0.0505

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	0.39	0.351		0.437	0.272	0.499	0.054	0.498	
BENNETT BROOK - EMU SWAMP DRAIN EXIT	BBCSN10	0.498	0.538	0.562	0.452	0.4531	0.53	0.051	1.401	0.512

Total Suspendid Solids (TSS) All data in blue were <1 (LOR)

DoW interim guideline 6 mg/L Max (red) 8 Min (blue) 0.5

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09				1	2	2	0.5	1	
EMU SWAMP DRAIN EXIT	BBCSN10			8	3	4	2	3	4	4

Total nitrogen (TN) (mg/L) N (tot) {TN, pTN} (mg/L) Limit of reporting 0.025 mg/L
ANZECC trigger value: 1.2mg/L Max (red) 2.3 Min (blue) 0.26

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	0.26	0.64		0.53	0.49	0.63	0.71	0.79	
EMU SWAMP DRAIN EXIT	BBCSN10	1.8	1.9	2.3	2.3	1.9	2.2	1.9	2.1	1.8

Total Oxidised Nitrogen (NOx) (mg/L) {NOx-N, TON} (mg/L) All data in blue were <0.01 (LOR)
ANZECC trigger value: 0.15mg/L Max (red) 1.3 Min (blue) 0.005

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	0.01	0.05		0.16	0.005	0.013	0.24	0.26	
EMU SWAMP DRAIN EXIT	BBCSN10	0.65	1	1.1	0.68	1.3	1.1	0.81	0.83	1.1
speciation	BBCSN09	4%	8%		30%	1%	2%	34%	33%	
speciation	BBCSN10	36%	53%	48%	30%	68%	50%	43%	40%	61%

Nitrogen as ammonia/ammonium (mg/L) NH3-N/NH4-N (sol) (mg/L) All data in blue were <0.01 (LOR)
ANZECC trigger value: 0.08 mg/L Max (red) 0.087 Min (blue) 0.087

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09					0.005	0.005	0.005	0.005	
EMU SWAMP DRAIN EXIT	BBCSN10					0.11	0.1	0.14	0.095	0.087
speciation	BBCSN09					1%	1%	1%	1%	
speciation	BBCSN10					6%	5%	7%	5%	5%

Dissolved Organic Nitrogen (DON) N (sum sol org) {DON} (mg/L) Limit of reporting 0.025 mg/L
ANZECC trigger value: ND Max (red) 0.46 Min (blue) 0.46

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09					0.47	0.53	0.45	0.45	
EMU SWAMP DRAIN EXIT	BBCSN10					0.51	0.98	0.82	1.1	0.46
speciation	BBCSN09					96%	84%	63%	57%	
speciation	BBCSN10					27%	45%	43%	52%	26%

Total Phosphorus (TP) (mg/L) P (tot) {TP, pTP} (mg/L) Limit of reporting 0.005 mg/L

ANZECC trigger value: 0.065mg/L Max (red) 0.086 Min (blue) 0.011

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	0.021	0.078		0.014	0.03	0.022	0.012	0.011	
EMU SWAMP DRAIN EXIT	BBCSN10	0.023	0.043	0.067	0.086	0.073	0.044	0.052	0.063	0.038

Soluble Reactive Phosphorus (SRP) (mg/L) PO4-P (sol react) {SRP, FRP} (mg/L) All data in blue were <0.005 (LOR)

ANZECC trigger value: 0.04mg/L Max (red) 0.051 Min (blue) 0.0025

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	0.014	0.01		0.007	0.006	0.0025	0.0025	0.0025	
EMU SWAMP DRAIN EXIT	BBCSN10	0.022	0.022	0.022	0.051	0.023	0.009	0.0025	0.019	0.01
speciation	BBCSN09	67%	13%			20%	11%	21%	23%	
speciation	BBCSN10	96%	51%	33%	59%	32%	20%	5%	30%	26%

Water Hardness (tot) (CaCO3) {Ca+Mg} (mg/L)

ANZECC recreational trigger value: 500 mg/L Max (red) 110 Min (blue) 56

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09		60		81	56	91	96	98	
BENNETT BROOK - EMU SWAMP DRAIN EXIT	BBCSN10		100	93	92	94	110	110	100	94

Aluminium (Al) (sol) ANZECC guideline only applicable if pH>6.5 Limit of reporting 0.005 mg/L

ANZECC trigger value: 0.055mg/L Max (red) 0.33 Min (blue) 0.087

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09					0.13	0.087	0.091	0.14	
EMU SWAMP DRAIN EXIT	BBCSN10					0.27	0.33	0.15	0.18	0.22

Arsenic (As) (sol) (mg/L) Limits of reporting 0.001 mg/L & 0.005 mg/L

ANZECC trigger value: 0.024mg/L Max (red) 0.0025 Min (blue) 0.0005

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	0.0005	0.0005		0.0025	0.0025	0.0005	0.0005	0.0005	
EMU SWAMP DRAIN EXIT	BBCSN10	0.0005	0.0005	0.0025	0.0025	0.0025	0.002	0.001	0.001	0.0005
	Limits of reporting	0.001 mg/L	0.001 mg/L	0.005 mg/L	0.005 mg/L	0.005 mg/L	0.001 mg/L	0.001 mg/L	0.001 mg/L	0.001 mg/L

Cobalt (Co) (sol) (mg/L) Limit of reporting 0.001 mg/L

Interim guideline: 0.0028 mg/L Max (red) 0.0025 Min (blue) 0.0005

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09					0.0025	0.0005	0.0005	0.0005	
EMU SWAMP DRAIN EXIT	BBCSN10					0.0025	0.0005	0.0005	0.0005	0.0005

Iron (Fe) (mg/L) Limit of reporting 0.005 mg/L

Interim guideline 0.3mg/L Max (red) 0.76 Min (blue) 0.12

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09					0.32	0.15	0.12	0.27	
EMU SWAMP DRAIN EXIT	BBCSN10					0.64	0.76	0.51	0.51	0.59

Mercury (Hg) (sol) (mg/L) Limit of reporting 0.0001 mg/L

ANZECC trigger value: 0.0006mg/L Max (red) 0.0001 Min (blue) 0.00005

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	0.00005			0.0001	0.00005	0.00005	0.00005	0.00005	
EMU SWAMP DRAIN EXIT	BBCSN10	0.00005	0.00005	0.00005	0.0001	0.00005	0.00005	0.00005	0.00005	0.00005

Manganese (Mn) (sol) (mg/L) Limit of reporting 0.001 mg/L

ANZECC trigger value: 1.9 mg/L Max (red) 0.012 Min (blue) 0.0005

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09					0.0005	0.006	0.003	0.01	
EMU SWAMP DRAIN EXIT	BBCSN10					0.002	0.007	0.008	0.012	0.007

Molybdenum (Mo) (sol) (mg/L) Limit of reporting 0.001 m/L & 0.005 mg/L

Interim guideline: 0.023 mg/L Max (red) 0.0025 Min (blue) 0.0005

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09					0.0025	0.0005	0.0005	0.0005	
EMU SWAMP DRAIN EXIT	BBCSN10					0.0025	0.0005	0.0005	0.0005	0.0005

Selenium (Se) (sol) (mg/L) Limit of reporting 0.001 mg/L & 0.005 mg/L

ANZECC trigger value: 0.011 mg/L Max (red) 0.0005 Min (blue) 0.0005

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09					0.0025	0.0005	0.0005	0.002	
EMU SWAMP DRAIN EXIT	BBCSN10					0.0025	0.0005	0.0005	0.002	0.0005
					Limits of reporting	0.005 mg/L	0.001 mg/L	0.001 mg/L	0.001 mg/L	0.001 mg/L

Cadmium (Cd) (mg/L) Limits of reporting 0.002 mg/L, 0.001 mg/L & 0.0001 mg/L

Site name	Site number	Year	Limit of reporting (mg/L)	Cd (tot)	Hardness (tot) (CaCO3) {Ca+Mg} (mg/L)	Adjust factor	Adjusted trigger value	Comparison to ANZECC trigger ADJUSTED value	Hardness (mg/L)	Cd	ANZECC trigger value*
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	2002	0.001	0.0005					0-59	1	0.0002
		2003	0.0001	0.00005	60	2.7	0.00054	Acceptable	60-119	2.7	
		2004							120-179	4.2	
		2005	0.002	0.001	81	2.7			180-240	5.7	
		2006	0.002	0.001	56	1			400	10	
		2007	0.0001	0.00005	91	2.7	0.00054	Acceptable			
		2008	0.0001	0.00005	96	2.7	0.00054	Acceptable			
		2009	0.0001	0.00005	98	2.7	0.00054	Acceptable			
		2010									
EMU SWAMP DRAIN EXIT	BBCSN10	2002	0.001	0.0005							
		2003	0.0001	0.00005	100	2.7	0.00054	Acceptable			
		2004	0.002	0.001	93	2.7					
		2005	0.002	0.001	92	2.7					
		2006	0.002	0.001	94	2.7					
		2007	0.0001	0.00005	110	2.7	0.00054	Acceptable			
		2008	0.0001	0.00005	110	2.7	0.00054	Acceptable			
		2009	0.0001	0.00005	100	2.7	0.00054	Acceptable			
		2010	0.0001	0.00005	94	2.7	0.00054	Acceptable			

Chromium (Cr) (mg/L) Limits of reporting 0.001 mg/L & 0.005 mg/L

Site name	Site number	Year	Limit of reporting (mg/L)	Cr (tot)	Hardness (tot) (CaCO3) {Ca+Mg} (mg/L)	Adjust factor	Adjusted trigger value	Comparison to ANZECC trigger ADJUSTED value
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	2002	0.001	0.0005				
		2003	0.001	0.0005	60	2.5	0.0025	Acceptable
		2004						
		2005	0.005	0.0025	81	2.5		
		2006	0.005	0.0025	56	1		
		2007	0.001	0.001	91	2.5	0.0025	Acceptable
		2008	0.001	0.0005	96	2.5	0.0025	Acceptable
		2009	0.001	0.0005	98	2.5	0.0025	Acceptable
		2010						
EMU SWAMP DRAIN EXIT	BBCSN10	2002	0.001	0.0005				
		2003	0.001	0.0005	100	2.5	0.0025	Acceptable
		2004	0.005	0.0025	93	2.5		
		2005	0.005	0.0025	92	2.5		
		2006	0.005	0.0025	94	2.5		
		2007	0.001	0.002	110	2.5	0.0025	Acceptable
		2008	0.001	0.0005	110	2.5	0.0025	Acceptable
		2009	0.001	0.0005	100	2.5	0.0025	Acceptable
		2010	0.001	0.001	94	2.5	0.0025	Acceptable

Hardness (mg/L)	Cr	ANZECC trigger value*
0-59	1	0.001
60-119	2.5	
120-179	3.7	
180-240	4.9	
400	8.4	

Copper (Cu) (mg/L) Limits of reporting 0.001 mg/L & 0.005 mg/L

Site name	Site number	Year	Limit of reporting (mg/L)	Cu (tot)	Hardness (tot) (CaCO3) {Ca+Mg} (mg/L)	Adjust factor	Adjusted trigger value	Comparison to ANZECC trigger ADJUSTED value
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	2002	0.001	0.0005				
		2003	0.001	0.0005	60	2.5	0.0035	Acceptable
		2004						
		2005	0.005	0.0025	81	2.5		
		2006	0.005	0.0025	56	1		
		2007	0.001	0.001	91	2.5	0.0035	Acceptable
		2008	0.001	0.001	96	2.5	0.0035	Acceptable
		2009	0.001	0.002	98	2.5	0.0035	Acceptable
		2010						
EMU SWAMP DRAIN EXIT	BBCSN10	2002	0.001	0.0005				
		2003	0.001	0.0005	100	2.5	0.0035	Acceptable
		2004	0.005	0.0025	93	2.5		
		2005	0.005	0.0025	92	2.5		
		2006	0.005	0.0025	94	2.5		
		2007	0.001	0.0005	110	2.5	0.0035	Acceptable
		2008	0.001	0.001	110	2.5	0.0035	Acceptable
		2009	0.001	0.002	100	2.5	0.0035	Acceptable
		2010	0.001	0.0005	94	2.5	0.0035	Acceptable

Hardness (mg/L)	Cu	ANZECC trigger value*
0-59	1	0.0014
60-119	2.5	
120-179	3.9	
180-240	5.2	
400	9	

Lead (Pb) (mg/L) Limits of reporting 0.001 mg/L & 0.01 mg/L

Site name	Site number	Year	Limit of reporting (mg/L)	Pb (tot)	Hardness (tot) (CaCO3) {Ca+Mg} (mg/L)	Adjust factor	Adjusted trigger value	Comparison to ANZECC trigger ADJUSTED value	Hardness (mg/L)	Pb	ANZECC trigger value*
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	2002	0.001	0.0005					0-59	1	0.0034
		2003	0.001	0.0005	60	4	0.0136	Acceptable	60-119	4	
		2004							120-179	7.6	
		2005	0.01	0.005	81	4			180-240	11.8	
		2006	0.01	0.005	56	1			400	26.7	
		2007	0.001	0.0005	91	4	0.0136	Acceptable			
		2008	0.001	0.0005	96	4	0.0136	Acceptable			
		2009	0.001	0.0005	98	4	0.0136	Acceptable			
		2010									
EMU SWAMP DRAIN EXIT	BBCSN10	2002	0.001	0.0005							
		2003	0.001	0.0005	100	4	0.0136	Acceptable			
		2004	0.01	0.005	93	4					
		2005	0.01	0.005	92	4					
		2006	0.01	0.005	94	4					
		2007	0.001	0.0005	110	4	0.0136	Acceptable			
		2008	0.001	0.0005	110	4	0.0136	Acceptable			
		2009	0.001	0.0005	100	4	0.0136	Acceptable			
		2010	0.001	0.0005	94	4	0.0136	Acceptable			

Nickel (Ni) (mg/L) Limits of reporting 0.001 mg/L & 0.005 mg/L

Site name	Site number	Year	Limit of reporting (mg/L)	Ni (tot)	Hardness (tot) (CaCO3) {Ca+Mg} (mg/L)	Adjust factor	Adjusted trigger value	Comparison to ANZECC trigger ADJUSTED value	Hardness (mg/L)	Ni	ANZECC trigger value*
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	2002	0.001	0.0005					0-59	1	0.011
		2003	0.001	0.0005	60	2.5	0.0275	Acceptable	60-119	2.5	
		2004							120-179	3.9	
		2005	0.005	0.0025	81	2.5	0.0275	Acceptable	180-240	5.2	
		2006	0.005	0.0025	56	1	0.011	Acceptable	400	9	
		2007	0.001	0.0005	91	2.5	0.0275	Acceptable			
		2008	0.001	0.0005	96	2.5	0.0275	Acceptable			
		2009	0.001	0.0005	98	2.5	0.0275	Acceptable			
		2010									
EMU SWAMP DRAIN EXIT	BBCSN10	2002	0.001	0.0005							
		2003	0.001	0.002	100	2.5	0.0275	Acceptable			
		2004	0.005	0.0025	93	2.5	0.0275	Acceptable			
		2005	0.005	0.0025	92	2.5	0.0275	Acceptable			
		2006	0.005	0.0025	94	2.5	0.0275	Acceptable			
		2007	0.001	0.0005	110	2.5	0.0275	Acceptable			
		2008	0.001	0.0005	110	2.5	0.0275	Acceptable			
		2009	0.001	0.0005	100	2.5	0.0275	Acceptable			
		2010	0.001	0.0005	94	2.5	0.0275	Acceptable			

Zinc (Zn)	(mg/L)			Limits of reporting 0.001 mg/L & 0.005 mg/L							
Site name	Site number	Year	Limit of reporting (mg/L)	Zn (tot)	Hardness (tot) (CaCO3) {Ca+Mg} (mg/L)	Adjust factor	Adjusted trigger value	Comparison to ANZECC trigger ADJUSTED value	Hardness (mg/L)	Zn	ANZECC trigger value*
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	2002	0.001	0.026					0-59	1	0.008
		2003	0.001	0.004	60	2.5	0.02	Acceptable	60-119	2.5	
		2004							120-179	3.9	
		2005	0.005	0.016	81	2.5	0.02	Acceptable	180-240	5.2	
		2006	0.005	0.02	56	1	0.008	Guideline exceeded	400	9	
		2007	0.001	0.08	91	2.5	0.02	Guideline exceeded			
		2008	0.001	0.06	96	2.5	0.02	Guideline exceeded			
		2009	0.001	0.018	98	2.5	0.02	Acceptable			
		2010									
EMU SWAMP DRAIN EXIT	BBCSN10	2002	0.001	0.029							
		2003	0.001	0.003	100	2.5	0.02	Acceptable			
		2004	0.005	0.007	93	2.5	0.02	Acceptable			
		2005	0.005	0.012	92	2.5	0.02	Acceptable			
		2006	0.005	0.009	94	2.5	0.02	Acceptable			
		2007	0.001	0.06	110	2.5	0.02	Guideline exceeded			
		2008	0.001	0.06	110	2.5	0.02	Guideline exceeded			
		2009	0.001	0.014	100	2.5	0.02	Acceptable			
		2010	0.001	0.011	94	2.5	0.02	Acceptable			

Aluminium (Al) (total sediment)	(mg/kg)			Limit of reporting 0.5 mg/Kg						
ANZECC guideline: Not Set (NS)	Max (red) 9,120			Min (blue) 270						
Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09					1,300		270	420	
EMU SWAMP DRAIN EXIT	BBCSN10					910	970	520	9,120	920

Arsenic (As) (total sediment)	(mg/kg)			All data in blue were <0.5 (LOR)						
ANZECC guideline: 20 mg/kg	Max (red) 7.2			Min (blue) 0.25						
Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	1.8	0.25		0.25	0.91		0.25	0.25	
EMU SWAMP DRAIN EXIT	BBCSN10	1.8	1.3	1.9	1.3	1.5	1.2	1.1	7.2	1

Cobalt (Co) (total sediments) (mg/kg) All data in blue were below limits of reporting 0.5 mg/Kg & 1.0 mg/Kg

ANZECC guideline: NS Max (red) 1.1 Min (blue) 0.25

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09					0.5		0.25	0.25	
EMU SWAMP DRAIN EXIT	BBCSN10					0.5	0.25	0.25	1.1	0.25

Iron (Fe) (total sediment) (mg/kg) Limit of reporting 0.5 mg/Kg

ANZECC guidelne: NS Max (red) 38,400 Min (blue) 400

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09					860		400	710	
EMU SWAMP DRAIN EXIT	BBCSN10					2,400	1,960	870	38,400	2,450

Mercury (Hg) (total sediments) (mg/kg) All data in blue were below limits of reporting 0.2 mg/Kg and 0.1 mg/Kg

ANZECC lower guideline: 0.15 mg/kg Max (red) 0.23 Min (blue) 0.05

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	0.23	0.1		0.05	0.05		0.1	0.1	
EMU SWAMP DRAIN EXIT	BBCSN10	0.1	0.1	0.05	0.05	0.05	0.1	0.1	0.1	0.1

Manganese (Mn) (total sediments) (mg/kg) All data in blue were <0.5 (LOR)

ANZECC guideline: NS Max (red) 24.0 Min (blue) 0.7

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09					4.9		1.1	2.6	
EMU SWAMP DRAIN EXIT	BBCSN10					4.1	4.4	0.74	24.0	5.2

Molybdenum (Mo) (total sediments) (mg/kg) All data in blue were below limits of reporting 0.5 mg/Kg & 1.0 mg/Kg

ANZECC guideline: NS Max (red) 0.6 Min (blue) 0.25

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09					0.5		0.25	0.25	
EMU SWAMP DRAIN EXIT	BBCSN10					0.5	0.25	0.25	0.6	0.25

Selenium (Se) (total sediments) (mg/L) All data in blue were <0.5 (LOR)

ANZECC guideline: NS Max (red) 72.0 Min (blue) 0.25

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09					0.25		0.25	4	
EMU SWAMP DRAIN EXIT	BBCSN10					0.25	0.25	0.25	72	0.25

Cadmium (Cd) (total sediments) (mg/L) All data in blue were below limits of reporting 0.2 mg/Kg, 0.5 mg/Kg & 1.0 mg/Kg

ANZECC lower guideline: 1.5 mg/kg Max (red) 0.5 Min (blue) 0.1

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	0.25	0.25		0.5	0.5		0.25	0.25	
EMU SWAMP DRAIN EXIT	BBCSN10	0.25	0.25	0.5	0.5	0.5	0.25	0.25	0.25	0.1

Chromium (Cr) (total sediments) (mg/L) All data in blue were <0.5 (LOR)

ANZECC lower guideline: 80 mg/kg Max (red) 14.0 Min (blue) 0.6

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	7.3	2.5		2.8	2.7		0.64	0.8	
EMU SWAMP DRAIN EXIT	BBCSN10	1.2	1.5	1.2	1.3	1.7	1.8	1.0	14.0	1.6

Copper (Cu) (total sediments) (mg/L) All data in blue were below limits of reporting 0.5 mg/Kg & 1.0 mg/Kg

ANZECC lower guideline: 65 mg/kg Max (red) 11.0 Min (blue) 0.25

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	6.7	2.2		4.1	4.0		0.25	0.59	
EMU SWAMP DRAIN EXIT	BBCSN10	0.25	0.25	0.5	0.5	0.5	0.25	0.25	11	0.97

Lead (Pb) (total sediments) (mg/L) All data in blue were below limits of reporting 1.0 mg/Kg

ANZECC lower guideline: 50 mg/kg Max (red) 28 Min (blue) 0.5

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	28	9		12	9.2		1.5	1.3	
EMU SWAMP DRAIN EXIT	BBCSN10	1.2	1.1	0.5	0.5	0.5	0.87	0.66	19	1.7

Nickel (Ni) (total sediments) (mg/L) All data in blue were below limits of reporting 0.5 mg/Kg & 1.0 mg/Kg

ANZECC lower guideline: 21 mg/kg Max (red) 3.5 Min (blue) 0.25

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	0.25	0.63		0.5	0.5		0.25	0.25	
EMU SWAMP DRAIN EXIT	BBCSN10	0.25	0.25	0.5	0.5	0.5	0.54	0.25	3.5	0.25

Zinc (Zn) (total sediments) (mg/L) All data in blue were <0.5 (LOR)

ANZECC lower guideline: 200 mg/kg Max (red) 39 Min (blue) 0.25

Site name	Site number	2002	2003	2004	2005	2006	2007	2008	2009	2010
BENNETT BROOK - COAST ROAD - UNIWELD	BBCSN09	38	29		39	28		4.7	0.25	
EMU SWAMP DRAIN EXIT	BBCSN10	8.8	7	8.4	7.8	12	7.7	4	0.25	9.7

Appendix 2 – Trigger Values and Guidelines

Trigger values and guidelines for nutrient concentrations and physical properties in lowland rivers and freshwater

Guideline	DO (% saturation)	pH	TN (mg/L)	NO_x-N (mg/L)	TP (mg/L)	FRP (mg/L)
ANZECC Water quality trigger value – lowland river (2000)	80-120	6.5 - 8.0	1.2	0.15	0.065	0.04
ANZECC Water quality trigger value – Recreational (2000)	>80	6.5 – 8.5	-	10	-	-
Swan Canning Cleanup Program Action Plan Targets (Bennett Brook)	-	-	2.0	-	0.1	-

ANZECC trigger values and guidelines for heavy metals in freshwater

Guideline	Al (mg/L)	As (mg/L)	Cd* (mg/L)	Cr* (mg/L)	Co* (mg/L)	Cu* (mg/L)	Fe (mg/L)	Pb* (mg/L)	Hg (mg/L)	Mn (mg/L)	Mo (mg/L)	Ni* (mg/L)	Se (mg/L)	Zn* (mg/L)	Hardness (mg/L)
ANZECC Water quality trigger value – Recreational (2000)	0.2	0.05	0.005	0.05	-	1.0	0.3	0.05	0.001	0.1	-	0.01	0.010	5.0	500
ANZECC Water quality trigger value – Freshwater 95% (2000)	0.055	0.024	0.0002	0.001	0.0028	0.0014	0.3	0.0034	0.0006	1.9	0.023	0.011	0.011	0.008	-

* Trigger values not adjusted for water hardness.

ANZECC trigger values for toxicants in sediments

Guideline	Al (mg/kg)	As (mg/kg)	Cd (mg/kg)	Co (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Pb (mg/kg)	Hg (mg/kg)	Mn (mg/kg)	Mo (mg/kg)	Ni (mg/kg)	Se (mg/kg)	Zn (mg/kg)
ANZECC Sediment Quality Guideline (Interim) Low trigger value (2000)	-	20	1.5	-	80	65	-	50	0.15	-	-	21	-	200
ANZECC Sediment Quality guideline (Interim) High trigger value (2000)	-	70	10	-	370	270	-	220	1.0	-	-	52	-	410