DIRK BROOK

ASSESSING CHANGE IN HABITAT QUALITY IN RURAL DRAINS USING THE AUSRIVAS BIOASSESSMENT PROTOCOL

WATER AND RIVERS COMMISSION REPORT
WATER RESOURCE TECHNICAL SERIES

Water and Rivers Commission

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Resource Science Division

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Cows in Dirk Brook
Robyn Paice

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Summary

The Dirk Brook Drainage network consists of a series of highly modified natural watercourses whose primary use is to provide a drainage function to surrounding agricultural land. Best management practices are to be implemented throughout the drainage network to improve the quality of the water entering the receiving waterbody (the Serpentine River) as well as to enhance the physical and social values of the drains themselves. Sampling was conducted in 1999 before the commencement of ground works to provide a background ecosystem status for the drains and allow comparisons against a baseline reference condition as the improvements are implemented.

The drains were in poor physical shape, all sites exhibiting some form of anthropogenic disturbance. The physical water quality was generally acceptable with the exception of specific conductivity which exceeded the Australian and New Zealand Environment and Conservation Council (ANZECC) guidelines for aquatic ecosystems in lowland rivers of south-western Australia at more than half of the sites sampled. Australian Rivers Assessment Scheme (AUSRIVAS) showed that a large proportion of the sites were below reference condition, as was the drainage network overall with an Observed over Expected (O/E) score of 0.67.

It is predicted that as the ground works are implemented the water and habitat quality will slowly improve and that this will be reflected in the macroinvertebrate community structure as an increase in the overall O/E score for the network.

The improvements will also help alleviate problems such as siltation and bank slumping and, once a buffer strip of native vegetation has established, the need for chemical weed control. The annual maintenance costs for the drainage network will consequently decrease as the requirements for mechanical sedimentation removal, bank slump correction and chemical weed control are reduced.

1. Introduction

1.1 Drains – history and use

Traditionally, rural drains have been constructed to provide an effective means of removing excess water, nutrients and sediments from surrounding land. Generally they are constructed as straight channels in a dendritic (branching) formation with the drain's capacity increasing downstream through the catchment and eventually flowing into a natural watercourse. A high level of annual maintenance (dredging to straighten meandering channels, remove siltation and correct bank slumping as well as chemical weed control) is required to ensure that the drainage function is not compromised. Drains have also been identified as one of the major contributors of nutrients and silt to their receiving waterbodies. This helps fuel nuisance algal blooms and contributes to other problems associated with eutrophication and siltation.

1.2 Drains – the future

It is now accepted that drains have the potential to perform their drainage functions whilst simultaneously providing ecological and aesthetic uses. Improving drainage systems by implementing Best Management Practices (BMPs) has the potential to reduce the amounts of nutrients and sediments entering receiving waterbodies. Vegetated drains also provide a habitat for a range of native fauna and are less prone to problems such as slumping, undercutting and erosion.

1.3 Best management practices (BMPs)

Best management practices can be used to convert traditional high-maintenance drains into low-maintenance, multipurpose watercourses. The objective of BMPs are to ensure that drains:

- perform their required drainage function;
- minimise the amount of nutrients entering receiving waters;
- act as wildlife corridors; and
- enhance the landscape amenity and recreational opportunities.

To achieve the above objectives a range of options can be taken including:

- restricting stock access to the drains;
- managing erosion;
- controlling weed species; and
- restoring native vegetation or re-vegetating where necessary.

It is expected that by adopting BMPs significant improvements will be detected in the water quality, ecological values and recreational opportunities within the drainage network. To encourage the widespread adoption of BMPs it is important that the benefits and improvements are measured and communicated to the agencies responsible for drain management and the broader community.

Improvements in water quality can be measured in many ways, in this case traditional chemical and physical analyses were used in conjunction with drain assessment and a biological method. This project set out to test the viability of using macroinvertebrate communities to assess ecological improvements arising from catchment management initiatives. The biological component will be assessed using macroinvertebrates and the AUSRIVAS (Australian River Assessment Scheme) model developed through the Monitoring River Health Initiative (MRHI).

1.3.1 Integrated catchment management

Catchment restoration and management rarely happens simultaneously on a whole of catchment scale. Rather, small stretches or pockets of rivers and streams are rehabilitated by concerned landowners or community groups. These small-scale changes will only have a very localised effect on water quality. As time progresses the number and reach of the rehabilitated pockets will increase and eventually some pockets will meet up. Ultimately a large proportion of the catchment will be rehabilitated and managed and the changes in water quality will be detected in routine monitoring.

1.4 Ecosystem monitoring

1.4.1 The importance of monitoring

Water quality monitoring programs must allow environmental managers to track changes in a system over time. By using the data generated it should be possible to determine if a system is improving or degrading and, when necessary, to implement remedial actions. They also allow the effectiveness of activities such as BMPs to be assessed.

1.4.2 The monitoring program design problem

Monitoring usually involves sampling at a fixed time interval at a fixed site (normally located at the bottom of a catchment). Often a number of such sites are sampled as a part of a program so that the major inflows to a receiving waterbody are monitored. These data are then used to make inferences regarding the condition of the catchments through which the rivers flow and to link changed in water quality to management initiatives. The problem with this style of monitoring is that improvements in water quality due to catchment management initiatives will not be detected until a substantial amount of work has occurred.

1.4.3 Biological monitoring

The use of biological indicators of pollution in surface water assessment began in Germany before the turn of the century (Metcalfe 1989). Since then the number of monitoring programs utilising biological information has soared. These methods can be divided into two distinct groups. Firstly, the Saprobic system, based mainly on the presence of micro-organisms belonging to the plankton ad periphyton communities, originated in the United Kingdom. Secondly, methods based on the presence or absence of macroinvertebrate indicators which were developed in the United States of America (Metcalfe 1989).

Opposition has been raised to the use of biological information in monitoring which has slowed its widespread acceptance. The most commonly advanced criticisms are:

a) the standardisation found in physico-chemical monitoring programs is lacking;

b) there is a perception that this type of monitoring is expensive; and

c) the data collected are difficult to interpret, especially by non-specialists.

(Norris and Norris 1995).

Recent work has shown that these arguments are not necessarily well founded. Standardised approaches to bio-assessment have been available since the early work by Kolkowitz and Marsson (1908, 1909) and more continue to be developed. The expense of biological monitoring is no more than that associated with a similar level of chemical monitoring (Norris and Georges 1986). Lastly, the number of indices and scores which have been developed to simplify biological data is immense (see Washington 1984). Norris and Georges (1986) further argue that biological specimens can be stored indefinitely and the data easily reproduced. This allows historical data to be updated as taxonomy changes, whereas water samples cannot be stored making comparison over time difficult as laboratory analysis methods change.

1.4.4 Macroinvertebrates in biological monitoring

Using biological methods, it is not feasible to monitor a complete ecosystem due to logistical and financial reasons and so it becomes necessary to select a representative group of organisms. In aquatic ecosystems there is a range of groups available, macroinvertebrates being the most widely used. They are not ideal biological indicators (no single component of an ecosystem is), but they are one of the groups most suited to this application (Camargo 1993, Campbell, 1978 and Horwitz and Davis 1997). Their advantages include:

a) they are relatively sedentary (Blyth 1980, Cairns and Pratt 1993 and Campbell 1978);

b) their collection and identification is fairly easy (Cairns and Pratt 1993 and Campbell 1978);

c) their reaction to human influences on the aquatic ecosystem is detectable and, often, predictable (Cairns and Pratt 1993);

d) their life cycles range from a few days to a few weeks so their communities only recover slowly after a disturbance (Cairns and Pratt 1993, Campbell 1978 and Chessman 1995);

e) they are utilised as a food source by fish and waterbirds and thus are explicable to the general public (Cairns and Pratt 1993);

f) As well as being the basis of many fish and waterbirds diets macroinvertebrate communities encompass many trophic levels and hence changes to their environment will alter their community composition (Chessman 1995).

Due to their numerous advantages, many biological monitoring systems, both in Australia and overseas, are based on macroinvertebrates.

1.4.5 Rapid assessment

Traditional biological monitoring is based on fully quantitative sampling techniques (taking a large number of replicate samples which are processed in the laboratory with every organism present identified to species level). Quantitative sampling and analysis techniques are both time consuming and require a high level of expertise to implement. To promote the adoption of biological monitoring there has a been a global move towards semi-quantitative rapid assessment techniques (Growns *et. al* 1995). These methods require less time both in the field and laboratory and consequentially are more financially viable (Growns *et. al* 1995, Hannaford and Resh 1995 and Trayler and Davis 1997). The collected data are usually transformed using a biotic index, model or score system to give a single, easily understood value.

1.5 Predictive models

1.5.1 AUSRIVAS

In 1992 the Federal Government established the National River Health Program (NRHP) in response to declining river conditions. The primary aims of this program were to:

1. monitor and assess the ecological condition of Australian rivers;

2. assess the effectiveness of current management practises; and

3. provide better ecological and hydrological data on which to base management decisions.

(Smith *et al.* 1999).

There were two phases to the NRHP. The first phase, which commenced in 1993, was the Monitoring River Health Initiative (MRHI) which was a national program using aquatic invertebrates to assess the ecological status of Australia's rivers. The aim of the MRHI was to develop mathematical models to predict the macroinvertebrates expected at a site based on a range of geographic and habitat measurements. A ratio is then formed using the predicted (or expected) invertebrate community and the observed community. These models are known as the Australian River Assessment Scheme (AUSRIVAS) models (Smith and Kay 1998).

The next phase of the NRHP, involved the use of the AUSRIVAS models to conduct the First National Assessment of River Health (FNARH), the results of which will be used to produce the first major State of the Environment report on Australia's rivers (Smith and Kay 1998).

1.5.2 Model construction

To construct the Western Australian version of the AUSRIVAS model, data were combined according to flow regime rather than season as was the case in most other states. This was due to the variability in flow regimes in West Australian rivers (ie northern rivers tend to have their peak flows during the summer whilst southern rivers have theirs in winter):

1. Firstly, reference sites were split into groups based on their invertebrate communities. Those sites with fewer than six families present were excluded from the classification as were those families that occurred at less than five percent of the sites to ensure that classification was not influenced by rare families. A number of different

classifications were trialed and the one that corresponded best to the known patterns in biological and physical data were used for model construction (Smith and Kay 1998).

2. Once the best classification system was selected it was necessary to identify which environmental variables most accurately discriminated between groups in the classification. Those variables which are commonly affected by anthropogenic activity were not included whilst those that contributed significantly ($P<0.05$) to discrimination were labelled as predictor variables. Only one predictor variable was allowed for every 20 reference sites (Smith and Kay 1998).

3. Next, predictor variables were incorporated into a discriminate function and sites were assigned to groups identified in the initial classification. It was then checked that sites were assigned to the correct groups and any incorrect allocations were identified. If these appeared to be geographical outliers or non-conformist in terms of habitat characteristics they were removed from the classification (Smith and Kay 1998).

4. Then, the number of families expected at each site (E) was calculated by summing the probability of each family occurring at each site. (The probability of a family occurring at a site was determined by multiplying the probability of a site belonging to a classification group by the probability of a family occurring in that group.) Only those families with a probability of occurrence greater than 0.5 were used in the calculations of E as uncommon families tended to cause large random fluctuations in O/E ratios. (Smith and Kay 1998).

5. Lastly, a preliminary model was used to calculate O/E ratios of reference sites. Those sites with ratios less than 0.75 were removed from the classification system as it was assumed they were not true reference sites and steps two to four were repeated, producing a final model (Smith and Kay 1998).

1.5.3 Model output

The final output of the model is an O/E ratio for each site examined. This is the ratio of the observed number of macroinvertebrate families to the number expected at the site. It is important to note that not all families observed at a site will be used to calculate the O/E ratio; in its calculations the model only includes those families that it predicted to occur at a site. To simplify the interpretation of results by managers the model assigns the O/E ratios to bands (see Table 1).

If an index value of one is scored it indicates that all the expected families for the site were collected. Index values greater than one indicate that more families were collected than expected. This could indicate one of three things:

1. Chance factors may have caused the high number of families collected. This includes factors such as sampler variability (a very efficient sampler will collect more families than an inefficient one).

2. There may be an unusual microhabitat or other ecological factor which permits the co-existence of more families than expected.

3. The site may be disturbed in a manner that allows additional families to establish. Such disturbance would include mild nutrient enrichment which has the potential to allow more diverse communities than normal to exist.

(Smith and Kay 1998)

Lower index values indicate varying levels of disturbance as outlined in Table 1.

Table 1. Division of the indices into bands or categories for reporting.

Band	O/E Score	Label
X	> 1.15	Slightly disturbed or biological hotspot
A	0.85 – 1.15	Undisturbed
B	0.55 – 0.84	Moderately Impacted
C	0.25 – 0.54	Significantly impacted
D	0.00 – 0.24	Extremely impacted

(Taken from Halse *et al* 2002)

1.5.4 Expected effects of ground works on macroinvertebrate fauna

The macroinvertebrate communities are expected to respond in a predictable manner to the ground works undertaken. It is expected that the average family and species diversity will increase for the drainage network (Cronin 1998). Further, the average O/E score for the drainage network would increase as the habitat is slowly restored to a more natural condition. The O/E scores should be viewed on a catchment scale for management purposes as the AUSRIVAS models are not considered to be sensitive enough to pick up changes on a site-by-site basis (Australian and New Zealand Environment and Conservation Council 2000).

1.6 Study area

The Dirk Brook catchment is located roughly 50km south of Perth (see Figure 1). It covers an area of approximately 69 km^2 with the major land uses being stock grazing, turf farming, piggeries and horticulture. Over 95% of the original vegetation has been cleared in the western two-fifths of the catchment and the land has been significantly drained to support rural uses. Dirk Brook itself begins in the Darling Scarp before flowing onto the Swan Coastal Plain, where it is joined by Myara Brook before flowing west and then north-west to the confluence with Dirk Brook Drain. North of this point the Dirk Brook drain has Karnup Brook and many smaller drains flowing into it after which it flows as a channel to its discharge point at Lake Amarillo on the Serpentine River. The total length of the brooks and drains is over 80km.

1.6.1 Climate

The climate on the Swan Coastal Plain is Mediterranean with cool wet winters and hot dry summers. The rainfall is highly seasonal with approximately 90% of the average annual rainfall of 840mm occurring in the period between May and August. It is only in these months of high rainfall that precipitation exceeds evaporation.

1.6.2 Geology

The majority of the Dirk Brook catchment is located on leached, deep grey, sands and duplex (sands over clays) soils. The deep grey sands, located directly to the east of the Serpentine River are porous with a low organic content and poor nutrient retention capacity. Located at the base of the scarp are the duplex soils which have a low phosphorous binding and retention capacity and are naturally infertile. The red earths are only present in a narrow band along the eastern fringes of the Swan Coastal Plain. They are porous and, due to their high iron content, possess a good phosphorous binding capacity.

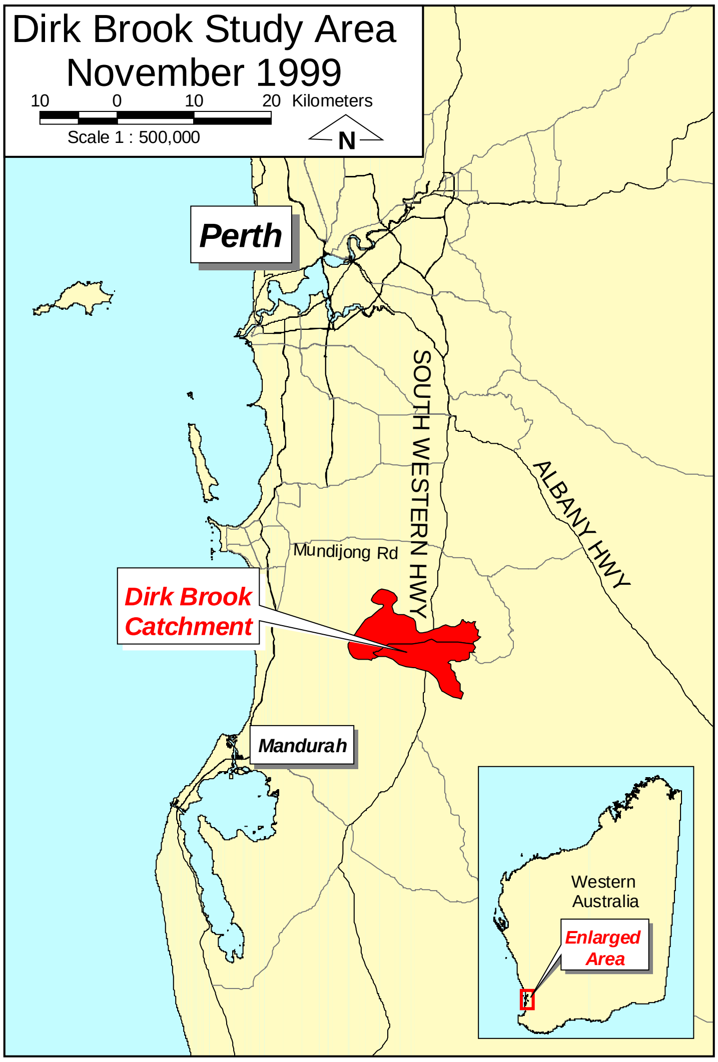

Figure 1. Location of Dirk Brook Catchment

1.7 Site selection

Sites to be sampled were selected using a random approach. A map of the drainage network was used to identify 250m sections of channel which were then numbered. A total of 213 sections were numbered and then random number selection was used to identify 30 sites. Of these, seven were found to be dry and were not sampled leaving a total of 23 sites (see Figure 2).

1.8 Site descriptions

See figure 3.

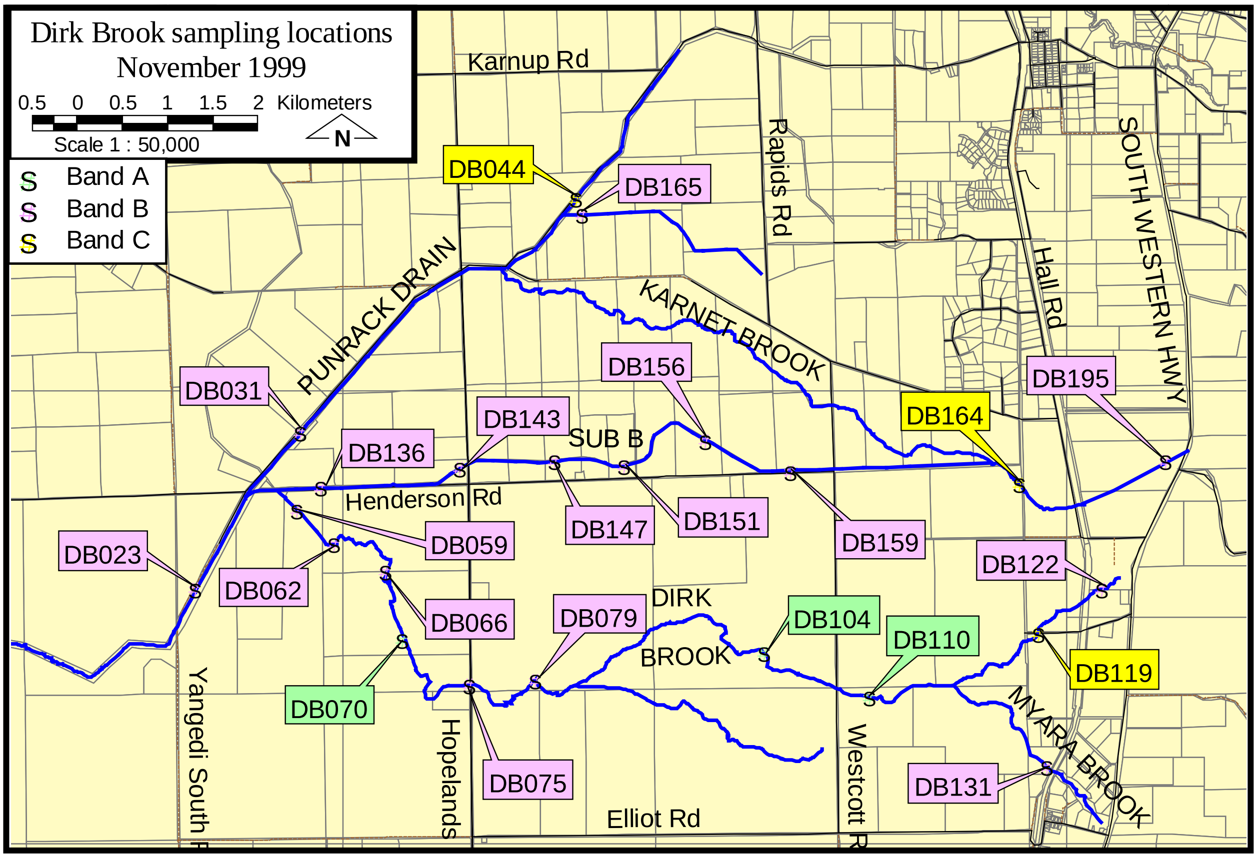

Figure 2. Dirk Brook sampling locations

Plate 1: DB023 – Punrack Road Drain
Latitude: 115.877; Longitude –32.417
A highly modified agricultural drain. The substrate was mostly sand with some silt. The predominant fringing vegetation consists of grasses, clovers, Watsonia and wild lupins.

Plate 2: DB031 – Punrack Road Drain
Latitude 115.889; Longitude –32.402
A highly modified agricultural drain with a sandy substrate and some silt. The fringing vegetation consists mainly of pasture grasses, Watsonia and some *Typha* sp. The dominant habitat was macrophytes.

Plate 3: DB044 – Punrack Road Drain
Latitude 115.922; Longitude –32.378
A substantially modified drainage channel. Fringing vegetation consists of wild oats, grasses and Watsonia. The substrate is bedrock with areas of gravel, sand, clay and silt. An algal scum was visible.

No picture available

Plate 4: DB059
Latitude 115.888; Longitude –32.408
A linear section of drainage channel. The riparian vegetation consists of various pasture species with some trees. The site was adjacent to a turf farm and has a sandy substrate.

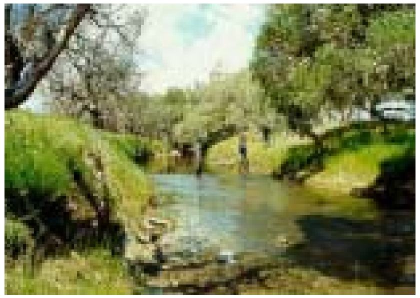

Plate 5: DB062 – Dirk Brook
Latitude 115.893; Longitude –32.412
A natural watercourse heavily impacted by clearing. The substrate is mainly gravel with some pebbles, sand, silt and bedrock. Fringing vegetation consists of Melaeleuca and *E. rudis* with an understorey of pasture grasses. A dense algal scum was observed.

Plate 6: DB066 – Dirk Brook
Latitude 115.899; Longitude –32.415
A natural looking watercourse. Substantial stands of *E. calophylla, E. rudis* and Melaleuca are present. The understorey consists mainly of grasses and Watsonia with some sedges. The substrate is sand with some gravel and silt.

Plate 7: DB070 – Dirk Brook
Latitude 115.901; Longitude –32.422
A modified natural watercourse. Riparian species were Melaleuca, *E. rudis* and *E. calophylla* with an understory of pasture grasses, sparse *Juncus pallidus* and Watsonia. The substrate is sand with some silt and gravel. Algae was present.

Plate 8: DB075 – Dirk Brook
Latitude 115.909; Longitude –32.426
A highly modified reach of a natural watercourse. Fringing vegetation is limited to pasture grasses and very sparse *Baumea articulata*. The substrate consists of sand with some silt, clay and bedrock.

Figure 3. Site descriptions

Plate 9: DB079 – Dirk Brook
Latitude 115.916; Longitude –32.426
A modified reach of the natural watercourse. Fringing vegetation consists of grasses and weeds and half of the reach had *E. calophylla* present. The substrate is sand with some bedrock and silt. Algal growth was present.

Plate 10: DB104 – Dirk Brook
Latitude 115.944; Longitude –32.424
A modified natural watercourse. Remnant Melaleuca and *Agonis linearifolia* are present with an understorey of *J. articulatus*. Poplars and wattles had been planted as part of a revegetation effort. The predominant substrate is clay with some gravel and bedrock. Algal mats were visible.

Plate 11: DB110 – Dirk Brook
Latitude 115.956; Longitude –34.428
A modified reach in a natural watercourse. Fringing vegetation is Watsonia with some *J. articulatus* and Melaleuca. The dominant substrate is gravel with some sand, clay and pebbles. Algal mats were present.

Plate 12: DB119 – Dirk Brook
Latitude 115.976; Longitude –32.422
A highly modified reach of the natural watercourse. Some remnant patches of *E. calophylla* and *A. linearifolia* are present with areas of dense *J. pallidus* and *J. articulatus* on the banks. The substrate is sand with some silt and gravel.

Plate 13: DB131 – Myara Brook
Latitude 115.977; Longitude –32.435
A modified reach of the natural watercourse. Remnant Melaleuca, *E. calophylla* and *E. rudis* are present with an understorey of grasses and Watsonia. The substrate is clay, gravel and silt with some areas of pebbles. Algal scums were present.

Plate 14: DB136 – Sub B Drain
Latitude 115.891; Longitude –32.407
A linear artificial agri-drain with little native vegetation present except for some remnant *E. calophylla*. The understorey is predominantly grasses. The substrate consists of gravel with some sand, silt and pebbles.

Plate 15: DB143 – Sub B Drain
Latitude 115.908; Longitude –32.405
Artificial linear drain running through a horse paddock. A few isolated *E. rudis* present with an understorey of pasture species. The dominant substrate is sand and silt with some gravel, pebbles and clay. Algal scums were present.

Plate 16: DB147 – Sub B Drain
Latitude 115.919; Longitude –32.404
An artificial linear channel with remnant *E. calophylla* on the banks and evidence of revegetation of shrubs and trees. Dense Kikuyu and some small stands of *J. pallidus* are present. The substrate is bedrock, gravel and cobbles. Dense algal scums were present

Figure 3. Continued.

Plate 17: DB151 – Sub B Drain
Latitude 115.927; Longitude –32.405
An artificial channel (last excavated in May 1999). Eucalyptus present on banks with an understorey of Kikuyu grass, Watsonia and other weeds. The substrate is mainly clay and gravel with some sand.

Plate 18: DB156 – Sub B Drain
Latitude 115.937; Longitude –32.403
A linear artificial drainage channel. The vegetation consists of pasture grasses and *J. pallidus* with some remnant *E. rudis*. The substrate is gravel mixed with some sand and silt. Algal scums were present.

Plate 19: DB164 – Karnet Brook
Latitude 115.974; Longitude –32.407
A highly modified natural watercourse. *E. calophylla* is present with an understorey of pasture grasses and *J. pallidus.* The substrate is bedrock and gravel with some sand and clay. Algal scums were present.

Plate 20: DB165 – Sub 1A1 Drain
Latitude 115.923; Longitude –32.380
A linear agri-drain. Fringing vegetation consists of Watsonia and pasture grasses. The substrate is clay with sand, gravel, pebbles and silt. Algal scums were present.

Plate 21: DB195 – Karnet Brook
Latitude 115.990; Longitude –32.405
A modified natural watecourse. Remnant eucalyptus are present with an understorey of mainly pasture grasses and some *J. pallidus* and Watsonia. The substrate is clay with sand and pebbles also present.

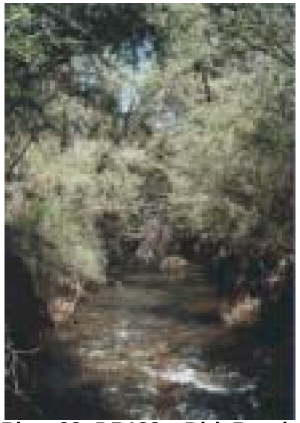

Plate 22: DB122 – Dirk Brook
Latitude 115.983; Longitude –32.418
A natural channel with stands of *A. linearifolia* and *E. calophylla* and an understorey of shrubs and herbs. The substrate is sand with some cobbles, pebbles, gravel and bedrock.

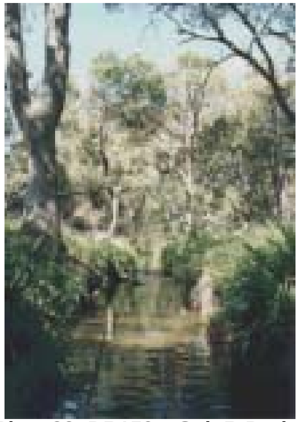

Plate 23: DB159 – Sub B Drain
Latitude 115.946; Longitude –32.406
A natural watercourse. Eucaypts are present with an understorey of Watsonia and other weeds. The substrate is bedrock with some pebbles, gravel and sand present. Algal scums were present.

Figure 3. Continued.

2 Sampling Methods

2.1 Drain condition and dimensions

At each site an assessment of drain condition was undertake using the assessment sheets developed for the Water and Rivers Commission by Regeneration Technology (see Appendix 1). This method uses a number of factors to give drains a rating for three sections; Stock access, Erosion/sedimentation and Revegetation. The ratings are defined as follows:

A	Good
B	Average
C	Poor
D	Very Poor

2.2 Water quality

A Hydrolab datasonde multiparameter probe was used to measure the following parameters in situ:

- dissolved oxygen (percent saturation);
- temperature (°C);
- salinity (ppt);
- specific conductivity (μS/cm);
- pH.

Water samples were also collected and forwarded to a chemical laboratory for nutrient analysis. The analysis performed were as follows:

- total phosphorus;
- total nitrogen;
- ammonium;
- oxides of nitrogen;
- dissolved ortho-phosphate.

2.3 Macroinvertebrate sampling

Macroinvertebrate samples were collected using the national AUSRIVAS protocols (Davies 1994).

A D-framed pond net (350mm wide and 250mm high) with 250µm mesh was used to take the sweep samples and the collected material was washed through a stack of sieves with mesh apertures of 10mm, 2mm, 500µm and 250µm to remove coarse organic material. The samples were then live picked in the field for 60 minutes and the collected specimens were preserved in 70% ethanol and forwarded to the CALM Wildlife Research Centre for subsequent identification. The macroinvertebrates were identified to species level where possible though the results presented here use the level of taxonomic resolution recommended for use in the AUSRIVAS model (family for most taxa, sub-family for the Chironomidae, class for the Oligochaetes and order for the Acarina). For convenience, all groups are referred to as family in this report. The Microcrustacea (copepods, ostracods and cladocerans) were not identified as the model places an emphasis on rapid bioassessment and collection and identification of the microcrustacea is time consuming.

3 Results

3.1 Drain condition rating

Table 2. Drain condition ratings

Site Code	Stock access rating	Erosion/ sediment rating	Reveg. rating
DB023	A	C	D
DB031	A	C	D
DB044	B	C	D
DB059	B	D	D
DB062	D	D	D
DB066	B	D	C
DB070	C	D	C
DB075	C	C	D
DB079	B	D	C
DB104	B	C	C
DB110	D	C	C
DB119	B	C	C
DB122	A	C	C
DB131	D	C	C
DB136	C	C	D
DB143	C	C	D
DB147	A	D	D
DB151	A	C	D
DB156	C	C	D
DB159	B	C	D
DB164	B	C	D
DB165	C	C	D
DB195	B	B	C

3.1.1 Stock access score

Of the 23 sites sampled 8 were fenced on both sides, 11 on one side and four were not fenced at all. Fourteen of the sites had current stock access to them at the time of the survey.

3.1.2 Erosion/sedimentation score

The majority of the sites showed some evidence of erosion and sedimentation. The overall erosion/sedimentation score was very poor for 6 of the sites, poor for 6 of the sites and one site was designated as average. Almost all sites showed evidence of undercutting, siltation and bank subsidence. Only 9 of the sites had a meandering flow, all the rest were straight, 14 of the sites had rocky bars or physical traps. The substrate at 15 of the sites was a sand or loose loam, 5 sites had a clay or clayey loam substrate and 3 had a rock or stone substrate.

3.1.3 Revegetation score

The overall revegetation score was very poor at one site, poor at 14 sites and average at 8. Only 6 sites had remnant vegetation (defined as native vegetation with at least two strata of plants) within 50m and 11 sites had priority weeds present. High nutrient evidence (manure in drain or algal scums) was present at 19 of the 23 sites.

3.1.4 Habitat composition

The dominant habitat at all sites with the exception of DB031 where macrophytes were dominant, was channel. Riffles and pool rocks contributed only a small percentage of the habitat at those sites in which they were present.

3.2 Water quality

The ANZECC guideline values referred to here are for aquatic ecosystem quality in lowland rivers of south-western Australia and have been taken from the draft ANZECC (2000) guidelines. It is recognised that these are guidelines only and that natural variation within the south-west region would fluctuate beyond these values, even within pristine areas. They are, however, useful as reference numbers against which to compare the collected data and that is the manner in which they have been utilised here.

3.2.1 Temperature (°C)

The minimum water temperature recorded was 16.4°C (DB122) and the maximum 31.5°C (DB165) with a median of 21.26°C (see Figure 4).

3.2.2 DO (% saturation)

Dissolved oxygen levels ranged from a minimum of 73.6% (DB131) to a maximum of 124.3% (DB165) with a median of 89.9%. Four sites fell outside the ANZECC water quality guidelines for aquatic systems. DB165 (124.3%) was over the maximum recommended level of 120% while DB131 (73.6%), DB159 (79.5%) and DB195 (75.4%) were under the recommended lower level of 80% (Australian and New Zealand Environment and Conservation Council 2000). (See Figure 4)

3.2.3 pH

pH values were fairly uniform throughout the study area with a range from 6.76 (DB031) to 9.25 (DB062) and a median of 7.46. Three values fell above the ANZECC water quality guideline for pH in aquatic systems of 8.0 (Australian and New Zealand Environment and Conservation Council 2000), these were sites DB059 (8.71), DB062 (9.25) and DB075 (8.08). (See Figure 4).

3.2.4 Conductivity (µS/cm)

The maximum conductivity was 2310µS/cm (DB031), the minimum 244µS/cm (DB122) with a median of 313µS/cm. There were only 3 sites with a conductivity greater than 500µS/cm, these were DB031 (2130µS/cm), DB044 (1045µS/cm) and DB165 (2044µS/cm). Thirteen of the sites exceeded the ANZECC guideline of 300µS/cm for aquatic systems (Australian and New Zealand Environment and Conservation Council 2000). (See Figure 4).

3.2.5 Ammonium (mg/L)

Ammonium ranged from a maximum of 0.12mg/L (DB151) to a minimum below the detectable limit of 0.005mg/L (DB031) the median was 0.028mg/L. Only one site (DB151) exceeded the ANZECC guideline for aquatic systems of 0.08mg/L (Australian and New Zealand Environment and Conservation Council 2000). (See Figure 4).

3.2.6 Oxides of nitrogen (mg/L)

NO_x levels ranged form a maximum of 0.27mg/L (DB122) to below the lower detectable limit of 0.005mg/L (DB044 and DB165) with a median of 0.098mg/L. Seven sites exceeded the ANZECC guideline of 0.15mg/L for aquatic systems (Australian and New Zealand Environment and Conservation Council 2000), these were DB059 (0.18mg/L), DB066 (0.19mg/L) DB104 (0.19mg/L, DB119 (0.25mg/L) and DB122 (0.27mg/L). (See Figure 4).

3.2.7 Total nitrogen (mg/L)

Four sites recorded total nitrogen levels above the ANZECC guidelines for aquatic systems of 1.2mg/L (Australian and New Zealand Environment and Conservation Council 2000) (DB031 (1.7mg/L), DB044 (1.2mg/L), DB143 (1.6mg/L)). The maximum concentration was at site DB031 (1.7mg/L) and the minimum at site DB159 (0.14mg/L) with a median of 0.37mg/L. (See Figure 4).

3.2.8 Dissolved ortho-phosphate (mg/L)

Dissolved ortho-phosphate levels ranged from a maximum of 0.072mg/L at DB023 to less than the lower detectable limit of 0.003mg/L at 13 sites. The median was 0.012mg/L. Only two sites exceeded the ANZECC guideline for aquatic systems of 0.04mg/L (Australian and New Zealand Environment and Conservation Council 2000), DB023 (0.072mg/L) and DB059 (0.052mg/L). (See Figure 4).

3.2.9 Total phosphorus (mg/L)

Total phosphorous levels ranged from less than the lower detectable limit of 0.01mg/L at 9 sites to a maximum of 0.17mg/L at DB031 with a median of 0.02mg/L. Five sites exceeded the ANZECC guidelines for aquatic systems of 0.065mg/L (Australian and New Zealand Environment and Conservation Council 2000), these were DB023 (0.09mg/L), DB031 (0.17mg/L), DB059 (0.08mg/L), DB151 (0.11mg/L) and DB165 (0.11mg/L). (See Figure 4).

Figure 4. Water quality graphs

3.3 Macroinvertebrate fauna

A total of 48 families were collected from the 23 sites sampled. The most common families were the Leptoceridae and the Dytiscidae, both of which were collected from all 23 sites. Other commonly collected families were the Chironominae (22 sites) and the Physidae, Corixidae and Orthocladiinae, all of which were collected from 20 sites.

The highest number of families collected was from DB031 (24 families) and the lowest was from DB164 (10 families). Both the mean and the median for the dataset were 16 families.

Ephemeroptera, Plecoptera and Trichoptera (EPT) families tend to be sensitive to a wide range of pollutants and so their presence is often linked to good water and habitat quality. DB079 had the largest proportion of its macroinvertebrate fauna composed of EPT taxa (46%) and DB147 and DB159 had the least (7% each).

3.3.1 AUSRIVAS results

The O/E values ranged from 0.37 to 0.89. 13% of the sites fell into band A, 74% into band B and 13% into band C. There were only three sites classified as equivalent to reference condition (DB070, DB104 and DB110) all of which were located on Dirk Brook. The average O/E score for the drainage network was 0.67 which places it in band B, moderately impacted.

The sites located on Dirk Brook, a modified natural watercourse tended to score higher than those on the Sub-B drain which is highly modified.

There was no significant correlation between the O/E scores and the total number of families collected or the number of EPT families collected. Neither was there a significant correlation between the O/E scores and any of the physical or chemical water quality data collected (see Figures 7 to 17).

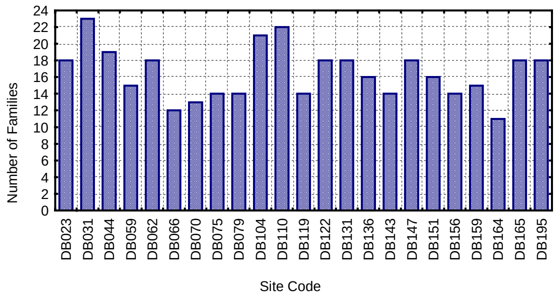

Figure 5. Number of families at each site

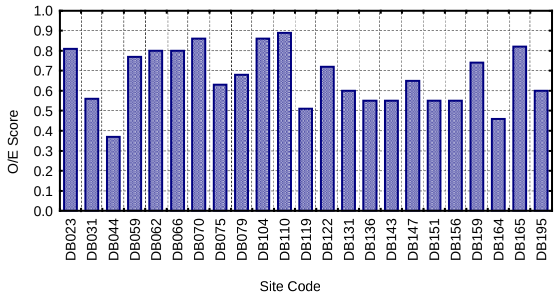

Figure 6. O/E score at each site

Table 3. Richness, EPT and O/E

	Richness		EPT		O/E	
Site Code	Species	Family	Species	Family	Score	Band
DB023	25	18	5	4	0.81	B
DB031	33	23	8	4	0.56	B
DB044	37	19	4	3	0.37	C
DB059	23	15	5	4	0.77	B
DB062	29	18	5	4	0.80	B
DB066	23	12	5	4	0.80	B
DB070	14	13	7	6	0.86	A
DB075	25	14	3	3	0.63	B
DB079	30	14	6	5	0.68	B
DB104	32	21	8	5	0.86	A
DB110	31	22	7	5	0.89	A
DB119	22	14	3	2	0.51	C
DB122	22	18	4	4	0.72	B
DB131	29	18	4	4	0.60	B
DB136	26	16	4	3	0.55	B
DB143	23	14	4	3	0.55	B
DB147	21	18	4	3	0.65	B
DB151	29	16	3	2	0.55	B
DB156	25	14	2	1	0.55	B
DB159	25	15	2	1	0.74	B
DB164	24	11	2	1	0.46	C
DB165	32	18	4	3	0.82	B
DB195	26	18	4	3	0.60	B

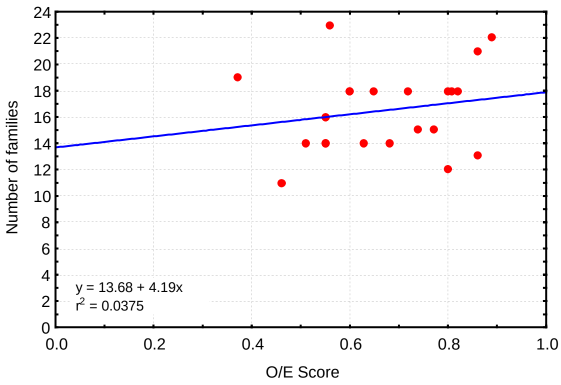

Figure 7. O/E score versus the number of families collected ate each site

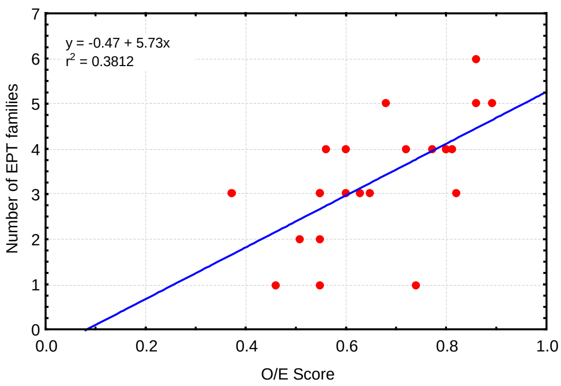

Figure 8. O/E Score versus the number of EPT families collected at each site

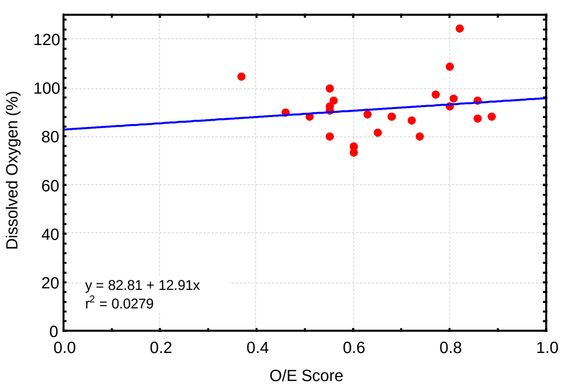

Figure 9. O/E score versus dissolved oxygen (% saturation)

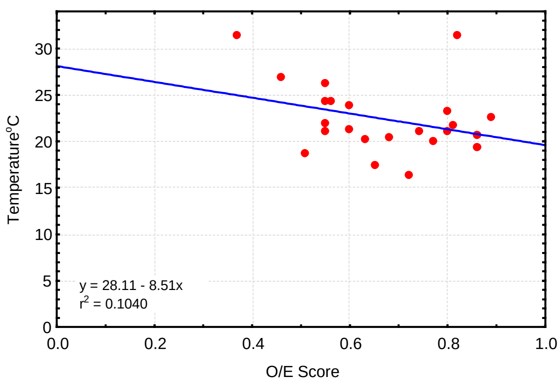

Figure 10. O/E score versus temperature (°C)

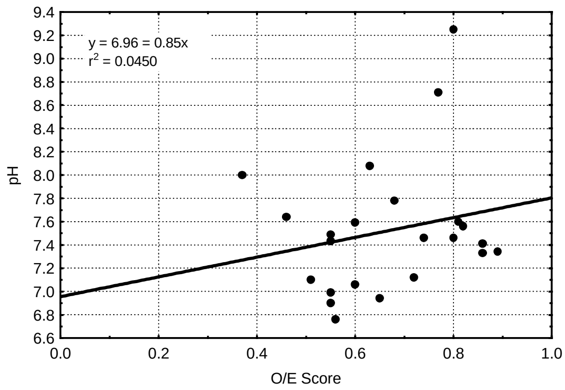

Figure 11. O/E score versus pH

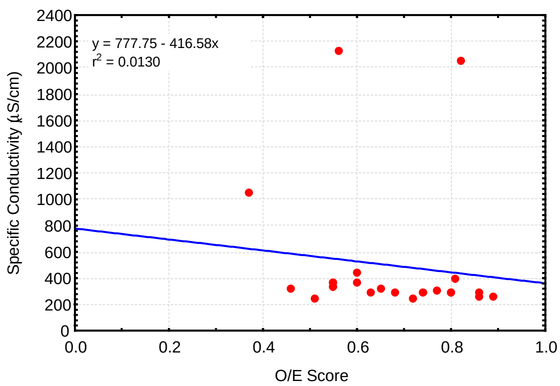

Figure 12. O/E score versus specific conductivity (µS/cm)

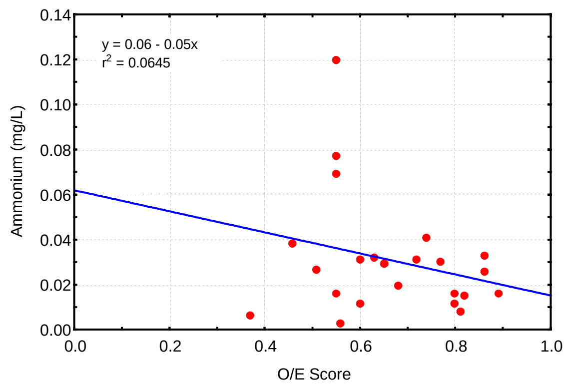

Figure 13. O/E score versus ammonium (mg/L)

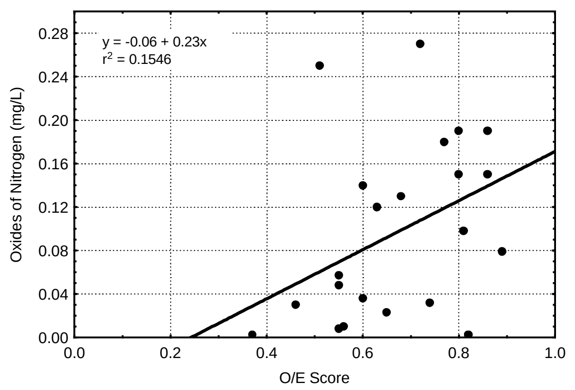

Figure 14. O/E score versus oxides of nitrogen (mg/L)

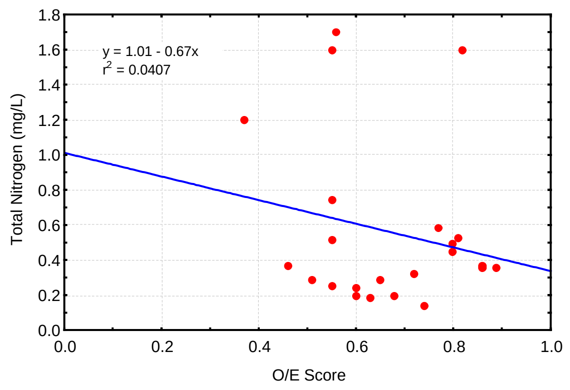

Figure 15. O/E score versus total nitrogen (mg/L)

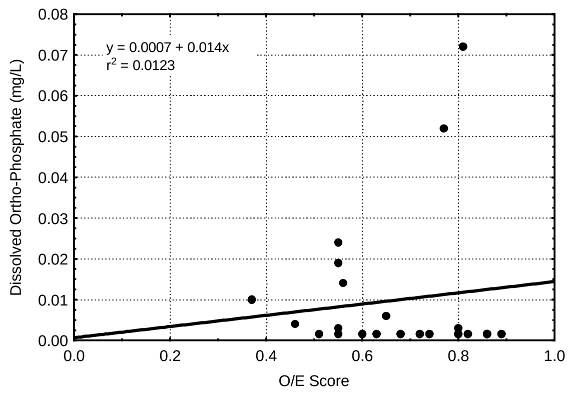

Figure 16. O/E score versus dissolved ortho-phosphate (mg/L)

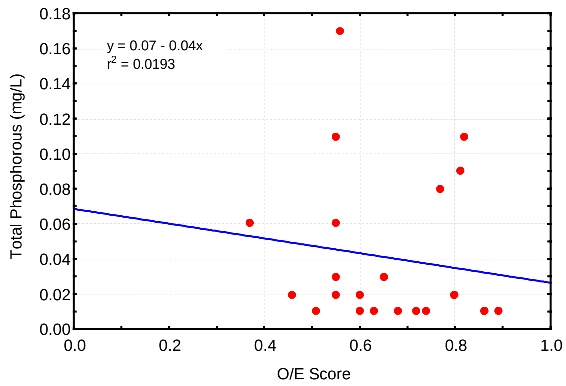

Figure 17. O/E score versus total phosphorus (mg/L)

4 Discussion

4.1 Drain condition

All the sites exhibited some form of anthropogenic disturbance. Most of them were physically in poor shape with undercutting, siltation and bank subsidence. The majority of sites had straight channels and little remnant vegetation present. The habitat composition was poor with most sites having a dominant habitat of channel and only very few having riffles, pool rocks or macrophytes. The depauperate physical condition of the drains and their location in and agricultural area will negatively affect the quality of the water entering the receiving waterbody (Serpentine River) as well as impinging on the macroinvertebrate fauna found within the drains.

4.2 Water quality

4.2.1 Physical quality

In general the physical water quality parameters were acceptable and within ANZECC guidelines for aquatic systems.

Water temperature plays a key role in a number of important processes. It affects the metabolism and growth rates of aquatic fauna and flora as well as the dissolved oxygen levels (warmer water can hold less oxygen than cooler water). Most of the sites sampled were shallow so changes in the amount of sunlight reaching the water (due to shading by overhanging vegetation, the time of day sampling was conducted or the weather conditions) will directly affect the water temperature. Water temperature will affect algal growth within streams and hence habitat availability. For example, the Hydroptilidae caddis flies who construct a purse retreat are generally most abundant in areas in which there is a suitable habitat for them to attach (ie filamentous algae). Endemic aquatic macroinvertebrates tend to be reasonably resilient to fluctuations in water temperatures, especially those that live in more ephemeral systems such as Dirk Brook. Therefore, temperature will usually only indirectly affect the macroinvertebrate community structure by its effects on habitat availability.

Dissolved oxygen levels were acceptable at most sites sampled. The high levels at some sites may possibly be attributed to the presence of algae which would have been photosynthesising and hence releasing oxygen into the waterbody at the time of sampling. It should be noted however that thick algal scums can actually cause anaerobic conditions due to a blanketing effect. Dissolved oxygen levels will also be affected by the time of year that sampling is conducted. As the amount of water travelling through the drainage network decreases, the dissolved oxygen levels will fall at some sited due to less mixing and higher water temperatures.

pH values were within ANZECC guidelines at all but a few sites. As the endemic aquatic macroinvertebrates are thought to be tolerant to a wide range of pH it will have had very little effect on the distribution or abundance of the macroinvertebrate fauna (Kay *et al.* 2000)

Specific conductivity exceeded ANZECC guidelines at more than half the sites sampled. It is unsure if this will have had a substantial effect on the macroinvertebrate fauna found as there are conflicting views on the halotolerance of the endemic fauna. Williams *et al.* 1999 found the fauna of the Blackwood River to show little longitudinality despite the presence of a distinct salinity gradient along its length. Whether this is due to the extreme halotolerance of the endemic fauna or to the fact that the less tolerant fauna has been eliminated (Trayler *et al.* 1996), is unclear. Therefore, the impact of elevated salinity levels on the aquatic macroinvertebrate fauna in Dirk Brook is difficult to determine. It is interesting to note however, that the site which recorded the highest specific conductivity also recorded the highest number of families.

4.2.2 Water chemistry

Nutrient levels were elevated at 14 sites with nitrogen levels being of more concern than phosphorous. Both total and dissolved ortho-phosphate were below the lower detectable limit at many of the sites sampled whereas nitrogen oxides, total nitrogen and ammonium were rarely below the lower detectable limit and exceeded the ANZECC guidelines for aquatic systems at a number of sites. The availability of nutrients helps promote algal growth as exhibited by the presence of algal scums at many of the sites sampled. The algal scums will provide a refuge and/or food source for some macroinvertebrate species and so can temporarily increase their diversity. This is especially true where the available habitat was depauperate before enrichment occurred.

4.3 Macroinvertebrate data

As expected from a visual assessment, most of the sampled sites scored poorly using AUSRIVAS with the exception of DB 070, DB104 and DB110 which were equivalent to reference. All three of these sites had some degree of shading and, with the exception of oxides of nitrogen at DB104 returned physical and chemical values within the ANZECC guidelines.

O/E score also seemed to correlate with the diversity of in-stream habitat available for the macroinvertebrate fauna. Sites which scored poorly tended to have little or no vegetation present within the stream whereas those that scored well generally had either submerged, emergent or fringing vegetation draped in the water.

The presence of vegetation could be affecting the macroinvertebrates in two ways. Firstly, where it is not present the range of habitats available for the macroinvertebrates to colonise is limited. Secondly, where there is no in-stream or overhanging vegetation the amount of carbon being added to the system is low.

Bunn *et al.* (1999) found that not only is the amount of carbon entering a stream important to ecosystem health, so is the carbon source. Most endemic macroinvertebrates are not capable of breaking down the leaves of exotic plant species and so those streams lined principally with exotics should have lower O/E scores than those lined by native species. This has not necessarily been demonstrated with the Dirk Brook data.

Another possible explanation for the high scores at these three sites is that when samples were being collected areas of instream vegetation were inadvertently being sampled. This would lead to different macroinvertebrates being collected than if solely open channel areas had been sampled.

The overall O/E score for the drainage network of 0.67 (Band B, moderatley impacted) reflects the negative impact that the depauperate habitat has on the macroinvertebrate communities.

4.4 Recommendations for best management practices

Best management practices should focus on improving the physical condition of the drains as a priority. The following should be considered:

- Limiting stock access to the drains and, where necessary, supplying alternative water sources.
- Re-contouring banks to alter the bank gradient to a level where the potential for bank slumping is reduced.
- Introducing pool-riffle sequences to enhance dissolved oxygen levels and expand on the habitat available to in-stream fauna.

Re-plant riparian buffer strips at least 30m wide along the edges of the drains. These will help absorb nutrients contained in runoff as well as reducing erosion by binding the soil. Further, vegetation has the potential to provide shading of the waterbody causing a drop in water temperatures as well as providing a carbon source.

Encourage surrounding landholders to adopt best management practices on their properties to reduce the amount of nutrients entering the drains.

Appendix A - Drain condition assessment form

DRAINAGE ASSESSMENT FORM

GENERAL DETAILS

1. Name:………………………………….. ……………………………………………...
2.Address:……………………………….……
……………………………………...
..…………………………………………...……
……………………………………...…………
………………………………...………………
…………………………….
3. Phone No:………………………………..
4. Date:……………………………………...
5. Farm/ locality name:……………………..
……………………………………………...
6. Location (address):………………………
……………………………………...…….
……………………………………...……..…….
………………………..………...…………………
…………………………...……………………..…
…………………….
6. Nearest road intersection:………………..
...…………………………………………...
……………………………………...…
……………………..……………………...…
……………………………………..
8. Catchment:………………………………
...……………………………………………
9. Drain name:……………………………...
…..………………………………………….
10. Location No:……………………………
……………………………………………...
11. Lot No:………………………………….
……………………………………………..
12. Drain starts (refer to topographical map or aerial photo):……………………………..
...……………………………………………
...……………………………………………
……………………………………………...
13. Drain end:………………………………
..……………………………………………
……………………………………………...
14. Approximate total drain length:………...
……………………………………………...
……………………………………………...
15. Owner/manager assent obtained:

Yes No

B. <u>Functions of the Drain</u>: (tick one or more)

16.What do you perceive as the current primary role of the drain?

☐ Improve crop productivity through removal of excess water.
☐ Reduce salinity potential (surrounding land).
☐ Limit development of disease in livestock and crops (footrot, liver fluke, mildew, infections, rootrot, *etc*).
☐ Improve farm machinery access.
☐ Retain water for farm/other use.
☐ Irrigation
☐ Flood protection
☐ Effluent disposal

Other…………………………………………..……
…………………………………………...…..………
……………………………………..………………….
…………………………...…………………………
……………………...

17. What are your key objectives ?
☐ same as above
☐ Wildlife corridor.
☐ Social (recreation), or economic.
☐ Nutrient removal.
☐ Erosion prevention.

Other…………………………………………...……
………………………………………..

...……………………………………………

..…………………………………………….

...……………………………………………

C. <u>Access</u>:

(access to drains will be dependent upon future maintenance requirements and the level of flood protection allocated to that drain)

18. Is there an access track
Yes No

19. Is the access track
Surfaced 2Wd 4Wd only

20. Is there access on
Both sides LHS RHS

21. Proximity to drain
0-5m away 5-10m >10m

22. Width of access road
<2m 2-3m 3-5m >5m

D. <u>Stock</u>:

23. Is the drain fenced One side [**1**]
both sides/on road verge [**2**] none [**0**]

24. Is there current stock access to the drain
Yes [**0**] No [**1**]

25. Is another water supply available Yes/road verge [**1**] No [**0**]

26. Is there a crossing point present? Vehicle
Livestock

Total score (D: Stock)……………………

[**Score: A (good) = 4; B (average) = 2-3; C (poor) = 1; D (very poor) = 0**]

E. <u>Erosion/Sediment</u>:

27. Is there evidence of siltation from bank wash or upstream?
Yes [**0**] No [**1**]

28. Has undercutting occurred?
Major [**0**] Minor [**1**] None [**2**]

29. Is there any evidence of bank subsidence?
Yes [**0**] No [**1**]

30. Have unintentional processes (erosion, livestock access, etc) modified the bank slope?
Yes [**0**] No [**1**]

31. Bank slope

> 60°	Very steep	[**0**]
45-60°	Steep	[**1**]
30-45°	Moderate slope	[**2**]
0-30°	Low slope	[**3**]

32. Is the flow
Meandering [**1**] Straight [**0**]

33. Is there rocky bars or physical traps within the drain (e.g. debris) ?
Yes [**1**] No [**0**]

34. What is your soil type?
clay, clayey loam [**2**] rock/stone [**1**]
sand, loose loam [**0**]

Total score (E: Erosion)……………………

[**Score: A (good) = 10-12; B(average) = 7-9; C (poor)= 3-6; D (very poor) = 0-2**]

35. Are there levees present?
Yes No

36. Drain shape (draw a cross section)

F. <u>Revegetation</u>:

37. Degree of surrounding clearing
High [**0**] Moderate [**1**] Low [**2**]

38. Distance to nearest remnant vegetation <50m [**2**] 50-100m [**1**] >100m [**0**]
(remnant vegetation refers to native vegetation with at least two different strata of native plants)

39. Is the water
Saline Brackish [**0**] Fresh [**1**]

40. Is there evidence of high nutrients (e.g. manure in the drain, algae scums)?
Yes [**0**] No [**1**]

41. Is there any evidence of possible biological/chemical contamination (e.g. oil film, carcasses)? Yes [**0**] No [**1**]

42. Percentage of entire drain length vegetated (aerial photo)

0-20% [**1**] 21-50% [**2**] 51-80% [**3**] 81-100% [**4**]

43. Native Vegetation development:

(None [**0**]; Few [**1**]; Many [**2**])

Zone / Stratum	Easement	Embankment	Bed
Trees			
Shrubs			
Sedges/ low herbs			

44. Introduced plant species

(Dense = [**0**]; Sparse = [**1**]; Absent = [**2**])

Zone / Stratum	Easement	Embankment	Bed
Pasture grasses			
Weed species			

45. Are priority weeds present?

Yes [**0**] No [**1**]

46. How wide is your easement?

RHS <5m [**0**] 5-10m [**1**] > 10 m [**2**]

LHS <5m [**0**] 5-10m [**1**] >10m [**2**]

Total score (revegetation)………………….

[**Score: A (good) = 41-45; B =31-40; C = 21-30; D =11-20; E (very poor) = 0-10**]

G. Fire:

47. Is there evidence of a recent fire?

Yes No

48. Is there a firebreak along the boundary of easement?

Both sides One side None

H. Fauna:

49. Is there evidence of native fauna using the drain and its associated easement?

Frogs Tadpoles Mussels Insects

Fish Birds

Mammals (specify)…………………………

……………………………………………...

I. SITE DIAGRAM: cross-section of drainage morphology (attach additional photo)

Appendix B - Summary of drain condition rating

	DB023	DB031	DB044	DB056	DB066	DB066	DB070	DB075	DB079	DB104	DB110	DB119	DB122	DB131	DB136	DB143	DB147	DB151	DB156	DB159	DB164	DB165	DB195
Stock access to drain																							
Drain fenced	2	2	2	2	1	1	0	1	1	2	0	1	2	0	1	1	2	2	1	1	1	1	1
Current stock access	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	1	0	0	1
Alternative water supply	1	1	0	1	1	1	1	0	1	1	0	1	1	0	0	0	1	1	0	0	1	0	1
Stock Access Score	4	4	3	3	2	2	1	1	2	3	0	2	4	0	1	1	4	4	1	2	2	1	3
Erosion/sedimentation assessment																							
Evidence of siltation	0	0	0	0	0	0	0	0	0	1	1	0	1	0	1	0	1	0	0	1	0	1	0
Undercutting	1	2	1	1	0	0	1	1	1	0	1	0	1	0	1	1	0	1	1	1	0	2	1
Bank subsidence	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	1	1
Bank modified	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bank slope	1	1	1	0	0	0	0	2	0	0	0	1	1	0	0	1	1	0	1	0	0	0	2
Meandering/straight channel	0	0	0	0	1	1	1	0	0	1	0	1	1	1	0	0	0	0	0	0	1	0	1
Rocky bars/physical traps	1	1	0	1	1	1	0	0	1	0	1	0	1	1	0	1	0	0	1	1	0	1	1
Soil type	0	0	0	0	0	0	0	0	0	2	0	1	1	2	0	0	0	2	0	1	2	0	2
Erosion/Sedimentation Score	3	4	3	2	2	2	2	4	2	4	3	3	6	4	3	3	2	3	3	5	3	5	8
Revegetation assessment																							
Degree of surrounding clearing	0	1	1	0	1	1	1	0	1	0	0	1	1	0	1	0	0	1	0	0	1	1	1
Distance to remnant vegetation	0	0	1	1	2	2	1	1	1	2	1	2	2	1	1	0	2	0	0	1	0	0	2
Fresh/brackish/saline	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Evidence of high nutrient levels	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	1
Evidence of contamination	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
% length vegetated	2	2	2	3	3	3	3	3	3	3	3	3	3	3	1	2	2	2	2	1	2	2	3
Native vegetation development	4	2	3	2	9	9	4	1	3	4	6	5	9	5	2	2	5	2	2	5	2	5	7
Introduced plant species	4	1	1	6	2	2	7	6	7	3	4	7	8	6	4	2	4	6	6	6	6	2	5
Priority weeds	0	0	0	1	0	0	1	1	1	1	1	1	0	1	0	0	1	0	1	0	1	0	0
Width of left easement	1	3	1	0	3	3	3	1	0	1	2	1	1	2	3	0	1	3	0	0	2	0	3
Width of right easement	1	1	2	1	3	3	3	1	3	1	2	1	1	2	0	1	1	3	3	0	2	1	3
Revegetation Score	13	12	13	16	25	25	25	16	21	17	21	23	28	22	15	9	18	20	16	15	18	13	27
Stock access rating	A	A	B	B	B	B	C	C	B	B	D	B	A	D	C	C	A	A	C	B	B	C	B
Erosion/sedimentation rating	C	C	C	D	D	D	D	C	D	C	C	C	C	C	C	C	D	C	C	C	C	C	B
Revegetation rating	D	D	D	D	C	C	C	D	C	D	C	C	C	C	D	D	D	D	D	D	D	D	C

For meanings of numbers, see Appendix A, Drain condition assessment sheet

Appendix C - List of invertebrates collected

Higher Order	Family	Genus/Species	DB023	DB031	DB044	DB059	DB062	DB066	DB070	DB075	DB079	DB104	DB110	DB119	DB122	DB131	DB136	DB143	DB147	DB151	DB156	DB159	DB164	DB165	DB195
Platyhelminthes	Temnocephalidea	*Temnocephala sp..*																							2
Mollusca	Ancylidae	*Ferrissia sp.*		2	1		3					1	2			1			1		2	1			
Mollusca	Lymnaeidae	Pseudosuccinea columella	1													1	2								
Mollusca	Physidae	*Physa acuta*	9	25	22	3	2	1		10	2	4	3	5		4	8	12	4	8	9	16	2	11	
Mollusca	Sphaeriidae	*Sphaerium sp.*																	1						
Oligochaeta	Naididae	*Chaetogaster diaphanus*				1																			
Oligochaeta	Naididae	*Nais variablis*				10	1								1								2		
Oligochaeta	Oligochaeta	?																		2		2			
Oligochaeta	Tubificidae	?	3					2		1					1								1		
Oligochaeta	Tubificidae	*Branchiura sowerbyi*							1																
Oligochaeta	Tubificidae	*Limnodrilus hoffmeisteri*										1													
Hirudinea	Glossiphoniidae	?		1		1												3	6	1					
Hirudinea	Richardsonianidae	?																							1
Hydracarina	Arrenuridae	*Arrenurus sp. 3*																							1
Hydracarina	Hydrachnidae	*Hydrachna sp.*		1	1					2							1					1			
Hydracarina	Hygrobatidae	*Coaustraliobaties longipalpis*		2																					2
Isopoda	Amphisopidae	*Paramphisopus palustris*		9			3				2	1					13		10	11	16			2	
Amphipoda	Ceinidae	*Austrochiltonia subtenuis*	4	5	7		2						1	10							3				3
Amphipoda	Perthidae	*Perthia acutitelson*	1	1		3	18	12	3	1		8	7		8	2	4	1	2					2	
Decapoda	Palaemonidae	*Palaemonetes australis*														1									
Decapoda	Parastacidae	*Cherax quinquecarinatus*			1							1	2	1			1	1							
Plecoptera	Gripopteryigidae	*Newmanoperla exigua*	1			1		1	3		1		3		1										
Ephemeroptera	Baetidae	?													1										
Ephemeroptera	Baetidae	*Cloeon sp.*		1	1																				
Ephemeroptera	Baetidae	*Genus 1. WA sp. 1*							10		2	2	5	4		1									
Ephemeroptera	Caenidae	*Tasmanocoenis sp.*		2																					
Ephemeroptera	Caenidae	*Tasmanocoenis rieki*	8	7	14	3	1	2	10		4	1	1		8	1	2		11					10	1
Ephemeroptera	Leptophlebiidae	*Atalophelbis sp. AV 17*	5			7	6	24	3	2	5	11	11				1		7					1	
Ephemeroptera	Leptophlebiidae	*Bibulmena kadijina*																							3
Odonata	Coenagrionidae	?		7															1	1					
Odonata	Coenagrionidae	*Ischura sp.*			1																				
Odonata	Gomphidae	*Austrogomphus collaris*													3										
Odonata	Hemicordulidae	*Hemicordulia tau*		16	12							2	3	2	1				1	1		2		7	
Odonata	Lestidae	*Austrolesties io*			1																				

Higher Order	Family	Genus/Species	DB023	DB031	DB044	DB059	DB062	DB066	DB070	DB075	DB079	DB104	DB110	DB119	DB122	DB131	DB136	DB143	DB147	DB151	DB156	DB159	DB164	DB165	DB195
Odonata	Libellulidae	*Orthetrum caledonicum*	1										2	1	1				2	3					
Odonata	Megapodagrionidae	*Miniagriolestes minimus*																						1	1
Odonata	Synthemistidae	*Archaeosynthemis macrostigma occidentalis*																							1
Odonata	Telephlebiidae	*Austroaeshchna anacantha*													1										1
Hemiptera	Corixidae	*?*		2																					
Hemiptera	Corixidae	*Agraptocorixa sp.*		1	10							4	4									1	4	5	
Hemiptera	Corixidae	*Agraptocorixa sp.*			4		2				2				1		2				1				2
Hemiptera	Corixidae	*Agraptocorixa eurynome*										2													
Hemiptera	Corixidae	*Micronecta sp.*			8		6				3							3		6			3	2	
Hemiptera	Corixidae	*Micronecta robusta*		21	3					9	6	1	1	1	7	2				7	1		1		
Hemiptera	Corixidae	*Sigara sp.*											1	2			2		2				1		1
Hemiptera	Corixidae	*Sigara truncatipala*			1	2						2								1					
Hemiptera	Gelastocoridae	*Nerthra sp.*	1																						
Hemiptera	Gelastocoridae	*Nerthra femoralis*	1	1																					
Hemiptera	Notonectidae	*?*			5																				
Hemiptera	Notonectidae	*Anisops sp.*												1				4		3			2		2
Hemiptera	Notonectidae	*Anisops thienemanni*		8	17		3			7							1				3	1		12	
Hemiptera	Veliidae	*Microvelia sp.*			1	1																			
Diptera	Ceratopogonidae	*Leptoconopinae sp.*		1									1												
Diptera	Chironominae	*Chironomus sp.*		2		2		1					2												
Diptera	Chironominae	*Chironomus aff. Alternans*	16		3	5	18	36	7	3	6	8		11	2	1	12	8		8		1		12	8
Diptera	Chironominae	*Chironomus occidentalis*																							1
Diptera	Chironominae	*Cryptochironomus grisedorsum*	3		1		2	1		1		1				2	3	1		1	2	1	1	8	
Diptera	Chironominae	*Dicrotendipes sp. A*		1							1		2												
Diptera	Chironominae	*Harrisius sp.*											2									1			
Diptera	Chironominae	*Polypedilum convexum*						1								1						1		1	
Diptera	Chironominae	*Polypeilum nubifer*			1					2	1							1							
Diptera	Chironominae	*Tanytarsus sp. A (NR K10)*	9		1	7	7	3		3	10	10		2	4		7	2		4		9	4		2
Diptera	Culicidae	*Anopheles sp.*		3						1															
Diptera	Culicidae	*Anopheles amictus*			6		4					1	2			5					8			22	
Diptera	Empididae	*Hemerodrominae sp.*	1										2												
Diptera	Orthocladiinae	*Corunoneura sp.*																						4	
Diptera	Orthocladiinae	*Cricotopus parbicinctus*	16	1		11	1		4	2	5	3	2	3		1	1	7	3	12	4	5		1	1
Diptera	Orthocladiinae	*Thienemanniella sp.*													2										

Higher Order	Family	Genus/Species	DB023	DB031	DB044	DB059	DB062	DB066	DB070	DB075	DB079	DB104	DB110	DB119	DB122	DB131	DB136	DB143	DB147	DB151	DB156	DB159	DB164	DB165	DB195
Diptera	Simuliidae	*Cnephia sp.*						2																	
Diptera	Simuliidae	*Simulium ornaipes*	3		5	3	11	23	28		15	4	24	7	7	1		27	7	8	2	7		1	
Diptera	Tanypodinae	*Parameria levidensis*					1					1										3	3	1	1
Diptera	Tanypodinae	*Procladius paludicola*							1		2					1									
Diptera	Tipulidae	*?*	1										2	2		2					2	4		1	
Lepidoptera	Pyralidae	*?*		1																					
Trichoptera	Hydropsychidae	*Cheumatopsyche sp. AV 2*							1									3							
Trichoptera	Hydroptilidae	*Acritoptila globosa*		2			1			2		2				1		1		3					
Trichoptera	Hydroptilidae	*Maydenoptila baymesi*										2													
Trichoptera	Leptocerida	*Condocerus aptus*											1												1
Trichoptera	Leptoceridae	*Lectrides parilis*													1										
Trichoptera	Leptoceridae	*Notalina spira*		1								1													
Trichoptera	Leptoceridae	*Oecetis sp.*	2	7	7	2	3	1	1		7	5	11	1		6	4	3	5	2	6	4	1	7	
Trichoptera	Leptoceridae	*Triplectides australis*	10	13	4	2	1	4	1	16	2	6	1	1			12	4	5	7	14	1	1	16	2
Coleoptera	Dytiscidae	*Alodessus sp.*																						3	
Coleoptera	Dytiscidae	*Allodessus bistrigatus*	1		2					1	1		12			1	1	1		2	12	1	3		
Coleoptera	Dytiscidae	*Hyphydrus sp.*		1																					
Coleoptera	Dytiscidae	*Liodessus sp.*																						2	
Coleoptera	Dytiscidae	*Liodessus inornatis*	1		1	1	5			3	1		1			1		1		4	5		1		1
Coleoptera	Dytiscidae	*Megaporus howitti*	1		2		3	1			1	3		1		3	2	2	2	1	2		1	4	
Coleoptera	Dytiscidae	*Necterosoma sp.*			14		16	2			3	6		1		21	7			3	11	11	10	7	10
Coleoptera	Dytiscidae	*Necterosoma darwini*			1	4		3			1			2		4	3	4		2		4	3	4	2
Coleoptera	Dytiscidae	*Onychohydrus scutellaris*		2																					
Coleoptera	Dytiscidae	*Paroster sp.*																		1				4	
Coleoptera	Dytiscidae	*Platynectes sp.*				1	8	5	4	3	6	17	14			12	6	35	6	13		19	3		
Coleoptera	Dytiscidae	*Platynectes decempunctatus*			2		1	1		1						1	3				1	1			
Coleoptera	Dytiscidae	*Rhantus sp.*		1		1	2			26	1									2	2				
Coleoptera	Dytiscidae	*Rhantus suturalis*	1				2			1						2		1	1		7	2	1	2	
Coleoptera	Dytiscidae	*Sternopriscus sp.*												1	4										
Coleoptera	Dytiscidae	*Sternopriscus browni*		1							1	3	2	4	6	2				3			1		2
Coleoptera	Dytsicdiae	*Sternopriscus mulimaculatus*					2				1			1	1		1								
Coleoptera	Dytiscidae	*Sternopriscus maedfooti*								2	1														
Coleoptera	Gyrinidae	*?*	1					2									2								1
Coleoptera	gyrinidae	*Aulonogyrus strigosus*				4						4	8		1										

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