4.0 RESULTS & DISCUSSION – LFA and VEGETATION

Section 4.1 describes the eight transects surveyed. Profile diagrams for the six tranects that also incorporated the soils aseesment (DS01 to DS06) are presented in **Appendix A**. **Section 4.2** collates and describes data for each of the five main 'zones' that characterise Coppin Creek. LFA and vegetation data for each transect are presented in **Appendix F**. A list of plant species found during this assessment and a vegetation map for the creekline are presented in **Appendix G**. Statistical analysis for these data sets is presented in **Appendix H**.

4.1 Individual transect assessment – LFA and vegetation summary

4.1.1 Site DS01

Transect Description

One transect comprising three zones was assessed at site DS01, within the proposed mining area upstream of Coppin Gap. These zones included; a flat wide bank on the western side of the transect; a creek bed; and a Flat wide bank on the eastern side of the transect. This site had comparatively wider and flatter slopes in relation to those at the remaining Spinifex Ridge creekline assessment sites (**Appendix A**).

Landscape Function Analysis (LFA) and drainage line assessment

The LFA indices of DS01 varied between sub-transects, being slightly higher on the western flat wide bank compared to that of the eastern flat wide bank (**Figure 15**). This was due to a greater amount of plant litter on the western bank contributing to all of the landscape function indices. Plant litter provides soil cover, protecting the surface from rain splash and aiding infiltration. The nutrient cycling index was also greater on the western bank than the eastern bank, due to the combined effect of slightly higher litter decomposition and the amount of cryptogam cover on the soil surface. The creek bed recorded the highest infiltration score, primarily because of the coarse particle size.

In general, the vegetated areas ('plant slope' zones, accounting for approximately 25% of the banks), were high in soil cover, perennial basal cover and had moderate litter cover. In these areas, inflow to the creek was considered to be generally diffuse with low flow rates through the denser vegetation. The remaining areas of the banks were made up of 'sandy slope' patch zones, and in these areas, there were a few inflow areas of greater focus and moderate flow rate. The creek was generally considered stable with low erosion activity. The creek bed showed signs of recent and/or frequent movement of loose sediments.

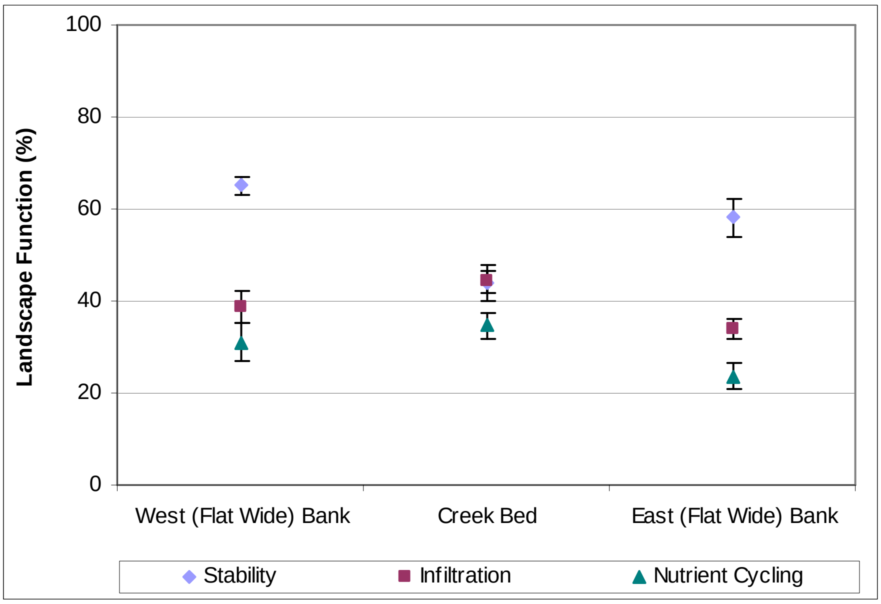

Figure 15 Landscape function indices for the creek cross section at site DS01

Vegetation

Flat wide bank, DS01-A (Plate 35a) – Hakea *lorea* ssp. *lorea* scattered tall shrubs over *Senna notabilis and Sida* sp. low shrubland over *Triodia epactia* open hummock grassland and *Cenchrus ciliaris* very open tussock grassland over *Ipomoea muelleri, Indigofera colutea* and *Euphorbia coghlannii* very open herbs.

Twenty species were recorded along the transect (mean density 16 plants/m² and mean cover of 57%). The lower stratum consisted predominantly of *Triodia epactia* (mean density 2.6 plants/m² and mean cover of 19%), **Cenchrus ciliaris* (buffel grass) (mean cover 5%), *Ipomoea muelleri* (mean cover 2%), *Indigofera colutea* (mean cover 2%), and *Euphorbia coghlannii* (mean cover 2%). The mid-stratum consisted of *Senna notabilis* (mean cover 16.6%) and *Sida* sp. (mean cover 3%). The upper-stratum consisted of *Hakea lorea* ssp. *lorea.* (mean cover 2%).

Creek bed, DS01-B (Plate 35b) – *Eucalyptus camaldulensis* var *obtusa and E. victrix* open woodland over *Acacia tumida* var. *pilbarensis, Melaleuca glomerata* and *Sesbania cannabina* high open shrubland over *Senna notabilis* low scattered shrubs over *Triodia epactia* very open hummock grassland and *Cenchrus ciliaris* and *Chloris pectinata* very open tussock grassland over *Cyperus vaginatus* open sedges over and *Pluchea rubelliflora* very open herbs

Thirty-eight species were recorded along the transect in the creek bed (mean density 3.8 plants/m² and mean cover of 43%). The lower stratum consisted predominantly of *Cyperus vaginatus* (mean cover 10%), **Cenchrus ciliaris* (mean cover 6%), *Chloris pectinata* (mean cover 5%), *Triodia pungens* (mean cover 3.5%), *Pluchea rubelliflora* (mean cover 2.7%) and *Senna notabilis* (mean cover 1.2%). The mid-stratum (to 3m) consisted of *Acacia tumida* var. *pilbarensis* (mean cover 3%), *Melaleuca glomerata* (mean cover 1.2%) and *Sesbania cannabina* (mean cover 1.2%). The upper-stratum (to 15m) consisted of *Eucalyptus camaldulensis* var. *obtusa* (mean cover 1.5%) and *E. victrix* (not recorded within transect).

Flat wide bank, DS01-C (Plate 35c) - *Senna notabilis, Solanum diversiflorum* and *Indigofera trita* low open shrubland over *Triodia epactia* open hummock grassland over *Euphorbia australis* very open herbs.

Five species were recorded along the transect (mean density of 4.4 plants per m^2 and a total mean cover of 33%. The lower stratum consisted predominantly of *Euphorbia australis* (mean cover 0.2%). The mid-stratum consisted of *Triodia epactia* (mean density of 2.4 plants/m^2 and mean cover 23%). The upper-stratum included *Senna notabilis* (mean cover 2%). *Indigofera trita* (mean cover 6%) and *Solanum diversiflorum* (mean cover 2%).

Plate 35 Transect DS01-a

Transect DS01-b

Transect DS01-c

4.1.2 Site DS02

Transect Description

Transect DS02 is located south of the ridge, within the proposed mining area upstream of Coppin Gap. The sub-transects or zones assessed at DS02 included; a flat wide bank; a creek bed; and a flat wide bank on the eastern side of the creek. The banks at this site were similar in topography to those monitored at site DS01; aside from the slightly steeper eastern incline at DS01 (**Appendix A**).

Landscape Function Analysis (LFA) and drainage line assessment

The LFA indices for the flat wide western bank and the flat wide eastern bank indicated similarities between the two areas, and differing from the creek bed (**Figure 16**). The range in stability indices was variable between the three sub-transects, according mainly to the presence or absence of cryptogams, which where absent within the creek bed (accounting for the lower stability index). Cryptogams contribute to soil surface stability by providing resistance to wind and water erosion and only occur on soil crusts that have been stable and undisturbed for long periods of time. A general assessment of the drainage line at DS02 showed well-armoured banks with insignificant erosion. Resource flows across the creek banks to the creek beds are probably low and mostly diffuse through dense grassland, although there are a few high-focus inflow areas where vegetation is sparser.

The creek bed infiltration index was greater than for the other two sub-transects due to a greater amount of litter cover and coarse sandy fraction in the soils. The loose deposits of sediment in the creek bed translated to a comparatively higher erosion potential than the creek banks. Litter cover has the potential to increase infiltration due to the water trapping properties of the biomass, allowing it to slowly infiltrate into the soil before it can cause erosion. Similarly, litter cover enhanced the nutrient cycling index, as litter decomposes and adds carbon and nitrogen to the surface soil layers.

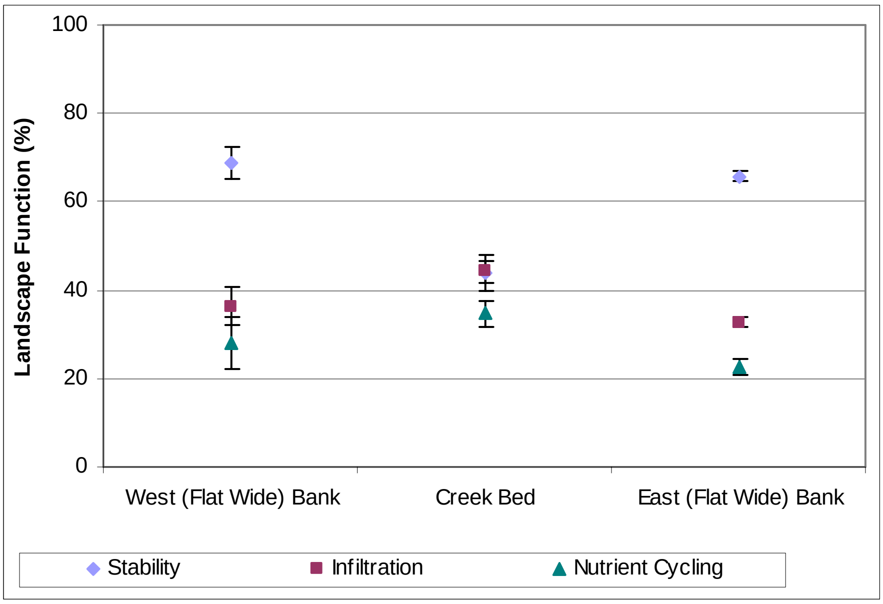

Figure 16 Landscape function indices for the creek cross section at site DS02

Vegetation

Flat wide bank, DS02-A (Plate 36a) - *Eucalyptus camaldulensis* var. *obtusa* open woodland over *Sesbania cannabina* and *Acacia tumida* var. *pilbarensis* scattered tall shrubs over *Senna notabilis, Corchorus incanus* and *Goodenia stobbsiana* low open shrubland over *Triodia epactia* very open hummock grassland and **Cenchrus ciliaris* very open tussock grassland over *Cyperus vaginatus* open sedges over *Pluchea rubelliflora* very open herbs.

Nineteen species were recorded along the transect (mean density 10 plants/m² and mean cover of 53%). The lower stratum consisted predominantly of *Cyperus vaginatus* (mean cover 20%), *Corchorus incanus* (mean cover 8%), *Senna notabilis* (mean cover 6%), *Triodia epactia* (mean cover 4.4%), *Goodenia stobbsiana* (mean cover 2.7%), *Pluchea rubelliflora* (mean cover 1.6%) and **Cenchrus ciliaris* (mean cover 2%). The mid-stratum (to 3m) consisted of *Sesbania cannabina* (mean cover 1%) and *Acacia tumida* var. *pilbarensis* (mean cover 0.4%). The upper-stratum (to 15m) consisted of *Eucalyptus camaldulensis* var. *obtusa* (mean cover 2.6%).

Creek bed, DS02-B (Plate 36b) – *Eucalyptus camaldulensis* var. *obtusa* open woodland over *Acacia tumida* var. *pilbarensis, Melaleuca glomerata* and *Sesbania cannabina* high open shrubland over *Goodenia stobbsiana* low scattered shrubs over **Cenchrus ciliaris* and *Setaria dielsii* scattered tussock grass over *Cyperus vaginatus* open sedges over *Pluchea rubelliflora* very open herbs.

Twenty one species were recorded along the transect in the creek bed (mean density 4 plants/m² and mean cover of 23%). The lower stratum consisted predominantly of *Pluchea rubelliflora* (mean cover 3%), *Cyperus vaginatus* (mean cover 3%), *Setaria dielsii* (mean cover 2.7%), *Goodenia stobbsiana* (mean cover 2%) and **Cenchrus ciliaris* (mean cover 1.3%). The mid-stratum (to 3m) consisted of *Acacia tumida* var. *pilbarensis* (mean cover 5.4%), *Sesbania cannabina* (mean cover 2.3%) and *Melaleuca glomerata* (mean cover 0.1%). The upper-stratum (to 15m) consisted entirely of *Eucalyptus camaldulensis* var. *obtusa* (mean cover 0.1%).

Flat wide bank, DS02-C (Plate 36c) - *Eucalyptus camaldulensis* var. *obtusa* woodland over *Sesbania cannabina* high shrubland over *Senna notabilis* and *Isotropis atropurpurea* low shrubland over *Triodia epactia* very open hummock grassland over *Polymeria ambigua* scattered herbs.

Seventeen species were recorded along the transect (mean density 8.4 plants/m² and mean cover of 60%). The lower stratum consisted predominantly of *Isotropis atropurpurea* (mean cover 11%), *Triodia epactia* (mean cover 7.5%), *Senna notabilis* (mean cover 2%) and *Polymeria ambigua* (mean cover 1.5%). The mid-stratum (to 3m) consisted of *Sesbania cannabina* (mean cover 0.3%). The upper-stratum (to 15m) consisted of *Eucalyptus camaldulensis* var. *obtusa* (mean cover 32%).

Plate 36 Transect DS02-a

Transect DS02-b

Transect DS02-c

4.1.3 Site DS03

Transect Description

DS03 is located approximately 600m further north east of the DS02 and south of the ridge, upstream of Coppin Gap. Although the sub-transects were generally classified as flat wide bank (western bank) and steep bank (eastern bank), they exhibited a slightly different morphology to that of DS01 and DS02, which were of similar classification (**Appendix A**). The creek bed, on the other hand, was similar to that of DS02.

Landscape Function Analysis (LFA) and drainage line assessment

The stability index at DS03 was higher on the eastern and western banks than the creek bed (**Figure 17**), corresponding with higher slake test scores, lower deposited material and lower micro-erosion scores for the banks. On the whole, the banks of this section of the drainage line were generally low flow areas characterised by diffuse resource regulation through dense grassland, punctuated by moderate-flow, highly-focussed inflow locations in more sparsely-vegetated areas. This equated with an overall low score for stream erosion activity, suggesting that accelerated erosion is not a problem.

Infiltration and nutrient cycling indices recorded less variability between the sub-transects than the stability index, but as for other transects, the creek bed recorded the highest infiltration index due to the higher cover of plant litter and coarser particle size. The creek bed showed signs of recent and/or frequent movement of loose sediments.

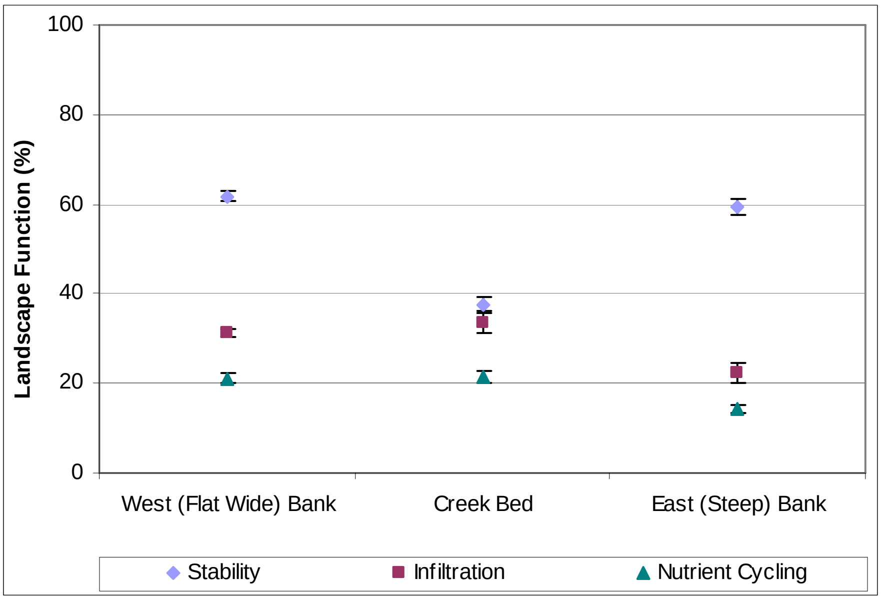

Figure 17 Landscape function indices for the creek cross section at site DS03

Vegetation

Flat wide bank, DS03-A (Plate 37a) – *Corymbia hamersleyana* open woodland over *Sesbania cannabina* scattered shrubs over *Corchorus incanus* low open shrubland over *Triodia epactia* very open hummock grassland and **Cenchrus ciliaris* scattered tussock grassland over mixed herbs.

Fourteen species were recorded along the transect (mean density 5 plants/m² and mean cover of 20%). The lower stratum consisted predominantly of *Triodia epactia* (mean density 2.5 plants/m² and mean cover of 10%), *Euphorbia coghlanii,* (mean cover 3%), *Corchorus incanus* (mean cover 2%) *and *Cenchrus ciliaris* (mean cover 1.8%). The mid-stratum (to 3m) consisted of *Sesbania cannabina* (mean cover 0.7%). The upper-stratum (to 15m) consisted entirely of *Corymbia hamersleyana* although it was not recorded in the transect on either bank.

Creek bed, DS03-B (Plate 37b) – *Corymbia hamersleyana* and *Eucalyptus camaldulensis* var. *obtusa* woodland over *Melaleuca glomerata* and *Sesbania cannabina* high shrubland over *Cyperus vaginatus* very open sedges over **Cenchrus ciliaris* open tussock grassland over mixed herbs.

DS03 had the highest mean density of all the creek beds at 6.5 plants/m and a total mean crown cover of 52%. The lower stratum (height to 1m) was dominated by **Cenchrus ciliaris* (mean cover 20%), *Cyperus vaginatus* (mean cover 7%) and *Ammannia baccifera* (mean density 2 plants/m² and mean cover of 2%). The mid-stratum (to 3m) was dominated by *Sesbania cannabina* (mean cover 7.5%), *Melaleuca glomerata* (mean cover 2%), and *Acacia tumida* var. *pilbarensis* (mean cover 0.1%). The upper-stratum (to 15m) consisted of *Corymbia hamersleyana* (mean cover 5%), and *Eucalyptus camaldulensis* var. *obtusa* (mean cover 3.1%).

Steep bank, DS03-C (Plate 37c) – *Cleome viscosa* and *Alysicarpus muelleri* very open herbs over *Triodia epactia* open hummock grassland.

Three species were recorded along the transect with a total mean density of 10.4 plants per m² and a total mean cover of 32%. *Triodia epactia* dominated (mean density of 8.5 plants/m² and mean cover 23%). Two herbs species, *Cleome viscosa* (mean density 1.7 plants/m² and mean cover 5%), and *Alysicarpus muelleri* (mean density 0.2 plants/m² and mean cover 3.7%) were also recorded.

Plate 37 Transect DS03-a

Transect DS03-b

Transect DS03-c

4.1.4 Site DS04

Transect Description

DS04 is located relatively close to DS03 (~200m), upstream of Coppin Gap and shares very similar bank and creek bed morphology. The western bank was classified as a flat wide bank, as was the eastern bank, and the creek bed was also relatively wide and flat (**Appendix A**).

Landscape Function Analysis (LFA) and drainage line assessment

As with sites DS01 – DS03, the stability index was variable between the three zones assessed (**Figure 18**), but was lowest in the creek bed due to the different particle size and cohesiveness traits in that zone. In comparison to sites DS01 – DS03, the creek bed at site DS04 recorded lower infiltration and nutrient cycling indices, reflecting less available plant litter, less deposited materials from upslope and fewer plants providing perennial basal cover. The creek bed was comprised of loose sediments, and showed signs of recent and/or frequent movement.

The overall assessment of the drainage line at transect DS04 showed that resource flow across the creek banks ranges from diffuse with low flow rates (through dense grassland), to moderate flow rates in highly-focussed inflow areas (through sparse grassland). The risk of accelerated erosion was considered to be low.

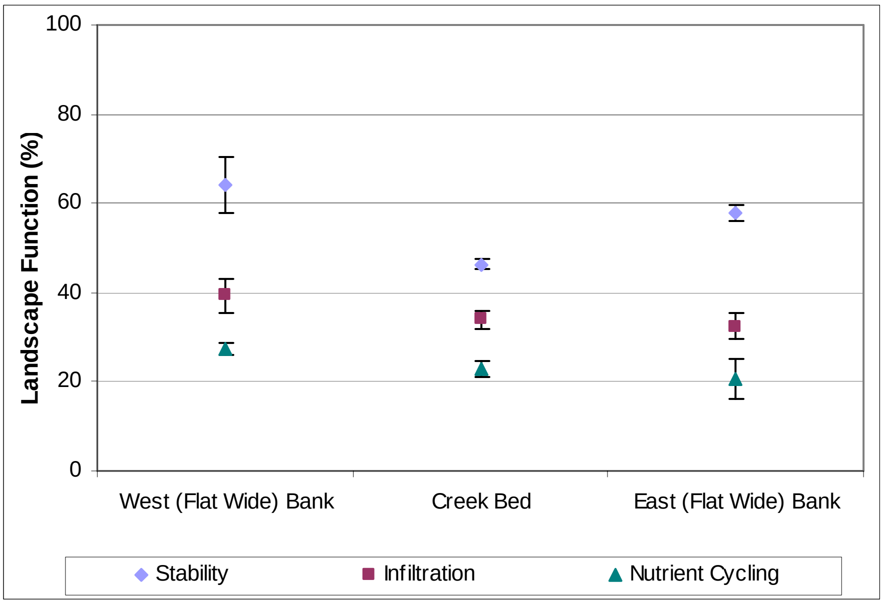

Figure 18 Landscape function indices for the creek cross section at site DS04

Vegetation

Flat wide bank, DS04-A (Plate 38a) - *Eucalyptus camaldulensis* var. *obtusa* open woodland over *Melaleuca glomerata* and *Sesbania cannabina* high open shrubland over *Goodenia stobbsiana* low open shrubland over *Triodia epactia* open hummock grassland over **Cenchrus ciliaris* very open tussock grassland over *Cyperus vaginatus* very open sedges over *Cleome viscosa* scattered herbs.

Twenty species were recorded along the transect (mean density 6 plants/m² and mean cover of 37%). The lower stratum consisted predominantly of *Cyperus vaginatus* (mean cover 5.4%), **Cenchrus ciliaris* (mean cover 4.6%), *Triodia epactia* (mean cover 2.6%), *Goodenia stobbsiana* (mean cover 2.4%), *Eriachne* sp. (mean cover 2.4%) and the herb *Cleome viscosa* (mean cover 1.6%). The mid-stratum (to 3m) consisted of *Sesbania cannabina* (mean cover 2.4%) and *Melaleuca glomerate* (mean cover 1%). The upper-stratum (to 15m) consisted entirely of *Eucalyptus camaldulensis* var. *obtusa* (mean cover 10%).

Creek bed, DS04-B (Plate 38b) – *Eucalyptus camaldulensis* var. *obtusa* scattered trees over *Melaleuca glomerata* and *Sesbania cannabina* high shrubland over *Goodenia stobbsiana* low open shrubland overCenchrus ciliaris* very open tussock grassland over *Cyperus vaginatus* very open sedges.**

Thirteen species were recorded along the transect in the creek bed (mean density 1.7 plants/m² and mean cover of 29%). The lower stratum consisted predominantly of *Cyperus vaginatus* (mean cover 6%), *Goodenia stobbsiana* (mean cover 5%) and **Cenchrus ciliaris* (mean cover 2.6%). The mid-stratum (to 3m) consisted of *Sesbania cannabina* (mean cover 7%) and *Melaleuca glomerata* (mean cover 6.3%). The upper-stratum (to 15m) consisted of *Eucalyptus camaldulensis* var. *obtusa* although none were recorded in this transect.

Flat wide bank, DS04-C (Plate 38c) - *Eucalyptus camaldulensis* var. *obtusa* woodland over *Melaleuca glomerata* and *Sesbania cannabina* high open shrubland over *Senna notabilis* open shrubland over *Corchorus incanus* low open shrubland over *Triodia epactia* open hummock grassland over scattered herbs.

Twelve species were recorded along the transect (mean density 8 plants/m² and mean cover of 66%). The lower stratum consisted predominantly of *Triodia epactia* (mean density of 5.6 plants/m² and mean cover 11%), *Corchorus incanus* (mean cover 2.9%), *Senna notabilis* (mean cover 2.8%) and *Rhynchosia minima* (mean cover 2%). The mid-stratum (to 3m) consisted of *Sesbania cannabina* (mean cover 9%) and *Melaleuca glomerate* although it was not recorded in this transect. The upper-stratum (to 15m) consisted entirely of *Eucalyptus camaldulensis* var. *obtusa* (mean cover 35%).

Plate 38 **Transect DS04-a**

Transect DS04-b

Transect DS04-c

4.1.5 Site DS05

Transect Description

DS05 is located north north-east of DS04, past two bends in the creek, resulting in a slightly differing transect description than sites DS01 - 4. The creekline morphology of DS05 was noticeably different as it was comprised of two definite banks with a moderately wide creek bed. The western sub-transect was classified as a steep bank, while the eastern bank was considered to be a medium bank.

Landscape Function Analysis (LFA)

The stability index was highly variable, being lowest for the creek bed and similar and higher for both the steep western bank and the medium eastern bank (**Figure 19**). The two banks generally attained higher scores for soil cover and other parameters. Infiltration and nutrient cycling were comparable across all three sub-transects at DS05. This is most likely due to the similarity microtopography, perennial basal cover and litter cover. The creek banks probably experience mostly low, diffuse flow through vegetation, with a few moderate-flow areas in focus points where vegetation is sparse. The banks were considered non-erosive in that context.

The LFA indices of the creek bed were quite different from the banks. Overall, the banks lacked micro-erosion features, while the creek bed recorded features ranging from moderate to severe. This is to be expected in a creek bed due to the normally looser, sandier soils. However, some sections of the creek were able to sustain cryptogams (contributing to soil stability).

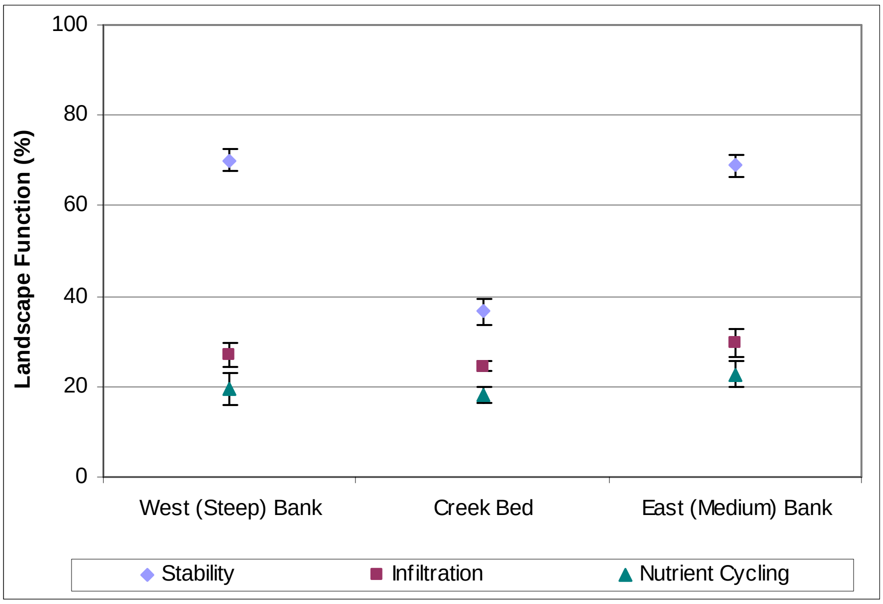

Figure 19 Landscape function indices for the creek cross section at site DS05

Vegetation

Steep bank, DS05-A (Plate 39a) – *Stemodia viscosa* low open shrubland over **Cenchrus ciliaris* very open tussock grassland (on lower slope) over very open mixed herbs.

Eleven species were recorded along the transect (mean density 8 plants/m² and mean cover of 25%). The lower stratum was dominated by *Amaranthus* aff. *pallidiflorus* (mean cover 4%). The mid-stratum was dominated by **Cenchrus ciliaris* (mean cover 5%). The upper-stratum of *Stemodia viscosa* was the dominant species (mean density 5.6 plants/m² and mean cover of 13%).

Creek bed, DS05-B (Plate 39b) – *Eucalyptus camaldulensis* var. *obtusa* woodland over *Melaleuca glomerata* and *Sesbania cannabina* high open shrubland over **Cenchrus ciliaris* open tussock grassland.

Nineteen species were recorded along the transect (mean density 5.5 plants/m² and mean cover of 57%). There was water present in the creek at the time of assessment (width 12m). The lower stratum (height to 1m) was dominated by **Cenchrus ciliaris* (mean cover 14.7%). *Cyperus vaginatus* (mean cover 4.4%) and **Echinochloa colona* (mean cover 2%) were also recorded. The mid-stratum (to 3m) was dominated by *Melaleuca glomerata* (mean cover 5%) and *Sesbania cannabina* (mean cover 4%). The upper-stratum (height to 15m) consisted of *Eucalyptus camaldulensis* var. *obtusa* (mean cover 20%).

Medium bank, DS05-C (Plate 39c) – *Acacia inaequilatera* high open shrubland over *Stemodia viscosa* low open shrubland over *Triodia epactia* open hummock grassland over **Cenchrus ciliaris* very open tussock grassland over *Cleome viscosa* scattered herbs.

Twelve species were recorded along the transect (mean density 6 plants/m² and mean cover of 49%). The lower stratum consisted predominantly of *Triodia epactia* (mean density 3 plants/m² and mean cover of 27.8%), *Stemodia viscosa* (mean cover 4.7%), **Cenchrus ciliaris* (mean cover 2.2%) and *Cleome viscosa* (mean cover 1.9%). The upper-stratum consisted of *Acacia inaequilatera* (mean cover 7.5%).

Plate 39 Transect DS05-a

Transect DS05-b

Transect DS05-c

4.1.6 Site DS06

Transect Description

The sixth transect to be assessed during this survey was DS06, located approximately 550m downstream of DS05. This transect is located immediately south of the ridge and Coppin Gap. The western bank was considered a medium slope with a flat creek bed, and the steep eastern bank tapered off to a flat area. This profile is most similar to that of site DS05, as it has two definite banks framing the creek bed (**Appendix A**).

Landscape Function Analysis (LFA)

The stability index was lowest in the creek bed and highest on the banks, as at other transects (**Figure 20**). This was attributed to the abundance of micro-erosion features within the creek bed, with ratings of ‘slight’ to ‘severe’, and lower slake test scores than the banks. The banks either side were relatively free from micro-erosion features, with scores ranging between ‘slight’ and ‘insignificant’. Overall, vegetative cover contributed to the stability of the three sub-transects.

Infiltration and nutrient cycling indices were similar between the three transects, most likely due to the uniform distribution of litter cover across the whole transect, provided from the Spinifex grasses, which allows filtration of the trapped water among the litter. The creek bed sediments were loose and showed signs of recent and/or frequent movement.

Across the whole transect (comprising the three sub-transects), the flow across the creek banks was considered to be diffuse and slow, due to the relatively-even coverage of grasses. The few bare areas on the banks probably act as focal points for moderate inflow. Overall the creek was considered stable, with a low likelihood of accelerated erosion. According to hydrological assessments, this site may be a potential depositional area for sediment during flow events, and flood waters may back-up within the vicinity of this site.

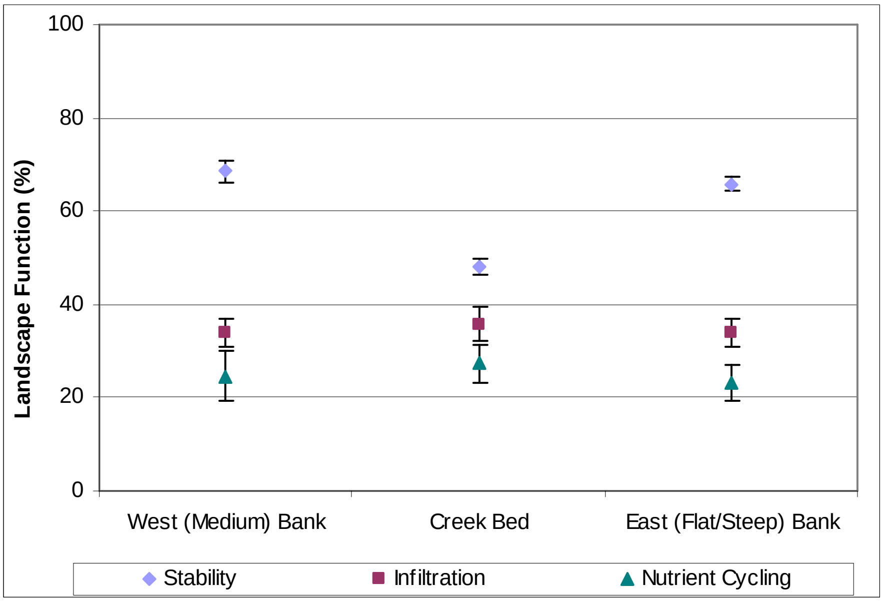

Figure 20 Landscape function indices for the creek cross section at site DS06

Vegetation

Medium bank, DS06-A (Plate 40a) – *Stemodia viscosa* low open shrubland over *Cleome viscosa* very open herbs over *Triodia epactia* open hummock grassland.

Thirteen species were recorded along the transect (mean density 20 plants/m² and mean cover of 32%). The lower stratum (to 1m) was dominated by *Triodia epactia* (mean density 5.4 plants/m² and mean cover of 4.5%), *Cleome viscosa* (mean cover 2.8%), *Oldenlandia crouchiana* (mean cover 2.2%) and immature *Senna notabilis* (mean cover 2.9%). The upper-stratum was dominated by *Stemodia viscosa* (mean density 11 plants/m² and mean cover of 16%).

Creek bed, DS06-B (Plate 40b) – *Eucalyptus camaldulensis* var. *obtusa* open woodland over *Acacia coriacea* ssp *pendens* low open woodland over *Melaleuca glomerata* and *Sesbania cannabina* high shrubland over **Cenchrus ciliaris* open tussock grassland over *Cyperus vaginatus* very open sedges over mixed very open herbs.

Seventeen species were recorded along the transect (mean density 3 plants/m² and mean cover of 62%). There was very little water present in the creek. The lower stratum (height to 1m) was dominated by **Cenchrus ciliaris* (mean cover 20%). *Cyperus vaginatus* (mean cover 7%) and *Phyllanthus maderaspatensis* (mean cover 3.3%) were also recorded. The mid-stratum (height to 3m) was dominated by *Melaleuca glomerata* (mean cover 14%) and *Sesbania cannabina* (mean cover 3%). The upper-stratum (height to 15m) consisted of *Acacia coriacea* ssp. *pendens* (mean cover 9%) and *Eucalyptus camaldulensis* var. *obtusa* (mean cover 1.5%).

Flat steep bank, DS06-C (Plate 40c) - *Corchorus incanus* low open shrubland over *Triodia epactia* very open hummock grassland over *Cleome viscosa* scattered herbs.

Nine species were recorded along the transect (mean density 16 plants/m² and mean cover of 32%). The lower stratum consisted predominantly of *Triodia epactia* (mean density 9 plants/m² and mean cover of 7%) and *Cleome viscosa* (mean cover 6.5%). The upper-stratum consisted of *Corchorus incanus* (mean density 4.5 plants/m² and mean cover of 7%).

Plate 40 **Transect DS06-a**

Transect DS06-b

Transect DS06-c

4.1.7 Site DS07

Transect Description

DS07 is located on the northern side of the ridge downstream of Coppin Gap, and is within in an area of a persistent water source. Water flows downstream of Coppin Gap to Kookenyia Creek, which feeds into the De Grey River. The morphology of the creekline tends to be more uniform further north of Coppin Gap, along a gently undulating, broad plateau. At site DS07, both banks were described as medium banks, and the creek bed being flat and wide with a narrow drop in the centre (**Appendix A**).

Landscape Function Analysis (LFA)

The LFA indices for the two medium banks were similar in terms of the stability and nutrient cycling indices. Infiltration was slightly higher on the eastern bank than the western bank (**Figure 21**). Both banks shared similarities in character with regards to perennial plant basal cover, a lack of cryptogams, a general lack of erosion features and few deposited materials. These aspects were reflected in the similar infiltration and nutrient cycling indices. The relatively lower stability index and higher infiltration and nutrient cycling indices of the creek bed, were related to the presence of predominantly loose sandy soils which are susceptible to movement in flow events, and lower density of stabilising vegetation. The creek bed at DS07 recorded higher LFA indices than at sites DS01 to DS06, probably because of the relatively higher litter cover in the creek bed. This also contributed to the infiltration and nutrient cycling indices at DS07.

The creek at DS07 was generally a low flow area that would collect and settle sediments from floodwaters that pass from the upstream sites through Coppin Gap.

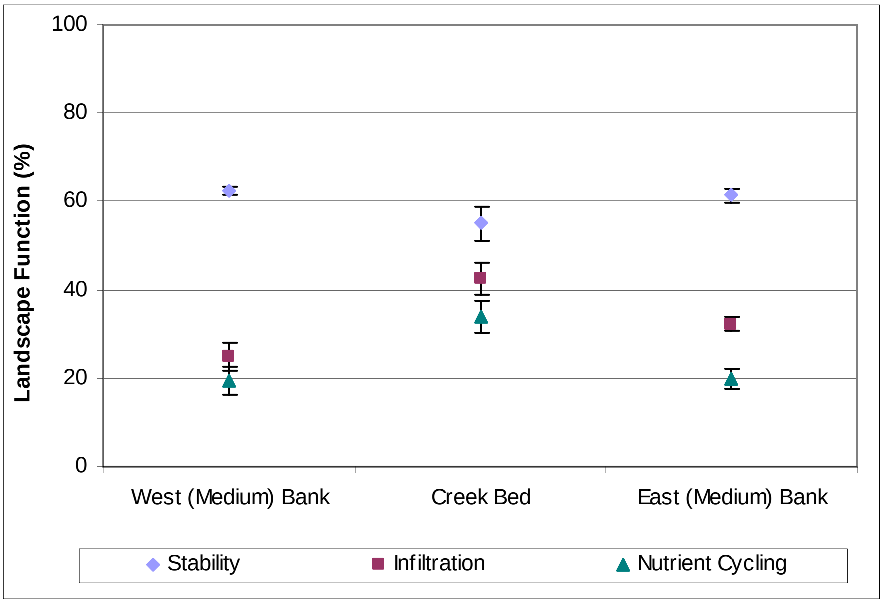

Figure 21 Landscape function indices for the creek cross section at site DS07

Vegetation

Medium bank, DS07-A (Plate 41a) - *Triodia epactia*hummock grassland.

The transect was dominated by *Triodia epactia* (mean density 11 plants/m² and mean cover of 43%), which was present in all 23 quadrats of the transect. In addition, a single plant of *Indigofera linifolia* was recorded along the transect.

Creek bed, DS07-B (Plate 41b) – *Eucalyptus camaldulensis* var *obtusa* woodland over *Triodia longiceps* open hummock grassland and **Cenchrus ciliaris* tussock grassland over *Cyperus vaginatus* very open sedges.

Twenty three species were recorded along the transect (mean density 4 plants/m² and mean cover of 88%). The lower stratum (to 1m) was dominated by **Cenchrus ciliaris* (mean cover 33%), *Triodia longiceps* (mean cover 16%) and *Cyperus vaginatus* (mean cover 3.3%). The upper-stratum (height to 15m) consisted predominantly of *Eucalyptus camaldulensis* var. *obtusa* (mean cover 29%).

Medium bank, DS07-C (Plate 41c) - *Triodia epactia* hummock grassland over scattered herbs.

Triodia epactia dominated the vegetation (mean density 2.4 plants/m² and mean cover of 29%). Other species present included *Mollugo molluginea, Indigofera colutea* and *Bulbostylis barbata*.

Plate 41 Transect DS07-a

Transect DS07-b

Transect DS07-c

4.1.8 Site DS08

Transect Description

DS08 is the northern-most transect of the survey, lying north of the ridge and approximately 600 metres north north-west of DS07. The banks at this site differ, in the most part, from all previous sites. The western bank is a steep bank with a flattened top and the eastern bank is relatively flatter and wide (**Appendix A**). The creek bed is relatively narrower than at other transects, and more similar to DS07.

Landscape Function Analysis (LFA)

As for other sites, the creek bed recorded the lowest stability index, and the eastern and western banks, the highest (**Figure 22**). This can be mostly attributed to a more cohesive soil type on both banks (indicated by the slake test) resulting in limited erosive features and a more resistant surface nature. Additionally, the greater amount of overhanging vegetation on the banks resulted in increased rain splash protection.

In contrast to other sites, the eastern (flat wide) bank recorded higher infiltration and nutrient cycling indices than the creek bed. This result reflects higher scores for perennial basal cover, litter cover and the slake test on the eastern bank, than at both the creek bed of DS08, and the eastern banks of other sites.

In the area downstream of Coppin Gap, encompassing site DS08, the floodplain expands to a broad plateau, which has the effect of slowing flow velocity and facilitating the settling of sediments from upstream.

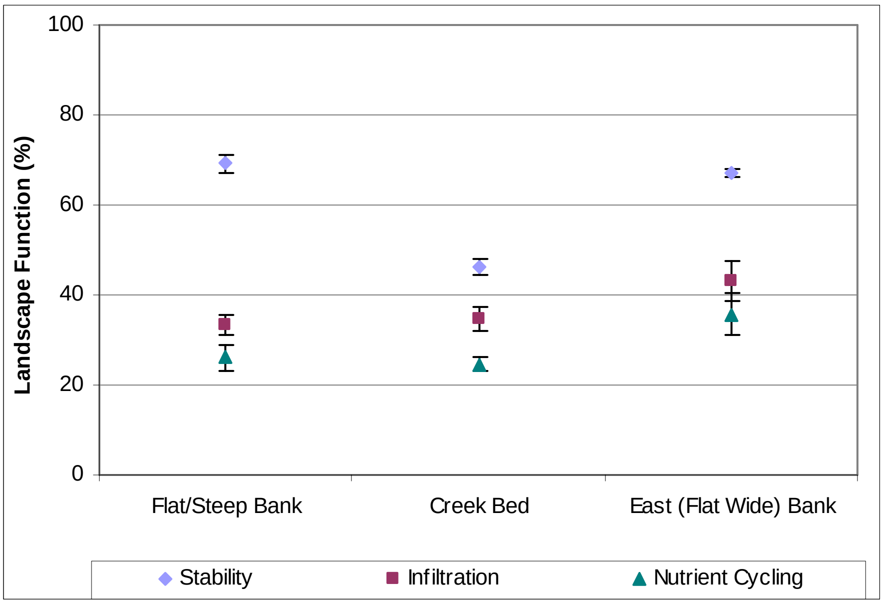

Figure 22 Landscape function indices for the creek cross section at site DS08

Vegetation

Flat steep bank, DS08-A (Plate 42a) –*Triodia longiceps* hummock grassland over **Cenchrus ciliaris* very open tussock grassland.

Five species were recorded along the transect (mean density 5 plants/m² and mean cover of 50%). The lower stratum consisted predominantly of **Cenchrus ciliaris* (mean density 3 plants/m² and mean cover of 3%) with the occasional occurrence of *Sporobolus australasicus, Euphorbia australis* and *Corchorus incanus.* The upper-stratum consisted predominantly of *Triodia longiceps* (mean density 2 plants/m² and mean cover of 47%).

Creek bed, DS08-B (Plate 42b) – *Eucalyptus camaldulensis* var. *obtusa* open woodland over *Acacia tumida* var. *pilbarensis* high open shrubland over *Triodia longiceps* and *T. epactia* very open hummock grassland and **Cenchrus ciliaris* very open tussock grassland over *Cyperus vaginatus* very open sedges.

Thirteen species were recorded along the transect (mean density 1.8 plants/m² and mean cover of 33%). This was the lowest density and cover data of all the creek beds, with 28 quadrats recording bare ground. The lower stratum (to 1m) was dominated by **Cenchrus ciliaris* (mean cover 5%), *Triodia longiceps* (mean cover 5%), *Triodia epactia* (mean cover 3%) and *Cyperus vaginatus* (mean cover 1.5%). The mid-stratum was dominated by *Acacia tumida* var. *pilbarensis* (mean cover 5%) and *Acacia inaequilatera* (mean cover 3%). The upper-stratum (height to 15m) consisted predominantly of *Eucalyptus camaldulensis* var. *obtusa* (mean cover 29%).

Flat wide bank, DS08-C (Plate 42c) – *Acacia inaequilatera* open shrubland over *Hybanthus aurantiacus* low open shrubland over *Triodia epactia* and *T. longiceps* hummock grassland.

Eight species were recorded along the transect (mean density 2.3 plants/m² and mean cover of 74%). The lower stratum (to 1m) was dominated by *Triodia epactia* (mean cover 34%), *Triodia longiceps* (mean cover 25%) and *Hybanthus aurantiacus* (mean cover 6.2%). The upper-stratum stratum consisted predominantly of *Acacia inaequilatera* (mean cover 8.1%).

Plate 42 Transect DS08-a

Transect DS08-b

Transect DS08-c

4.2 Flora and vegetation summary

4.2.1 Summary of Flora in all transects

A total of 87 plant taxa (including subspecies and varieties) were identified within the surveyed transects in Coppin Creek. The 87 taxa were from 28 families and 65 genera. In addition, a further 15 taxa were identified within floristic sample sites placed in Coppin Creek during baseline surveys of Exploration Licence E45/2226 and an area of EA45/2825 within July 2005 and April 2006. In total, 102 plant taxa from 34 families and 71 genera have been identified within Coppin Creek. Of these taxa, approximately 37% were annual species, the most dominant of which was *Sesbania cannabina (*Sesbania Pea). This spindly annual herb or shrub grows to 3m in height and favours areas subjected to seasonal water-logging (FloraBase, 2006). This species was common across areas of Coppin Creek that had been burnt in February 2005.

The Poaceae, Papilionaceae, Euphorbiaceae and Mimosaceae families were dominant across the survey area (**Table 22**) with *Acacia* being the most common genus (**Table 23**). Species diversity of the creekline vegetation was higher downstream of Coppins Gap, where the creek was over 100m in width in a floodplain structure. Upstream of Coppins Gap, the creekline is narrower and deeper, with vegetation dominated by *Eucalyptus camaldulensis* var. *obtusa, Acacia* species, **Cenchrus ciliaris* and *Triodia longiceps*.

Table 22 Summary of dominant plant families within the Coppin Creek survey area.

Family	Number of Taxa
Poaceae	13
Papilionaceae	12
Euphorbiaceae	8
Mimosaceae	8
Myrtaceae	6

Across the survey area the most widespread species included: *Cyperus vaginatus, Eucalyptus camaldulensis var. obtusa, Melaleuca glomerata, Sesbania cannabina, Triodia epactia,*Cenchrus ciliaris, Senna notabilis* and *Cleome viscosa.*

Table 23 Summary of dominant genera within the Spinifex Ridge survey area.

Genus	Number of Taxa
Acacia	8
Euphorbia	5
Eucalyptus	3
Indigofera	3
Pluchea	3
Triumfetta	3

4.2.2 Introduced Flora

A total of seven weed species were located within the surveyed project area of Coppin Creek, one of which is a Declared Plant species (as listed by the Department of Agriculture and Food, WA). **Datura leichhardtii* (Native Thornapple) is classified as either Priority 1, 3 or 4 across much of the state, the exception being the Pilbara region where it appears relatively widespread. A single plant of this species was recorded within the area surveyed along Coppin Creek.

**Cenchrus ciliarus* (Buffel grass) was widespread within Coppin Creek. This species is known to be well established in the adjacent Meentheena Conservation Park (Kendrick and McKenzie, 2001). Other weed species included **Aerva javanica* (Kapok bush), **Citrullus colyocynthis* (a melon weed), **Passiflora foetida* (Stinking Passion Flower), **Malvastrum americanum* (Spiked Malvastrum) and **Echinochloa colona* (Awnless Barnyard Grass). These species did not appear widespread at the time of assessment. In addition, **Choris virgata* (Feathertop Rhodes Grass) was identified within a tributary of Coppin Creek during the baseline survey.

4.2.3 Declared Rare and Priority Flora

No Rare or Priority Flora species were identified within the areas surveyed of Coppin Creek.

4.2.4 Vegetation Condition

Much of Coppin Creek south of Coppins Gap was burnt during a wildfire in February 2005. At the time of survey in April 2006, the vegetation appeared to be recovering with the majority of *Eucalyptus* and *Melaleuca* species re-sprouting. However, short term changes in botanical composition are likely to have occurred. Grazing of vegetation by cattle was evident and **Cenchrus ciliaris* (Buffel grass) is present along the length of the creekline.

4.3 EFA and summary vegetation in typical 'zones' in Spinifex Ridge

Following independent assessment of each site (4.1), multivariate statistical analysis (Principal Component Analysis, or PCA) was carried out on the 'typical zones' of the creek, identified as; creek bed (C), flat wide bank (FW), flat steep bank (FS), medium banks (M), steep bank (S). Flora and vegetation identified in Coppin Creek were also described.

The aims of the statistical analysis were to;

- Identify whether there were significant relationships between individual parameters,
- identify whether zones could be clearly delineated according to specific traits, or combinations of specific traits, and
- determine whether transects within a zone were similar to each other, and therefore, the 'robustness' of zone classifications.

This information would be valuable in setting rehabilitation targets.

Initially, Pearson's correlation showed several significant relationships between specific variables (**Appendix H**). Significant positive correlations, where a higher value for one parameter is a predictor of a higher value for another parameter, included;

- infiltration index and nutrient cycling index
- infiltration index and length of the zone
- nutrient cycling index and transect length
- stability index and plant density
- nutrient cycling index and plant cover
- transect length and plant cover
- infiltration index and plant diversity
- nutrient cycling index and plant diversity
- transect length and plant diversity

Significant negative correlations, where a higher value for one parameter is a predictor of a lower value for another parameter, were limited to;

- stability index and transect length

Subsequently, One Way Analysis of Variance (ANOVA) identified values for some parameters that were 'unique' to particular zones (**Appendix H**), in particular;

- Stability index (significantly lower in creek beds than all other zones) (**Figure 23**),
- Infiltration index (significantly higher in creek beds than medium and steep banks, flat wide banks significantly higher than steep banks) (**Figure 24**),
- Transect length (significantly longer and more variable for creek beds than all other zones) (**Figure 25**),
- Species richness (significantly higher for creek beds than all other zones) (**Figure 26**).

The results show clear distinction of the creek beds from all other zones, and general similarity between the four bank zones for all parameters except infiltration.

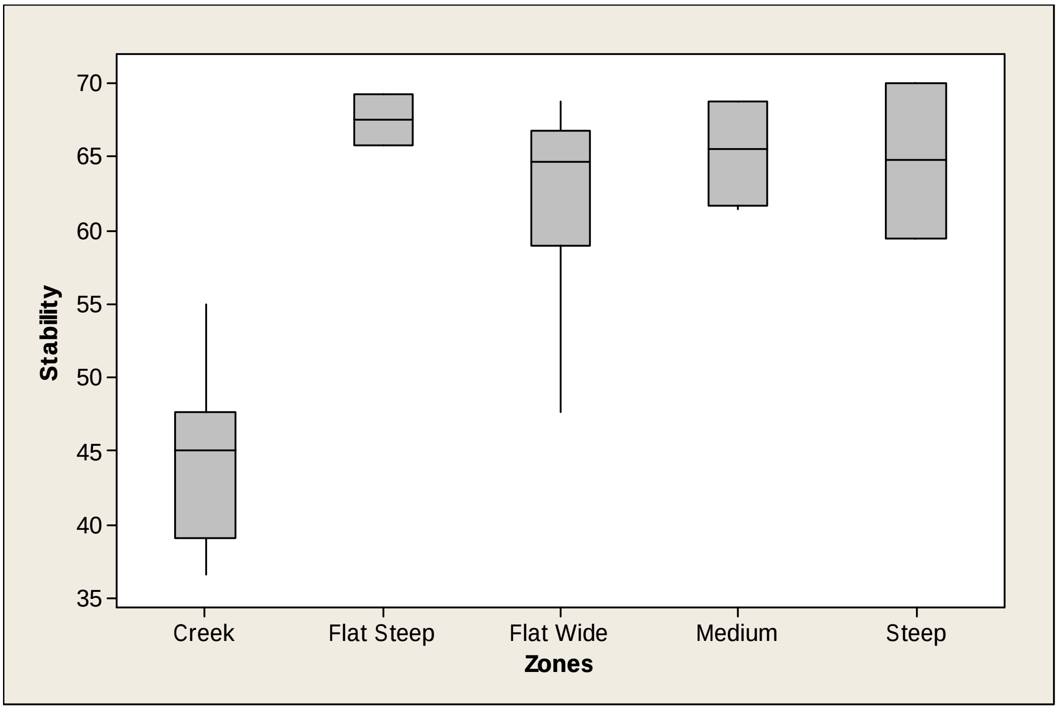

Figure 23 Data ranges (grey boxes and whiskers) and median values (line within box) of stability index for each zone identified in Coppin Creek

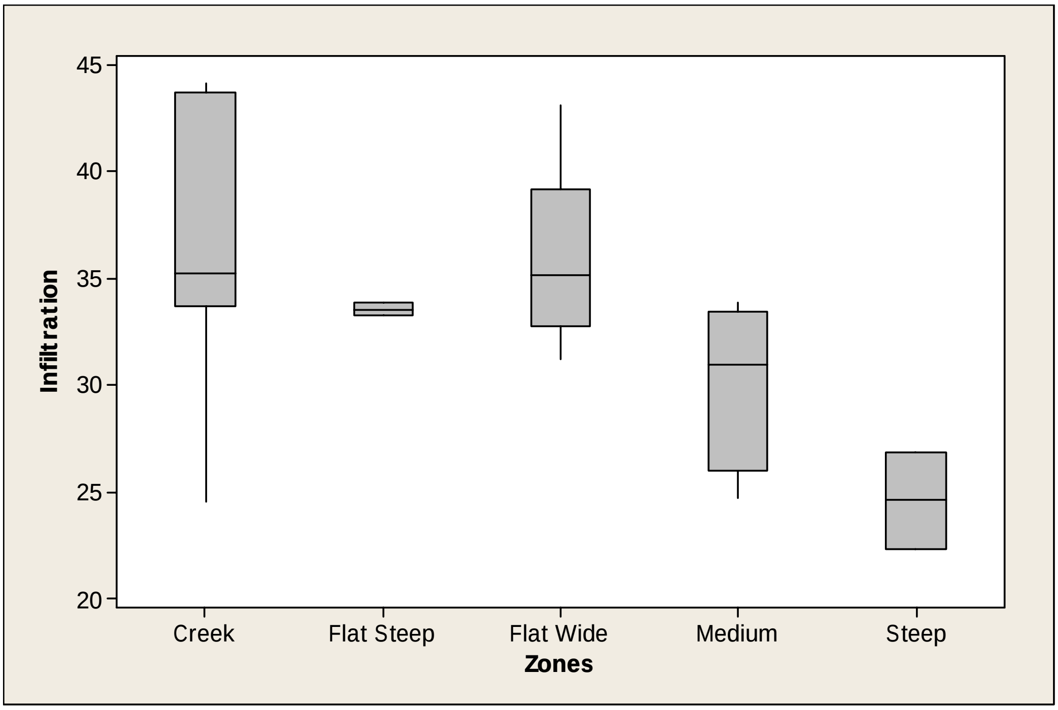

Figure 24 Data ranges (grey boxes and whiskers) and median values (line within box) of infiltration index for each zone identified in Coppin Creek

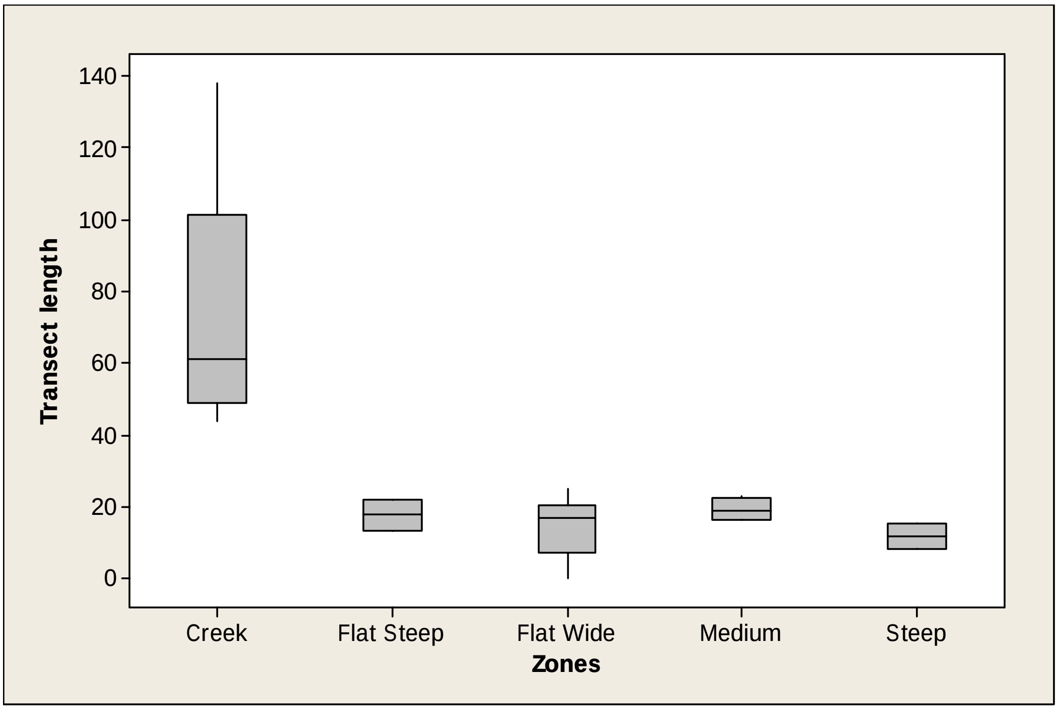

Figure 25 Data ranges (grey boxes and whiskers) and median values (line within box) of transect length for each zone identified in Coppin Creek

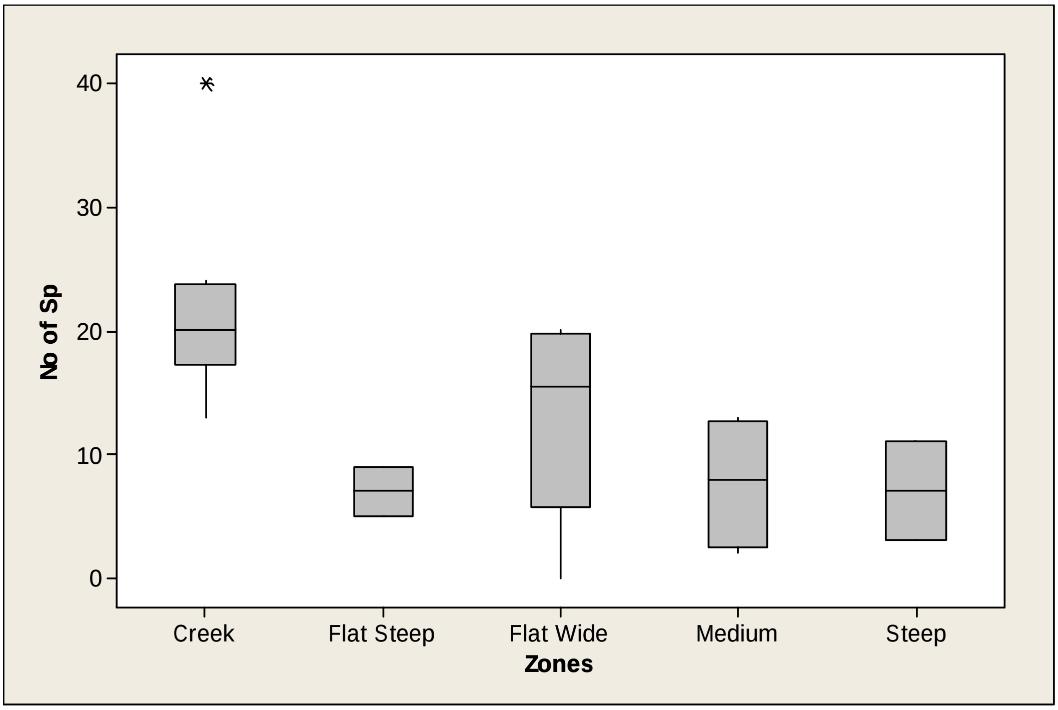

Figure 26 Data ranges (grey boxes and whiskers) and median values (line within box) of species richness for each zone identified in Coppin Creek (asterisk indicates an extreme or 'outlier' value)

There was greater statistical difference between the creek zone and the four bank zones, and little difference between the four bank zones. The lack of difference between the four bank zones was reflected in overlap of data ranges for each parameter. Despite this, Principal Component Analysis (PCA) showed some delineation between and similarity within the bank zones, according to the general clustering of transects on the plot (**Figure 27**). These results indicate reasonable robustness in the transect classifications. The analysis confirms the ANOVA results, that the creek beds were clearly different to the banks, as indicated by the separation of the creek points from others on the PCA plot. The bank zones recorded the highest stability index (‘stability’) and mean plant density (‘DENS/m’) of all indices measured, due to their proximity to the stability and density vectors on the PCA plot. Of the four bank zones, the stability index and plant density were highest but most variable for the flat wide banks and lowest and least variable for the steep banks.

PCA analysis of the LFA and transect length data only, excluding vegetation, showed no difference in the grouping or position of data (data not shown). This indicates that vegetation parameters did not have a significant influence on the grouping of the transects.

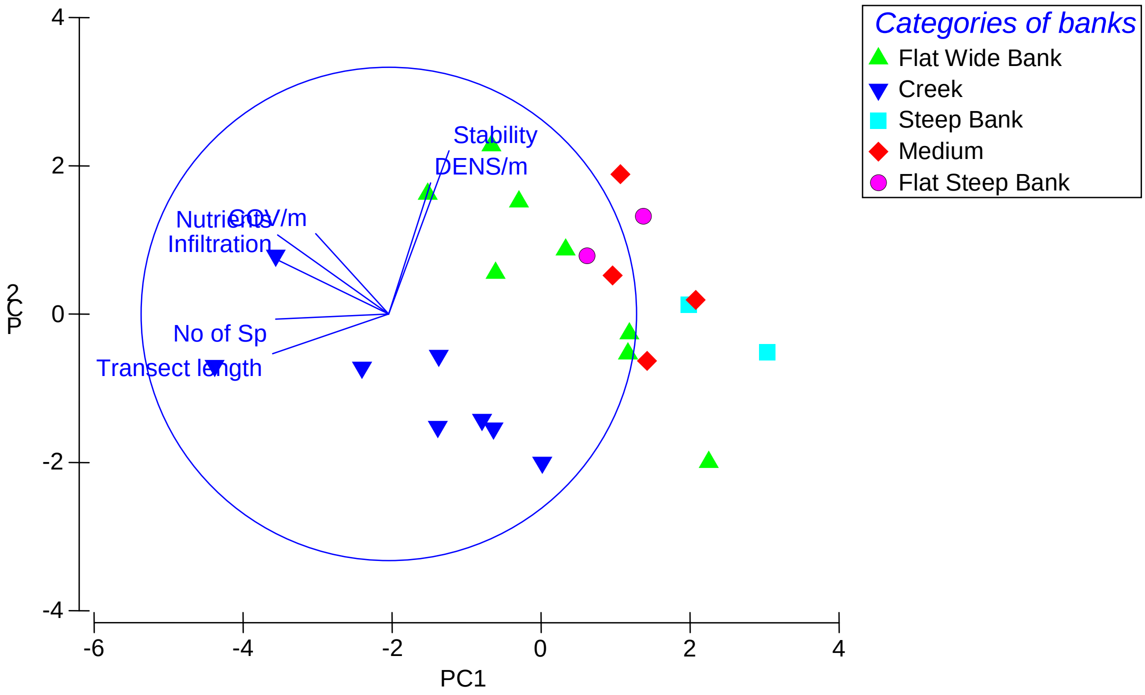

Figure 27 PCA plot of Coppin Creek LFA and vegetation data for August 2006. 70% of variation is explained by the two axes of the plot

4.3.1 Creek bed (DS01-b, DS02-b, DS03-b, DS04-b, DS05-b, DS06-b, DS07-b, DS08-b)

The eight creek beds assessed in this survey showed variability between individual transects, but some ‘sub-grouping’ on the PCA plot (**Figure 27**). Sites DS01-b and DS02-b were very similar to each other, and sites DS03-b, 4-b, 5-b and 8-b were also closely grouped (data not shown).

In terms of the data ranges for the parameters assessed in each creek bed site, all values were within 10% of each other except for plant cover, and a single outlier for the number of species (which was high for one of the eight reek beds assessed) (**Figure 28**). The ranges for the stability, infiltration and nutrient cycling indices, and plant density and number of species (diversity), fall within a well-defined range for the creek bed habitats of Coppin Creek. These habitats were characterised by low stability and nutrient cycling indices, high infiltration index, low plant density and high species richness compared to other zones in the creek. The creek beds also recorded the highest number of ‘patches’ (obstacles on the transect) of all zones, implying greater resource/flow regulation.

In comparison with data from a previous study of Marillana Creek to the south (OES, 2005) (data not shown);

- The stability, infiltration and nutrient cycling indices were less variable in the creek beds of Coppin Creek,
- Overall, the stability and infiltration index value ranges were lower at Coppin Creek,
- The plant species richness of the creek bed zones in Coppin Creek was higher and more variable

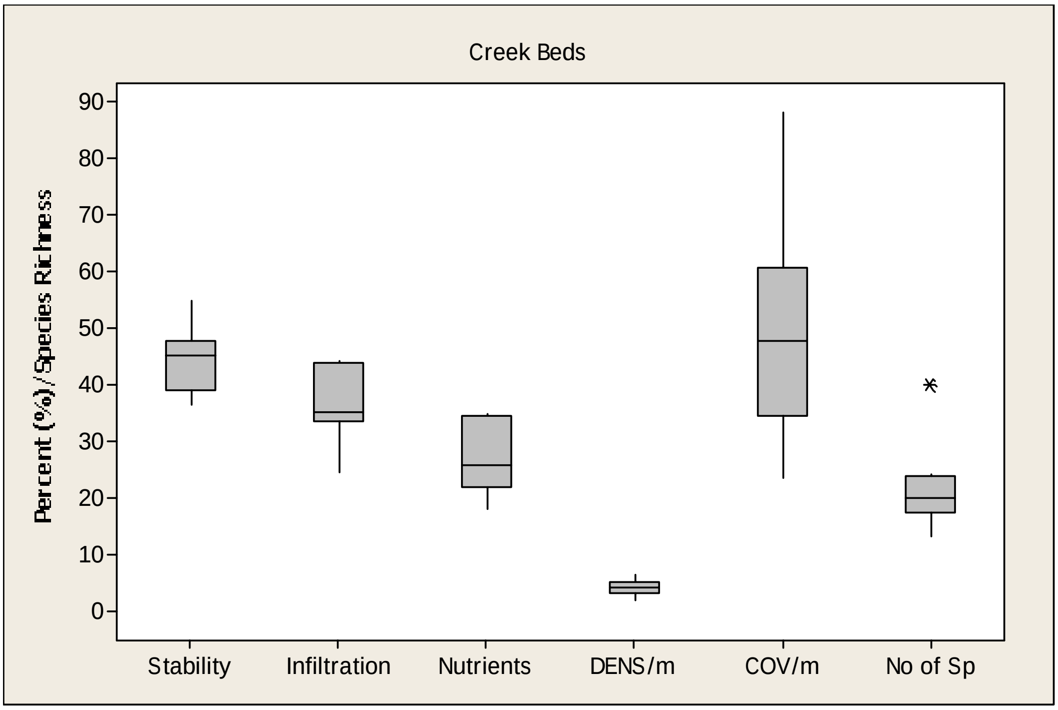

Figure 28 Data ranges (grey boxes and whiskers) and median values (line within box) of six parameters recorded from eight transects located on the creek bed zones ‘No of Sp’ is the actual number of species, not a percentage value. DENS/m = plant density per metre, while COV/m = plant cover per metre)

The upper vegetation stratum was dominated by *Eucalyptus camaldulensis* var. *obtusa*, which varied in density from scattered trees to woodland. Three main associations were identified across the eight creek bed transects;

- *Eucalyptus camaldulensis* var. *obtusa* open woodland over *Melaleuca glomerata* and *Sesbania cannabina* high open shrubland over *Cyperus vaginatus* open sedges.
- *Eucalyptus camaldulensis* var. *obtusa* open woodland *over Acacia tumida* var. *pilbarensis* high open shrubland over *Triodia longiceps* and *T. epactia* hummock grassland.
- *Eucalyptus camaldulensis* var. *obtusa* woodland over mixed *Triodia longiceps* open hummock grassland;

4.3.2 Flat wide bank (DS01-a, DS01-c, DS02-a, DS02-c, DS03-a, DS04-a, DS04-c, DS08-c)

The eight flat wide banks showed some variability in characteristics, with two distinct subgroups within this zone on the PCA plot (**Figure 27**). DS01-c, DS03-a and DS04-c were grouped together, while DS01-a, 2-a, 2-c, 8-a and 4-a formed a second subgroup (data not shown). The number of patches or obstacles on the transects within this zone, was intermediate to other zones.

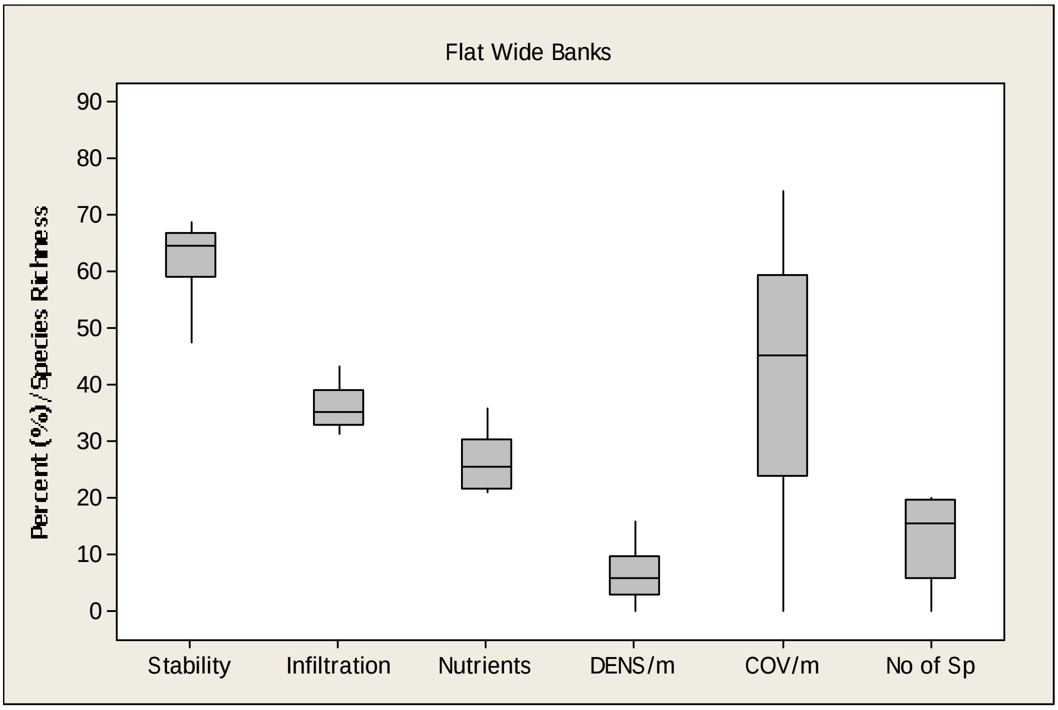

Figure 29 Data ranges (grey boxes and whiskers) and median values (line within box) of six parameters recorded from eight transects located on the flat wide bank zones. 'No of Sp' is the actual number of species, not a percentage value. DENS/m = plant density per metre, while COV/m = plant cover per metre)

The flat wide bank transects were consistent in most parameters, except plant cover (**Figure 29**). The suite of indices is distinctive for flat wide banks in Coppin Creek. Most noticeably, the number of plant species was relatively high compared to other three bank zones.

In a regional context, comparison with data from the 'flat wide banks' of Marillana Creek to the south (data not shown) indicates;

- The stability index range was higher at Coppin Creek,
- The infiltration index range was lower at Coppin Creek,

- The nutrient cycling indices of the two creeks were similar,
- The vegetative cover and species richness in Coppin Creek were higher, and were more variable (larger range), than Marillana Creek.

Within the eight flat wide banks studied at Coppin Creek, vegetation composition was variable compared to other zones. The upper storey of Coppin Creek's flat wide banks was dominated by scattered to open shrubland or open woodlands, while the lower storey was comprised of either shrubland or grassland, with five broad vegetation associations identified;

- *Hakea lorea* ssp. *lorea* scattered tall shrubs over *Senna notabilis* and *Sida* sp. low shrubland
- *Senna notabilis* low scattered shrubs over *Triodia epactia* open hummock grassland
- *Corymbia hamersleyana* open woodland over mixed open shrubland
- *Eucalyptus camaldulensis* var. *obtusa* open woodland over *Sesbania cannabina* shrubland
- *Acacia inaequilatera* open shrubland over *Hybanthus aurantiacus* low open shrubland

4.3.3 Flat steep bank (S06-c, DS08-a)

There were only two flat/steep banks assessed in Coppin Creek, and the data ranges for most parameters (except plant cover) for the two transects were very narrow (**Figure 30**), and were similar to each other, (**Figure 27**). As for other banks, high stability and high plant density were key features of the flat/steep banks. While this zone was poorly represented in the survey with only two replicates, the data for both transects were similar. The stability index was relatively high compared to other LFA indices within this zone, and plant diversity was relatively low compared to other zones in the creek.

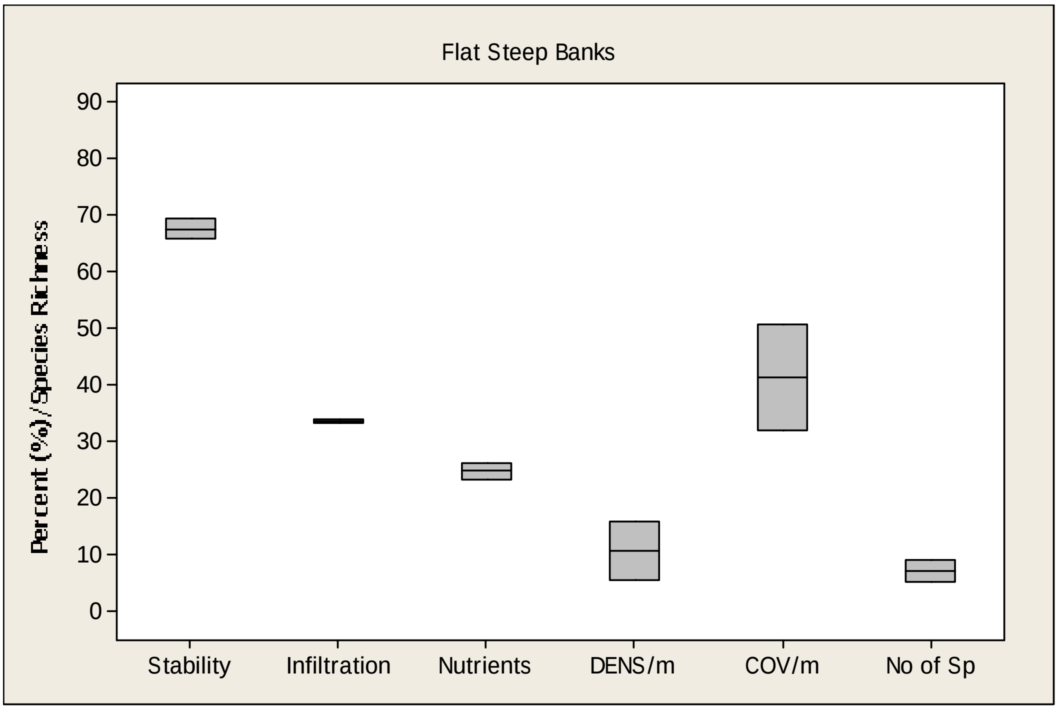

Figure 30 Data ranges (grey boxes and whiskers) and median values (line within box) of six parameters recorded from two transects located on the flat steep bank zones. 'No of Sp' is the actual number of species, not a percentage value. DENS/m = plant density per metre, while COV/m = plant cover per metre)

The number of patches or obstacles on the transects within this zone was low compared to other zones.

On a regional scale, the LFA data for flat steep bank zones in Coppin Creek was compared with flat steep bank zones in Marillana Creek to the north (data not shown);

- The zone was poorly represented at both creeks (n = 2),
- The stability index range was higher at Coppin Creek,
- The infiltration index range was lower at Coppin Creek,
- The nutrient cycling index range was smaller and higher overall at Coppin Creek,
- Plant cover was higher and plant diversity was lower at Coppin Creek.

Two different vegetation associations were identified on the transects across flat steep banks at Coppin Creek, and can be broadly described as;

- *Corchorus incanus* low open shrubland over *Triodia epactia* very open hummock grassland
- *Triodia longiceps* hummock grassland and **Cenchrus ciliaris* very open tussock grassland.

4.3.4 Medium bank (DS05-c, DS06-a, DS07-a, DS07-c)

The four medium banks showed reasonable similarity to each other in terms of LFA indices (**Figure 31**). These four sites recorded high values for the stability index and plant density, as for other bank zones at Spinifex Ridge (**Figure 27**). The values for vegetation parameters were quite variable within the medium bank sites, as indicated by data ranges that varied by more than 10%.

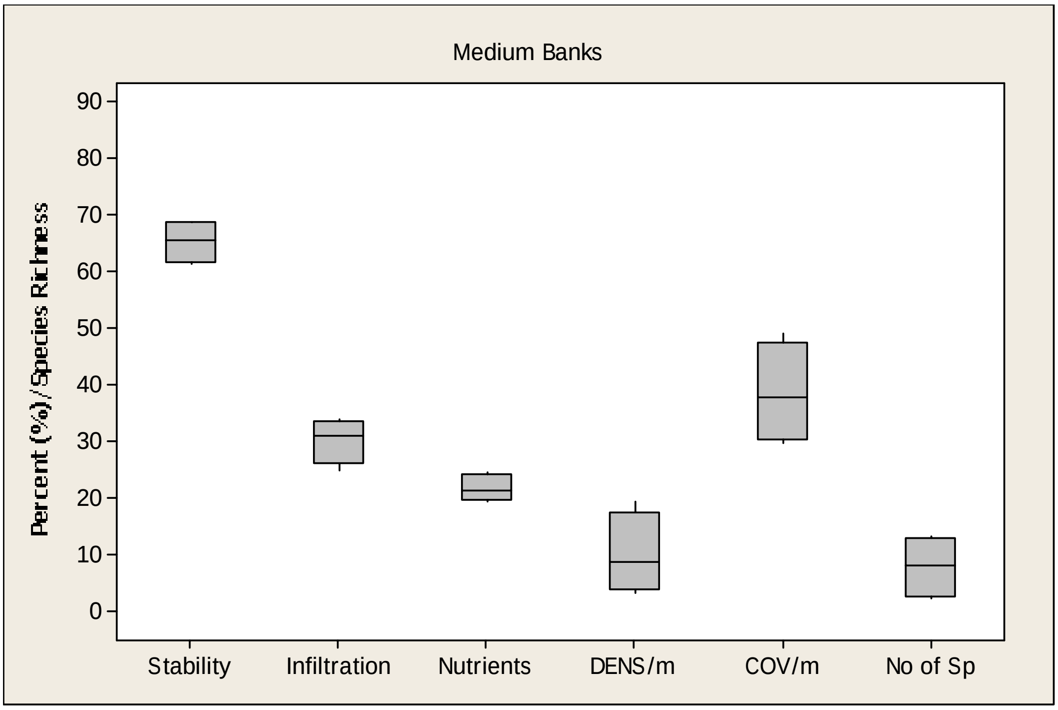

Figure 31 Data ranges (grey boxes and whiskers) and median values (line within box) of six parameters recorded from four transects located on the medium bank zones. 'No of Sp' is the actual number of species, not a percentage value. DENS/m = plant density per metre, while COV/m = plant cover per metre).

The number of patches or obstacles on the transects within this zone was intermediate to other zones.

The main vegetation types were shrubland and grassland, as noted for the Flat Steep banks, and vegetation was quite variable, with three vegetation associations being recorded for four transects, as follows:

- *Acacia inaequilatera* open shrubland over mixed shrubland and grassland
- *Stemodia viscosa* open shrubland over *Triodia epactia* hummock grassland
- *Triodia epactia* hummock grassland.

4.3.5 Steep bank (DS03-c, DS05-a)

There were two transects classified as steep banks at Coppin Creek, and they were very similar to each other (<10% variation). The data ranges for all LFA and vegetation indices were considered characteristic of this zone (**Figure 32**). Overall, this zone recorded the least variability between transects, of the five zones identified in Coppin Creek, as indicated by close proximity of transects on the PCA plot (**Figure 27**). The stability indices for the two transects were relatively high compared to other LFA indices within the zone, and plant cover was low compared to other zones. The number of patches or obstacles on the transects within this zone was low compared to other zones.

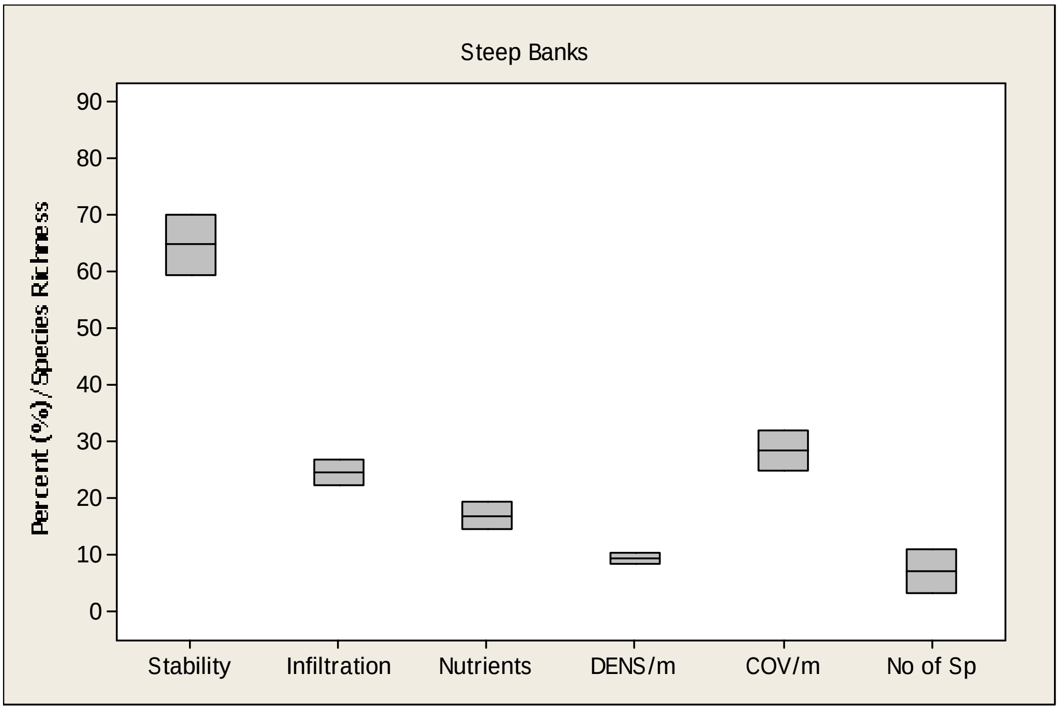

Figure 32 Data ranges (grey boxes and whiskers) and median values (line within box) of six parameters recorded from two transects located on the steep bank zones. ‘No of Sp’ is the actual number of species, not a percentage value. DENS/m = plant density per metre, while COV/m = plant cover per metre).

The vegetation associations recorded on the Steep bank zones were broadly considered to be;

- *Triodia epactia* open hummock grassland,
- *Stemodia viscosa* low open shrubland.

The vegetation associations were variable, with different associations recorded on the two transects.

Overall, landscape function and vegetation parameters differed between the five zones identified in Coppin Creek (**Table 24**).

Table 24 The ranges of LFA parameters for zones assessed at Coppin Creek. All values are in percent (%) except species richness (number of species per m) and the number of transects.

Zone	Stability	Infiltration	Nutrient Cycling	Density/m	Cover/m	Diversity	Number of transects
Creek Bed	37 - 55	25 - 44	18 - 35	2 - 7	23 - 88	13 - 40	8
Flat Steep Bank	65 - 69	33 - 34	23 - 26	5 - 16	32 - 51	5 - 9	2
Flat Wide Bank	48 - 69	31 - 43	21 - 36	0 - 16	0 - 75	0 - 20	8
Medium Bank	61 - 69	25 - 34	19 - 25	3 - 19	30 - 49	2 - 13	4
Steep Bank	59 - 70	22 - 27	14 - 19	8 - 10	25 - 32	3 - 11	2

5.0 RESULTS & DISCUSSION – AQUATIC ECOLOGY

5.1 Site Descriptions

DS01

Site DSO1 was located in a small coarse sandy section of Coppin Creek, upstream of the mine site. A small pool approximately 3 m long by 1 m wide and 0.1 m deep was sampled during the assessment **(Plate 43).** The water contained dark green filamentous algae (most likely *Nostoc*) present on the fringes of the water body. Some minor erosion was noted on the banks of this site. Riparian vegetation was very dense and formed a continuous buffer along the edge of the creek. Approximately 85 % of the water body was shaded during the assessment.

Plate 43 Pool at site DSO1 (3 m x 1 m x 0.1 m), sampled in May 2006

DS02 (formerly SR8)

Site DS02 was located approximately 640 m downstream (north) of DS01, and a long pool, approximately 5 m wide by 0.3 m deep, was sampled (**Plate 44**). The sediments at this site were described as sandy clay, with approximately 50 – 75 % cover of larger rocky material. The pool at this site was contained an olive green algal mat (*Nostoc*). The banks were described as wide and flat and did not display any signs of erosion. During the assessment approximately 80% of the waterbody was shaded by overhanging vegetation. Riparian vegetation cover was estimated to range between 50 and 80 % and was fairly continuous up and downstream of this site. The width of the riparian buffer at this site ranged between 30 and 40m.

Plate 44 Pool at site DSO2 (formerly SR8) (8.5 m x 0.3 m), sampled in May 2006

DS03 (formerly SR4)

DS03 was located approximately 920 m downstream of site DS01. A floating algal mat (*Gloeotrichia*) was present at this site (**Plate 45**). The pool of water that was sampled was approximately 8.5 m wide by 0.3 m deep. Charophytes (attached, submerged algae) were also present. The sediments at this site were sandy and contained approximately 25-50% rocky material. The banks were wide and flat, with no evidence of erosion. Riparian vegetation cover of the banks at this site was high, exceeding 80%, however the riparian zone was small compared to other sites, at only 10 m wide. Approximately 30% of the waterbody was shaded by vegetation during the assessment.

DS04

Site DS04 was located 1 km downstream of DS01. The site was characterised by a coarse sandy base. Water was present in a small, shallow pool, which was 3 m wide and 0.12 m deep (**Plate 46**). The banks were low and flat with a high degree of stability, as determined by the lack of erosion features on the shore and the high degree of rocky material present. Vegetation cover was estimated between 50-80 % and the width of the riparian buffer was estimated to be greater than 40 m wide. The vegetation community consisted of patchy sedges. Vegetation at this site was healthy with no evidence of stress.

Plate 45 Pool at site DS03 (8.5. m x 0.3 m), sampled in May 2006

Plate 46 Pool at site DS04 (3m x 0.12 m), sampled in May 2006

DS05 (formerly SR10)

Site DS05 was located 1.5 km downstream of DS01. A filamentous algal matt (*Mougeotia*) was present on the waters surface and there was a thick charophyte bed on the fringes of this site (**Plate 47**). Sediments were sandy, consisting of a rocky fraction of about 25%. The banks were considered to be fairly stable. Vegetation cover was estimated to range between 50 – 80 % and the riparian zone was approximately 30 – 40 m wide.

Plate 47 Pool at site DS05 (est. 3 m x 0.2 m), sampled in May 2006

DS06 (formerly SR7)

Site DSO6 was located 2 km downstream of DS01. This site was characterised by a very rocky base with very little sandy material present. A brown algal mat (*Nostoc*) had dislodged from the sediment of this site and was floating on the fringes (**Plate 48**). Water was not flowing during the assessment and occurred in an isolated pool. The width of the water body was approximately 7 m by approximately 0.3 m deep. The banks were low lying and very stable with a high degree of cover provided from *Eucalyptus camaldulensis* var. *obtusa* and a large amount of rocky material. The riparian vegetation cover of this site was estimated to range between 50 and 80 % and the riparian zone was around 40 m wide.

SR6

This site was located approximately 2km north-east of DS01, close to the main access road to the site. The site was located at a creek junction upstream of Coppin Gap. The creek bed consisted of large rocky cobbles (**Plate 49**). Although dry during the assessment, sediment was sampled in a small depression which had recently dried. A dried algal mat (*Nostoc*) was present and there was a large amount of organic material recorded. Riparian vegetation cover was sparse at about 25 % and was approximately 5 m thick.

Plate 48 Pool at site DS06 (7 m x 0.3 m), sampled in May 2006

Plate 49 Dry site SR6, sampled in May 2006

SR11

Site SR11 was located upstream of Coppin Gap and was on a tributary which meets up with Coppin Creek just upstream of the Gap. A filamentous algae (*Oscillatoria*) was attached to the benthos of this site and had dislodged in some areas. Water at this site was deep in some places, exceeding 1 m. One of the creek banks consisted of a sheer rock face while the other was a gently sloping rocky bank (**Plate 50**). The sediment consisted of coarse sand. Riparian vegetation cover of the shores ranged between 25 and 50 % and was approximately 10 m wide. The vegetation consisted of tall trees and dense sedges. Two species of fish, the Western Rainbow Fish and the Spangled Perch (Grunters), were observed in the pooled water.

Plate 50 Pool at site SR11 (>1m deep), sampled in May 2006

SR5 (Coppin Gap)

Site SR5 represented Coppin Gap, a large permanent pool (**Plate 51**). The shallow fringes of this site were characterised by dense charophyte beds. The banks were steep rock, with some sediment on the banks. Fringing vegetation was sparse and consisted of a number of large *Eucalyptus camaldulensis* trees. The water body was mostly shaded by the steep rocky banks.

Three fish species including the Western Rainbow Fish (Rainbow Fish), Spangled Perch (Grunters), and Hyrtl's Tanden (Eel-tailed Catfishes) have been recorded at this site during baseline fauna surveys.

Plate 51 Pool at site SR5 (Coppin Gap), sampled in May 2006

DS07

Site DS07 was located downstream of Coppin Gap. The creek bed was approximately 6 m wide at this site and depth was approximately 0.5 m. Water was flowing at the time of sampling. The creek bed consisted of coarse rocky material with no fine fraction (**Plate 52**). One bank was steep and eroded while the other was flat and very stable. Riparian vegetation was around 50% and the zone was about 40 m wide.

DS08

Site DS08 was dry during the assessment, and was also located downstream of Coppin Gap. At this site the creekline was shallow and very wide (est. 20 m) (**Plate 53**). The creek bed consisted of both rocky and fine sandy material. There was no evidence of algal mats at this site and it is likely that it has been dry for some time. The banks were flat and stable, covered in Spinifex. Riparian vegetation cover was estimated to range between 50 and 80 % and was greater than 40 m wide.

Plate 52 Pool at site DS07 (6m x 0.5 m), sampled in May 2006

Plate 53 Dry site DS08, sampled in May 2006

SR9

Site SR9 was located at Kitty's Gap, approximately 3.1 km north-west of the exploration camp. The base of this site was rocky, and consisted of a small pool approximately 10 m in diameter (**Plate 54**). The depth of water was approximately 1 m in the deepest sections. A thick filamentous algae (consisting of *Spirogyra*, *Zygnema* and *Mougeotia*) was present on the surface of this pool. Riparian vegetation provided a cover of approximately 25 % at this site, and ranged between 30 and 40 m in width.

Plate 54 Pool at site SR9 (10 m x 10 m x >1 m), sampled in May 2006

5.2 Water Quality

5.2.1 Water Quality, May 2006

Water quality from the ten creekline and Gap sites within the Spinifex Ridge leases was highly variable in this assessment (**Table 25**). The pH was alkaline, ranging from 7.9 to 8.8. Salinity (measured as EC) at all sites was classified as fresh (i.e. below 4800 µS/cm) (DOE, 2003), and all sites were similar with values falling within a narrow range (2020 - 3160µS/cm). Site SR9, a small permanent pool at Kitty's Gap, recorded the highest salinity. This site has a rocky base with low permeability. In contrast, the freshest site, DS05, had a very sandy base with higher permeability, allowing water to infiltrate to the subsurface rather than concentrating.

The cationic balance (order of dominance of major cations in the water) at most sites was Na>Mg>Ca>K, as is typical of most inland Australian waters (Hart and McKelvie, 1986), except at DS05 where the balance was Na>Ca=Mg>K. The anion balance followed the expected order of dominance (HCO_3>Cl>SO_4) at all sites except SR9 (Kitty's Gap) where it was Cl>HCO_3>SO_4.

Several of the dissolved metals targeted for analysis were at concentrations below detection (**Table 25**). Those at measurable concentrations of dissolved metals included As, Ba, Cu, Mn, Mo, Ni and Zn. Where ANZECC data was available for comparison, concentrations of metals were mostly below the ANZECC trigger value for protection of 95% of species in fresh water. The exceptions were Cu at sites DS02, DS06, DS07 and SR9, Mn at DS05 and Zn at all sites except DS03 and DS04. Note that due to the hardness (concentration of $CaCO_3$) of water at sites DS03 and DS04, data conversion was required (ANZECC 2000). .

Concentrations of total nitrogen (N-T) ranged from below detection (<0.1mg/L) to 1.9 mg/L at the sites assessed in May 2006 (**Table 25**). Such high concentrations of N-T are more typical of streams in agricultural areas which have been impacted by fertilisers (DOE, 2003), so the result was unexpected for this Pilbara creekline. During this 2006 assessment N-T decreased with increasing distance downstream from site DS01. The water sample taken from this site was collected from a small isolated pool approximately 1.1 m wide by 2 m long and was a likely sink for nutrients, hence the high concentration of all nutrients at this site. Total phosphorus (P-T) ranged from below detection (<0.01) to 0.28 mg/L in surface water. Similarly to N-T, concentrations the high P-T value was also recorded at DS01. The value for P-T recorded at this site was also typical of an agriculturally impacted stream in the Wheatbelt of Western Australia (DOE, 2003), and as for N-T, the results were unexpected for this Pilbara creekline.

Reactive phosphorus is the portion of P-T which is available for phytoplankton growth. In most cases this portion made up most of the P-T at the Spinifex Ridge sites. The remainder of P-T was made up of organic and inorganic particulate phosphorus.. Sites with a high degree of particulate phosphorus included DS01, DS02, DS04, DS05 and SR9.

Concentrations of Chlorophyll *a* (Chl *a*) generally remained below 10 mg/m^3 with the exception of DS01 which recorded 41 mg/m^3. Chl *a* is a measure of the primary productivity and therefore plant biomass of a system (ANZECC, 2000). In terms of Chl *a,* the trophic (level of organic pollution) status of most sites was oligotrophic (low), however DS05 was classified as mesotrophic (medium) and DS01 was hypereutrophic (high) (ANZECC, 2000).

Table 25 Surface water quality collected at Spinifex Ridge creek sites, Coppin Gap, Unnamed Creek and Kitty's Gap, compared to ANZECC Guidelines for Fresh Water and Upland Rivers, May 2006

Parameter	Coppin Creek							Unnamed Creek	Coppin Gap	Kittys Gap	ANZECC Guidelines*	ANZECC Guidelines (hard)***
	DS01	DS02	DS03***	DS04***	DS05	DS06	DS07	SR11	SR5	SR9		
pH (pH unit)	8.1	8.4	8.7	8.8	8.3	8.5	8.2	7.9	8.3	8.2		
Electrical Conductivity (µS/cm)	2260	2480	2700	2960	2020	2280	2180	2090	2350	3160		
Total Dissolved Solids	1070	1880	1720	945	1990	1410	1190	1340	1540	2440		
Suspended Solids^{+}	10 - 1030							5	<1 - 30	6		
Hydroxide Alkalinity	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1		
Carbonate Alkalinity	<1	30	116	134	<1	49	<1	<1	<1	<1		
Bicarbonate Alkalinity	669	570	497	487	526	465	414	434	512	491		
Sulphate	53	71	77	88	61	108	103	128	115	192		
Sulphur	18	24	26	29	20	36	34	43	38	64		
Chloride	220	312	381	437	261	302	286	283	310	509		
Calcium	25	35	20	22	43	37	48	64	58	85		
Magnesium	30	57	56	57	41	84	80	103	96	165		
Sodium	406	376	447	500	315	341	253	183	267	213		
Potassium	2	<1	2	4	4	4	4	4	3	7		
Arsenic	0.008	0.004	0.004	0.003	0.004	0.016	0.007	0.006	0.012	0.005	0.024	
Beryllium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		
Barium	0.113	0.109	0.138	0.128	0.132	0.092	0.1	0.063	0.076	0.083		
Cadmium	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	0.00084
Chromium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.0037
Cobalt	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		
Copper	0.001	0.002	0.003	0.002	<0.001	0.002	0.002	<0.001	0.001	0.002	0.0014	0.00546
Lead	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0034	0.02584
Manganese	0.607	0.018	0.005	0.01	0.192	0.003	0.056	0.035	0.017	0.005	1.9	
Molybdenum	0.007	0.006	0.02	0.02	0.094	0.131	0.046	0.001	0.076	0.003		
Nickel	0.002	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.011	0.0429
Selenium	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.011	
Vanadium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05		
Zinc	0.026	0.013	0.014	0.01	0.027	0.01	0.018	0.035	0.016	0.028	0.008	0.0312
Iron	<0.05	<0.05	<0.05	<0.05	0.05	<0.05	<0.05	<0.05	<0.05	<0.05		
Mercury	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0006	
Total Nitrogen	1.9	0.4	0.4	0.7	<0.1	0.4	0.1	0.2	<0.1	0.5	0.3**	
Total Phosphorus	0.28	0.01	<0.01	0.01	0.03	0.02	<0.01	<0.01	<0.01	0.01	0.010**	
Reactive Phosphorus as P	0.191	<0.010	<0.010	<0.010	0.029	0.02	<0.010	<0.010	<0.010	<0.010	0.005**	
Chlorophyll a (mg/m^{3})	41	<5	<5	<5	6	<5	<5	<5	5	<5		

All measurements in mg/L except where indicated, dissolved metals reported.
*Trigger values for freshwater for protection of 95% of species. ** Trigger values for Tropical Western Australia: Upland Rivers. *** Trigger values for hard water (above 30mg/L $CaCO_3$). + indicates data provided by Moly Mines and/or 2005 baseline survey.

The principal component analysis (PCA) plot of water quality for all sites sampled in May 2006 shows a high degree of variability in water quality between the sites, due to the disrupted and non-continuous nature of the creek system (**Figure 33**). Sites DS03 and DS04 were similar, which may have been related to their close geographical location. These two sites differed from the other sites, having high concentrations of Cu, pH and Co. Site SR9 (Kitty's gap) reported the highest concentrations of TDS, Mg and So4, while stagnant site DS01 reported the highest concentrations of Mn, Ni, HCO3, P-T and Chl *a*. The PCA indicates that sites outside of Coppin Creek itself were similar to each other and SR5 (Coppin Gap), despite being on different tributaries.

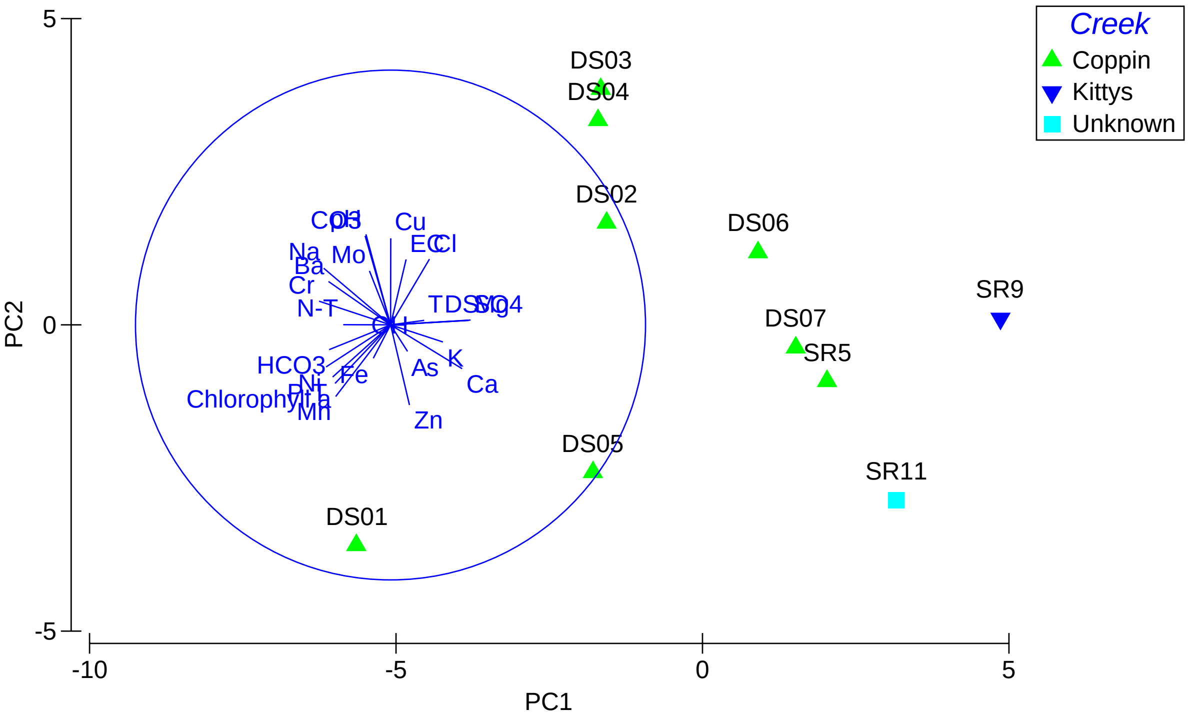

Figure 33 PCA plot of water quality at Spinifex Ridge during May 2006. 65.8% of variation was explained by the first two axis.

5.2.2 Comparison with selected other creeks

Water quality at Coppin Creek was compared to another local creek (Kitty's Gap) and a regional creek, Marillana Creek (data collected in 2005, not shown elsewhere) (**Figure 34**). Comparisons with the DeGrey River were also made during the 2005 assessment (OES, 2005c).

Concentrations of most salts, such as Na, CO_3 and HCO_3 were highest at Coppin Creek. Concentrations of SO_4 and Mg were highest at Kitty's Gap. This indicates that while salinity of these two creeks was similar, the composition of salts was dissimilar, a function of differences in local catchment weathering. Salinity at Marillana creek was much lower that that of Coppin Creek and Kitty's Gap, however, concentrations of N-T and Cu were higher at Marillana Creek than Coppin Creek and Kitty's Gap. The differences in salinity between the sites may be a function of each sites position in its hydrocycle. That is, the Coppin Creek sites may have been much drier at the time of sampling, in comparison to the Marillana Creek sites. Comparison with this regional site is limited in that regard, but provides an indication of similarity between the different areas. Most importantly, the ionic balance of the two sites was similar (data not shown) indicating that if in the same position of the hydrocycle, water chemistry would likely be similar.

Comparison of regional water quality in the De Grey River with local data collected from Coppin Creek in 2005 showed that water quality was generally similar (OES, 2005c). A comparison of the 2006 data set for Coppin Creek with De Grey River data shows that Coppin Creek reported higher levels of some ions and metals than the De Grey River (data not shown), following the trend noted in the comparisons with local creeks.

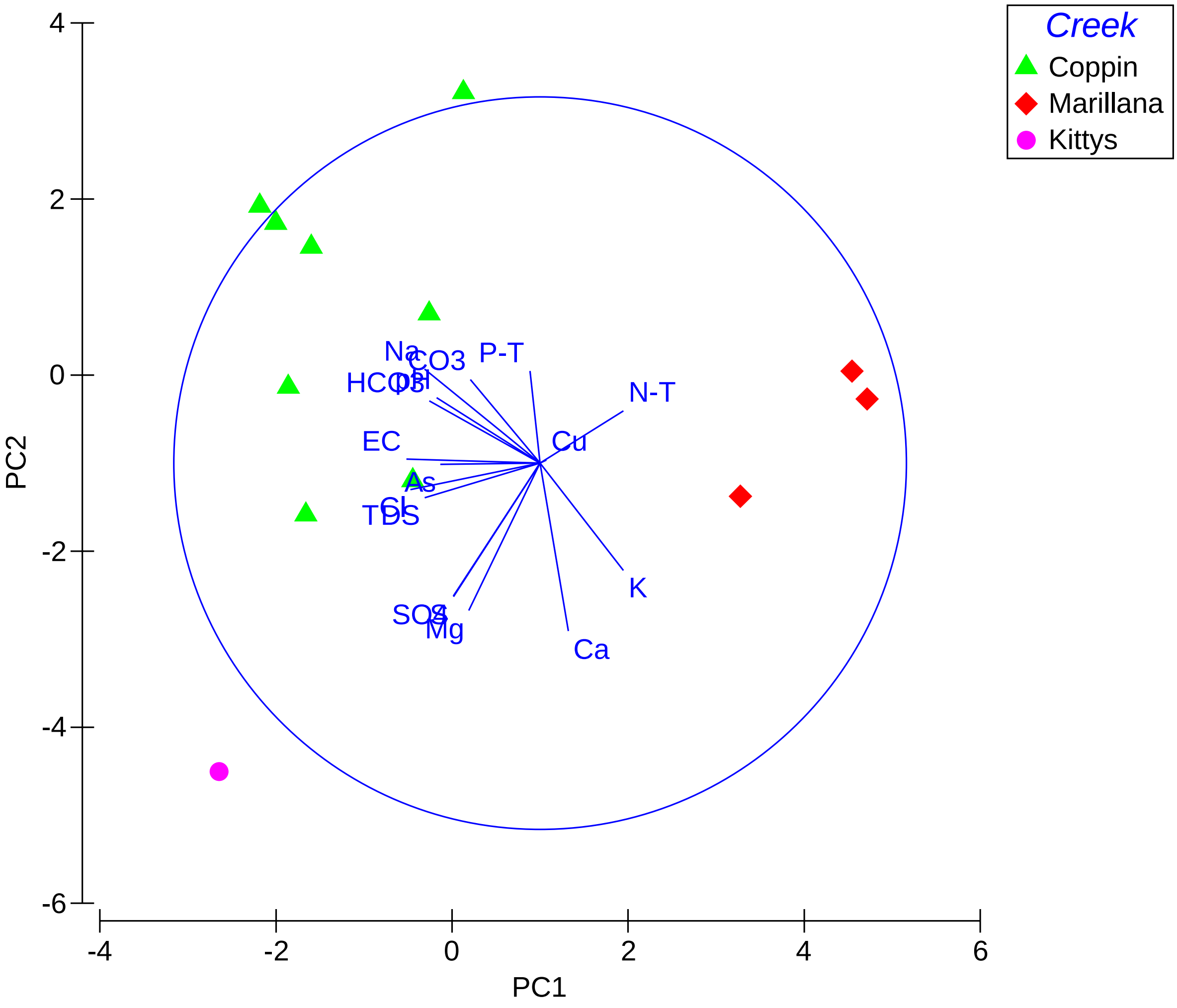

Figure 34 PCA plot of water quality at creeks in the Pilbara - 70.6% variation explained by first two axes

5.3 Sediment Chemistry

5.3.1 2006 Assessment

The pH of sediments was alkaline at all sites, ranging from 7.7 to 9.1 (**Table 26**). Sediment salinity was highest at sites SR6 and SR5 during the assessment (**Table 26**). Sites downstream of Coppin Gap (DS07 and DS08) recorded the lowest sediment salinity during the May 2006 assessment. Mg and HCO_3 were the major anions and cations in the sediment during the May 2006 assessment.

In the absence of site-specific data, total concentrations of metals in sediment were compared with the ANZECC interim sediment quality guidelines (ISQG) (**Table 26**). Generally, concentrations of most parameters remained below these ANZECC guideline values. The exceptions were Cr at SR9 (Kitty's Gap) and Ni at SR5 (Coppin Gap), SR11 and SR9.

Concentrations of N-T were below detection at most of the Coppin Creek sites, however N-T was elevated at SR5 (Coppin Gap) and at another tributary entering Coppin Gap (SR6) (**Table 26**). Site SR6 was dry during the assessment, and the sediment sample was taken in a small pool which had just recently dried, and had an algal mat on the sediment surface. Due to the rocky nature of the site, the sample consisted mainly of organic material with little sediment. This was also the case at Coppin Gap, where organic material on the rocky base was sampled (due to the lack of a true sediment layer). The dominance of organic matter and lack of sediments at these two sites explains their high N-T concentrations.

In comparison to N-T, there was less variability in concentrations of P-T between each of the sites (**Table 26**). P-T was highest at the smaller tributaries which enter Coppin Gap (SR6 and SR11) and lowest at the sites downstream of Coppin Gap (DS07 and DS08).

Total organic carbon (TOC) is the combination of the active organic carbon (plant roots etc), the humic fraction (degraded organic matter) and the inert carbon (e.g. charcoal) (Ouyang et al, 2003). Only three sites; DS05, DS08 and SR6, reported detectable concentrations of TOC in the 2006 assessment. Two of these three sites (DS08 and SR6) were dry during the assessment leading to water-borne organic matter being sampled in the sediment. DS05 was a stagnant pool which would have had high contribution from the breakdown of organic matter (predominantly algae).

Concentrations of most parameters were low in Coppin Creek itself compared to other sites, reflecting the mainly rocky cobble or coarse sands in Coppin Creek, which have little affinity for retaining metals, nutrients or salts.

Table 26 Sediment quality of creeklines at Spinifex Ridge in May 2006

Parameter	Coppin Creek								Coppin Gap	Unnamed Creeks		Kitty's Gap	ANZECC sediment guidelines*
	DS01	DS02	DS03	DS04	DS05	DS06	DS07	DS08	SR5	SR11	SR6	SR9	
pH Value (ph unit)	8.5	8.9	8.8	9	8.2	8.9	9.1	8.8	8	8.4	7.7	9	
Electrical Conductivity (µS/cm)	99	108	119	150	89	99	54	57	230	120	343	114	
Total Soluble Salts	322	352	388	486	290	321	177	186	748	392	1110	369	
Moisture Content (%)	20.7	19.7	22.7	19.4	20.1	17.7	10.8	<1.0	32.3	30.8	46.4	11.6	
Bicarbonate (meq/kg)	66	58	63	72	67	54	42	51	112	62	151	45	
Carbonate (meq/kg)	<1	2	<1	7	<1	2	8	2	<1	<1	<1	8	
Sulphate	20	20	30	40	30	20	<10	10	90	50	130	40	
Sulphur	<10	<10	<10	10	<10	<10	<10	<10	20	10	20	10	
Chloride	40	70	90	100	30	60	20	20	130	100	370	60	
Sodium	210	180	220	230	130	130	110	120	260	200	700	130	
Potassium	350	350	330	280	440	240	280	390	770	980	1050	510	
Calcium	1070	1120	4560	1710	1470	1470	4300	4500	8110	4780	11000	4230	
Magnesium	3120	2150	5080	3390	7920	3720	6380	6520	14100	23400	6130	22500	
Arsenic	<5	<5	<5	<5	<5	6	5	<5	8	21	14	9	70
Barium	20	20	20	20	50	20	20	20	30	50	50	40	
Beryllium	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	
Cadmium	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	10
Chromium	31	13	47	49	114	35	94	72	184	358	64	676	370
Cobalt	5	3	5	5	11	6	8	11	20	36	20	26	
Copper	7	11	13	10	28	30	31	26	45	63	108	45	270
Iron	7770	6400	7880	5700	17000	6940	16700	11800	30500	54600	21500	39100	
Lead	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	9	10	220
Manganese	133	97	164	96	343	164	242	371	466	730	377	528	
Molybdenum	<2	<2	<2	<2	<2	<2	4	<2	<2	<2	2	<2	
Nickel	16	6	21	18	45	28	33	37	79	134	42	207	52
Selenium	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	
Vanadium	15	11	16	11	36	14	30	37	72	38	60	75	
Zinc	15	13	11	9	24	59	15	21	41	69	43	47	410
Mercury	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1
Total Nitrogen	<20	<20	<20	20	<20	<20	<20	<20	120	30	390	<20	
Total Phosphorus	18	12	15	11	22	19	13	7	36	41	52	16	
Total Organic Carbon (%)	<0.5	<0.5	<0.5	<0.5	2.6	<0.5	<0.5	0.5	<0.5	<0.5	4.1	<0.5	

All measurements in mg/kgxcept where mentioned, total metals reported
*ISQG – sediment guidelines

The principal component analysis (PCA) plot of basic sediment chemistry (TSS, pH and nutrients) and total metals shows some differences between the sites located on Coppin Creek itself, and those located on separate, smaller tributaries that feed into Coppin Gap. Site SR6 (a dry site) recorded the highest salinity and concentrations of nutrients (N-T and P-T), which separated SR6 from other sites on the PCA plot (**Figure 35**). Higher concentrations of Ni and Cr at Kitty's Gap (SR9) contributed to the separation of this site from other sites on the PCA plot. Site 11, located on a separate tributary entering Coppin Creek just before Coppin Gap was also dissimilar to the Coppin Creek sites due to comparatively higher concentrations of Co, Zn, Mn and Fe.

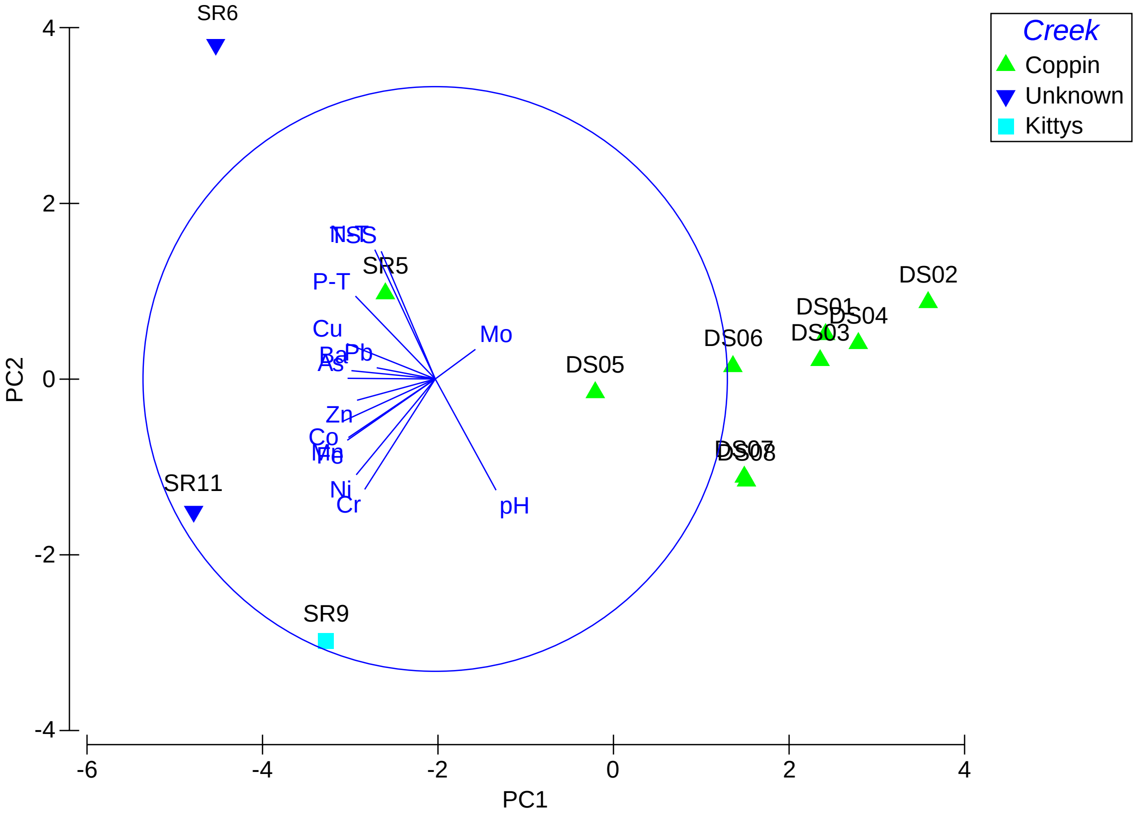

Figure 35 PCA plot of metals and basic sediment quality at Spinifex Ridge during the May 2006 assessment. 76.9% of variation explained within the 1st two axes.

Sediment chemistry of a site is a function of the catchment geology, inputs from surface and groundwater and biological processes (Boulton and Brock, 1999; Simpson *et al*. 2005). While the nature of the sediment in the Coppin Creek sites (DS01 to DS08) was similar and consisted mainly of coarse cobble, sites from other creeks (SR11, SR9 and SR5) were characterised by large boulders with little true sediment. Sediment samples at the latter three sites consisted of mainly organic material and detritus, contributing to a different metal profile, given the adsorbing properties of organic matter (ANZECC, 2000).

5.4 Algae

Water bodies can be classified as either lentic (standing) or lotic (flowing), with the rate of flow in rivers and creeks influencing environmental conditions and the aquatic biota, including algae (Boulton and Brock 1999). In the lotic environment, water flows in a constant and predictable direction and because of this a true planktonic (floating algae) community does not exist (Williams 1983; Hynes 1970). Water flow is the overriding theme in lotic systems, acting as a transport agent and determining the shape and behaviour of organisms that exist in this environment, and determining their habitats (Boulton and Brock 1999). Therefore the algae of running waters are mostly of two main forms; those that form mats (also known as benthic microbial communities or BMCs) on the surface of the littoral zone (edge or shore region), or those that attach to other substrates such as rocks or vegetation (known as periphyton).

Charophytes, or stoneworts, are a third group of attached algae that are commonly found in both lentic and lotic environments. They are a submerged macroalgae that attach to the sediment, and are clearly visible to the naked eye.

The microalgal species (mats and periphyton) that are found in lotic environments are mostly opportunists, which appear and flourish when conditions are optimal. Changes in community structure and dynamics are common, and are triggered by changes in water quality and quantity. Most algal species tend to be cosmopolitan, and even species that are in low abundance within a community, tend to be widespread through the system. Within a lotic system, most attached algae prefer more protected habitats such as amongst emergent vegetation (Hynes, 1970).

Within the microalgae, the dominant groups are the diatoms, the cyanobacteria (blue-green algae), and the chlorophytes (green algae). The following sections describe the three main micro and macroalgal groups identified in Coppin Creek.

5.4.1 Benthic Microbial Communities (‘mats’)

The benthic microbial communities located in the littoral zone of water bodies are usually made up of forms that attach to a substrate. Within streams, the common algal forms are filamentous, and are able to withstand currents and the process of sedimentation. Filamentous algae also can combine to form cohesive mats that bind to the surface of the stream bed or engulf a substrate. These mats are often found floating on the surface of the water as they can become dislodged from the benthos (sediment).

Many of these mats survive by being covered in a mucilaginous sheath that enable them to re-hydrate with the presence of water, as well as by producing resting stages such as akinetes and vegetative cells for the cyanobacteria (Lee 1980), zygotes (hypnozygotes) for the green algae (van den Hoek *et al.* 1995), and spores for diatoms (Edlund and Stoermer 1997). The large amounts of mucilage produced by the cyanobacteria not only allows them to survive extended periods of desiccation and protect them against harsh UV radiation, but also allows the filaments to bind with each other, forming a cohesive mat and enables them to glide preventing sedimentation. Many of the diatoms seek refuge in the epilithic (on rocks) algal mats as they act as “reservoirs” trapping water within the mucilage (Mosisch 2001).

Mats were collected from the sampling sites within Coppin Creek (DS02-DS07) and adjoining tributaries (SR6, SR11) and Kitty’s Gap (SR9). This included a few dry algal mats from sites that had dried. Typically, the samples were dominated by filamentous, freshwater forms belonging to both the Cyanobacteria (blue-green algae) and Chlorophyceae (green algae). The filaments were also covered with epiphytic diatoms, with some mats supporting diatoms on large amounts of mucilage. Eight algal taxa from two Kingdoms (Monera and Algae) were identified from the mats (**Table 27**). Within the Kingdom Monera, three Cyanobacteria taxa were identified from two orders, Oscillatoriales and Nostocales. The Kingdom Algae was more diverse, including the Chlorophyceae represented by five taxa from three orders; Oedogoniales, Conjugales, Microsporales – all filamentous types.

The mats collected from sites DS02, DS03, and SR6 (which was a dry mat), were dark in colour and cohesive structures and composed predominantly of the cyanobacterium, *Nostoc* (Nostocales) intermingled with filamentous chlorophytes (**Table 27**). *Nostoc* is a common, cosmopolitan genus with some 50 species worldwide. It is well known for inhabiting damp soils and covering rocks and other substrate (van den Hoek *et al.* 1995; Entwisle *et al.* 1997). It is often seen as shiny, compact black mat or as balls on the surface of rocks. The Nostocales are nitrogen-fixing cyanobacterium (Boulton and Brock 1999).

Algal mats from all other sites, apart from DS02, DS03, DS07 and SR6, contained similar composition of algae to each other. The mat at DS07 was comprised of *Spirogyra*. This mat was very fine and floating and the filaments could be easily seen with the naked eye. Conjugation was observed, with a number of filaments containing zygospores. *Spirogyra* is one of the most common freshwater species and is cosmopolitan. This site had a coarse, rocky bed which is the preferred habitat of this group.

Site SR9 recorded a high diversity of filamentous chlorophytes, with four different taxa from one order comprising the mat. These taxa often dominate together in a wide range of stream habitats (Biggs and Kilroy 2000).

The chlorophyte groups that were recorded in Coppin Creek are known to be adapted to lotic environments (filamentous forms) and are resistant to desiccation. The dominant families within this group produce hypnozygotes, which are zygotes that become resting stages, germinating only after a period of dormancy and thereby being able to survive extended periods of desiccation (van den Hoek *et al.* 1995).

Table 27 Microalgae and diatoms in benthic microbial mats collected from Spinifex Ridge, May 2006

	Sites								
Taxa	**DS02**	**DS03**	**DS04**	**DS05**	**DS06(drymat)**	**DS06**	**DS07**	**SR9**	**SR11**
Cyanophyceae									
Oscillatoriales									
Oscillatoria		++	++	++	+++	+++			+++
Nostocales									
Nostoc	++++		++++		++++			+++	++
Gloeotrichia		++++				++++			
Chlorophyceae									
Oedogoniales									
Oedogonium		++	++	++	+++	++		++++	++
Conjugales									
Mougeotia				+++				++++	
Spirogyra	+++		+++				+++++	++++	
Zygnema								++++	
Microsporales									
Microspora				+					
Bacillariophyceae									
Pennate Diatoms	++++		++++					+	+++++

Scale: + = sparse; +++++ = dense composition of sample. Different colours delineate the four key taxa that were recorded.

In summary, the benthic microbial community and the periphytic algal community that comprised the mats in the Coppin Creek samples were composed of freshwater filamentous forms that are well known, cosmopolitan taxa. Not only do they have a wide distribution, they are excellent colonisers and are typical of lotic systems.

- No rare or endemic taxa were identified from the samples.
- The algae were mostly found amongst the emergent vegetation in the relatively-protected, shallow edges of the creek.
- All taxa had the ability to form resting stages and the dominant cyanobacteria had nitrogen fixing abilities.

5.4.2 Periphytic (attached) diatoms

The diatoms are a group of microscopic algae considered to be a major component of periphyton in flowing waters (John 2000). Diatoms are unicellular, belonging to the division Bacillariophyta, and have a cosmopolitan distribution in aquatic systems. One of their most characteristic features is a thick cell wall made of silica, with distinct patterns unique to each species, useful for identification purposes (Cox 1996). Diatoms have specific tolerance limits for a range of environmental variables, as has been documented in a number of studies on rivers and streams from south-western Australia (John 1998b; Taukulis and John 2006).

Periphyton samples collected from Coppin Creek recorded a total diversity of 46 diatom taxa representing 24 genera (**Table 28**).

Within these, one species was recorded from Coscinodiscophyceae (centric), two from Fragilariophyceae (araphid-pennate diatoms), and 43 from Bacillariophyceae (raphid–pennate diatoms). There were no rare or endemic diatom taxa observed in the samples. A high level of diversity was recorded from the samples, indicating that the creek is productive and conducive to diatom colonisation.

Overall the number of species recorded from Coppin Creek was high, with a maximum of 27 taxa found at site SR5, followed by DS07 and DS08, which had more than 20 taxa (**Table 28**). The lowest number of species was seven at site SR6, most likely due to a lack of water and the rocky substrate type, which limits diatom colonisation (Townsend and Gell 2005).

Periphytic communities were similar in terms of composition (**Figure 36**), indicating an influence from inundation recent to the survey. This resulted in the majority of sites displaying some degree of connectivity and constant flow (Williams 1983), which provides uniform habitats for the establishment of diatom assemblages. This would be expected in a lotic environment.

Species that frequently dominated the samples included *Thalssionema* sp. aff. *nitzschiodes* and *Nitzschia palea*, which were recorded from all locations (**Figure 36**). Both of these taxa are salt-indifferent, and prefer alkaline habitats (Ehrlich 1995; John 2000), in keeping with water chemistry results from this assessment. *Achnanthidium exiguum* and *Nitzschia frustulum* were also common and are indicative of high pH and low salinity levels (Ehrlich 1995). The genus *Nitzschia*, in particular, is characteristic of stream environments and eroded sediments (John 2000), reflecting the exposed nature of the creek bed, and possibly exaserbated due to recent fires over the catchment.

5.4.3 Comparison of the 2005 and 2006 periphytic diatom results

The results from the 2006 Spinifex Ridge samples showed a much higher species richness than the 2005 assessment. For example overall taxa numbers on this monitoring occasion were 46, compared to 30 from the 2005 assessment and may be attributed to increased inundation levels and persistence of surface water.

The species richness recorded from individual sites was also greater in 2006, with a maximum of 27, compared to the 2005 assessment, where the highest number was 13. However the lowest number of species (less than 10) occurred at site SR6 during both sampling periods.

Table 28 Periphytic diatom taxa recorded from Spinifex Ridge Creek (June 2006)

TAXA	**SITES**											
	DS01	**DS02**	**DS03**	**DS04**	**DS05**	**DS06**	**DS07**	**DS08**	**SR5**	**SR6**	**SR9**	**SR11**
Coscinodiscophyceae												
Cyclotella meneghiniana				1			3	2				
Fragilariophyceae												
Synedra ulna						8	6	10	1			5
Thalassionema sp. aff. *nitzschiodes*	30	22	43	26	32	17	15	6	12	25	60	22
Bacillariophyceae												
Achnanthidium exiguum	78	71	40	101	62	57	14	61	10			29
Achnanthidium minutissimum	1								3			
Eunotia pectinalis											1	
Caloneis bacillum				2	6	3	22	17	11		5	6
Caloneis sp. aff. *ventricosa*							3					
Craticula cuspidata		1	1	2	1	1						
Diploneis subovalis		1				7		6				
Fallacia tenera									3			
Luticola mutica										2		
Navicula cryptocephala					2	1		1	4			1
Navicula rynchocephala	1										4	
Navicula sp. aff. *exigua*									6			
Navicula sp. 1	2	18	16	11	11	24	3	8	10		9	21
Navicula subrynchocephala	4	5		4	6	1	2	6	23		8	7
Navicula symmetrica					2				5			2
Mastogloia sp. aff. *pseudoexigua*							3	1				
Pinnularia gibba										11		
Sellaphora pupula									1			4
Stauroneis dubitabilis			3									
Stauroneis spicula									2			
Gyrosigma sp. aff. *spencerii*									1			
Pleurosigma sp. aff. *saliniarum*						2	6	1	45			
Gomphonema auritum									1			
Gomphonema parvulum						1	3	2	1		23	
Encyonema minutum							8	1	2		2	1
Entomoneis alata									1			
Rhopalodia gibba							7		1			2
Hantzschia amphioxys					1					3	1	
Hantzschia sp. aff. *virgata*											1	
Nitzschia closterium							2	1	8			
Nitzschia dissipata											4	
Nitzschia desertorum	1	1	1	1				1				
Nitzschia frustulum	17	8	25	9	20	17	12	23	2			3
Nitzschia gracilis	2	2	5	3	2				1			5
Nitzschia microcephala	5	22	21	5	23	39	30	6	5			4
Nitzschia obtusa var. *scalpelliformis*			2		1		1					
Nitzschia palea	50	47	39	32	28	17	25	3	7	150	47	15
Nitzschia punctata							9	10				
Nitzschia sp. aff. *subinflata*	4	2										
Nitzschia sp. aff. *scalaris*			4	3		2	2	1		3	1	
Nitzschia sp. 1	5				3	3	24	33	26	6		73
Nitzschia sp. 2											34	
Tryblionella levidensis									8			
Total	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**
Diversity	**13**	**12**	**12**	**13**	**15**	**16**	**21**	**21**	**27**	**7**	**14**	**16**

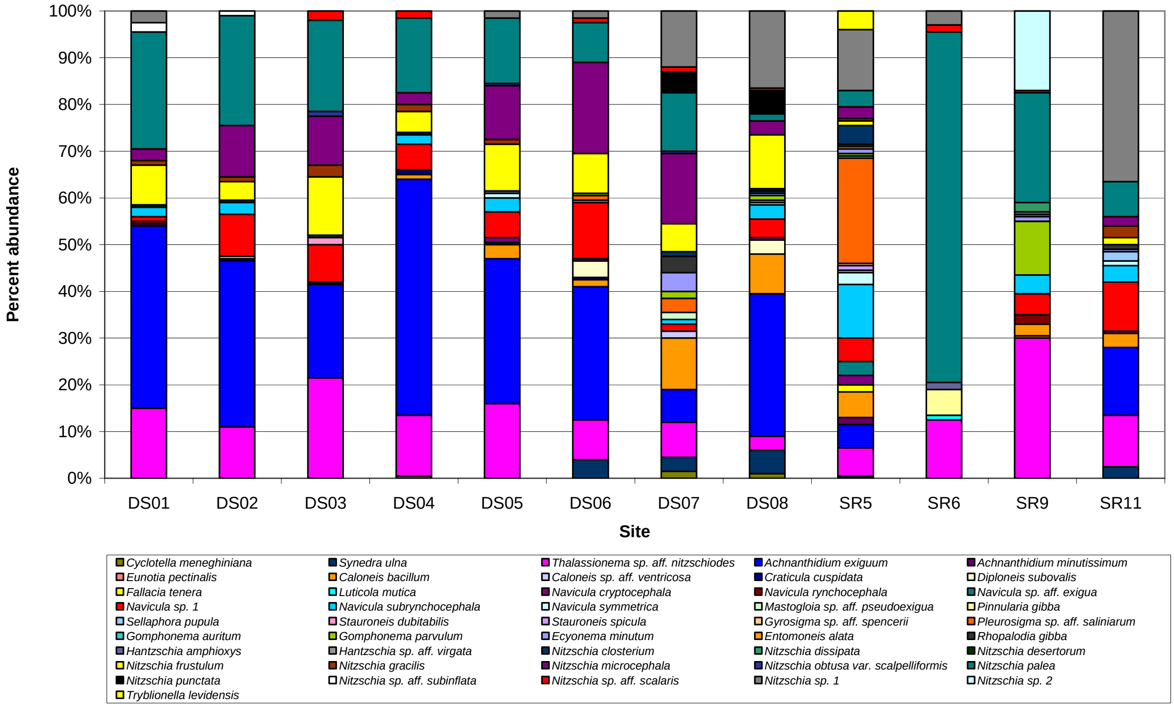

Figure 36 Percentage abundance of periphytic diatoms from Spinifex Ridge Creek (June 2006)

In general, diatom communities were similar at each site between the two years. This was highlighted by the presence of *Nitzschia palea*, which was found in all sites in 2005 and 2006, and reflected the alkalinity and low salinities that appear typical of Coppin Creek (OES, 2005c). Species composition was also related to the lotic environment, and the erosion of sediments.

The diatom species composition at sites SR6, and site SR9, differed from all other sites and each other (**Figure 37**). For site SR6 this would have been due to the high number of *Nitzschia palea*, while SR9 was distinguished by a high number of *Nitzschia* sp. 1.

Of the other sites, SR5 and SR11 had a 60% similarity in terms of diatom community composition, have a high percentage of Naviculoids. The Coppin Creek sites were similar to each other, with the exception of DS08 and DS07, possibly due to the presence of *Syndera ulna* at these two sites (Figure 28).

The differences in grouping between the creek sites and sites on other tributaries appeared to be related to differences in water regime. A different diatom community would be expected to inhabit more persistent water bodies, and diversity is typically lower than in temporary systems, whose communities reflect their “boom and bust” nature (J.John *pers. comm*. 2006).

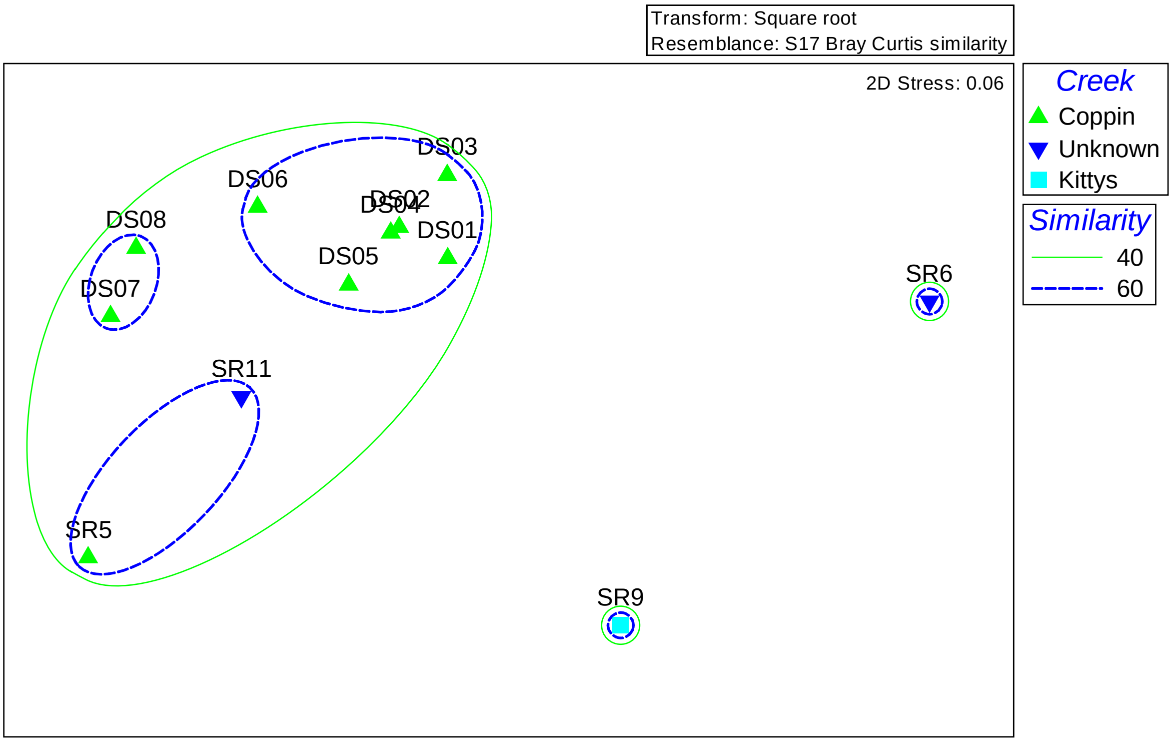

Figure 37 MDS plot of periphytic diatoms at Coppin Creek sites (June, 2006)

In summary, the majority of periphytic diatoms identified from the Spinifex Ridge Project Area have a cosmopolitan distribution in stream environments throughout Western Australia. There were no rare or endemic taxa observed in the samples; however, there was a high level of diversity indicative of a productive environment and conducive to diatom colonisation. There were no defining habitat characteristics for the diatoms, although the sites with the highest diversity tended to be the least shaded, and with mostly rocky substrate, such as Coppin Gap. The greater inundation during the 2006 survey as opposed to that of 2005 resulted in a relatively-uniform community structure throughout the samples, most likely related to a higher degree of connectivity and flow between sites.

5.4.4 Charophytes (submerged macroalgae)

Charophytes, a large aquatic, multicellular algae (macroalgae) that are known commonly as stoneworts, muskgrass or bassweed, were recorded from six sites in Coppin Creek; DS03, DS04, DS05, DS06, DS07 and SR5. Only one species of Charophyte was identified at all sites, *Chara globularis* Thuil. This species is known to be hardier than many others, in that it can tolerate slightly warmer waters, and salinities up to 3.0 g/L (Garcia 2002). Charophytes favour a range of water qualities from fresh to saline, but the genus *Chara* is exclusively freshwater and is selective of hard waters where it may undergo calcification (Ward, 1995).

Chara globularis has a wide distribution and in Coppin Creek it formed extensive beds, usually in combination with filamentous algal mats which had dislodged from the sediment surface. Where charophytes were present, the substrate was always rocky and sandy. Charophytes generally require a soft substrate in which to anchor themselves, via rhizoids.

Charophytes, along with the associated filamentous green algae, also have the ability to withstand periods of desiccation as they produce resting stages known as oospores. They are often pioneering species in newly created or inundated wetlands, with several species often coexisting in many Australian wetlands (Casanova and Brock 1996). *Chara globularis* and its varieties are known to have a cosmopolitan distribution with wide distribution in Australia, preferring fresh to hyposaline alkaline waters and will grow on muddy, sandy and clayish bottoms (Garcia 1999).

Charophytes generally occur in permanent and temporary waters world-wide, and are ecologically important as a source of food, and for their contribution to reducing sedimentation in surface water. They also have the ability to remove large quantities of heavy metals from the water column (hyperaccumulation), and are therefore often used in bioremediation projects (Ward, 1995).

5.5 Aquatic invertebrates

The ten sites that were inundated at the time of May 2006 sampling were assessed for aquatic invertebrates. These included seven sites on Coppin Creek (DS01 – DS07), two from other tributaries (SR9 – Kitty's Gap, SR11 – unnamed creek feeding into Coppin Gap) and Coppin Gap (SR5). A total of 63 invertebrate taxa were identified from the water samples from two Phyla – the Arthropoda (Insecta, Crustacea, Arachnida) and the Mollusca (Molluscs). The subphylum Insecta was the dominant group of aquatic invertebrates with 28 taxa from 22 families. The Insecta was dominated numerically by the Chironomid larvae and Mayfly nymph, *Cloeon* sp. They were followed by large numbers of the cyclopoid copepod (Crustacea: Copepoda) (**Table 29**). The three Classes of Arthropoda represented in the Coppin Creek and the tributary sites, the Insecta, Arachnida and Crustacea, are all typical of Australian inland waters. The Insecta is one of the most primitive, dominant and important classes in running waters, both temporary and permanent (Hynes 1970; Williams 1980). All the taxa recorded from this survey were typical of the northern inland waters of Western Australia. No rare or endangered species were recorded and many of the taxa were cosmopolitan, with species being endemic within Australian, rather than locally. All were classified as freshwater groups.

It was only the semi-permanent water in Coppin Gap that lacked a diverse insect community and was dominated by a crustacean zooplankton population instead. Most inland, dryland rivers are predominantly comprised of a disconnected network of ephemeral channels and pools (Marshall *et al.* 2006). They are renown for their 'boom and bust' ecology with intense productivity and reproduction by opportunistic plants and animals (Shiel *et al.* 2006). Many recorded belonged to the Insecta which are strong dispersers, as is typical of many temporary systems (Ballinger and Lake 2006) and often in arid environments it is the aerial dispersers that show the greatest diversity (Marshall *et al.* 2006).

A greater number of invertebrates were recorded in 2006 than the previous study of 2005 (OES, 2005) as a result of collection of samples from two different habitats in the water body along with extended resident time of the surface water. Between 2005 and 2006, total diversity had increased from 22 to 28 taxa. Community structure was similar with the same classes represented in both surveys. The Mayfly larva, *Cloeon* sp. (Family Baetidae), was the only taxon to be recorded from all sites and in high numbers, particularly in Coppin Gap. *Cloeon* species are normally associated with wetlands of low nutrient levels (Davis *et al.* 1993) and the low nutrient levels and semi-permanence of water at Coppin Gap would account for their high numbers.

The non-biting midges – the Chironomids (Diptera: Chironomidae) again dominated in high numbers at most sites except for DS01 and DS04 (**Figure 38**). They were the dominant group in the 2005 assessment and are common in all types of water bodies (Davies and Christidis 1999). As a group they are a cosmopolitan taxa, some with drought-resistant larvae (Colless and McAlpine 1991).

Large numbers of the cyclopoid copepods were recorded from all sites except DS01 and DS04. Coppin Gap and DS07 recorded the highest numbers of this zooplankter and this may have been due to the open water bodies at these sites. Cyclopoids are carnivorous and tend to benefit from more-open grazing areas. Of interest is the high number of *Anisops* sp. (Hemiptera: Notonectidae) (backswimmers) at site DS04. This is one of the most widely distributed genera of this family preferring still waters and ponds as was found at site DS04 (Davies and Christidis 1999).

Most of the sites in Coppin Creek recorded similar species richness, averaging eight to ten taxa. The site with the highest diversity was Kitty’s Gap with 18 different taxa. Coppin Gap recorded an average diversity and high abundance, mostly due to the dominance of copepods and mayfly nymphs.

While there was no major difference in species richness or composition between the two habitats sampled at each site, there was a lower diversity and greater dominance of one or two genera at those sites where there was minimal emergent vegetation in the littoral zone. Sites SR11 and DS07 were such examples. The multi dimensional scaling (MDS) plot (**Figure 39**) of the invertebrate community shows that many of the sites were similar according to their species composition. Sites SR9 and DS01 were similar in terms of the presence of Microveliinae (Hempitera – true bugs), while the others sites did not support this species. This cosmopolitan group is found within the vegetated areas of still waters, such as at Kitty’s Gap, and have been known to inhabit temporary habits such as pools or puddles (Carver *et al.* 1991), as recorded at DS01.

Site DS04 was different from other sites in terms of species composition, and this would have been due to the high number of *Anisops* sp. (Hemiptera: Notonectidae) at this site. The only other sites with this species were DS01 and SR9 which shared similarities with DS04 (**Figure 39**). Similarities between SR5 and DS07 were due to the high number of cyclopoida in the samples – both open water bodies which benefited zooplankton more than shredders and grazers - though they recorded 40%

similarity with the other sites as they recorded common species such as the Chironomidae, Baetidae and Neoplea.

There was a depauperate insect community at Site SR5 (Coppin Gap), with only four taxa. This site did not contain diverse littoral vegetation compared to other sites, and the existing vegetation was sparse due to the morphology of the site (a gap in the Talga range), and lithic (rock) base. The insect taxa at this site were mostly higher order consumers – carnivores such as the copepods or sucking insects such as the Prostigmata. Charophyte beds provide a habitat for mayfly nymphs, by supplying enough detritus and diatoms for their consumption, as was observed in the samples from DS06, DS07 and SR11. The Insecta are a very important order in aquatic systems particularly in running waters. They play an important role as shredders, detritivores, recycling nutrients within the system. In order to support a diverse insect community, emergent littoral vegetation is necessary, particularly in an ephemeral aquatic environment such as the Pilbara that has sporadic and fast surface flow during the wet season. Emergent vegetation provides shelter not only in the dry but also during the high wet season as fast flowing systems can be unstable habitats.

In summary, the 2005 and 2006 surveys of Coppin Creek and environs showed a difference in the abundance of certain taxa rather than a change in species composition. The dominant aquatic invertebrate groups were the Chironomids, Baetidae (Insecta) and Cyclopoid copepods (Crustacea). There was no apparent difference between the open water and emergent vegetation habitats of the same sites, though sites that recorded a higher percentage of emergent vegetation appeared to have a more diverse insect population. The taxa recorded were either cosmopolitan groups or showed national endemism. No localised endemism was observed, and no rare or endangered taxa were recorded. All were freshwater groups.

Table 29 Aquatic invertebrate taxa recorded from the Spinifex Ridge Creek (DS01 – DS07, SR5) and regional sites (SR9, SR11) (June, 2006)

					Sites					
Taxa	**DSO1**	**DS02**	**DS03**	**DS04**	**DS05**	**DS06**	**DS07**	**SR5**	**SR9**	**SR11**
ARTHROPODA										
Insecta										
Diptera										
Ceratopogonidae		67				1				4
Chironomidae		47	8		23	23	5	45	26	27
Culicidae										
Culex sp.	4								1	
Psychodidae										
Psychodidae larvae	3								1	2
Stratiomyidae										
Stratiomyidae larvae	3									
Coleoptera										
Dytiscidae										
Cybister sp.									2	
Eretes sp.			1	1						
Laccophilus sp.				1					14	
Gyrinidae										
Macrogyrus sp.									3	
Hydrochidae										
Hydrochus sp.	2									
Hydrophilidae										
Hydrophilidae larvae	2	3								
Helochares sp.		1			1					
Paracymus sp.	1								1	
Ephemeroptera										
Baetidae										
Cloeon sp.	18	53	16	9	61	44	12	237	60	9
Caenidae										
Tasmanocoenis sp.						4	5	3	3	
Anisoptera										
Libellulidae										
Diplacodes sp.	1									
Zygoptera										
Coenagrionidae										
Ischnura aurora						1				
Hemiptera										
Corixidae										
Corixidae (juvenile)		1	2		4		3	1		
Micronecta sp.	1									
Gerridae	9			2					4	
Mesoveliidae										
Mesovelia sp.									1	
Naucoridae										
Naucoris sp.									1	
Nepidae										
Laccotrephes sp.									1	
Ranatra diminuta				1						
Notonectidae										
Anisops sp.	16		2	84					60	
Pleidae										
Neoplea sp.		3	7	1	4	12				
Veliidae										
Microveliinae	10	1					1		17	
Trichoptera										
Ecnomidae						3				
Arachnida										
Acari										
Prostigmata			3		9		21	37	5	1
Araneae				1						
Crustacea										
Ostracoda			14		3					
Rotifera										7
Copepoda										
Copepoda nauplii								4	38	
Cyclopoida		20	15		25	6	136	104	7	11
MOLLUSCA										
Gastropoda										
Lymnaeidae								2		
Planorbidae										
Gyraulus sp.		3								
Abundance	**70**	**199**	**68**	**100**	**130**	**94**	**183**	**433**	**245**	**61**
Diversity	**12**	**10**	**9**	**8**	**8**	**8**	**7**	**8**	**18**	**7**

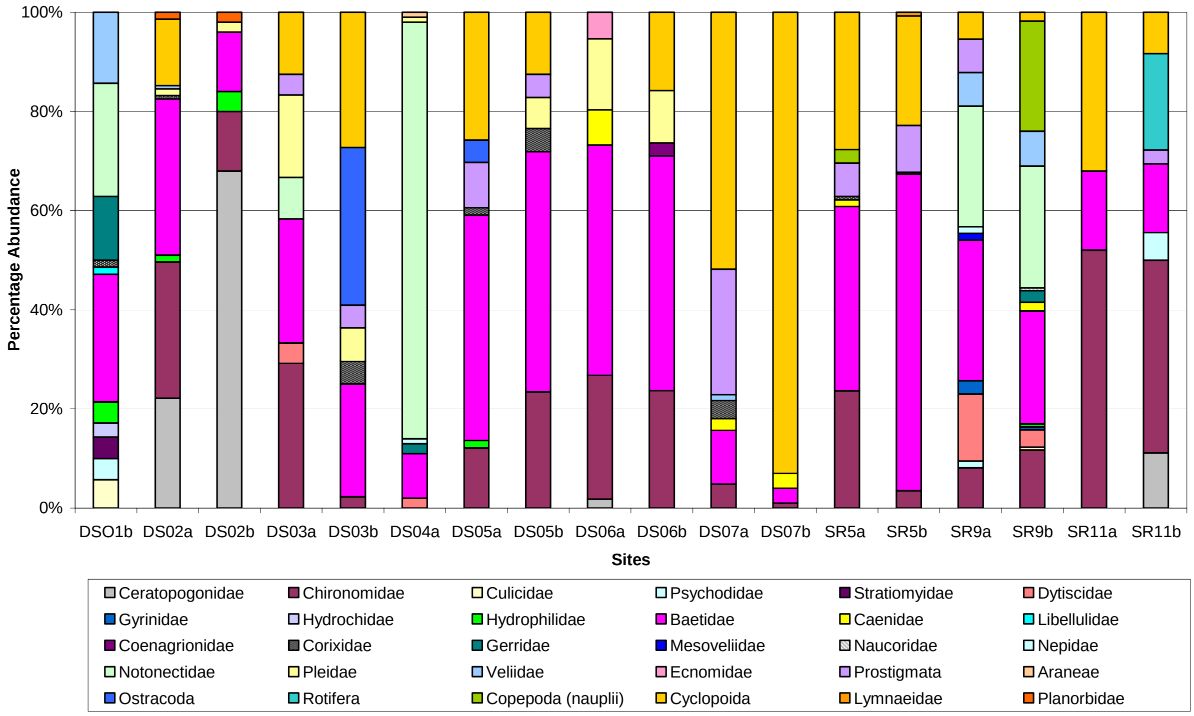

Figure 38 Percentage abundance of aquatic invertebrate families recorded from the littoral zone (amongst emergent vegetation – habit = a) and the transect sweep (transect = b) from Coppin Creek and regional sites (June, 2006)

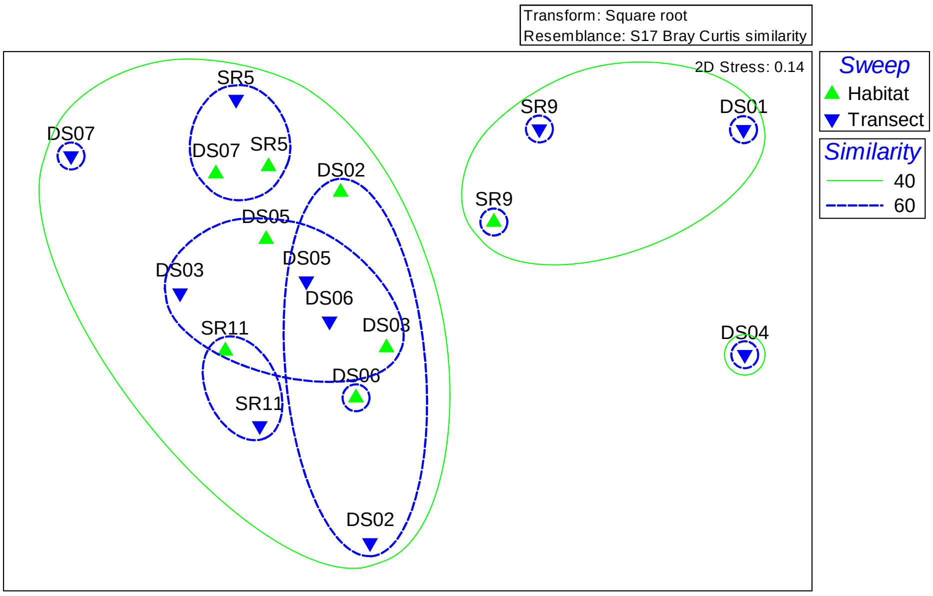

Figure 39 MDS plot of aquatic invertebrates at Coppin Creek and regional sites. Different collection zones indicated (sweep net of habitat and transect), groupings indicate 40% and 60% similarities of species composition (June, 2006)

5.6 Habitats within the aquatic environment

Three habitat types were identified within the aquatic environment of the Project Area (**Table 30**);

1. Semi-permanent water bodies with minimal emergent vegetation and littoral zone, and a mostly-rocky base (Coppin Gap and Kitty's Gap),
2. Temporary creekline habitats with emergent vegetation, slightly sloping banks, sandy base, connected during high flow events, and
3. Temporary creekline comprised of isolated pools, little to no emergent vegetation or submerged macrophytes, minimal retention of surface water.

Within the three broad habitat types identified a variety of finer-scaled habitat units exist within the littoral zone. Macrophytes, in particular, with many different architectural structures (both submerged and emergent) provide diverse habitats for invertebrates at the edges of streams (Boulton and Brock 1999). Recent research has found that the physical environment of rivers are the primary determinant of the macrophyte community (Daniel *et al.* 2006).

The riparian zone along the periphery of water bodies are important zones both for aquatic and terrestrial fauna in the transfer of allochthonous material in and out of the system. It is considered a critical transition zone between catchment and channel, with riparian zones having their own distinct vegetation type which may define the extent of the area (Lake 2005).

The substrate, particularly the presence of sand, appears to be a determining factor in the presence of charophyte communities and emergent vegetation at Coppin Creek. These habitat types and features form reasonable rehabilitation targets, for the new section of the creekline that will be created.

Table 30 Summary of habitat features in Spinifex Ridge Creek and regional sites (June, 2006). Yellow highlighted sites were dry during the survey. Embeddedness = % of cobble, gravel & boulders

Site	Habitat Type	Sediment Type	Emergents	Charophytes	BMC
DS01	TC Wet	Coarse Sand	present	none	present
DS02	TC Wet	Sandy Clay - 50-75% Embeddedness	present	none	present
DS03	TC Wet	Sandy Clay - 25-50% Embeddedness	present	present	present
DS04	TC Wet	Sandy - 0-25% Embeddedness	present	present	present
DS05	TC Wet	Sandy - 0-25% Embeddedness	present	present	present
DS06	TC Wet	Sandy - >80% Embeddedness	present (sparse)	present	present
DS07	TC Wet	Sandy - >80% Embeddedness	present but fully exposed	none	present
DS08	TC Dry	Sandy - 50-75% Embeddedness	none	none	none
SR5	SPW	Rock	present (sparse)	present	none
SR6	TC Dry	Sandy - >80% Embeddedness	none	none	present
SR9	SPW	Rock	present	none	present
SR11	TC Wet	Sand - 50 - 75% Embeddedness	present but fully exposed	none	present

* Emergents = emergent vegetation, BMC = benthic microbial communities.

* SPW = Semi-permanent water body; TC Wet = Temporary creek, connected; TC Dry = Temporary creek, dry, isolated pools

6.0 CONCLUSION

This report has quantified properties of soils, vegetation, landscape function, and aquatic biology and chemistry, for the Coppin Creek ecosystem and associated tributaries. Data from other catchments was used to provide comparisons where appropriate. Given the breadth of the report, a substantial amount of data was collected and presented. To assist in comparing data for different locations the key data for each aspect measured, within the key landscape zones, has been summarised in **Table 31**. These landscape zones essentially represent a transition from the run-off areas of the vegetated creek banks, to the run-on zones of the minor and major drainage lines within the Creek itself.

6.1 Soils

The soil profiles of the creek bank and creek bed within the Coppin Creek survey transects have a wide range of morphological features, variations in soil structure and soil textures, reflecting the dynamic creek system subject to cycles of deposition and erosion. The soil surface characteristics within the creek bed vary according to position within the major drainage line and sub-channels, with the structure and texture of the surface soils ranging from single grained alluvial sands to sandy clay loams forming a distinct crust at the surface. The abundance of coarse fragments at the creek bed surface ranged from very few (<2%) in depositional areas, to abundant (50-90%) and very abundant (>90%), in major channel areas.

Soil textures within the creek bank profiles ranged from clayey sands (approximately 5-10% clay) to sandy clay loams (20-30% clay), with sandy loams (5% clay) to light clays (35-40% clay) present within the creek bed profiles.

The majority of soil materials from within the creek bed and creek banks were not dispersive, and exhibited low soil strengths upon drying. Soil pH values were classed as moderately to highly alkaline, with the surface soils of the creek bed being slightly more alkaline that the surface soils of the adjacent creek banks. Most soils collected were classed as non-saline.

The amount of plant available nutrients held within the soils sampled was generally low, being typical of such native soils. The majority of sites indicated little consistent trend in nutrient level (plant available N, P, K and S) or levels of organic carbon corresponding to position within the creek profile.

Very low concentrations of water soluble Al, As, Cd, Cu, Pb, Mn, Mo and Zn were present in the soil samples collected. Most materials sampled were below the detectable limit for the bulk of the elements measured, with only Al regularly identified at a detectible level. Trace amounts of As, Cu and Mn were also detected in a small number of samples. For the metals detected, there was no apparent correlation with sample depth or position within the creek profile.

6.2 LFA and Vegetation

Landscape function and vegetation parameters differed between the five habitat zones identified within the eight transects in Coppin Creek. In particular, the creek beds showed clear differences from the other four zones, being characterised by a lower stability index, higher infiltration index, longer zone length and higher species richness. The parameters that were most useful for characterising the main habitat zones were the infiltration index, the nutrient cycling index and species richness.

Of all variables tested, plant cover recorded the greatest data ranges (variability) within zones, therefore was not considered useful for distinguishing the different zones. The parameters that were most different between zones were the infiltration index, the nutrient cycling index and species richness.

The steep banks generally recorded relatively high values for stability, but low values for the infiltration and nutrient cycling indices, compared to other zones. The steep banks also recorded the second lowest plant density and species richness of all zones.

The medium banks recorded the second lowest infiltration and nutrient cycling indices. The flat steep and flat wide banks were generally similar to each other in terms of LFA indices and recorded relatively high values compared to the steep and medium banks. The vegetation indices were generally higher in the flat wide banks than the flat steep banks.

A total of 102 plant taxa from 34 families and 71 genera have been identified within Coppin Creek. Of these taxa, approximately 37% were annual species, the most dominant of which was *Sesbania cannabina (*Sesbania Pea). This spindly annual herb or shrub grows to 3m in height and favours areas subjected to seasonal water-logging (FloraBase, 2006). This species was common across areas of Coppin Creek that had been burnt in February 2005. No Rare or Priority Flora species were identified within the areas surveyed of Coppin Creek.

Species richness of the creekline vegetation was higher downstream of Coppin Gap, where the creek was over 100m in width in a floodplain structure. Upstream of Coppin Gap, the creekline is narrower but deeper with vegetation dominated by *Eucalyptus camaldulensis* var. *obtusa, Acacia s*pecies, **Cenchrus ciliaris* and *Triodia longiceps*.

A total of seven weed species were located within the surveyed project area of Coppin Creek, one of which is a Declared Plant species (as listed by the Department of Agriculture and Food, WA). Species included **Datura leichhardtii* (Native Thornapple, classified as either Priority 1, 3 or 4 across much of the state, the exception being the Pilbara region where it appears relatively widespread), **Cenchrus ciliarus* (Buffel grass), **Aerva javanica* (Kapok bush), **Citrullus colyocynthis* (a melon weed), **Passiflora foetida* (Stinking Passion Flower), **Malvastrum americanum* (Spiked Malvastrum) and **Echinochloa colona* (Awnless Barnyard Grass) and **Choris virgata* (Feathertop Rhodes Grass), identified within a tributary of Coppin Creek during the baseline survey.

Much of Coppin Creek south of Coppin Gap was burnt during a wildfire in February 2005. At the time of survey in April 2006, the vegetation appeared to be recovering with the majority of *Eucalyptus* and *Melaleuca* species re-sprouting. However, short term changes in botanical composition are likely to have occurred. Grazing of vegetation by cattle was evident and **Cenchrus ciliaris* (Buffel grass) is present along the length of the creekline.

6.3 Aquatic Ecology

Coppin Creek is a temporary inland dryland river that is dry outside of seasonal rainfall events, when the creek flows and then forms isolated pools during the drying phase. Water is typically fresh and reports an alkaline pH. Some dissolved metals concentrations were above-detection limits in surface water; As, Ba, Cu, Mn, Mo, Ni, Zn, and some total metals concentrations were above-detection limits in sediments; As, Ba, Cr, Co, Cu, Fe, Pb, Mn, Mo, Ni, Va, Zn, in 2006

The flow events support a transient aquatic community that is composed of cosmopolitan species that are opportunistic pioneers. During high flow (or ‘boom’ periods) it can support a diverse ecosystem consisting of insects and crustaceans, charophytes, filamentous algae and nitrogen fixing cyanobacteria and a highly diverse periphytic diatoms community (indicating a productive ecosystem). Many of these groups are highly adapted to ephemeral systems and the diversity in the temporary water bodies of Coppin Creek exceeds that of the semi-permanent Coppin Gap.

The algal community is dynamic, and therefore useful as an indicator of changing conditions. The algal communities recorded in 2005 and 2006 have varied, probably in response to fire, temporary nutrient enrichment, and lotic conditions that are susceptible to erosive forces, pH and salinity.

All the invertebrate taxa identified are typical of northern inland freshwaters of Western Australia, with no new or rare species recorded. Results show that sites are inhabited by cosmopolitan species that respond to, or are strongly correlated with, changes in water level, salinity, nutrient concentrations and riparian vegetation, and may also be useful indicators of changing conditions.

The importance of the riparian zone which extends into to the littoral zone of the creek is crucial to the success of the creek diversion. Many of the taxa identified from all the divisions; invertebrates to diatoms, preferred and therefore flourished in the sheltered littoral zone amongst the vegetation. Not only does the riparian vegetation provide an increase in oxygen levels, refuge and nutrients, it minimises extremes of desiccation that are common in the Pilbara. The vegetation and the BMCs provided a substrate for many of the diatoms to establish themselves and therefore a food source for many of the grazing invertebrates. All the aquatic taxa recorded form the creek were typical lotic groups that establish themselves on a substrate.

The establishment of the emergent vegetation in the diverted creek is vital for the re-establishment of a healthy riverine community. Many have resting stages that can easily be transplanted, such as the charophytes which are able to reduce turbidity and readily establish on muddy sediment.

In light of the variation in local and regional water quality (particularly those due to local geological influences), and the paucity of guidelines, if there is any future requirement for setting water quality targets they should be based on water quality values from monitored control sites in the local creek system. According to ANZECC (2000), derivation of site-specific guidelines is an acceptable and justified practise in these situations, and ongoing monitoring of control sites on a regular basis (at least annually) is therefore recommended.

The development of a site-specific water and sediment quality database at control sites will allow appropriate comparison with future water and sediment quality data, particularly if impact assessment is required. Data collected during the 2005 and 2006 assessments can form basis of such a database, but additional data collation is required to improve the robustness of the data set.

Table 31 Summary of key attributes of Coppin Creek

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5.0 GLOSSARY

Aggregate (or ped)

A cluster of primary particles separated from adjoining peds by natural planes of weakness, voids (cracks) or cutans.

Anthropogenic

Produced by humans.

Biota

The plant and animal life of a particular site, area or period.

Bulk density

Mass per unit volume of undisturbed soil, dried to a constant weight at 105°C.

Calcrete

Soil cemented by calcium carbonate

Cation exchange capacity (CEC)

The total potential of soils for adsorbing cations, expressed in millimoles of charge per kg (mmolc/kg) of soil.

Clay

The fraction of mineral soil finer than 0.002mm (2µm).

Coarse fragments

Particles greater than 2mm in size.

Consistence

The strength of cohesion and adhesion in soil.

Cosmopolitan

Of worldwide distribution.

Cutan

Coatings or deposits of clay material on the surface of peds, stones, etc.

Diatoms

Member of the algal division Bacillariophyta, characterised by a cell wall of two siliceous valves.

Dispersion

The process whereby the structure or aggregation of the soil is destroyed, breaking down into primary particles.

Drainage diversion

Region of major river catchments.

Electrical conductivity

How well a soil conducts an electrical charge, related closely to the salinity of a soil. In water, it is a measure of salinity, and refers to the total concentration of ions in the water and how well they conduct an electrical charge.

Emergent

General term for a plant growing or protruding above the surface of a water body.

Endemic

Organisms that are confined to a particular area or geographical location, restricted in distribution to one region.

Exchangeable Sodium Percentage (ESP)

Is calculated as the proportion of the cation exchange capacity occupied by the sodium ions and is expressed as a percentage. Sodic soils are categorised as soils with an ESP of 6-14%, and strongly sodic soils have an ESP of greater than 15%.

Habitat

The place where a plant or animal lives.

Humic

Material obtained from organic matter of soils, produced by decomposition of plant or animal matter.

Lentic

Aquatic environments with standing water.

Littoral Zone

Edge or shore region where the water is shallow enough for continuous mixing.

Lotic

Aquatic environments with running or flowing surface water.

Macroinvertebrate, Invertebrate

Larger invertebrates, defined as those >500 µm. Body length usually exceeds 1mm.

Macrophytes

Large aquatic plants, comprising submerged, floating and emergent types.

Modulus of Rupture (MOR)

This test is a measure of soil strength and identifies the tendency of a soil to hardset as a direct result of soil slaking and dispersion.

Organic Carbon

Carbon residue retained by the soil in humus form. Can influence many physical, chemical and biological soil properties.

Periphyton

The biota attached to submerged surfaces.

pH

The negative logarithm of the hydrogen ion concentration of a soil solution or surface water. The degree of acidity or alkalinity of a soil expressed in terms of the pH scale, from 2 to 10.

Plankton

Community of microscopic organisms freely moving in the open water.

Plant available water

The ability of a soil to hold that part of the water that can be absorbed by plant roots. Available water is the difference between field capacity and permanent wilting point.

Riparian zone

Any land which adjoins, directly influences, or is influenced by, by a body of water.

Slaking

The partial breakdown of soil aggregates in water due to the swelling of clay and the expulsion of air from pore spaces.

Soil horizon

Relatively uniform materials that extend laterally, continuously or discontinuously throughout the profile, running approximately parallel to the surface of the ground and differs from the related horizons in chemical, physical or biological properties.

Soil structure

The distinctness, size, shape and arrangement of soil aggregates (or peds) and voids within a soil profile. Can be classed as *'apedal'*, having no observable peds, or *'pedal'*, having observable peds.

Soil strength

The resistance of a soil to breaking or deformation. '*Hardsetting'* refers to a high soil strength upon drying.

Soil texture

The size distribution of individual particles of a soil.

Subsoil

The layer of soil below the topsoil or A horizons, often of finer texture (i.e. more clayey), denser and stronger in colour. Generally considered to be the 'B-horizons' above partially weathered or un-weathered material.

Taxon

A taxonomic group of any rank (plural is taxa).

Topsoil

Soil consisting of various mixtures of sand, silt, clay and organic matter; considered to be the nutrient-rich top layer of soil – The 'A-horizons'.