Top End Waterways Project

DALY RIVER CATCHMENT

Part 1
An Assessment of the Physical and Ecological Condition of the Daly River and its Major Tributaries

Technical Report No TR99/10

J.J. Faulks
Department of Lands, Planning and Environment
Katherine, NT

July 1998

Natural Heritage Trust
Helping Communities Helping Australia

LANDS PLANNING ENVIRONMENT
Northern Territory Government

NATIONAL LANDCARE PROGRAM


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by

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The report on the Daly River Catchment consists of two parts:

Part 1 Daly River Catchment – An Assessment of the Physical and Ecological Condition of the Daly River and its Major Tributaries
Part 2 Daly River Catchment – Accompanying Sub-catchment Information

The reports are available from the Parks and Wildlife Commission of the Northern Territory (PWCNT) Library and the National Library, Canberra, through interlibrary loan.

The reports may also be obtained from the Katherine Regional Office of the Department of Lands, Planning and Environment (DLP&E). Inquiries should be addressed to:

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Photograph front cover: Flora River, a major tributary of the Daly River (taken by Judy Faulks)

Acknowledgements

The project commenced in February 1995 and has been partly funded by the National Landcare Program (now known as the Natural Heritage Trust). I was employed to undertake the field assessment of the Daly River and major tributaries; produce a database to store the information collected and assist with data analysis; and to produce a report and associated maps on the outcomes.

The majority of the field surveys were conducted between June and November 1995; with the remaining surveys carried out April to May 1996, August 1996, October to November 1996 and August 1997. The following people assisted me with my field survey work:

Angus Cameron (volunteer)
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Robert Hodges (Department of Lands Planning and Environment - DLP&E)
Tundra Morscheck
Miriam Lang (DLP&E)
Debbie Telfer (DLP&E)

At times the survey work was 'challenging', with not only crocodiles to contend with, but mudflats, tidal bores, rapids, fires and hot November weather. The helpfulness of everyone throughout the field surveys was extremely appreciated. The great sites and experiences will never be forgotten.

During 1996 field surveys were also completed for the Victoria River and major tributaries and will form the basis of another report.

The contribution made by the following people was very much appreciated:

I am extremely grateful to Redgum Technology for the tireless effort made in designing and implementing the database and associated queries to my satisfaction. The GIS support and mapping were provided by Caroline Green and Renee McPhee, DLP&E (Katherine), whose attention to detail and expertise were extremely appreciated. Flow and water quality data was supplied by Doug Kinter and Bob Masters, DLP&E (Darwin). Support, information and water quality data, collected as part of the 'Ausrivas Project', was supplied by Jane Suggit, DLP&E (Darwin). Background information on water resources was supplied by various people within DLP&E (Darwin). Stream ordering was undertaken by Dave Williams, DLP&E (Darwin). Regrouping of landform information was undertaken by Miriam Lang, DLP&E (Katherine). Identification of the large quantity of vegetation samples was carried out by Diane Napier and the NT Herbarium (PWCNT). Presentation of the vegetation profiles was carried out by Debbie Telfer, DLP&E, based on vegetation sketches done by Caroline Green, DLP&E (Katherine). Support, information and comments were also supplied by a number of other DLP&E staff members within the Katherine and Darwin offices as well as PWCNT, DPI&F, Northern Territory University and Queensland DPI. I am very appreciative of the efforts made by the technical working group that was set up to review the stability and condition ratings used, so that they would reflect Northern Territory conditions more closely.

I am grateful to the property owners/managers who allowed access to the survey sites located on their properties and provided background information on the rivers and creeks.

Thanks also to Wolf Sievers (former Regional Director, DLP&E, Katherine) for recognising the need for such a project, for seeking initial funding and for providing continued support while in Katherine.

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EXECUTIVE SUMMARY

Overview

The 'Top End Waterways Project' commenced in 1995 and has been partly funded by the National Landcare Program (now known as the Natural Heritage Trust). The Department of Lands, Planning and Environment has overseen the project.

The overall aim of the project was to assess, describe and report on the land and water resources of the major waterways in the Katherine Region of the Northern Territory and to prepare for publication a comprehensive report on each of those waterways. Throughout 1995-1997 the major tributaries within the Daly River and Victoria River catchments were assessed. This report provides an assessment of the Daly River catchment and major tributaries, in terms of the physical and environmental condition of these streams at the time of survey. The use and management of the waterways within the Daly River catchment have been identified, major river management issues have been highlighted and broad river management recommendations have been proposed. The results for the Victoria River catchment will form the basis of another report.

The general methodology framework that has been adapted for this project was developed by J.R. Anderson for the Queensland Department of Primary Industries, where it is currently being used to assess river condition and stability on a catchment by catchment basis. From the Qld 'State of the Rivers' methodology, the 'Top End Waterways Project' adapted the sampling strategy, survey methods and data collection sheets. The condition and stability ratings developed by J.R. Anderson were modified or completely altered by a NT Technical Working Group so that the results would reflect Northern Territory conditions more closely. Section 3 discusses in more detail the methods used including the sampling strategy, survey components and the condition and stability ratings.

It is expected that the main users of the information provided by this project will be the Northern Territory government and other groups interested in waterway management, including landcare and community groups, best practice groups and property owners or managers.

The information provided by this project is intended to assist in developing regional and catchment management strategies. In particular the results will contribute to the Katherine-Daly Natural Resources Management Strategy and the Environmental Flows Initiative program. The results can also generally contribute to the NT Weeds Management Strategy, vegetation clearing guidelines, buffer width recommendations and track and river crossing construction guidelines.

Linkages to other projects and initiatives that address other issues relating to rivers is important to aid overall river management decision-making processes. The 'Top End Waterways Project' has established links with, for example, the Ausrivas project and riparian vegetation assessments by overlapping survey sites with those projects in order to allow possible correlations to be drawn between these studies. Linkages to long term water flow and quality databases (eg Hydsys), development of environmental flows guidelines, vegetation databases, Wild Rivers assessments would also prove useful.

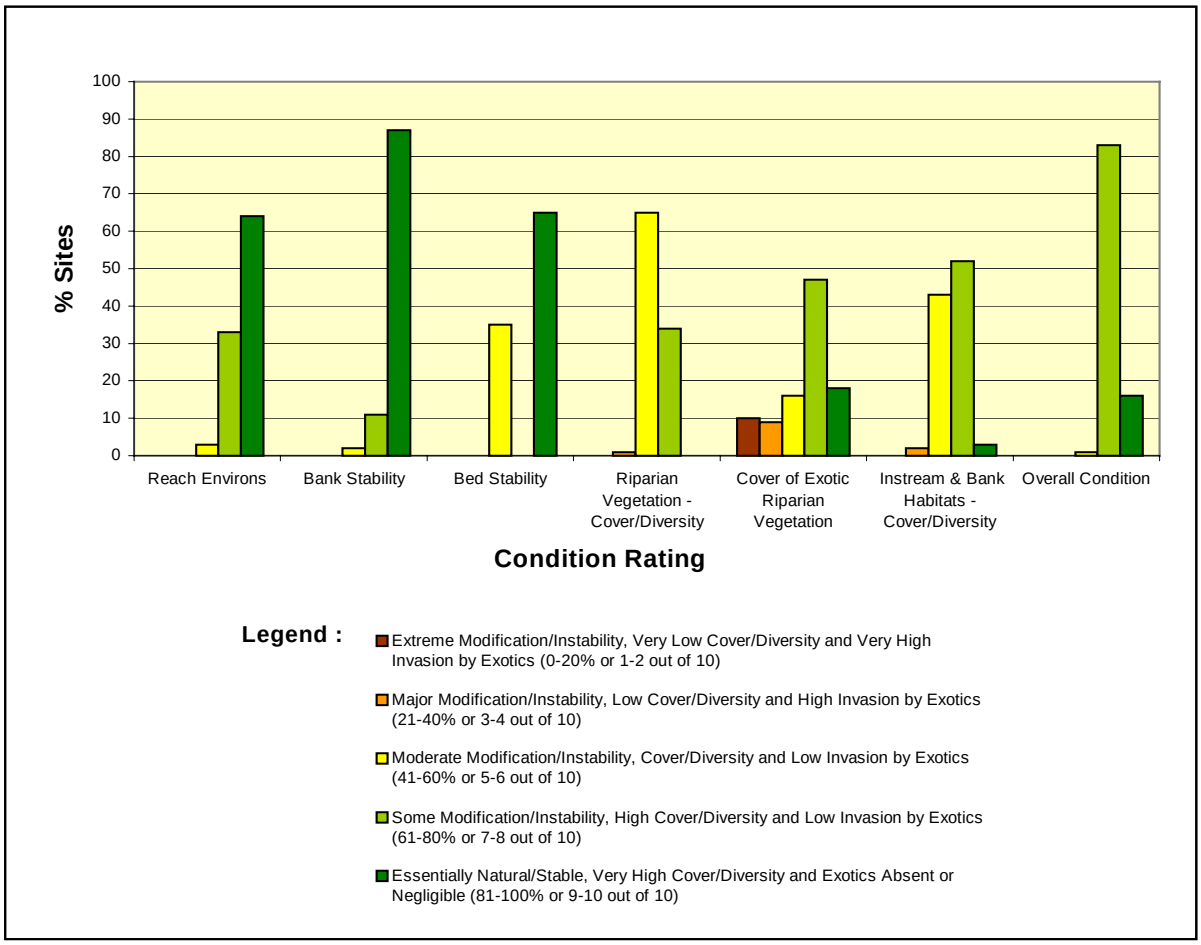
The project will help to identify key issues, problems and priorities with the rivers. It will also help to recognise the extent, processes and causes of river degradation and thereby pinpoint actions that would have to be taken in order to reverse any deterioration. Rivers and creeks that are showing signs of degradation (eg weed infestation, accelerated erosion, concentrated use, *etc*) will be highlighted as requiring more specific river management guidelines or plans.

The project, through the collection of baseline data, provides a reference point or "snap-shot" of what the rivers and creeks are like now. Follow-up surveys of rivers in priority areas would need to be carried out over time in order to look at the rate of change in condition and stability. The project therefore can be used as a monitoring tool.

Summary of Daly River Catchment Condition

Maps 10-26 show the results for the condition and stability ratings and other attributes examined.

A summary of the condition and stability ratings results recorded for the Daly River Catchment are shown below:



♦ *Reach Environs and Site Features*

Nearly two-thirds of the reach environs assessed were rated as being essentially natural, while one-third had some modification (refer Map 11). Generally, these sites had relatively lower impact land uses that had not greatly modified the reach environs (eg grazing on native or thinned pastures), undisturbed vegetation and few local disturbances. The few sites that recorded moderate modification to the reach environs were predominantly associated with the population centre of Katherine where land uses and disturbances to the reach environs were more intensive and varied ranging from rural or urban residential to tree cropping. Subjective reach environs disturbance ratings indicated that nearly half the sites recorded either a low level of disturbance or were low to moderately disturbed.

Land tenure along the reaches studied was predominantly freehold or leasehold (refer Map 10). Grazing was the major land use adjacent to streams in the catchment. The major disturbances to stream reaches were grazing activity and, to a lesser extent, roads/tracks or causeways/river crossings. Only 3% of sites throughout the catchment recorded no local disturbance to the reach environs.

♦ *Channel Habitat Types, Diversity and Dimensions*

Reaches studied averaged 824m in length. Pools were the dominant habitat type located throughout the catchment. Pools also dominated the reach lengths averaging 74%. Riffles were also quite prevalent and occurred at over half the sites. Cascades and waterfalls were associated with areas of steeper topography (eg gorge systems, tufa formations). Rapids were predominantly located along mid to upper sections of Daly River and along Katherine River where river gradients were steeper. Runs were mostly located along Daly, Katherine and Douglas Rivers.

When the sites were assessed for their variability or diversity of channel habitat types, nearly three-quarters of the sites recorded a high diversity (refer Map 12). The majority of reaches were comprised of only 2 habitat types. Few sites (13%) recorded more than 2 habitat types present. 77% of sites recorded either 10-30% or >30% of the reach being occupied by habitat types other than pools. One to two sections of Douglas River, Daly River, Flora River, Fergusson River and Hayes Creek recorded a very high diversity of channel types. Low channel type diversity was recorded for: a section of the Daly River estuary where pool habitats were very uniform; along one other Daly River section where very long pools dominated the reach extensively; or where only one habitat type was recorded along the reach (i.e. a section of Katherine and Edith Rivers). Reaches with very low diversity ratings were located on Birdie Creek and a tributary of Stray Creek where only one habitat type was noted and there was little or no variation in depths.

The dimensions for most habitat types varied considerably throughout the catchment. Pools located along the tidal section of Daly River were the deepest and longest in the catchment, except for those assessed in Katherine Gorge, which were somewhat deeper (i.e. ranging up to 10.2m in depth).

♦ *Bank Condition and Stability*

The majority of river banks throughout the catchment were stable and, to a much lesser extent, had limited instability (refer Map 13). No river banks were suffering from extensive or extreme instability. Those very few reaches with moderate bank instability (ie Depot and Aroona Creeks) were suffering from localised erosion problems. A subjective assessment of the stability of the banks indicated that most sites recorded low overall bank instability. The high level of bank stability recorded throughout the catchment is reflected in the fact that the riparian vegetation is relatively in tact and has not been impacted on by extensive clearing or development.

Bank erosion, even though minor in places, was the dominant process recorded throughout the catchment, with some aggradation also being noted. Lower banks were more stable than upper banks with an average of 91% and 87% of the bank length respectively being recorded as stable. The erosion was occurring mostly at obstacles, like tree roots, and outside bends. Aggradation occurred mostly along inside bends and at obstacles.

The major factors affecting bank stability were high flow and stock, although infrastructure (ie roads, tracks, river crossings, *etc*) and floodplain scours or breakout points along the river were also prevalent at over one-third of the sites. Bank protection measures, including fencing, were rarely observed.

♦ *Bed and Bar Condition and Stability*

An assessment of the stream bed stability indicated that two-thirds of sites had stable beds, while nearly one-third of sites were assessed as moderately aggrading (refer Map 14). Few sites recorded moderate bed erosion and no sites had beds that were severely eroding or aggrading.

Moderate bed aggradation was generally confined to: a section of the Daly River between Oolloo Crossing and Fergusson River junction; lower Daly River estuary; Stray Creek; Upper Chilling and Muldiva Creeks; upper Katherine River (downstream of Centipede Dreaming Gorge); lower Birdie Creek; sections of Fergusson, Edith and Cullen Rivers; sections of Eight Mile and Copperfield Creeks. In many cases, these channels were described as being shallow, uniform in cross-sectional shape and carrying a large amount of sediment. Large instream bars and high flow deposits were often very common along these reaches which may indicate increased sediment supply to these stream systems.

Moderate bed erosion was infrequent and generally was linked to local disturbances caused by river crossings (eg upper Hayward, Depot and Bamboo Creeks), stock activity (eg Bamboo Creek) or recent high flow events (eg a section of Edith River).

The major factor that was considered to affect bed stability throughout the catchment was agriculture/grazing activities, which was occurring at less than half the sites, while instream siltation was affecting one-fifth of the sites. At one-third of the sites, no factors were affecting bed stability.

Bars were recorded along the majority of reaches, averaging 16% of the bed and ranging to as high as 70%. Point bars were the most prevalent type of bar and were present at over one-third of sites. Rock outcrops, which provide a degree of bed stabilising influence, were quite prevalent throughout the catchment, being present at over half the sites.

- *Bed and Bank Sediments*

A range of size classes, from clays to boulders, was recorded for river beds. Pool, run and glide habitats had a higher proportion of smaller bed sediments; riffles had a range of bed sediments sizes; rapids had a higher proportion of larger bed sediments; and cascades and waterfalls had boulder beds. Lower and upper banks consisted mainly of clays and small sand. Organic material was present in both bed and bank material.

- *Riparian Vegetation*

Nearly two-thirds of the riparian vegetation along the reaches assessed had moderate cover and structural diversity, with a further one-third having high cover and diversity (refer Map 15). A mangrove-dominated community on the lower part of the estuary rated poorly due to a lack of structural diversity. The majority of sites along the Daly River upstream of the estuary (mid section) to Fergusson River junction were assessed as having a high cover and structural diversity. Other sections that rated highly include Douglas River (lower and mid), Flora River (lower and upper), upper Katherine River, mid Edith River as well as sections along other smaller creeks.

The results provide an indication of how structurally diverse and dense the riparian vegetation is throughout the catchment. Generally the riparian vegetation is relatively in tact and has not been impacted on by extensive clearing or development, although stock activity was recorded as a factor affecting river banks to varying degrees at over two-thirds of sites.

The average width of the riparian zone was 22m (refer Map 16), which can be considered to be the natural width because little clearing of the riparian vegetation has occurred. This width is similar to the mean width of the upper bank (ie 18m) and emphasises the importance of the upper bank as a 'refuge area' for riparian vegetation. Most sub-catchments recorded a site (or sites) with a riparian zone width of <10m. Those sites that recorded a riparian zone width of >31m were mostly located on the Daly River and, to a lesser extent, the Katherine and lower sections of the Douglas, Flora and Fergusson Rivers.

Throughout the catchment, grasses were present at all sites. Forbs, woody shrubs, regenerating trees, trees (2-30m) and vines were also very prevalent. Rushes and sedges, phragmites and ferns were not as prevalent. Trees (taller than 30m), mangroves and palms recorded a more scattered distribution. Trees (2-30m tall) and grasses dominated the riparian vegetation providing the highest covers. The other structural categories each averaged <10% cover. At the majority of sites, overstorey vegetation provided a greater cover than understorey vegetation.

Exotic vegetation was widely distributed with over three-quarters of sites recording the presence of exotic species (refer Map 17). Vegetation species that are declared noxious within the Northern Territory were located at over half the sites. Nearly half the sites recorded a low level of invasion by exotic species (1-5% cover), whereas over one-third of the sites recorded a greater level of invasion (>5% cover and up to 32%). Overall, exotic species within the riparian zone averaged 6% cover and were predominantly vines and forbs. *Passiflora foetida*, a naturalised vine, was the most prevalent exotic species throughout the catchment being present at over half the sites (refer Map 18). *Hyptis suaveolens* (Hyptis) and *Xanthium occidentale* (Noogoora Burr), noxious weeds, were also quite prevalent being present at 37% and 23% of sites, respectively (refer Maps 19 and 20).

Passiflora foetida was widely distributed throughout the catchment and covers between 1-20% were recorded. *Hyptis suaveolens* also had a wide distribution and was recorded throughout the majority of sub-sections, although not at every site (excluding upper Daly and Fergusson Rivers, Chilling Creek, Dead Horse Creek, King and Dry Rivers and the low/mid sections along Katherine River). Covers for *Hyptis* were generally low (<5%) although a lower Flora River site recorded much higher covers (11-15%). *Xanthium occidentale* was more confined in its distribution and was located at all non-tidal sites along the Daly River and one-third of sites in the tidal area. Other sub-sections where *Xanthium occidentale* was recorded, at one or more sites, included Chilling, Hayward, Limestone and Dead Horse Creeks and lower Fergusson and Katherine Rivers. Where present, the average cover of *Xanthium occidentale* was relatively high, averaging 11%, although along the Daly River covers between 5-28% were recorded.

- *Aquatic Vegetation*

Over half the sites recorded the presence of aquatic vegetation, mostly in the form of emergent vegetation (refer Maps 21 and 22). One-fifth of sites recorded the presence of submerged aquatic vegetation and only one upper catchment reach recorded the presence of floating vegetation. There was no aquatic vegetation species recorded that were exotic. Pandanus, Melaleucas, rushes or sedges and Phragmites dominated the emergent vegetation types. Chara or Nitella and filamentous algae dominated the submerged aquatic vegetation. Covers for all structural types were low with only Melaleucas and Pandanus averaging over 5% cover.

Sites along Daly, Flora, Katherine and Fergusson Rivers, and to a lesser extent the lower Douglas River, recorded the presence of both submerged and emergent aquatic vegetation. Factors influencing the distribution and abundance of aquatic plants throughout the Daly River catchment may include suitability of flow regimes, appropriate water quality and channel form, including the width, depth and sediment composition of the channel.

- *Instream and Bank Habitats*

Just over half the sites were rated as having high cover and diversity of instream and bank habitats, while just under half the sites rated moderately (refer Map 23). Sections on Dead Horse Creek and Limestone Creek rated the worst in the Daly River catchment. The few sites recording very high cover and diversity were located on Flora and Douglas Rivers and Green Ant Creek. Nearly half the sites were subjectively assessed as having a good to very high overall rating for all aquatic life. While another one-fifth of sites had poor aquatic habitat and nearly one-third of sites poor to good.

The most commonly occurring instream habitat types were logs, leaves and twigs, branches, rock faces/boulders, and permanent pool habitats deeper than 1m. Stream bed cover provided from the banks was dominated by vegetation canopy cover, which occurred along an average of 63% of the bank length. Vegetation overhang, which was less than 1m from the water, was also very prevalent although it occurred over only one-fifth of the bank length.

The fact that instream habitat is provided predominantly by vegetative debris, such as logs and leaves, and the bank habitat from canopy cover, which involves the presence of trees and shrubs, emphasises the importance of riparian zones to aquatic organisms.

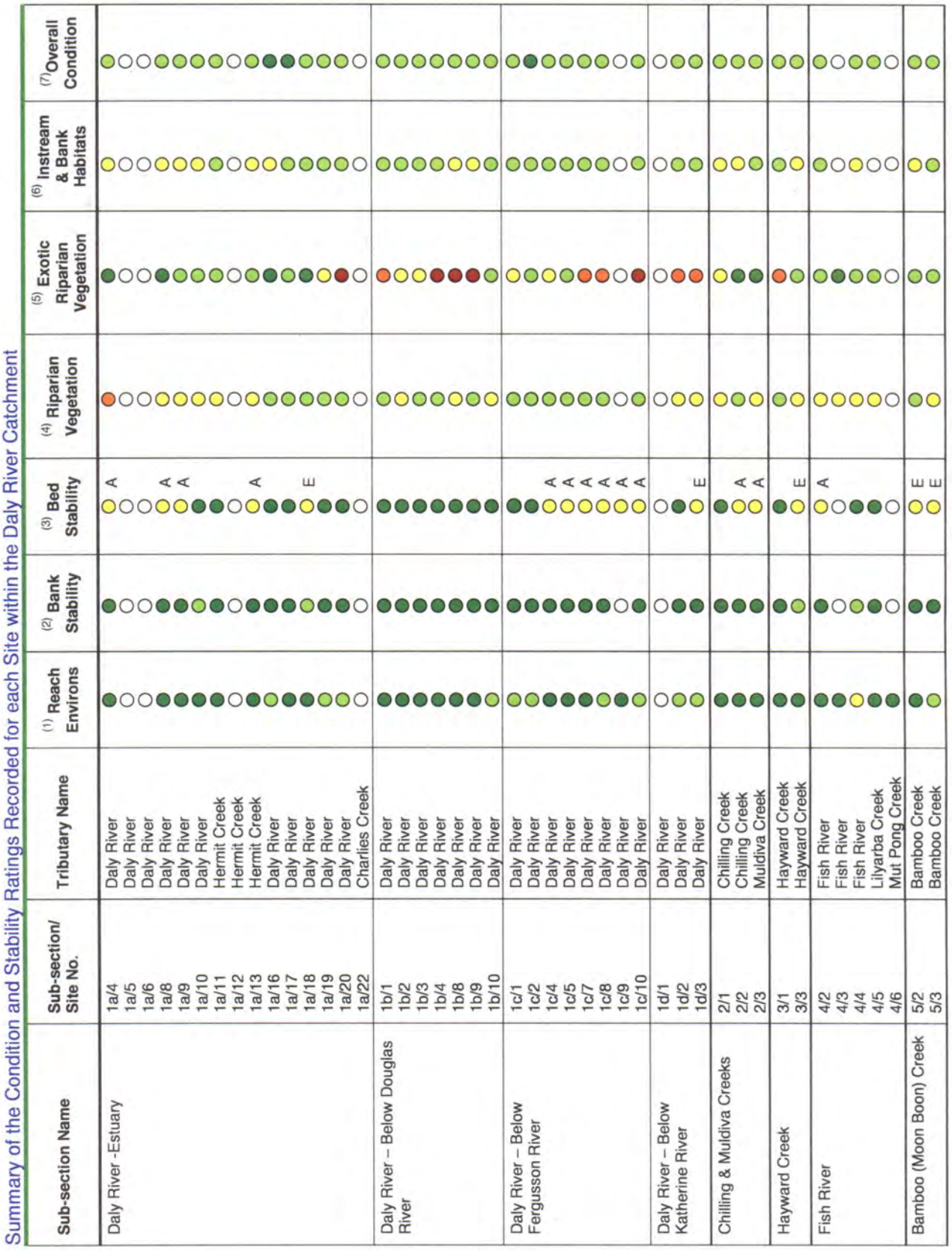
Passage for aquatic organisms at half the sites was generally partly to very restricted at the time of the survey, although one-third of sites had no passage. Assessments of passage at the water mark indicated that some form of restriction remained at 72% of sites.

- *Overall Condition*

The overall condition of the majority of sites (83%) throughout the Daly River catchment was high (refer Map 24). Reaches that rated very highly overall (16%) were located on Douglas River (5 sites), Daly River (3), Green Ant Creek (3), Flora River (2), Katherine River (2), Edith River (1) and Dry River (1). The only site to record a moderate overall condition, the poorest rating in the Daly River catchment, was located on Eight Mile Creek. No sites were rated as being degraded overall.

Summary of Daly River Sub-catchments Condition

A summary of the condition and stability ratings recorded for each site is shown below.



Sub-section Name	Sub-section/ Site No.	Tributary Name	(1) Reach Environs	(2) Bank Stability	(3) Bed Stability	(4) Riparian Vegetation	(5) Exotic Riparian Vegetation	(6) Instream & Bank Habitats	(7) Overall Condition
Green Ant Creek	6/1	Green Ant Creek	dark green	dark green	dark green	yellow	dark green	light green	dark green
	6/2	Green Ant Creek	dark green	dark green	dark green	light green	dark green	dark green	dark green
	6/3	Green Ant Creek	dark green	dark green	dark green	yellow	light green	light green	dark green
	6/4	Green Ant Creek	dark green	light green	dark green	yellow	light green	yellow	light green
	6/5	Station Creek	white	white	white	white	white	white	white
Douglas River	7/1	Douglas River	light green	dark green	dark green	light green	dark green	light green	dark green
	7/2	Douglas River	dark green	dark green	dark green	light green	light green	light green	dark green
	7/4	Douglas River	dark green	dark green	dark green	light green	dark green	dark green	dark green
	7/5	Douglas River	dark green	dark green	dark green	yellow	light green	light green	dark green
	7/6	Douglas River	white	white	white	white	white	white	white
	7/7	Douglas River	dark green	dark green	yellow A	yellow	light green	yellow	light green
	7/8	Depot Creek	light green	yellow	yellow E	yellow	light green	yellow	light green
	7/9	Douglas River	white	white	white	white	white	white	white
	7/10	Douglas River	dark green	dark green	dark green	light green	dark green	light green	dark green
Hayes Creek	8/2	Hayes Creek	dark green	light green	dark green	yellow	light green	light green	light green
	8/4	Hayes Creek	dark green	dark green	dark green	light green	red	light green	light green
Middle Creek	9/1	Middle Creek	dark green	light green	dark green	yellow	light green	light green	light green
	9/2	Middle Creek	light green	dark green	dark green	yellow	light green	yellow	light green
Stray Creek	10/1	Stray Creek	dark green	light green	yellow A	yellow	light green	yellow	light green
	10/3	Stray Creek	dark green	dark green	yellow A	light green	orange	light green	light green
	10/4	Stray Creek (arm)	dark green	dark green	yellow A	yellow	yellow	yellow	light green
Bradshaw Creek	11/2	Bradshaw Creek	light green	dark green	dark green	yellow	light green	yellow	light green
	11/3	Bradshaw Creek	light green	white	white	white	white	white	white
Dead Horse Creek	12/1	Dead Horse Creek	light green	light green	dark green	yellow	orange	yellow	light green
	12/2	Dead Horse Creek	light green	dark green	dark green	yellow	dark green	orange	light green
Fergusson River – Below Edith River	13a/1	Fergusson River	light green	dark green	yellow A	yellow	light green	yellow	light green
	13a/2	Fergusson River	light green	dark green	yellow A	yellow	light green	light green	light green
Fergusson River – Above Edith River	13b/1	Fergusson River	light green	dark green	dark green	yellow	light green	light green	light green
	13b/3	Fergusson River	dark green	dark green	yellow A	yellow	yellow	light green	light green
Edith River	14/2	Edith River	light green	dark green	yellow A	yellow	light green	yellow	light green
	14/3	Edith River	dark green	light green	yellow E	light green	red	light green	light green
	14/4	Edith River	dark green	dark green	dark green	light green	light green	light green	dark green
	14/6	Granite Creek	white	white	white	white	white	white	white
Eight Mile Creek	15/2	Eight Mile Creek	light green	light green	yellow A	light green	red	light green	yellow
Cullen R & Copperfield Creek	16/1	Cullen River	dark green	dark green	yellow A	yellow	yellow	yellow	light green
	16/2	Copperfield Creek	dark green	light green	yellow A	yellow	light green	yellow	light green
	16/5	Copperfield Creek	dark green	dark green	dark green	yellow	yellow	yellow	light green
Flora River & Hayward Creek	17/1	Flora River	dark green	dark green	dark green	light green	red	light green	light green
	17/2	Flora River	dark green	dark green	dark green	yellow	light green	dark green	dark green
	17/5	Flora River	dark green	dark green	yellow A	yellow	dark green	light green	light green
	17/6	Flora River	light green	dark green	dark green	light green	light green	light green	dark green
	17/8	Hayward Creek	light green	dark green	dark green	yellow	light green	yellow	light green
Mathison & Aroona Creeks	18/2	Mathison Creek	light green	dark green	dark green	yellow	red	yellow	light green
	18/3	Mathison Creek	dark green	dark green	dark green	yellow	yellow	yellow	light green
	18/5	Aroona Creek	dark green	yellow	dark green	yellow	red	yellow	light green

Katherine River – Below King River	19a/2	Katherine River							
	19a/3	Katherine River							
Katherine River – Below Seventeen Mile Creek	19b/1	Katherine River							
	19b/2	Katherine River							
	19b/3	Katherine River							
	19b/4	Katherine River							
	19b/5	Katherine River							
	19b/6	Katherine River							
Katherine River – Below Grace and Fanny Creeks	19c/1	Katherine River							
	19c/2	Emu Creek							
	19c/3	Katherine River							
Katherine River – Below Birdie Creek	19d/1	Katherine River							
	19d/3	Katherine River			A				
	19d/4	Ironbark Creek							
	19d/5	Snake Creek							
	19d/6	Grace Creek							
Katherine River - Upper	19e/1	Birdie Creek			A				
	19e/2	Katherine River							
	19e/3	Katherine River			A				
	19e/4	Katherine River			A				
	19e/5	Katherine River			A				
	19e/6	Katherine River							
	19e/7	Unnamed Creek							
	19e/9	Jackys Creek							
	19e/10	Hardys Creek							
Limestone & Scott Creeks	20/1	Limestone Creek							
	20/2	Limestone Creek							
	20/5	Scott Creek							
King River – Below Dry River	21a/1	King River							
	21a/2	King River							
	21a/3	King River							
	21a/7	Collins Creek							
King River – Above Dry River	21b/1	King River			A				
	21b/3	King River							
	21b/4	King River							
Dry River	22/1	Dry River							
	22/2	Dry River							
	22/3	Dry River							
Durrinyan Creek	23/1	Durrinyan Creek							
	23/2	Durrinyan Creek							
Seventeen Mile Creek	24/1	Seventeen Mile Ck			A				

Legend:

- Essentially Natural (1); Stable (2) and (3); Very High Cover/Diversity (4) and (6); 0% Cover for Exotics (5); and Very High Overall Condition (7). ***(Rating 81-100%)***
- Some Modification (1); Limited Instability (2); High Cover/Diversity (4) and (6); 1-5% Cover for Exotics (5); and High Overall Condition (7). ***(Rating 61-80%)***
- Moderate Modification (1); Moderate Instability (2); Moderate Erosion (E) or Aggradation (A) (3); Moderate Cover/Diversity (4) and (6); 6-10% Cover for Exotics (5); and Moderate Overall Condition (7). ***(Rating 41-60%)***
- Major Modification (1); Extensive Instability (2); Low Cover/Diversity (4) and (6); 11-15% Cover for Exotics (5); and Low Overall Condition (7). ***(Rating 21-40%)***
- Extreme Modification (1); Extreme Instability (2); Severe Erosion (E) or Aggradation (A) (3); Very Low Cover/Diversity (4) and (6); 16-32% Cover for Exotics (5); and Very Low Overall Condition (7). ***(Rating 0-21%)***
- Site Not Assessed

Conclusions, Broad Management Issues and Recommendations

The major conclusions that can be drawn from the survey of the Daly River and its tributaries, including broad management issues and recommendations, are:

1. The overall condition of the majority of rivers and creeks studied throughout the Daly River catchment was high.

When the six components that make up the overall condition rating were taken into account, the majority of rivers and creeks studied throughout the Daly River catchment rated highly, with areas along Douglas, Daly, Flora, Katherine, Edith and Dry Rivers and Green Ant Creek rating very high overall. As the overall condition of the reaches surveyed was high, there is an opportunity to monitor for any deterioration in this high status over time.

The only site to record a below average overall condition was located on Eight Mile Creek.

No sites were rated as being degraded when all six components were taken into account.

Even though the overall condition ratings were relatively consistent, the six components that make up the overall condition rating varied.

2. Even though two-thirds of reach environs were classified as essentially natural, very few sites recorded reach environs that were unimpacted or recorded no local disturbance.

The degree of modification to the reach environs depended on the level of intensity of the land use and the types and extent of local disturbances. Grazing, the major land use and disturbance factor recorded throughout the Daly River catchment, was generally classed as being less disturbing to the reach environs than was extensive clearing and development for rural/urban residential or cropping (including broadacre cropping and horticulture), as was seen in the results for sites close to the population centre of Katherine.

In areas where:

(i) land uses and disturbances to the reach environs becomes more intensive and diversified through increased agricultural activity (eg cropping and horticulture);
(ii) clearing of floodplains occurs; and
(iii) the sub-division of lands bordering rivers and creeks into smaller units or rural residential blocks occurs,

the modification to the reach environs will change (rate lower) over time from being essentially natural to having some or a greater level of modification, as has been shown in areas close to Katherine. It will, therefore, be important to particularly monitor the state of the reach environs in areas where (i), (ii) and (iii) (mentioned above) are occurring.

Steps to ensure that the river corridor and reach environs are kept intact need to be implemented. Any regional strategy should ensure that the riparian vegetation is protected, ad hoc access points and river crossings are restricted, fencing and off-river watering points for stock are encouraged and that weed invasion of the riverine environment is managed. In the Katherine region, consideration should be given to extending the current “Katherine River Plan of Management for the Central Katherine Zone” to cover the ‘Shady Lane’, ‘The Rural River’ and ‘Manbulloo’ zones identified in that plan.

3. The majority of river banks throughout the catchment were stable.

The majority of river banks throughout the catchment were stable or had limited instability, however, some form of erosion was recorded. The few sites that recorded a below average bank stability were suffering from localised erosion problems.

High flow was contributing to the erosion of river banks as was stock accessing the streams to water, shelter or graze. Infrastructure, such as roads, tracks and crossings, was identified as the third major factor affecting bank stability and, in several instances, was the cause of localised bank instability problems.

Monitoring the proportion of bank lengths that are stable, eroding or aggrading assists with monitoring the extent of change in bank stability over time throughout the catchment; and making the link between bank stability and human activities within the catchment.

Bank protection measures, such as controlled stock access points to rivers and fencing along rivers, were rarely observed. If, over time, there is a deterioration in the stability of the river banks, or areas of important riparian habitat or unique riparian vegetation communities are identified, practices like those mentioned above will need to be encouraged. If fencing along rivers does occur, the responsibility for management of the riverine corridor needs to be addressed so that activities, such as, weed and feral animal control and maintenance of fencing does occur.

4. The river beds throughout the catchment were not as stable as the river banks

Two-thirds of the sites surveyed had stable river beds. This bed stability is quite probably linked to low interference to flow and sediment regimes as well as a relatively low level of clearing throughout the catchment.

Nearly one-third of the sites were experiencing moderate bed aggradation problems. Generally many of these reaches were located within, or downstream of, sandstone and/or granite country; were relatively remote; and, aside from feral animals and fires, had low impact land uses. Several of these reaches were located within the Fergusson River sub-catchment (granite and sandstone country) and upper Katherine River (sandstone country). As well, the Daly River, below the junction with the Fergusson River, and Stray Creek, recorded instream siltation problems. Both these streams were very shallow in places and were observed to be carrying a large amount of sediment, including sands.

Sandstone and granite rock formations could be a source of sand to these river systems following high flow and runoff events. High flow events would be required to transport this sediment through the river system. Large instream bars and high flow deposits were often very common along the reaches experiencing moderate levels of aggradation. Further investigation into the level of bed aggradation within these sub-catchments is required in order to identify the causes and to make appropriate management recommendations.

Moderate bed erosion was infrequent and was generally linked to local disturbances caused by river crossings, stock activity or high flow events.

5. The riparian vegetation was relatively intact and had predominantly a moderate cover and structural diversity.

Riparian zones are a vital link between land and water environments. Riparian vegetation perform many essential functions, including: the protection of river banks from erosion processes; acting as a buffer or filter for sediments and their attached nutrients and pollutants; maintaining good water quality; providing organic material, shade and shelter for instream communities; increasing the physical habitat diversity in aquatic ecosystems; and acting as a wildlife corridor. The effectiveness of the riparian zone in carrying out these functions is significantly influenced by its structural diversity, width and integrity (species diversity, overall cover, and the degree of invasion and impact caused by exotic species).

It was found from this study that the riparian vegetation was relatively intact and had generally not been impacted on by extensive clearing or development. Several factors, of varying degrees, were found to be impacting on the reach environs and river banks at many sites, including high flows, grazing/stock and infrastructure like roads, crossings and bridges.

When the cover and structural diversity were assessed, the riparian vegetation rated moderately and, to a lesser extent, highly. The results showed that the diversity of the different vegetation structural types present (eg small trees, large trees, woody shrubs, forbs, grasses, vines, *etc*) rated higher than did the cover provided by these structural types. Although most sites recorded the presence of many structural types, aside from trees (2-30m tall) and grasses, most structural categories recorded very low covers. Overstorey and understorey vegetation (trees and shrubs >1.3m) generally provided a greater cover than did ground cover vegetation, although sites within Fish, Cullen, Dry and King Rivers and Dead Horse, Eight Mile, Mathison, Limestone and Durrinyan Creek sub-sections had grass-dominated riparian vegetation communities.

It is possible that the density of shrubs and ground covers (particularly forbs, vines, rushes and sedges) is naturally low due to seasonal aspects. Continual high flows over the wet season, particularly along the lower parts of the banks, and deposition of sediment during this period, or water availability during the dry season, may influence the occurrence of ground covers and, therefore, the structural diversity and covers recorded.

The cover and structural diversity of the riparian vegetation varied somewhat, even in instances when the stability of the river banks did not vary. River bank stability does influence the condition of the riparian zone but, as has been shown in these results, other factors were also contributing to the cover and diversity of the riparian vegetation. These factors may include aspects like water availability, climate and location within the catchment.

The average width of the riparian zone throughout the catchment was 22m. The width of riparian vegetation is the 'natural' width at most sites and, therefore, this width can be used as a guideline for planning or recommending appropriate buffer widths throughout the catchment. From this study the following average riparian vegetation widths and ranges were recorded for the three stream sizes (as categorised on Map 8 'Stream Orders'):

- Minor streams (stream orders 1 and 2) - 7m (range 3-19m)
- Medium-sized streams (stream orders 3, 4 and 5) - 16m (range 2-88m)
- Major streams (stream orders 6 and 7) - 35m (range 8-50m)

Larger bands of vegetation are required along larger streams. A minimum width of riparian vegetation is necessary for the sustainability of aquatic ecosystems and processes as well as the sustainability of the riparian buffer itself.

Priority should be given to ensuring that the riparian vegetation is maintained at its natural width and that this is recognised in tree clearing guidelines or recommendations on appropriate riparian buffer widths.

Further interpretation of the vegetation species found throughout the catchment is also required in order to identify important or unique riparian vegetation communities. Once identified, steps should be taken to ensure that these riparian vegetation communities are preserved.

6. The distribution of exotic riparian vegetation was widespread.

Exotic species, particularly vines and forbs, were generally widely distributed. Over three-quarters of sites throughout the Daly River catchment recorded the presence of exotic vegetation and over half the sites recorded species that are declared noxious within the Northern Territory. The degree of invasion of the riparian zone by exotic species varied greatly, with most sites recording a low level of invasion. At times, the reaches rated poorly for exotic species compared to the other attributes assessed.

The three major exotic species recorded included *Passiflora foetida* (a naturalised vine), *Hyptis suaveolens* (a noxious forb) and *Xanthium occidentale* (a noxious forb). *Passiflora foetida* and *Hyptis suaveolens* (Hyptis) were both widely distributed throughout the catchment. *Xanthium occidentale* (Noogoora Burr), on the other hand, was more confined in its distribution and was particularly prevalent along the Daly River and several tributaries that were close to the junction with the Daly River, including: Chilling, Hayward, Limestone and Dead Horse Creeks and lower Fergusson and Katherine Rivers.

Invasion of the riparian zone by exotic/noxious species is of concern, particularly if it is displacing other native ground covers. Control of weed species should be considered so as to maintain or to improve the condition of the riparian vegetation. There is a need to understand whether exotic species are out-competing native species and generally how the level of weed invasion has affected the riparian vegetation. For example, the issue of whether the exotic species have resulted in a significant change to the integrity and structure of the native riparian vegetation communities, should be addressed.

Noxious weeds should be controlled in protected and high use areas, such as National Parks and Nature Parks. Other high use areas and recreational areas along rivers and creeks, including Claravale and Oolloo Crossings and Black Bull Yard on the Daly River, should be targeted for the control of noxious weeds in order to prevent their spread by people to other areas. This is particularly the case for Noogoora Burr that readily attaches itself to clothing, and Hyptis, which can be transported via vehicles.

Controlling weeds along streams should be approached on a catchment basis. There is limited use in controlling weeds and preventing their spread in one particular area if a continual supply of weed seed is brought into that area from upstream. In order to manage weed control on a catchment basis, it is imperative that weed control strategies and distribution maps are formulated. Such strategies and maps are also required in order to monitor the distribution and abundance of weeds, to target specific weeds and to make best use of available resources.

The active involvement of land owners and managers along rivers in controlling weeds is required. Public awareness of what weed species should be controlled and information on how to undertake this is important. The current research and trials being conducted into the biological control of certain weeds is important due to the large property and lease sizes that exist within the Northern Territory.

7. Larger rivers recorded the presence of both submerged and emergent aquatic vegetation.

Nearly two-thirds of the sites surveyed recorded the presence of aquatic vegetation. Emergent vegetation was the most common type of aquatic vegetation and was found at over half the sites. Submerged aquatic vegetation was much more confined in its distribution, being recorded at one-fifth of sites; and only one site recorded floating aquatic vegetation. The larger rivers (ie Daly, Flora, Katherine and Fergusson Rivers and, to a lesser extent, lower Douglas River), recorded the presence of both submerged and emergent aquatic vegetation. Covers for all types of aquatic vegetation were generally low.

Factors influencing the distribution and abundance of aquatic plants throughout the Daly River catchment may include suitability of flow regimes (dry season baseflows being maintained, high wet season flows), appropriate water quality and channel form, including the width, depth and sediment composition of the channel. Further studies would be required to determine the factors influencing the distribution and abundance of aquatic vegetation within the Daly River catchment.

No exotic aquatic vegetation species were recorded along the reaches surveyed.

8. Instream and bank habitats were quite diverse and provided a fair degree of cover.

Most sites had a high to moderate cover and diversity of instream and bank habitats. Sections along Dead Horse and Limestone Creeks rated below average, whilst sections along Flora and Douglas Rivers and Green Ant Creek rated highly for this attribute.

The ratings reflect the level of cover and diversity provided by instream organic debris, aquatic vegetation and other habitat types on the river bed, as well as the cover and diversity provided by the canopy and other habitats along the river banks. The most commonly occurring instream habitat types were organic debris, such as logs, leaves, twigs and branches; rocks; and permanent pool habitats deeper than 1m. Stream bed cover provided from the banks was dominated by vegetation canopy cover. The vegetation canopy along the banks did not provide a continuous cover, averaging 63% of the bank length.

The results suggest that the instream and bank habitats were fairly diverse and provided a fair degree of cover or habitat areas to support a diversity of instream fauna, including macro-invertebrates, and fauna associated with the riparian zone. A comparison with other fauna diversity studies, such as the 'Ausrivas Program' and recent studies of bird populations in riparian zones, would be required to determine if this is the case.

9. The diversity of channel habitat types was predominantly high.

The variability or diversity of channel habitat types throughout the catchment varied yet was predominantly high. Although the site reaches were generally dominated by two channel habitat types, the proportion of the reach occupied by pools versus other habitat types rated more highly. The reaches recording low channel type diversity ratings coincided with very long, uniform pools, as found along the Daly River estuary, and where only one uniform habitat type was recorded along a section of stream (eg Birdie Creek).

Channel diversity is related to natural features such as topography and geology. The results, therefore, reflect not only the diversity of channel habitats along rivers, but also the natural variations throughout the catchment. Cascades, waterfalls and rapids were associated with areas of steeper topography (gorge systems, tufa formations) or where river gradients were steeper. Very long pools were associated with the lower sections of the Daly River.

A comparison with other studies of fauna diversity, such as the 'Ausrivas Program', would be required to determine whether the high channel habitat diversity has influenced the diversity of fauna throughout the Daly River catchment.

10. Some protected areas were being impacted on by disturbances, such as feral animals and noxious weeds.

Some protected areas, including National Parks and Nature Parks, were being impacted on by feral animals and noxious weeds.

In order to benefit the stability of the rivers and creeks, there is a need to control the large number of feral animals (including buffaloes, donkeys, wild horses and pigs) along sections of the upper Katherine River that lie within Nitmiluk and Kakadu National Park and Arnhem Land Aboriginal Land. Noxious weeds (mainly *Hyptis suaveolens*) were also recorded along some of these upper catchment streams, and considering the areas are relatively remote, could indicate that their spread is assisted by motor vehicles.

The site along lower Seventeen Mile Creek, which lies within Nitmiluk National Park, recorded the presence of three types of noxious weeds - *Senna occidentalis*, *Hyptis suaveolens* and *Sida acuta*. Even though the covers for these noxious weeds were generally low, their control should be considered as they are not only located within a National Park, but they are also located on a walking trail, which may aid in their spread throughout the park.

A site located within Flora River Nature Park also recorded disturbances to the riparian zone by the presence of *Hyptis suaveolens* and *Sida acuta*. Upstream of the Nature Park though there was a moderate infestation along Mathison and Aroona Creeks by several noxious species including *Hyptis suaveolens*, *Parkinsonia aculeata*, *Jatropha gossypiifolia*, *Pennisetum polystachion* and, a weed identified by DPI&F, *Martynia annua* (Devil's Claw). Control of these noxious species should be considered to prevent their spread downstream to Flora River Nature Park where visitation levels are higher.

Other protected areas to record the presence of noxious weeds included Butterfly Gorge and Umbrawarra Gorge Nature Parks.

11. Grazing and stock activity were identified as the most common detrimental influence impacting upon stream and riparian attributes.

Grazing and stock activity were identified as one of the main disturbances to stream reaches and river bank and bed stability at many sites and, therefore, the impacts of this activity should be monitored.

Consideration should be given to fencing off any areas along rivers and creeks that are showing signs of localised erosion problems or are suffering from stock activity. Stock watering points away from rivers can be used where fencing along rivers has occurred.

12. Measures required to maintain or, in some cases, to improve the stability and condition of rivers.

As the majority of rivers and creeks within the Daly River catchment are physically quite stable, the Northern Territory is well placed to be proactive in order to ensure that the streams are not degraded over time and that they remain in a stable condition.

Measures that are required to maintain or, in some cases, to improve the stability and condition of rivers include:

- Maintaining and protecting the riparian vegetation and, in so doing, the aquatic habitat;
- Ensuring that tracks and river crossings are properly designed, constructed and maintained; and
- Monitoring and controlling the impacts of grazing/stock activity along rivers (discussed in 11).

Ensuring that riparian vegetation is kept in tact will help to maintain a good level of bank stability. As well, the riparian vegetation can perform its many other essential roles (mentioned in 5 above). In so doing, the condition of the aquatic habitat is maintained because instream cover is largely provided by organic material derived from riparian vegetation, and bank cover mostly involves the presence of trees and shrubs.

Extensive clearing or development within the riparian zone should be avoided. This allows the banks to have a greater chance of withstanding the annual high flows during the wet season that was identified, along with stock activity, as the major factor affecting bank stability.

Infrastructure was identified as the third major factor affecting bank stability. Several reaches, including those along King River, upper Hayward Creek and Douglas River, lower Depot and Stray Creeks, were experiencing localised problems due to eroding river crossings and/or access tracks. The results show that poor track and river crossing design and maintenance can influence the condition of streams at a local scale.

It is important to properly locate crossings, avoiding outside bends or steep banks, and targeting areas where the creeks are shallower and have larger sediments along the bed, like gravels, cobbles or boulders. As little riparian vegetation should be disturbed as possible when constructing the crossings. Tracks should be maintained on a regular basis and should be properly designed.

13. There is a need to actively involve the community in river management.

Land tenure along the rivers and creeks is predominantly freehold or leasehold. Therefore, any on-ground river management activities or promotion of river management issues (eg through plans) needs to actively involve the landowners, property managers and community groups.

There is a 'window of opportunity' within the Northern Territory to be proactive with regard to river management issues because the rivers and creeks within the Daly River catchment are not degraded. Maintaining or, in some cases, improving the condition of rivers and creeks should be a priority.

14. Ensure linkages are made with other projects and initiatives.

The results of this study can contribute to:

- Katherine-Daly Natural Resources Management Strategy;
- Environmental Flows Initiative Program;
- NT Weeds Management Strategy;
- Vegetation clearing guidelines;
- Recommendations on riparian vegetation buffer widths; and
- Construction guidelines for tracks and river crossings.

Linkages to other projects and initiatives that address other issues relating to rivers is important to aid overall river management decision-making processes. These include:

- 'Ausrivas' project;
- Riparian vegetation assessments;
- Long term water flow and quality databases (eg Hydsys);
- Developing environmental flows guidelines;
- Vegetation databases; and
- 'Wild Rivers' assessment.

15. There is a need to design and implement a suitable strategy and schedule for ongoing surveys.

There will need to be follow-up surveys over time in order to monitor the rate of change in river condition and stability, as has been benchmarked by this project. The project can, therefore, be used as a monitoring tool to look at management induced improvements or to monitor areas where management practices and land uses have changed or intensified within the catchment.

Department of Lands, Planning and Environment are the custodians of the project and the data and therefore will need to be responsible for designing and implementing a suitable strategy and schedule for ongoing surveys within the Daly River catchment. There will also be a need to identify what raw data should be re-collected. It is envisaged that selected priority sub-sections (or preferably sub-catchments) be targeted if the whole of the Daly River catchment cannot be re-surveyed. Long time periods (5 years or more) are generally required before changes in indicators like river channel physical form (eg river bank and bed stability) and the streamside zone (eg assessment of riparian vegetation and reach environs) can be measured.

1. INTRODUCTION

Major waterways of the Northern Territory are being utilised for recreation, pastoralism, cropping, horticulture and mining. Little is known about the condition of these rivers. The waterways are a major resource and require appropriate management in order to minimise their degradation and to achieve sustainable use.

Each of Australia's major drainage divisions can be topographically sub-divided into river basins. Each basin defines the watershed or the catchment area of each major river system. The drainage divisions and basins for the Northern Territory, as defined by the Australian Water Resources Council, are shown in Map 1.

The 'Top End Waterways Project' commenced in February 1995 and has been partly funded by the National Landcare Program (now known as the Natural Heritage Trust). The Department of Lands, Planning and Environment has overseen the project.

The overall aim of the study was to assess, describe and report on the land and water resources of the major waterways in the Katherine Region of the NT and to prepare for publication a comprehensive report on each of those waterways.

Throughout 1995-1997 the major tributaries within the Daly River and Victoria River catchments were assessed. This report focuses on the Daly River catchment. Results for the Victoria River catchment will form the basis of another report.

The majority of the field surveys for the Daly River Catchment were conducted between June and November 1995; with the remaining surveys carried out April to June 1996, August 1996, October to November 1996 and August 1997.

The objectives of the project were to:

(i) identify the current physical and ecological condition of the major waterways and land corridors within each river catchment studied;
(ii) identify the use and management of the waterways (ie land tenure, types and levels of use, impacts, *etc*), highlight major river management issues and propose appropriate broad river management recommendations;
(iii) establish a 'baseline' for use in the long-term monitoring of the condition of these river systems; and
(iv) raise the profile of river management issues.

The general methodology framework (ie sampling strategy, survey methods and data sheets) that has been adapted for this project was developed by J.R. Anderson for the Qld Department of Primary Industries (refer Section 3 'Methods').

Unlike the majority of other states, the Northern Territory has no Integrated Catchment Management (ICM) framework in place. The Northern Territory government has a statutory requirement to monitor natural resource condition and has responsibilities for *State of the Environment* reporting and, more recently, the *National Land and Water Resources Audit.*

It is expected that the main users of the information provided by this project will be the Northern Territory government and other groups interested in waterway management, including landcare and community groups, best practice groups and property owners or managers.

The information provided by this project is intended to assist in developing regional and catchment management strategies. In particular the results will contribute to the Katherine-Daly Natural Resources Management Strategy and the Environmental Flows Initiative program. The results can also generally contribute to the NT Weeds Management Strategy, vegetation clearing guidelines, buffer width recommendations and track and river crossing construction guidelines.

The project will help to identify key issues, problems and priorities with the rivers. It will also help to recognise the extent, processes and causes of river degradation and thereby pinpoint actions that would have to be taken in order to reverse any deterioration. Rivers and creeks that are showing signs of degradation (eg weed infestation, accelerated erosion, concentrated use, *etc*) will be highlighted as requiring more specific river management guidelines or plans.

The project, through the collection of baseline data, provides a reference point or "snap-shot" of what the rivers and creeks are like now. Follow-up surveys of rivers in priority areas would need to be carried out over time in order to look at the rate of change in condition and stability. The project therefore can be used as a monitoring tool.

The Daly River Catchment report consists of two parts. Part 1 provides and overview of the Daly River catchment, the methodology and the results on an overall catchment basis as well as for each sub-catchment. Part 2 provides additional sub-catchment information including sub-section maps, river cross-section diagrams and riverine vegetation profiles or lists.

2. OVERVIEW OF THE DALY RIVER CATCHMENT

2.1 Location

The study area includes the catchment of the Daly River and its tributaries (refer Map 2). The Daly River is one of the Northern Territory's largest rivers, having a catchment area of 52,577 km^2, and is one of a relatively few to have a perennial flow (Morrison, 1970). The main tributary of the Daly River is the Katherine River. Other important tributaries are the Flora, Fergusson, Edith and Douglas Rivers. The King and Dry Rivers have large catchments but are in a lower rainfall area and contribute nothing to the dry season flow of the Daly. (Morrison, 1970). Map 2 shows the tidal, permanent (or perennial) flowing and dry (or ephemeral) sections of the rivers and creeks within the Daly River catchment.

The Katherine River headwaters are formed in the high relief sandstone escarpment country of the Arnhem Land Plateau approximately 150km upstream of Katherine. The river drops down from the escarpment through a series of sandstone gorges, which make up the Katherine Gorge, before reaching the lowlands upstream of Katherine. Approximately 60km west of Katherine, the Katherine and Flora Rivers join to become the Daly River, which continues westward for 354km before entering the Timor Sea at Anson Bay.

The main valley of the Daly River is a broad undulating area bounded by low ranges on the south-west or north-east. After the incised passage through the Rock Candy and Mt Nancar ranges, the Daly River traverses a predominantly alluvial coastal plain for some 99km, and is under tidal influence for this distance. The normal tidal limit is at Daly River Crossing (shown on Map 2).

Within the Daly River catchment there are several towns, of which Katherine is the regional centre. Others include Pine Creek and Daly River.

There are two weirs along the Katherine River located upstream of Katherine at Knott's Crossing and Donkey Camp Pool (refer Map 2). Knott's Crossing weir is a concreted rock fill wall that was constructed in the 1960's, raising the water level by approximately 1.5m. Donkey Camp weir, which was commissioned in 1983, is located on a natural rock bar and is used to increase water storage for the supply of water to Katherine township.

There are currently no large surface water storages on the Daly River or its tributaries, although possible future sites have been identified.

2.2 Climate

The study area is located within the monsoonal tropics. The dominant feature of the north-west monsoon is the occurrence of two distinct seasons, an almost rainless dry season from May to September, and a wet season from November to March. April and October are transitional months. (Woodroffe *et al.*, 1986). Table 2.1 summarises climate details for several locations within the Daly River catchment.

Over 90% of the rainfall at Mango Farm (Daly River), Douglas River, Pine Creek and Katherine falls during the wet season (November to March). Rain is usually high-intensity falls. Most of the region's rain comes as hard, intermittent, tropical showers, often associated with thunder and lightning (Bauer, 1964) or as monsoon troughs and tropical lows, which are often the remains of cyclonic depressions. Intensity of rainfall is important in relation to rate of runoff and soil erosion. The normal falls are quite sufficient to cause local flooding and erosion.

The highest recorded daily rainfall at Mango Farm (Daly River), Douglas River and Katherine is 218.5mm, 206.4mm and 128.5mm, respectively (NT Bureau of Meteorology, 1997). Figures 2.1 and 2.2 shows the mean monthly rainfall for Katherine and Mango Farm at Daly River.

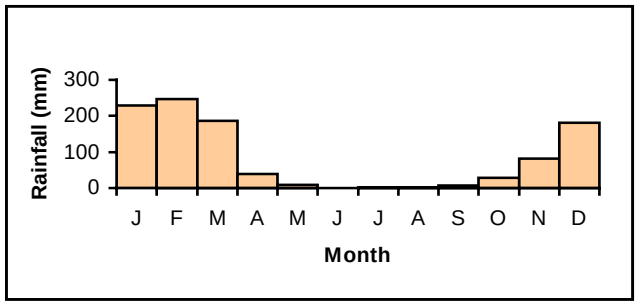


Figure 2.1 Mean Monthly Rainfall for Katherine (1942-1997)

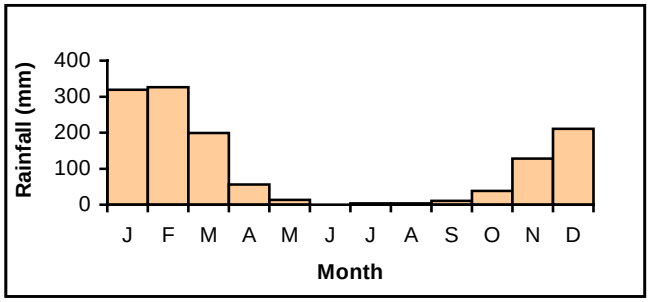


Figure 2.2 Mean Monthly Rainfall for Mango Farm at Daly River (1980-1997)

At Mango Farm (Daly River) the average yearly evaporation of 2,418.0 mm greatly exceeds the average rainfall (1,308.4 mm), which is typical for the northern Australian climate (Sivertsen and Day, 1985). Figures 2.3 and 2.4 show the total annual rainfall for Katherine (1873-1998) and Mango Farm at Daly River (1980-1998), respectively.

Mean monthly temperatures range from 19.8°C – 34.4°C. Relative humidity varies daily and seasonally. Dry season (May-September) relative humidity averages range from 58.4–62.2 percent at 9am and 28.4-32.2 percent at 3pm. Whilst wet season (November to March) relative humidity averages range from 75.6-84.2 percent at 9am and 46.6-58.6 percent at 3pm.

Table 2.1 Summary of Climate Data for Locations within the Daly River Catchment

	Katherine	Pine Creek	Douglas River (Douglas-Daly Research Stn)	Mango Farm (Daly River)
Mean Daily Min-Max Temp. Range (°C)	20.4 – 34.3	20.1 – 34.1	19.8 – 34.4	20.4 – 34.1
Mean 9am Relative Humidity (%)	66.0	63.6	71.0	73.0
Mean 3pm Relative Humidity (%)	37.0	36.2	39.0	43.0
Mean Annual Rainfall (mm)	1,009.3	1,147.6	1,157.4	1,308.4
Mean Monthly Rainfall Range (mm)	0.1 – 245.9 (June – Feb)	1.2 – 272.0 (Aug – Jan)	0.5 – 271.0 (Aug – Jan)	0.3 – 326.2 (June – Feb)
Highest Recorded Daily Rain (mm)	128.5	-	206.4	218.5
Mean Number of Rain Days	79.8	74.7	82.3	95.3
Mean Annual Evaporation (mm)		-	-	2,418.0

Source: Climate and Consultancy Section, NT Bureau of Meteorology (1997)

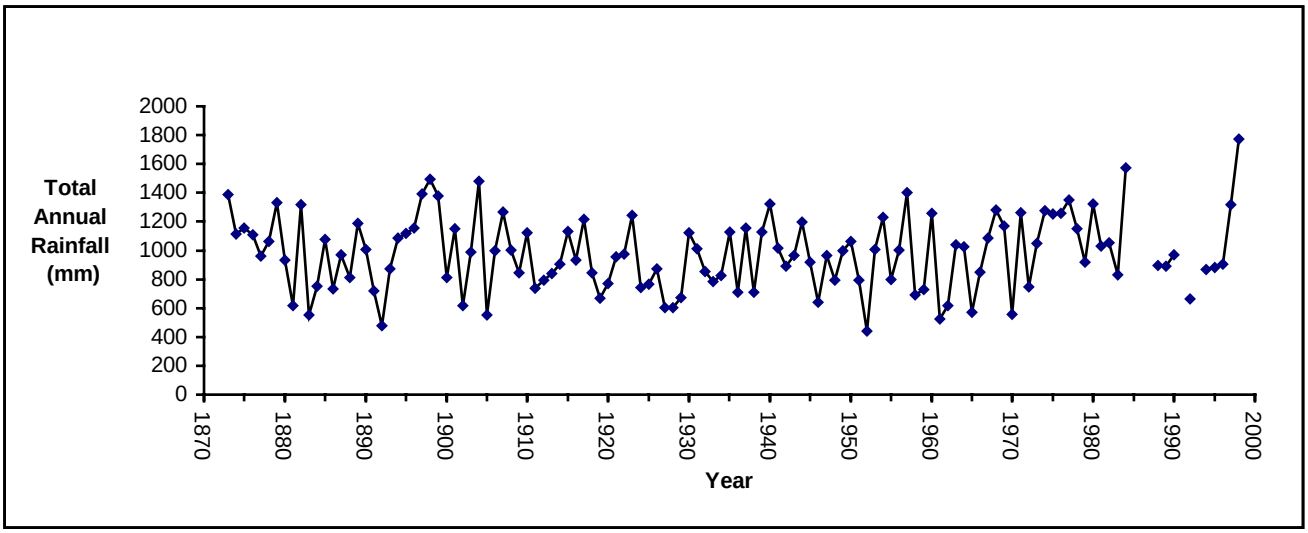


Figure 2.3 Total Annual Rainfall for Katherine (1873-1998)

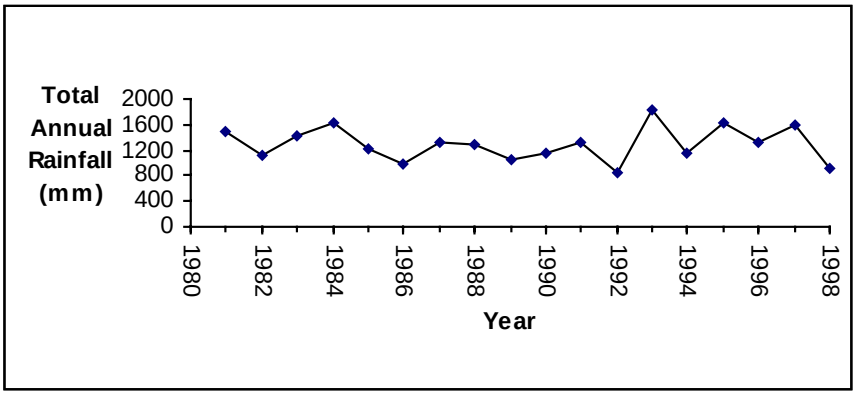


Figure 2.4
Total Annual Rainfall for Mango Farm at Daly River (1980-1998)

2.3 Geomorphology and Landform

Surveys providing detailed land systems or land unit mapping have been carried out for areas throughout the Daly River catchment. There is no one survey that covers the entire Daly River catchment. Land systems mapping is based on recurring patterns of topography, soils and vegetation (Christian & Stewart, 1952). Each land system can be described in terms of its component parts, which are land units. Each unit, while generally representing a uniform assemblage of data on topography, soils and vegetation, also describes the potential or capability of the land represented (Aldrick & Robinson, 1972).

The first systematic study of the land systems (at a scale of 1:500,000) of the Katherine-Darwin region was completed by Christian and Stewart (1952), 'General Report on Survey of Katherine-Darwin Region, 1946'. The survey was of a broad reconnaissance nature and covered areas along the Daly, Douglas, Fergusson, Flora and Katherine Rivers. Five geomorphological units were distinguished within this area and are summarised in Table 2.2.

The report of the Katherine-Darwin region (Christian and Stewart, 1952) described 18 land systems and recommended further investigation into three due to the possibilities of economic crop production under natural rainfall conditions. The Tipperary land system, which lies within the Daly River Catchment, was one of these three systems and a more detailed survey was carried out in 1961 by Speck *et al* (1965), 'General Report on Lands of the Tipperary Area, Northern Territory, 1961'. Aldrick and Robinson have described the land units for part of the 'Tipperary area' at a larger scale of 1:50,000 in 'Report on the Land Units of the Katherine-Douglas Area' (1972).

Land units have also been described for the Daly River Agricultural Area (Fogarty and Gibbs, 1976); areas around Katherine; and several pastoral properties including Mathison Creek, Elizabeth Downs, Manbulloo, Dorisvale and Litchfield Stations.

The geology of the Daly River catchment has been mapped (at 1:100,000 and 1:250,000) and described by the Department of Mines and Energy. The geology, geomorphology and land resources of the Katherine Gorge National Park have also been described and mapped by Baker and Pickup (1987), Mulder and Whitehead (1988) and Sivertsen and Day (1985).

Map 3 shows the predominant landforms throughout the Daly River Catchment. This map is based on the Northern Territory Soil Survey mapping at a scale of 1:2,000,000 (Northcote, 1968) but has been re-grouped according to landform. Within the catchment, landforms vary from high relief sandstone escarpment country in south-western Arnhem Land to an extensive level floodplain system, extending up to five kilometres from the river banks, along the lower sections of the Daly River.

The Arnhem Land Plateau is a rugged sandstone formation (Kombolgie Sandstone) rising up to 370m above sea level. This plateau is extensively faulted and dissected forming narrow, steep-sided gorge systems which are commonly 60m deep, and are incised along joint sets trending north-east and north-west; and waterfalls from hanging tributary valleys. Katherine Gorge is one such feature, with a prominent north-easterly orientation (Baker and Pickup, 1987; Kruse *et al.*, 1994). There are 15 gorges covering a distance of 15 km, with cliff faces between 50 to 90 metres in height. Other mountain ranges within the catchment include Rock Candy Range, Mt Nancar Range and Wingate Mountains (shown in Map 3).

Table 2.2 Major Geomorphological Units within the Daly River Catchment (Source: Christian & Stewart, 1952)

Geomorphological Unit	Land System	General Topography	Major Vegetation Communities and Soils
Elevated Lateritic Residuals	Mullaman	Flat-top tablelands bordered by steep dissection slopes	Tall Open Forest/Tertiary Lateritic Red Earths on tablelands; Mixed Open Forest/skeletal soils on slopes
Elevated Backbone Country	Brocks Creek Ridge	Steep north-south ridges and hills	Deciduous and Mixed Open Forest; rock outcrops and skeletal soils
	Brocks Creek Foothill	Hills and small flats	Mixed Open Forest, Parkland on flats; gravelly soils, some “Acid” Alluvial soils
	Brocks Creek Undulating	Undulating with scattered hills and flats	Orchard, Mixed Open Forest with Parkland on flats; Yellow Podsolic soils, some “Acid” Alluvial soils, gravelly soils
	Batchelor	Mostly hills, some undulating and flat country	Tall or Mixed Open Forest, patches of Grassland on flats; stony, yellow, Podsolic, Lateritic and “Acid” Alluvial soils
	Cullen	Mixed hills and undulating plains	Deciduous or Mixed Open Forest or Scrubby Open Forests; rocky skeletal and Granite Yellow Podsolic soils, Granite Lateritic Podsol
	Buldiva	Mostly rocky hills with gorges and scarps, some gentle slopes and alluvial fans	Sparse eucalypts with *Triodia* and *Plectrachne*; skeletal soils or bare rock, small areas of Sandstone Lateritic Podsol and Deep Sandy, Light Grey soils
	Volcanics	Low hills, some undulating and flat	Open forest and *Dichanthium* Savannah; stony soils and Heavy Grey Pedocals
Daly River Basin	Tipperary	Mixed low hills and undulating plains	Mostly Low, Mixed or Scrubby Open Forest; Limestone Red soil, Sandstone Lateritic Podsol, “Elliott Creek” soil, Deep Red Sandy soil and skeletal soils, small areas of Levee soils
Western Fault Block Plains	Litchfield Granite	Gently undulating with some scattered rocky hills	Mostly Palm Scrub, some Mixed Open Forest; mostly Granite Lateritic/Yellow Podsolic soils, some rocky skeletal soils and “Acid” Alluvial soils
	Elliott Creek	Gently undulating plains	Palm Scrub or Low Open Forest; “Elliott Creek” soil, small areas of Limestone Red soil
	Moyle	Gently undulating plains	Tall Open Forest with Palm understorey; Sandstone Lateritic Podsols, “Moyle” soil, and Deep Sandy Light Grey soils
Estuarine Alluvia	Sub-coastal Plain	Flat plains liable to deep seasonal flooding	Grass-reed Swamp Communities, patches of tall *Melaleuca* forests; Estuarine Plain Clays and Peats
	Littoral	Salt/mud flats liable to saline flooding, beaches, and sand-dunes, lateritic-capped cliffs	Salt meadows, samphire flats, mangroves, dune scrubs; Salt Flat soils, dune soils

2.4 Vegetation and Important Habitat Areas

2.4.1 Vegetation

Prior to 1985, the Northern Territory had no systematic vegetation mapping program, although much local and regional mapping had been carried out in the course of land system/unit surveys (Wilson *et al.*, 1990). Map 4 is based on the 'Vegetation Survey of the Northern Territory, Australia' (Wilson *et al.*, 1990)', mapped at a scale of 1:1,000,000, but has been re-grouped according to the dominant vegetation community (eg Eucalypt with grass understorey, Melaleuca, *etc*) and structural formation (eg closed-forest, open-forest, woodland, *etc*).

Within the Daly River catchment, which lies within the 'Humid Zone', Eucalypt woodland with grass understorey is the dominant vegetation type occurring. Of the map units that have been grouped together under woodland, *Eucalyptus tetrodonta*, *E. miniata*, *E. dichromophloia*, *E, tectifica*, *E. terminalis*, *E. latifolia*, *E. ferruginea*, *E. papuana*, *E. patellaris* and *E. polycarpa* are the dominant overstorey species. Grass understorey species include *Sorghum*, *Chrysopogon fallax*, *Plectrachne pungens* and *Sehima nervosum*.

This broad scale mapping meant that some distinctive and widespread communities (eg riparian *Casuarina* forests) were not specifically described (Wilson *et al*., 1990). Although these vegetation communities may be widespread, they occur in small patches (less than 3-5km across) or narrow strips (usually along watercourses).

According to Dames and Moore (1991), riverine forests may be very dense often forming a closed canopy and the dominant species show constant variability. The vegetation may also show clear zonation which, on the Katherine River, broadly corresponds to the terracing of the banks (ie *Lower Bank*, *Upper Bank* and *Hinterland Margin*) and reflects the annual flow regime.

Christian and Stewart (1952) have described and mapped (at 1:500,000) the vegetation of land systems within a section of the Daly River catchment (refer Section 2.3 and Table 2.2).

Aldrick and Robinson (1972) have mapped the Land Units of the Katherine-Douglas area (at 1:50,000). Vegetation associated with the *tributary creeks, drainage floors and back plains* are described as being woodland, open woodland, very open woodland and grassland. Whilst vegetation associated with the *major river alluvials* are described as open forest, woodland, variable woodland and swamps.

Sivertsen and Day (1985) describe the vegetation associated with the *River Land System* within Nitmiluk (Katherine Gorge) National Park as 'Tall Closed Forest to Tall Open Forest', with a very diverse and characteristic vegetation community.

The Flora River Nature Park contains a diverse flora, with a closed forest (or "monsoon vine thicket") on islands and river banks, and a tropical savannah on the levee banks and floodplains (PWCNT, 1997). The riparian forest is extremely rich in species, many of which are often found in tropical closed forests, such as *Nauclea orientalis* (Leichardt Pine). Extensive stands of *Livistona rigida*, a tall palm with limited distribution in the Northern Territory, occur along the river banks and on numerous islands within the river. There are also dense stands of *Casuarina cunninghamiana, Melaleuca* species and *Acacia auriculiformis. Pandanus aquaticus, Barringtonia acutangula* and *Terminalia erythrocarpa* line the waters edge.

Fogarty and Gibbs (1976) have described the land units of the Daly River Agricultural Area, downstream of Mt Nancar. The vegetation within this area fell into three broad categories: the *upland communities*; the *levee communities* of the Daly River (ie bank, levee and flood channel); and the *plains communities*. The bank community is described as a 'Closed Fringing Forest' occurring along the Daly River and some of its tributaries. It varied from a very narrow single line of trees to denser areas of monsoon forest. The most prominent tree species included *Nauclea orientalis*, *Melaleuca* species, *Terminalia microcarpa* and *Casuarina cunninghamiana*. *Barringtonia acutangula* (as an understorey species) and areas containing dense stands of *Bambusa arnhemica* also occur.

Only ten mangrove species have been recorded along the Daly River estuarine area due to the lack of extensive periods of brackish water inundation (Wells, 1985). These include *Acanthus ilicifolius*, *Avicennia marina*, *Excoecaria agallocha*, *Aegiceras corniculatum*, *Aegialitis annulata*, *Rhizophora stylosa*, *Lumnitzera racemosa*, *Xylocarpus australasicus*, *Bruguiera exaristata* and *Camptostemon schultzii*. According to Wells (1985), the Daly River system, although occurring in what is the wettest region, has amongst the lowest diversity of mangrove species.

Messel *et al*. (1979) noted that mangrove associations form the fringing riverside vegetation up to 37.5km along the Daly River from the mouth. The dominant tree association consisted of *Avicennia marina* and *Excoecaria agallocha*. Along concave portions of river meanders up to 37.5km along the Daly River from the mouth, *Lumnitzera racemosa* forms an association with *A. marina* (Messel *et al.*, 1979).

According to Messel *et al*. (1979) vast areas of swampland that lie adjacent to the Daly River estuarine area are vegetated by the tall canegrass, *Phragmites karka,* along with scattered *Melaleuca* species. The sedge, *Cyperus javanicus*, has colonised accreting mudbanks and cut off meanders of the mainstream that are silting up. The broad-leafed tree, *Hibiscus tiliaceus*, occurs as fringing riverside vegetation from 35-80km from the Daly River mouth. *Melaleuca leucadendra* occurs as riverside vegetation upstream of 40km and thickets of bamboo (*Bambusa arnhemica*) occur upstream of 60km.

Noxious weed species identified as being widespread within the Daly River Catchment (particularly along Katherine and Daly Rivers) include *Hyptis suaveolens* (Hyptis), *Alternanthera pungens* (Khaki Weed), *Sida acuta* (Spinyhead Sida), *Tribulus terrestris* (Caltrop) and *Xanthium occidentale* (Noogoora Burr) (DPI&F, 1994). *Mimosa pigra* (Mimosa) was identified as being widespread in the Daly floodplain-estuary system (Australia Nature Conservation Agency ANCA, 1993).

Other noxious weed species, occurring in more restricted areas or isolated patches, include: *Martynia annua* (Devil's Claw), *Ziziphus mauritiana* (Chinee Apple), *Jatropha gossypiifolia* (Bellyache Bush), *Senna alata* (Candle Bush), *Acanthospermum hispidum* (Goat's Head Burr), *Calotropis procera* (Rubber Bush), *Parkinsonia aculeata* (Parkinsonia), *Senna occidentalis* (Coffee Senna), *Sida cordifolia* (Flannel Weed), *Stachytarpheta spp.* (Snakeweed), *Themeda quadrivalvis* (Grader Grass) and *Pennisetum polystachion* (Mission Grass) (DPI&F, 1994).

Introduced species were identified as being of concern in some sections of Nitmiluk (Katherine Gorge) National Park (CCNT, 1993). *Hyptis suaveolens* (Hyptis) was identified as being widespread in even quite remote areas of the Park, particularly around developed areas, and was also forming massive thickets along the banks of Seventeen Mile Creek along with *Senna obtusifolia* (Sicklepod), *Senna occidentalis* (Coffee Senna) and *Sida acuta* (Spinyhead Sida).

According to PWCNT (1997), there are a number of weed species occurring in the Flora River Nature Park, most being associated with the land units within or adjacent to the Flora River or its drainage channels. The following noxious weeds were recorded: *Hyptis suaveolens* (Hyptis), *Senna occidentalis* (Coffee Senna), *Sida acuta* (Spinyhead sida), *Themeda quadrivalvis* (Grader Grass) and *Xanthium occidentale* (Noogoora Burr).

Phragmites karka swamplands along lower Daly River

2.4.2 Important Habitat Areas

There are three important wetlands identified within the Daly River Catchment (ANCA, 1993) and these are shown in Map 4. They are: (i*) Daly-Reynolds Floodplain-Estuary System,* which is a major floodplain-tidal wetlands system with the largest catchment of any major freshwater floodplain system; (ii) *Daly River Middle Reaches* which is a good example of a permanent freshwater river occurring in low relief country; and (iii) *Katherine River Gorge* which is a major, permanent river-pool system situated in one of the largest gorges in the NT, and one of the best known tropical gorge wetlands in Australia.

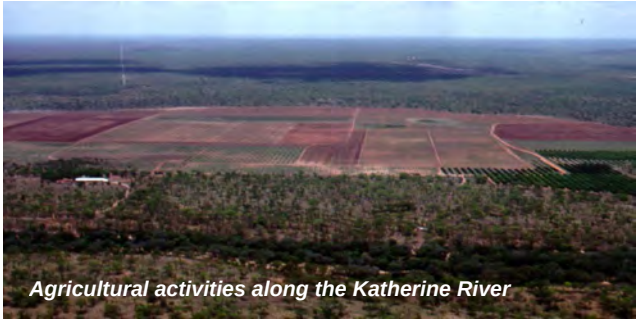
The floodplain-estuary system (shown as 1 in Map 4) is a major breeding area for Magpie Goose *Anseranas semipalmata*, herons and allies; a major dry season refuge area for waterbirds and a significant migration stop-over area for shorebirds (ANCA, 1993). The *Phragmites* swamplands draining into the Daly River provide important habitat and breeding areas for the Saltwater Crocodile *Crocodylus porosus* (Messel *et al*., 1979). The saline coastal swamps also provide an important nursery habitat for Barramundi *Lates calcarifer* during the wet season (Griffin, 1987).

The middle reaches of the Daly River (shown as 2 in Map 4) is a major breeding and dry season refuge area for freshwater turtles (6 species, notably *Carettochelys insculpta*), fishes, and the Freshwater Crocodile *Crocodylus johnstoni* (ANCA, 1993). The Saltwater Crocodile *C. porosus* also occurs. The freshwater turtles, in particular, are reliant on the resources of riparian vegetation, especially in the dry season, and on undisturbed bars and banks for nest sites.

The section of the Daly River within 20km upstream and downstream of Oolloo Crossing supports six species of freshwater turtle. In particular, this area is the prime feeding and breeding grounds for the unique Pig-nose Turtle *Carettochelys insculta*, due to the quality sandy beaches for nesting and the high presence of *Vallisneria spiralis* (or *V. nana*) beds and freshwater snails, their main food source in the Daly River (Welsh, pers. com.). Fallen trees in deeper sections of the Daly River also provide important habitat areas for juvenile Pig-nose Turtles. The 20km stretch of the Daly River upstream of Daly River Crossing is also another important habitat area for two species of Yellow-face Turtle, *Emydura subglobosa* and *Emydura tanybaraga* (Welsh, pers. com.). Other freshwater turtle species include *Chelodina rugosa*, *Elseya dentata* and *Emydura victoriae*.

The Katherine River Gorge (shown as 3 in Map 4) is a major dry season refuge for aquatic fauna, particularly fish, freshwater crocodiles and turtles (*C. rugosa*, *E. dentata* and *E. victoriae*).

A broad-scale survey of bird distribution in riparian vegetation in the Top End of the Northern Territory (Woinarski *et al*., in press), found that despite their relatively small total extent, riparian areas were extremely important for birds. Species richness and total abundance of birds was greater in the riparian zones than in non-riparian zones especially where they contained more extensive cover of rainforest plants and Melaleucas. This study concentrated on the mid-reach of rivers with permanent freshwater pools (that is, the Daly, Douglas, Fergusson, Flora and Katherine Rivers within the Daly River catchment).



Agricultural activities along the Katherine River

2.5 Land Tenure, Use and Management

Current land classification and areas used for recreational purposes within the Daly River catchment are shown in Map 5. The majority of land is held under pastoral lease, Aboriginal land trusts, freehold and crown lease titles or national parks/reserves, with localised vacant crown land titles and mining leases.

Crown leases contain covenants that control their usage or development and can be issued for any length of time, including "in perpetuity". Term leases are normally issued to allow developments to proceed and can often be converted to freehold title or perpetual leasehold once the development is complete. Pastoral leases are for broadacre areas specifically used for pastoral purposes.

The rivers and creeks within the Daly River catchment are a major focus for recreational activities, including fishing. Commercial fishing also occurs along the lower estuary and adjoining coastal waters (Griffin, 1987) and catches contribute to the NT barramundi and salmon catches. The waterways are also utilised for traditional hunting and gathering, mining, domestic and stock water supplies, irrigation and urban water supplies.

The major public boat ramp on the Daly River is located at Browns Creek (refer Map 5). Other public boat ramps are located on the Flora River and the Katherine River (within the urban area and upstream within Nitmiluk National Park). Major public receational areas are located along the Daly River including at Robbie's Bar, Mango Farm, Daly River Crossing, Black Bull Yard, Oolloo and Claravale Crossings. Other public recreational areas include Douglas Hot Springs, Douglas River Crossing, Butterfly Gorge Nature Park, Edith River Falls, Umbrawarra Gorge and along the Katherine River (eg Katherine Gorge, Low Level Nature Park, Galloping Jacks, *etc*) (refer Map 5).

The Northern Territory has only ever been sparsely populated by humans (Wilson *et al.*, 1990). As of 1997, the population of the Northern Territory was 187,000. The majority of people are concentrated in Darwin and surrounds (100,400), Alice Springs (25,700) and Katherine (9,700) (Australian Bureau of Statistics unpubl., 1997).

Various Aboriginal tribes settled in the region *ca* 50,000 years ago (sighted in Wilson *et al.*, 1990). The land around Katherine is traditionally that of the Jawoyn and Dagoman Aborigines. Sites of cultural significance to the Aboriginal people exist throughout the Daly River catchment, including

along rivers and creeks. These sites are listed with the Aboriginal Areas Protection Authority under the *Northern Territory Aboriginal Sacred Sites Act, 1989.*

Europeans established settlements within the Northern Territory from 1824 onwards (Wilson *et al.*, 1990). The first cattle (and sheep) were overlanded to the Katherine region from Queensland in 1879 to Springvale station on the Katherine River (PWCNT, 1997). The Daly River itself was used for river transport for over 100 years. European heritage sites exist throughout the catchment and generally represent remnants or features associated with pioneering, the pastoral industry, mineral exploration, communication and transport, and WW11.

Currently, the big industries in the Daly River catchment include tourism and conservation, primary industries (including beef, cropping and horticulture production), mining and the military. Pastoral activity is generally extensive cattle grazing. Land clearing for dryland cropping and some pasture improvement, is restricted largely to the Daly Basin (cropping) and, more recently, the Katherine area, where there is a variety of agricultural uses (Wilson *et al.*, 1990) including horticulture and vegetable cropping. Aboriginal lands support a variety of uses, mainly as traditional or semi-traditional living areas with small portions under cattle grazing and mining (Wilson *et al.*, 1990).

Clearing of native vegetation for agriculture has occurred to a limited extent throughout the Daly River catchment. Areas are often confined to higher population centres or where agriculture is being researched or promoted (eg Douglas-Daly area, Daly River and Katherine). Fogarty and Gibbs (1976) noted that at the time of their survey of the Daly River agricultural area, difficulties were experienced in recording the vegetation communities in the levee farms area (ie along the Daly River from Mt Nancar downstream to Brown's Creek) due to selective or total clearing of native vegetation. Clearing for agriculture within the 18,210.4 km^2 region defined as the 'Katherine-Douglas Area' has been estimated at 45 km^2 for the period 1990 to 1995 (ie 0.2%). Very approximate figures for the total clearing within this same area is estimated at 1,044 km^2 or 5.7%.

Riverine corridors, by their very nature and linear shape, are vulnerable to 'edge effects', and can suffer from management problems such as: infestation and modification by pests and weeds, rubbish-dumping, clearing, overgrazing, stream bank erosion, pollution, difficult access, and private occupation and use (LCC, 1989).

Unlike other states, the NT has no Integrated Catchment Management (ICM) framework in place. Currently, the responsibility for river management in the Northern Territory lies predominantly with the NT government. The *Northern Territory Water Act* (1992) provides for the "investigation, use, control, protection, management and administration of water resources" for surface water, groundwater and water quality.

The *NT Water Act* restricts and controls the way in which water quality can be affected, and is the basis for the Northern Territory's water quality management strategy. 'Beneficial Uses', or preferred uses, are determined for natural waterways under the Act. The uses include (1) protection of aquatic ecosystem; (2) recreation and aesthetics; (3) raw water for drinking water supply; (4) agricultural water supply; and (5) industrial water supply. The Beneficial Uses for the Katherine River were formally declared in February 1997. That is, above Donkey Camp Pool: 1 & 2; Donkey Camp Pool: 1 & 3; and below Donkey Camp Pool: 1, 2 and 4. Beneficial Uses for Katherine River tributaries and groundwater are in the process of being determined and declared.

Other NT legislation that has relevance to river management includes:

- *Aboriginal Sacred Sites Act* (1989);
- *Environmental Assessment Act* (1982);
- *Fisheries Act* (1996);
- *Heritage Conservation Act* (1991);
- *Mining Act* (1990);
- *Noxious Weeds Act* (1994);
- *Planning Act* (1993); and
- *Soil Conservation and Land Utilisation Act* (1992).

Management plans currently in place include:

- Nitmiluk (Katherine Gorge) National Park Plan of Management (1983);
- Katherine River Plan of Management, Central Katherine Zone, Draft (1996); and
- Flora River Nature Park, Draft Plan of Management (1997).

'Water dependent ecosystems', defined as rivers, riparian zones, wetlands, floodplains, springs and waterholes, now have a legal entitlement to water. Where water use is underway or planned, there is a requirement, on a catchment basis, to recommend an 'environmental flow regime' which is a recommended water regime needed to sustain the ecological values of aquatic ecosystems at a low level of risk. Research is being undertaken in the NT in order to recommend an appropriate environmental flow regime for the Daly catchment.

2.6 Water Resources

2.6.1 Stream Flow

Stream gauging in the Northern Territory commenced in April 1952, when gauge boards were established on the Katherine River in Katherine. Only scattered information is available for significant events before 1952. Following the establishment of the Australian Water Resources Council in 1964, the Northern Territory's hydrographic network experienced accelerated growth and this expansion continued until 1973, when there was approximately 250 instrumented gauge stations throughout the Territory. These stations were established as part of the Australian Surface Water Assessment Program (Dept of Transport & Works, 1980; Dept of Mines and Energy, 1986).

At present, stream flow data are available from 16 automatic water level recorders (including two high flow gauge stations) in the Daly River catchment. Section 4.10 summarises stream flow information for these gauge stations and discusses in more detail the variation in monthly discharge recorded.

Rainfall data for the region are supplemented by information from pluviometer stations. In addition to daily rainfall recording carried out by the Bureau of Meteorology there are 14 pluviographs (automatic rainfall recorders) operating in the Daly River catchment for flood hydrology work. These are located within the upper Katherine River area, within Seventeen Mile Creek sub-catchment, in Katherine and along the Douglas and Daly Rivers.

The concentration of monsoonal rains during one part of the year, the wet season, is reflected in marked seasonal changes in stream flows. In a normal wet season the rainfall is more or less uniformly distributed from December through March, but river discharge tends to increase as the wet season advances (Chappell and Bardsley, 1985). Flood peaks occur after heavy rainfalls. Heavy falls later in the wet season tend to generate larger discharges than do equivalent falls early in the season. Variation of discharge from one wet season to another is much greater than variation of rainfall input (Chappell and Bardsley, 1985).

Summer monsoonal rains flood the Daly River annually. Discharge of the highest flood in the wet season varies considerably from year to year. One wet season may be marked by several flood peaks, whilst others have only one. Wet season floods of different levels are described in terms of their statistical return periods, or recurrence intervals (Chappell and Bardsley, 1985).

Since 1897, there has been five flood events with a peak level higher than 19m on the Railway Bridge gauge, located in Katherine. These flood events are listed in Table 2.3. The largest flood on record in the Katherine-Daly system occurred in January 1998, with a peak level in Katherine of 20.4m (gauge height). The previous record flood occurred 40 years ago in 1957 and peaked in Katherine at 19.29m (gauge height), about 1.1m lower than the 1998 flood.

Table 2.3 Katherine River – Recorded Floods

Date	Flood Level Gauge Height	Flow m^3/sec
December 1897	19.0-19.5	4,800-6,500
April 1931	19.05	4,828
January 1940	19.26	5,500
March 1957	19.29	5,677
January 1998	20.40	*12,000

*Based on preliminary analysis. Source: Kinhill Pty Ltd (1998) "Katherine Flood Report – Hydrology Study".

According to Kinhill Pty Ltd (1998), a preliminary estimate of the peak discharge of the 1998 flood was 12,000 m^3/sec, compared with 5,700 m^3/sec for the 1957 flood. The estimated annual exceedence probability of the 1998 flood was between 0.5 and 1%; that is between 100 and 200 year average recurrence interval. An annual exceedence probability of 1% was previously adopted for the 1957 flood, but according to Kinhill Pty Ltd (1988) it has a probability of more than 2%; that is less than a 50 year average recurrence interval.

There is a close interaction between surface and groundwater systems in the Daly River catchment (also refer Section 2.6.2). During the almost rainless dry season from May to December, the baseflow (or minimum discharge) in larger rivers and creeks, is atttributed mainly to groundwater discharge. This baseflow may be vital to the character and composition of instream and near-stream ecosystems (Hatton & Evans, 1998).

The Daly River is a perennial or permanent flowing river and the dry season flow within it can be largely attributed to a number of springs emanating from Daly groundwater basin storages (Water Resources Branch, 1975). Groundwater discharge also provides important permanent flow, particularly during the dry season, in the Katherine, Flora, Fergusson, Edith, Douglas, King and Fish Rivers and Chilling, Green Ant and Seventeen Mile Creeks (refer Map 2).

Extraction of water from rivers and creeks (ie surface waters) occurs for stock and domestic purposes within the Daly River catchment. Where greater volumes of surface waters are needed for irrigation, domestic or mining purposes, 'Water Extraction Licences' are required. These extraction licences are issued and managed by the Department of Lands, Planning and Environment under the *NT Water Act* (1996). Water Extraction Licences currently exist on the Daly, Katherine and Edith Rivers and Green Ant Creek (refer Table 2.4). Maximum volumes for water extraction are set for each licence.

Table 2.4 Water Extraction Licences within the Daly River Catchment

River Name	No. Licences/ Purpose Of Licence	Max. Total Extraction May-Oct* (ML)
Daly River	4 - Irrigation (4)	1,612.9
Edith River	2 - Irrigation (1) - Mining (1)	572.0 Var
Katherine River	13 - Irrigation (12) - Domestic (1)	3,199.0 2,268.7
Green Ant Creek	1 - Irrigation (1)	400.0

*The extraction figures are maximum licensed levels. Data on water actually extracted is not available.

Flow gauge station on Seventeen Mile Creek

2.6.2 Groundwater

There are substantial groundwater resources in the Katherine region (Dames & Moore, 1991). Tindall Limestone is the major groundwater aquifer within this region. According to Smith (1980) other possible groundwater sources in the area include Burrell Creek Formation, Kombolgie Formation, Antrim Plateau Volcanics, Springvale Beds, Jinduckin Formation, Mullamen Beds and alluvial aquifers.

Jolly (1984) and Water Resources Branch (1975) recognise three stratigraphic formations within the Daly Basin. The oldest, Tindall Limestone, is 150-200m thick and is made up of limestone with some thick interbeds of mudstone. In common with most limestones, those of the Tindall have locally undergone solution by the action of acidic groundwater either on a large scale to form caves like those near Katherine, or on a small scale to form vugs. This aquifer can be high yielding. Water from the Tindall Limestone is generally of good quality though hard and supplements the town water supplies for Katherine.

The Jinduckin Formation overlies the Tindall Limestone and contains 350-400m of mudstone with minor interbedded limestones. Yields from this formation are extremely variable, as is the water quality. The Oolloo Limestone, which is the youngest of the three formations and overlies the Jinduckin Formation, outcrops from Douglas River southward; consists of a maximum thickness of 150-200m of dolomite and dolomitic limestone; and can be high yielding. Numerous springs do occur along river channels within the Daly Basin, contributing to river baseflows. These springs in the main are fed from aquifers in the sandstones and limestones of these three formations.

As discussed briefly in Section 2.6.1, there is a close and important interaction between ground and surface water systems in the Daly River catchment. As outlined by Chin (1995), during the wet season, run-off events occur and aquifers are recharged. During the almost rainless dry season, the ground and surface water systems are not being replenished and are "in decline". This seasonal decline of groundwater levels is due to evapotranspiration and the natural discharge of groundwater to rivers and creeks and, in some situations, billabongs. As the dry season progresses, the surface flows in creeks recede and billabongs dry up. By the end of the dry season, smaller tributaries cease to flow and, at this point, baseflow in the larger rivers and creeks is generally all attributed to groundwater discharge.

The Daly River has a strong permanent flow that is largely attributed to groundwater discharge during the dry season. Groundwater discharge also provides important permanent flow in the Katherine, Flora, Fergusson, Edith, Douglas, King and Fish Rivers and Chilling, Green Ant and Seventeen Mile Creeks. Map 2 shows the tidal, permanent flowing and dry sections of streams within the Daly River catchment. Also refer to Section 4.10 'Stream Flow' and Map 25, which shows the springs that have been recorded throughout the Daly River catchment, many of which are contributing to stream flow.

According to Chin (1995), the Daly River baseflow or minimum discharge between gauge stations at Dorisvale and Beeboom crossings, a distance of 120km, during 1981 to 1994 was some $12m^3$/sec. This baseflow is maintained almost entirely by groundwater discharge from the Oolloo Limestone. Groundwater discharge has been recorded between the gauged locations on Edith and Fergusson Rivers and their confluence downstream (Chin, 1995).

Tindall Limestone is the sole source of late dry flows along the Katherine River in most years. Springs in the Katherine town reach of the river have been gauged at rates exceeding 20 megalitres per day, flowing directly from Tindall Limestone in the river bank (Smith, 1980).

The perennial flow of the Flora River is generated by groundwater emanating from a network of caves and tunnels in the underlying Tindall Limestone aquifer. Wet season rains recharge this aquifer, replenishing the source of the river and sustaining flow in the following dry season. The average dry season flow over Kathleen Falls on the Flora River is approximately 3,000 litres a second (or 259 megalitres a day). A large spring upstream of Kathleen Falls contributes around 2,000 litres a second (or 173 megalitres a day) to the flow during the dry season and has an inflow temperature of approximately 34^oC. Overall, the springs along Flora River maintain the river's flow at between 250 to 350 megalitres a day throughout the dry season (PWCNT, 1997).

The discharge into Seventeen Mile Creek is generally dependent on the recharge from previous wet seasons' rainfall, since the groundwater baseflow contribution from the underlying sediments is small (Dames and Moore, 1991).

Groundwater uses include: urban water supplies, irrigation, stock watering, private domestic supplies, mining, industrial, and for investigation, observation and monitoring purposes.

Investigation bores are those that are drilled for the purpose of obtaining information on water quality, potential yield and geology. Observation bores are drilled for the purpose of determining groundwater yields. Monitoring bores are those that are drilled by the government for the purpose of monitoring groundwater levels on a regional basis (refer Section 4.10 and Map 25 for the location of monitoring bores).

All bores drilled have to be registered by the licensed drillers. Information provided by the drillers to the Department of Lands, Planning and Environment include depth, strata, construction and estimated yield. A 'water balance' for the Katherine region is currently being undertaken by Department of Lands, Planning and Environment and licensing to pump water from bores is being considered.

2.6.3 Water Quality

It was not until 1984 that a surface water quality network was established in the Northern Territory and a program of spot measurements for basic key quality parameters (ie pH, temperature, electrical conductivity and turbidity) was introduced at flow gauge stations (Dept of Mines and Energy, 1986). Total phosphorus and total alkalinity are two other water quality parameters that are measured at some gauge stations on an irregular basis.

Water quality monitoring is carried out on a project basis and is managed by the Department of Lands, Planning and Environment (DLPE). At present, there are over 400 water quality sampling stations (located away from flow gauge stations) recorded throughout the Daly River catchment. These stations not only include sites located on rivers and creeks but on springs, billabongs and within sewage treatment ponds. Sampling at these water quality stations has generally been carried out on an ad hoc basis and may have been part of a one-off water quality survey. There is no long-term time series data collection without it being an identified requirement of an endorsed project.

Most of the water quality data available on Hydsys, the principal water quality database for DLPE, are for sites on the Katherine River near Katherine township for the C1 suite of analyses (Padovan *et al*., 1999). These are: pH, conductivity, total dissolved solids, sodium, potassium, calcium, magnesium, chloride, sulphate, nitrate, fluoride, iron, reactive silica, total hardness, total alkalinity and bicarbonate.

Routine water quality analysis is conducted on the Katherine town water supply off-take from Donkey Camp Pool (ie for standard water treatment plant operations) and includes: dissolved oxygen, turbidity, pH, colour, conductivity and hardness. There are also regular bacterial counts done specifically for coliforms and *E. coli.*

The discharge of secondary-treated water from the sewage treatment works opposite Springvale into the Katherine River occurs during the wet season when dilution is greatest. The quality of this discharge from the sealed evaporation ponds is monitored. Discharge from the waste disposal dump is also monitored on an ad hoc basis (Katherine River Advisory Committee, 1996).

Groundwater used for the town water supply is monitored regularly. The water quality of each new bore is tested for pH, electrical conductivity, total dissolved solids, alkalinity, hardness and minerals after drilling is complete. Water quality sampling and monitoring of groundwater in other areas are carried out on an ad hoc basis (Katherine River Advisory Committee, 1996) or as part of a specific project (eg investigation bores).

Section 4.11 summarises water quality information for flow gauge stations and other water quality sampling points on rivers and creeks (where greater than 10 results for a parameter has been recorded and/or results are from 1985 onwards). Ausrivas (Australian River Assessment Scheme) is part of the National River Health Program and has been developed as a rapid, integrated way of assessing the ecological health of rivers, involving sampling aquatic macroinvertebrates (insects and crustaceans). Water quality information for Ausrivas project sites has also been summarised in Section 4.11.

The following lists the major water quality surveys that have been conducted on rivers within the Daly River Catchment:

- Baseflow Water Quality Surveys in Rivers in the NT Volume 1 – Katherine and East Alligator Rivers (Dept Transport & Works, 1983);
- Baseflow Water Quality Surveys in Rivers in the NT Volume 2 – Finniss and Daly Rivers (Dept Mines & Energy, 1985a);
- A Wet Season Water Quality Survey in the Daly River Basin (Dept Mines & Energy, 1985b); and
- Baseflow Water Quality Surveys in Rivers in the NT Volume 7 – Douglas, Flora and Reynolds Rivers (Power & Water Authority, 1988).

These surveys were initiated on the basis that there was very little reliable water quality information for many rivers in the Northern Territory. Rivers where there was the possibility of increased development were regarded as most likely to have their quality varied and were given priority for these surveys.

Seasonal changes in water quality are a feature of streams in the Top End, due to the influence of a wet and dry season. During the dry season water levels are reduced and in rivers and creeks which eventually dry up, most of the water is confined in relatively small areas (ie broken channels, billabongs and swamps) where evaporation and chemical changes occur. Dry season water quality within the Daly River is influenced by the majority of groundwater emanating from limestone formations in the Daly Groundwater Basin and, as a result, generally has a high calcium content (Water Resources Branch, 1975).

First storms of the wet season bring minor freshes ('early wet season flushes') down the river that are very turbid, resulting from surface wash in the catchment. Turbidity tends to decrease as the wet season becomes established but is very variable depending on the actual flow conditions. The early wet season rains also flush high levels of decayed organic matter from stagnant pools in the river bed and from surface wash, which have a high bacterial pollution and low oxygen content. These flushes have resulted in fish deaths and a rapid deterioration of water quality (Townsend *et al*., 1992; Dames & Moore, 1991).

Sources of contamination of rivers and creeks can include gross pollutants (eg rubbish dumping along the river, litter, floating debris, *etc*), town stormwater run-off, periodic contamination at the start of the wet season, erosion within the catchment, agricultural practices in the catchment (use of pesticides and fertilizers), intensifying landuse adjacent to the river (rural residential subdivisions along the river), septic tank leakage, increased access tracks and possible increased runoff, and discharge from mine sites.

Major sources of pollution to groundwater can include pesticides, fertilisers, animal wastes, runoff from urban areas, septic tanks and other domestic wastes.

2.7 Characteristics of the Daly River

2.7.1 Evolution of the Daly River and Estuarine Plains

According to Woodroffe and Chappell (1990), three phases can be recognised in the evolution of the South Alligator River estuarine plains: *transgressive phase, big swamp phase* and *sinuous/cuspate phase.* The recognition of 'big swamp phase' mangrove muds in several other river floodplains (including the Daly, Adelaide, Ord and Mary Rivers) implies that the three phase model describes the evolution of the majority of estuarine systems in northwestern Australia (Woodroffe and Chappell, 1990).

As discussed by Chappell (1987) and Chappell and Woodroffe (1985), channels and floodplains of the large macrotidal rivers of Northern Territory have changed substantially in the last 10,000 years. Before 6,000 years ago, sea level was rising from an extremely low position of 18,000 years ago when the coastline was out near the edge of the continental shelf. This rise was caused by melting of the great ice caps which covered northern North America and north-west Europe during the last ice age. Valleys were devoid of their present floodplain sediments, and their floors were as much as 15 to 20 metres lower than present floodplain levels. Normal freshwater rivers flowed through them and out across the continental shelf, which at the time was dry land.

Rising seas began invading the valleys 8,000 to 10,000 years ago and has been termed the *transgressive phase* (Woodroffe and Chappell, 1990). There was mangrove establishment in the prior valley as sea level rose. This marine flooding finished when sea level stopped rising, approximately 6,500 to 6,000 years ago (Chappell, 1987; Woodroffe *et al.*, 1986).

The *big swamp phase* followed, with mangrove forests becoming widespread. The big swamp is believed to have formed because sediments were uniformly distributed throughout the infilling estuary during the last stages of rising sea level (Chappell, 1987). The valley infill by sedimentation created the present floodplains (Woodroffe *et al.*, 1986).

Mangrove forests were reduced in extent as sediment built up to a level at which tidal flooding ceased, and the tidal river adopted a sinuous meandering, and subsequently in part a cuspate meandering (sharply pointed inner bend to the meander), channel morphology (Woodroffe and Chappell, 1990).

The transition from sinuous to cuspate river phases appears to involve considerable channel instability (Chappell and Woodroffe, 1985). Macrotidal estuaries of northern Australia have been shown to pass through a series of stages in channel morphology, with gradual development of cuspate meanders in a reach of the river previously characterised by sinuous meanders (Chappell and Woodroffe, 1985).

The lower Daly River plains, showing the track of active channel migration, ancient shorelines, and the 6000-year mangrove swamp region is shown in Appendix A. According to Chappell (1987), much of the lower Daly River plains are underlain by 6000 year old mangrove muds, showing that they evolved in the same way as the South Alligator, and the channel shows similar forms to the South Alligator.

However, the Daly River channel differs significantly in that its river meanders are very actively migrating through continued deposition of new sediment. Evidence from aerial photographs, taken at several different times over the last 40 years, shows that cuspate meanders no sooner form than they begin to grow back into the sinuous type (Chappell, 1987). In the Daly River, historical migration of meander loops which are seen from successive aerial photos have shown them to move by up to 30 metres per year (Woodroffe *et al*., 1986). The Daly River channel is "ever-changing".

The deltaic-estuarine system is that section of the river that is influenced by both fluvial and tidal processes. Chappell and Woodroffe (1985) and Woodroffe *et al.* (1986) identify four channel segments within this tidal system: (i) the *estuarine funnel* at the river mouth, (ii) the *sinuous meandering segment*, (iii) the *cuspate segment, and (iv)* the *upstream segment*.

Appendix A describes the features of each of these four channel segments, shows a hypothetical tidal river composed of four channel segments, and shows the different segment types and how they vary for/between the Adelaide, South Alligator and Daly Rivers. The proportion of each of these segments have changed through time in ways which affect tidal and flooding patterns of the rivers (Chappell, 1987).

Wright in Speck *et al.* (1965), and discussed in Aldrick & Robinson (1972), described three substages of river rejuvenation in the Tipperary land system area (mid to upper Daly River). According to Wright in Speck *et al.* (1965) the first

substage was probably due to a geological uplift which resulted in the removal by erosion of much weathered colluvial material from hill slopes which had become less stable as a result of a change to a drier climate. Alluvial banks and plains were then deposited along the major rivers.

The second substage was thought by Wright in Speck *et al.* (1965) to have been caused by a change to a wetter climate. During this substage extensive younger levees and river backplains were formed from flood deposits and laid down on top of the older levees.

The third substage, according to Wright in Speck *et al.* (1965), was brought about by a further climatic change that led to increased runoff and to drainage rejuvenation, and to the rivers actively incising. Entrenchment of the major rivers occurred during this substage. The Daly River is now deeply entrenched and is cutting into bedrock in many areas.

According to Aldrick and Robinson (1972) the Daly River has meandered across a broad area downstream from its junction with Stray Creek and old river courses are still evident. Bordering the old river courses is low almost flat, medium to heavy-textured levees. Where the river has not changed its course the younger levees overlie the older ones. Hence the older levees sometimes occur as a margin on the land side of the new ones. The younger levees are extensive along the Katherine and Fergusson Rivers, but they occur only as thin strips along most of the Daly River. They show little evidence of active aggradation, but they may suffer erratic flood deposition or erosion during rare high flows.

2.7.2 Tidal Behaviour on the Daly River

River basins in the top end of northern Australia are dominated by summer monsoonal rainfall averaging roughly 1,000mm or so. Runoff efficiencies rise towards the end of the wet season and can exceed 30% for the month of March in large basins such as the Daly River (Chappell, 1984). These rivers are characterised by massive floods in the wet season, which contrast with very high tidal fluxes in the dry. The high tidal flows substantially impede the transit of sediment to the sea, and the rivers typically have very extensive floodplains about their lower reaches (Chappell, 1984).

According to Water Resources Branch (1975), salinity influence from the sea has been recorded as encroaching upstream from the Daly River mouth for a maximum distance of approximately 65km.

The saline intrusion limit usually lies between 49 and 65km in the dry season. The sea/freshwater-mixing zone recorded for the Daly River for the months of June and August by Chappell and Ward (1985), extended to just over 40km from the river mouth. The base flow of the Daly River, averaging about 10 cumecs (Chappell and Bardsley, 1985), is probably sufficient to arrest the sea/freshwater-mixing zone (Chappell and Ward, 1985).

According to Chappell and Ward (1985), when in flood, the Daly River has a sea/freshwater-mixing zone in the vicinity of the river mouth although the location of this point varies with the tide. When sampled within a few days of the highest discharge of the season (30 March-2 April 1984), the Daly River was entirely freshwater upstream of 5 to 8 km from the mouth and no tidal reversal of flow was recorded upstream of 15 to 16km.

The salinity profile of the Daly River after flood recession (July 1984) is shown in Figure 2.5. The profile shows that seawater mixed steadily further upstream as the dry season advanced.

Tides influence the water levels over the last 99km of the Daly River, before it enters the Timor Sea. The normal tidal limit is the causeway at Daly River Crossing (shown on Map 2). At intermediate stages of flow (about 3 to 5m above gauge datum), tidal effects may propagate across the causeway, and a small effect may occur 9km upstream at Mount Nancar gauge station (G814040) on occasions (Chappell and Bardsley, 1985).

According to Chappell and Ward (1985), coasts of the top end of the Northern Territory, from northern Arnhem Land to the Joseph Bonaparte Gulf, are macrotidal, having a maximum spring tide range of 6 to 8 m. Tidal areas within the Daly-Reynolds floodplain-estuary system experience twice-daily inundation and have a tidal range of 8.1m (Australia Nature Conservation Agency, 1993).

According to Wells (1985), from the Kimberley region of Western Australia to Gove in the Northern Territory, semi-diurnal tidal patterns occur. Although within the Gulf of Carpentaria diurnal tidal patterns normally occur and lunar differences, particularly for spring and neap tides, are not nearly so pronounced to those experienced in areas with semi-diurnal tides.

Tidal bores occur on some river systems across the northern coastline during spring high tides (Wells, 1985). These were experienced on the Daly River during field work in September 1995. According to Messel *et al.* (1979), high spring tides are accompanied by a small tidal bore, which has a maximum height of about a metre.

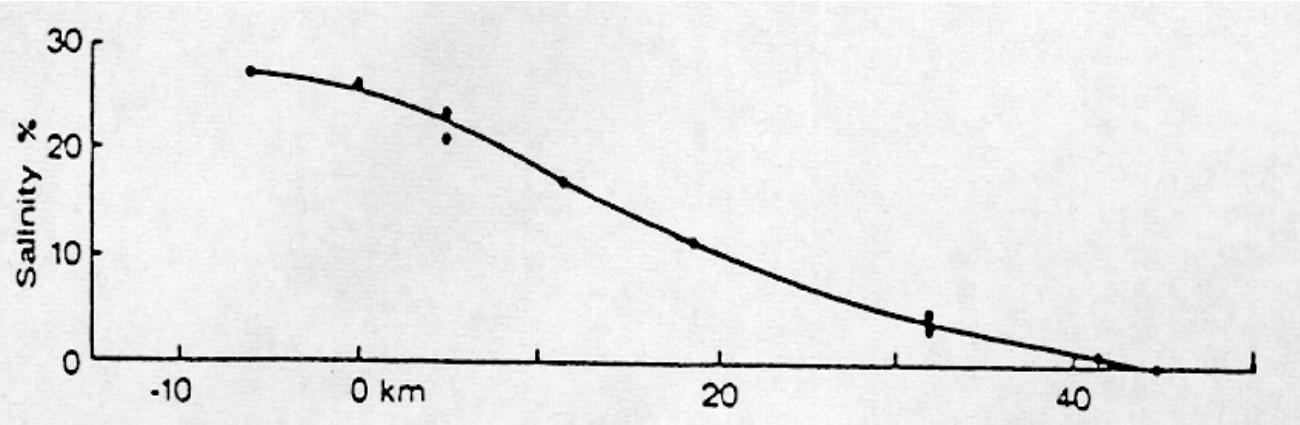


Figure 2.5 Salinity Profile of the Daly River after Flood Recession - 3 – 5 July 1984
(Source: Chappell and Ward, 1985)

2.7.3 Drainage Pattern and Density

An important feature of drainage systems as seen from the air or on a map is their drainage patterns. These patterns are often developed in response to the underlying local geology (Land Conservation Council, 1989). There are eight major drainage patterns (refer Figure 2.6). Of these, the dendritic and rectangular patterns can be seen within the Daly River catchment.

Dendritic drainage patterns develop in regions composed of rocks with uniform resistance to erosion (Land Conservation Council, 1989). The resulting pattern is like the branching of a tree and is the most common drainage pattern in the Daly River catchment. Alluvial streams, composed of unconsolidated sediment, adjust their morphology over time in response to flow events of intermediate magnitude and frequency (discussed in Baker and Pickup, 1987) and are termed 'fluvial-dominated streams'.

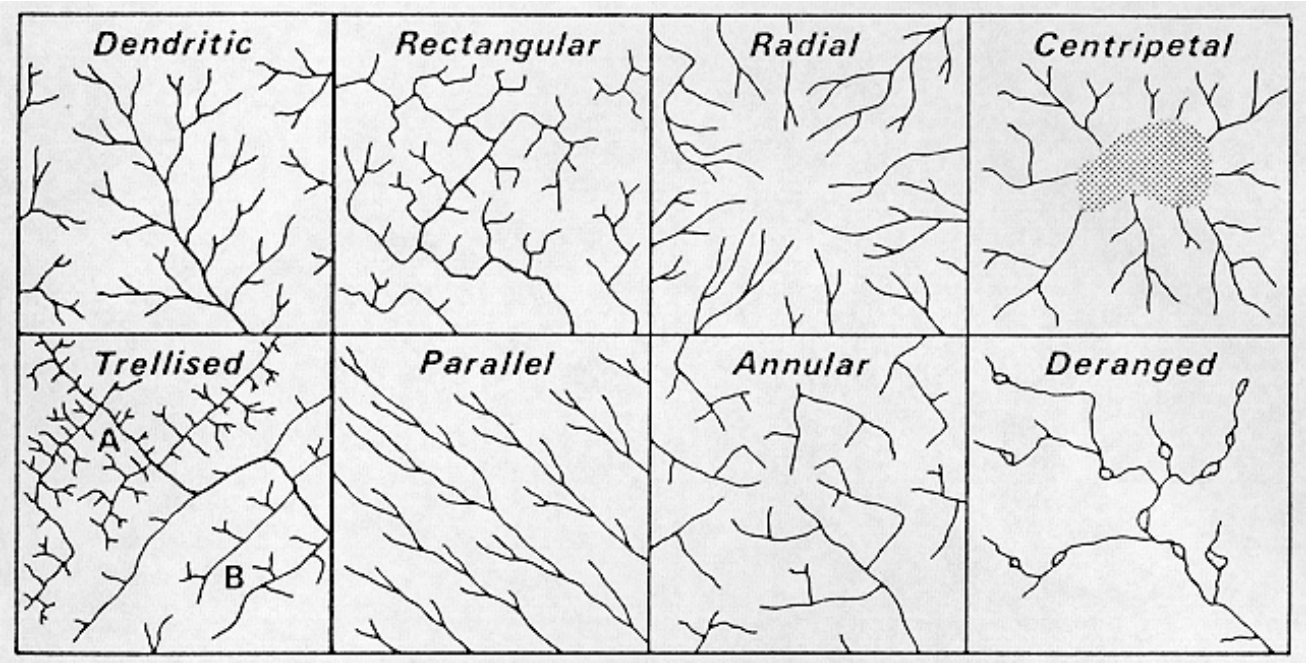


Figure 2.6 Classification of Drainage Patterns
(Source: Gregory and Walling, 1973)

Rectangular drainage patterns are also evident within the Daly River catchment along, for example, the Katherine Gorge. These drainage patterns develop where the underlying rock has major joints that meet at right degrees, which create weaknesses in the rock that erode more easily. The Katherine Gorge is a narrow, deep canyon system developed in jointed, resistant sandstone. Unlike the alluvial streams, these rivers are constrained in their ability to respond to varying conditions of water and sediment because the bank and bed resistance is extreme (Baker and Pickup, 1987) and are termed 'bedrock-dominated streams'.

Another important feature of drainage systems is the drainage density of the catchment or amount of drainage network (that is, number of channels) for a given area. The amount of channel development reflects the rainfall and the properties of the underlying rock (Land Conservation Council, 1989). The drainage density has not been determined for the Daly River catchment for inclusion in this report.

Katherine Gorge – bedrock-dominated stream

Katherine Gorge

2.7.4 Stream Profile

As water flows from the highest to the lowest point in a catchment the loss of gravitational energy results in a change from areas dominated by the transport of eroded material to areas of active deposition (Land Conservation Council, 1989). The downstream change in height above sea level is known as the stream's longitudinal profile. The profile tends to be concave, with the steepest sections in the headwaters of the basin.

According to Land Conservation Council (1989), longitudinal profiles provide an indication of the amount of energy in the water, and whether the stream is likely to erode or deposit sediment. Rivers can erode or deposit material an any point along their course, but will generally erode material where the profile is steeper and deposit it at points along the flatter part of the profile.

Important features of a profile are the base levels, which set the lower limits for erosion. For streams flowing into the sea, sea level is the base and streams rarely erode below this depth. Consequently, the rising sea levels, discussed in Section 2.7.1, have fundamentally affected stream profiles and the distribution of erosion and deposition along them. Local base levels are also important in stream profile development and are often formed where the river crosses hard rocks that are resistant to erosion, like the resistant sandstone along Katherine Gorge. Waterfalls often occur on the downstream side of such base levels or knick points in the profile.

Figure 2.7 shows the longitudinal profile for the Daly River and three of its major tributaries (the Douglas, Flora and Katherine Rivers). The Daly River traverses a length of 195km to the junction of the Douglas River, rising only 25m in elevation. The Douglas River continues for another 85km, rising much more steeply over this length to reach 200m in elevation at its headwaters.

The Flora and Katherine Rivers junction with the Daly River is located approximately 354km upstream from the mouth. Over this distance, the Daly River rises only 55m in elevation. The Flora River continues upstream for another 105km, approximately, rising steeply over this length to reach 280m in elevation. The Katherine River is almost as long as the Daly River and continues for approximately 321km upstream of their junction. The Katherine River rises to an elevation of around 421m at its headwaters.

The Katherine River flows through two gorge systems, one downstream of Snowdrop Creek junction and the other at Katherine Gorge, upstream of Seventeen Mile Creek junction (refer Figure 2.7). The Douglas River also flows through a gorge system at Butterfly Gorge. These gorges are comprised of rocks that are more resistant to erosion and appear as steeper sections in the longitudinal profile shown in Figure 2.7. Other areas that are alluvial in nature and, therefore, can erode more easily in response to flow events, are represented by smoother, concave curves in the longitudinal profile.

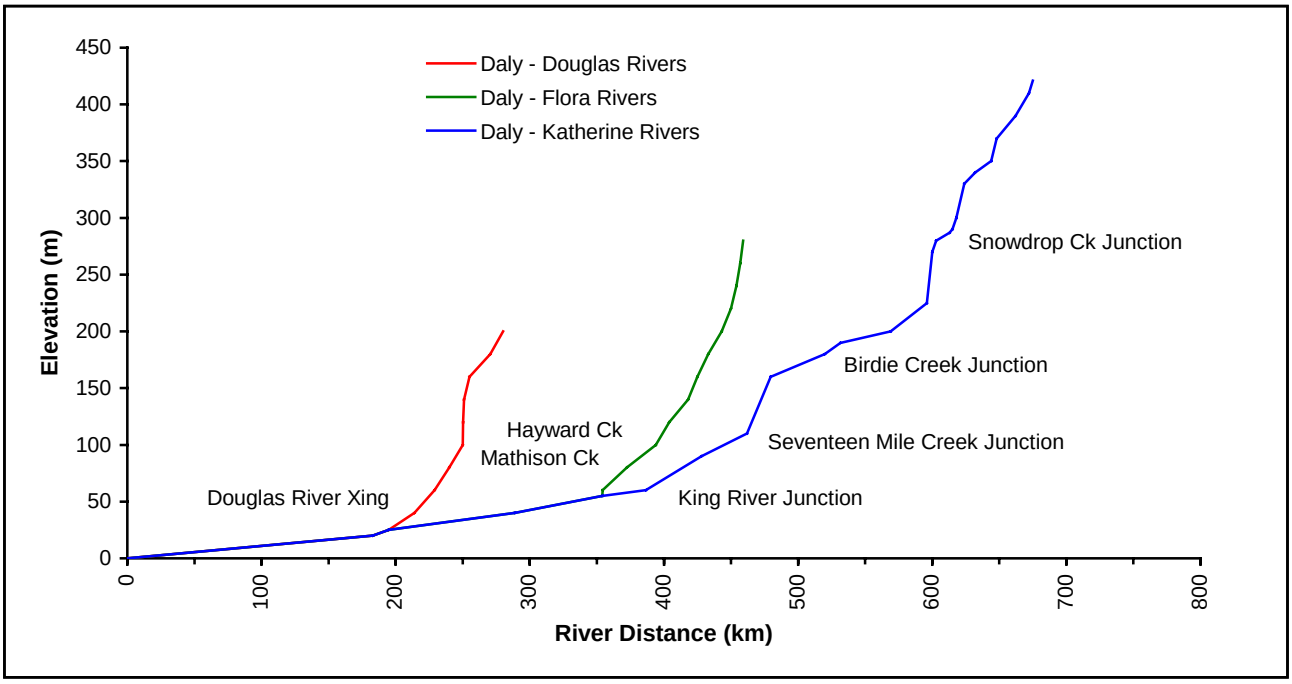


Figure 2.7 Longitudinal Profile for the Daly River and Three of its Major Tributaries (the Douglas, Flora and Katherine Rivers).

2.7.5 Stream Orders

Naming or numbering streams according to their order allows ready geomorphic and ecological comparisons to be made between streams. There are several methods of doing this (refer Chow, 1964; Gregory and Walling, 1973; Land Conservation Council, 1989). In the Strahler system, stream order starts in the headwaters and increases in units of one in a downstream direction. First order streams are the smallest unbranched channels in the headwaters of a catchment. When two of these streams meet, they become a second order stream. Third-order streams form when two second-order streams meet, and so on.

The Daly River catchment has 7 stream orders based on the Strahler system and on a 1:250,000 map scale (refer Section 3.4 'Sampling Strategy' and Map 8).


Daly River – Stream Order 7 (A major stream)


Upper Hayes Creek – Stream Order 1 (A minor stream)

3. METHODS

3.1 Background to Methodology

The 'Top End Waterways Project' was required to assess, describe and report on the current physical and ecological condition of the major rivers and their tributaries within the Katherine Region, commencing with the Daly River catchment. Developing a suitable methodology was beyond the scope of the project. Therefore, an appropriate methodology, that could be adapted for use by the 'Top End Waterways Project', had to be selected for this study.

The 'State of the Rivers' methodology (Anderson, 1993b,c) was assessed and selected to provide a general framework for the 'Top End Waterways Project'. The methodology was developed by J.R. Anderson for the Department of Primary Industries in Queensland where it is currently being utilised, following its testing and validation, to assess the States' rivers on a catchment by catchment basis (Anderson, 1993a,b,c; Phillips and Moller, 1995).

Other existing studies and approaches to measuring stream condition that were reviewed and considered for possible implementation included:

- An Index of Stream Condition (ISC) – Development of an Index of Stream Condition, Reference Manual, User's Manual and Trial Applications (CEAH & ID&A Pty Ltd, 1995 & 1997; ID&A Pty Ltd & CEAH, 1997a,b);
- Conservation Value and Status of Victorian Rivers – Part 1 Methodology and Part 2 East Gippsland Rivers (Macmillan & Kunert, 1990; Macmillan, 1990);
- The Environmental Condition of Victorian Streams (Mitchell, 1990);
- Environmental Flow Studies for the Wimmera River, Victoria – Parts A-E (Anderson & Morison, 1989a,b,c,d; Anderson *et al.*, 1989e);
- Rivers and Streams Special Investigation – Victoria (Land Conservation Council, 1989);
- Water Victoria – An Environmental Handbook (Dept of Water Resources Victoria, 1989);
- State of the Environment Report 1988 – Victoria's Inland Waters (Office of the Commissioner for the Environment, 1988); and
- Statewide Assessment of Physical Stream Conditions – Phase 1 (Ian Drummond & Associates Pty Ltd, 1985).

Of the approaches reviewed, the ISC method could have had possible application within the Northern Territory to benchmark stream condition, but because the concept was still being developed in 1995 and had not been trialed, the ISC method was not considered appropriate for this study.

From the 'State of the Rivers' methodology (refer Anderson, 1993b,c), the 'Top End Waterways Project' adapted the sampling strategy, survey methods and data collection sheets for use in assessing the condition of rivers in the Katherine Region. Following the collection, preliminary analysis and presentation of the data for the Daly River catchment, the condition and stability ratings developed by Anderson (1993b,c) were modified or completely altered by a NT Technical Working Group. The alterations to the condition and stability ratings were thought necessary so that results would reflect Northern Territory (ie wet/dry tropical) conditions more closely. Sections 3.4, 3.5 and 3.6 discuss in more detail the sampling strategy, survey components and the condition and stability ratings, respectively.

The 'State of the Rivers' method adopted a "snapshot" survey approach with the aim of comparing different stream sections within a catchment in terms of their current physical and ecological condition, and assessing the extent to which that condition has deteriorated from a "pristine" condition. The 'Top End Waterways Project' seeks to establish the condition of the streams at the time of the survey relative to a benchmark. The benchmark used is an "ideal" undisturbed or natural state that has been defined by the NT Technical Working Group as well as from a preliminary analysis of the Daly River catchment data.

The snapshot highlights the most severe and urgent problems and also sets a baseline or benchmark against which future trends and the rate of change can be assessed. It does not directly measure the rate of change or trend but relies on comparisons between the condition at the time of the survey and after follow-up surveys.

3.2 Scope and Limitations

The methodology is a snapshot of stream condition in whole catchments or sub-catchments at one point in time and does not allow for close examination of particular areas or reaches. This is principally due to the lack of survey sites at that scale and the likelihood that survey sites are put in areas of easier access.

The method is not intended to provide all the information that managers may require about stream condition when planning management programs. It will help to identify key issues, problems and priorities and also help to broadly recognise what processes are causing river degradation. It will also help to identify where more detailed investigations are needed. Consequently, it is an important management tool but it should be only one source of information on which to base decision making processes.

The 'State of the Rivers' survey is focussed on collecting physical and ecological information on instream and riparian habitats (ie the river itself, the banks and the channel). The survey does not include lakes and wetlands (eg billabongs, swamps and oxbows) unless they occur along defined stream channels. The ecological condition assessment is based on assessing the condition of the instream aquatic and riparian habitats and the vegetation structure, rather than conducting flora and fauna surveys or assessing community structure or integrity. The abundance and type of aquatic life (eg macroinvertebrates, fish, *etc*) or other fauna using the riparian zone has not been assessed. The 'Top End Waterways Project' has incorporated a vegetation survey component to more adequately describe the riparian vegetation.

Stream flow measurements are not an obligatory part of the methods even though one-off measurements were taken where possible throughout the catchment. To overcome this lack of information, the 'Top End Waterways Project' has summarised the stream flow information that exits for gauge stations within the Daly River catchment (refer Sections 2.6.1 and 4.10). The extent of changes to hydrology is not an inherent part of the methods. This would involve taking into account any change in volume and seasonality of flows from natural conditions; and changes to the balance and close interaction between ground and surface water, which is particularly important during the dry season when groundwater maintains baseflows in many rivers and creeks. The influence of artificial barriers on the hydrology of streams is also not assessed.

Water quality measurements are also not an obligatory part of the 'State of the Rivers' methods. It was felt that rather than carry out one-off water quality sampling as part of the 'Top End Waterways Project', it would prove more useful to summarise longer term water quality information that currently existed for the Daly River catchment (refer Sections 2.6.3 and 4.11). Temporal variability in water quality (eg seasonal changes, influence of groundwater particularly during the dry season) was not assessed.

The survey includes estuaries. Their inclusion was important for completeness, but the survey methodology was primarily designed for the non-estuarine sections of rivers and streams, and so certain additions were made to the 'State of the Rivers' methodology to allow for estuaries to be included, rather than specifically designing estuarine survey techniques.

Linkages to other projects and initiatives that address other issues relating to rivers is important to aid overall river management decision-making processes. The 'Top End Waterways Project' has established links with, for example, the Ausrivas project and riparian vegetation assessments by overlapping survey sites with those projects in order to allow possible correlations to be drawn between these studies. Linkages to long term water flow and quality databases (eg Hydsys), development of environmental flows guidelines, vegetation databases, Wild Rivers assessments would also prove useful.

3.3 Follow-up Surveys

The 'State of the Rivers' survey methods were designed for use as a baseline or benchmark against which future trends (ie rate of change in condition) can be established through follow-up replicate surveys (Anderson, 1993a). The method allows for future partial or complete follow-up surveys to not only assess the rate of change but to try and assess the effectiveness of remedial measures. This has been achieved by adopting a standard methodology that can be repeated at a later date. Photographs, access notes, sketches and a GPS recording for each site will enable survey sites to be re-located for future surveys.

In order to monitor the rate of change in river condition as has been benchmarked by the 'Top End Waterways Project', or to look at management induced improvements or areas where management practices/land uses have changed or intensified, there will need to be follow-up surveys. It is recommended that a suitable strategy and schedule for ongoing site surveys, including what raw data should be re-collected, be designed and implemented by Department of Lands, Planning and Environment who are the custodians of the data and the project. It is envisaged that selected priority sub-sections (or preferably sub-catchments) be targeted if whole catchments cannot be re-surveyed. Long time periods (5 years or more) are generally required before changes in indicators like river channel physical form (eg river bank and bed stability) and the streamside zone (eg assessment of riparian vegetation and reach environs) can be measured.

The best time for conducting surveys is during the dry season. This avoids problems with bad weather and access problems, but it is also more practical for many aspects of the survey that are best done when water levels are not elevated and water clarity is highest.

3.4 Sampling Strategy

A stratified sampling approach is the basis of classifying the current physical and ecological condition of the streams, as described in the Qld 'State of the Rivers' methodology (Anderson, 1993a,b,c; Phillips and Moller, 1995). The catchment being studied is divided into "homogeneous stream sections" which represent stream sections that share similar natural features and conditions.

The delineation of the "homogeneous stream sections" involved a progressive division of the catchment into smaller and smaller units. Initially, the Daly River catchment was divided into 16 major sub-catchments (shown in Map 6). These represent the major tributaries within the Daly River catchment.

The major tributaries were further sub-divided into 33 sub-sections (shown in Map 7). Planning of these sub-section boundaries was done using 1:250,000 topographic map sheets initially and finalised using 1:50,000 sheets, along with a combination of aerial photography/landsat imagery, where available. A brief reconnoitre trip was also carried out in April 1995 for three days to investigate areas and access.

Sub-section boundaries were established at major tributary junctions. The tributaries were further sub-divided according to attributes including geology, stream gradient, altitude, natural and artificial barriers (such as weirs, waterfalls, gorge systems), bed and bank substrates, stream order, landuse and the tidal limit.

The number of sub-sections delineated for this project was substantially less than selected for Qld 'State of the Rivers' projects to date. The reasons for this include: variation in altitude does not exist within the Daly River catchment as compared to the river catchments being studied in Queensland (ie all of the Daly River catchment is less than 460m); there are very few artificial barriers, like weirs, on rivers; the rivers are not impounded by dams; the catchments are far less developed; access is far more difficult and time consuming; the resources available (ie time, staff) to sample a large number of sub-sections is not available.

It was the aim of this project methodology to select a number of sites within each sub-section to represent the range and extent of stream types and conditions, including a range of stream orders.

Section 2.7.5 outlines the Strahler system of assigning stream orders. Map 8 shows the 7 stream orders for the Daly River catchment, based on the Strahler system and on a 1:250,000 map scale. The Daly River and lower Katherine River recorded the largest stream order of 7, on which 31 sites were sampled along an approximate stream length of 362km. Map 8 also shows the approximate stream length and number of sites sampled for each stream order. Fewer sites were recorded from the minor stream orders (1 and 2), even though they made up a large proportion of the stream lengths. It was generally felt that due to the constraints on the number of sites that could be sampled, a greater focus should be placed on the medium and larger-sized rivers and creeks.

Aerial photography/landsat imagery, where possible, and 1:250,000 topographic map sheets were used to select sites within each sub-section. Access for both vehicles and boats are a major determinant of the precise location of the sites. If a structure existed within the river (eg a low level crossing or bridge), the site would be selected upstream of it where possible so as to avoid any influence/ interference it may be causing.

A total of 131 sites were sampled throughout the Daly River Catchment (refer Map 9). Of these sites, 109 were full survey sites. The remaining 21 'photo sites' were visited in order to gain a greater understanding of the range and extent of stream types throughout the catchment. On average, 1-2 sites were sampled per day by a team of two people (ie 131 sites sampled over 96 days).

The Qld 'State of the Rivers' methodology was designed as a rapid survey where 8-10 sites could be surveyed per day. The considerably fewer number of sites sampled per day, as well as throughout the Daly River catchment, reflects the difficult access, particularly in remote areas; the greater distance between sites; the requirement to use boats to undertake surveys because of the presence of crocodiles; the collection of additional information (eg longitudinal profile and vegetation surveys, water flow, etc); and the limited resources available (staff, timeframe, *etc*).

To allow for the fewer number of sub-sections that were delineated for the Daly River catchment and the fewer number of sites that were surveyed, the condition and stability rating results for each site have been shown individually rather than as a

result for the entire sub-section. It was felt that although a site provides an indication of the condition of the stream along a particular reach, from this a general interpolation of the results or trends can be made regarding the condition of the stream length between sites within a sub-section.

3.5 Survey Components

At each full survey site, the boundary for the survey (ie the 'reach') was chosen in the field. The reach was generally representative of the channel habitat types, instream physical and ecological condition. Each reach usually consisted of at least two complete pools and riffle/run habitats.

Assessments are made on data sheets that are set up to describe the stream, banks and environs. The components of the field surveys are summarised below. Refer to Appendix B for a summary of the data sheet information. Those survey components that have been modified from the 'State of the Rivers' method or are new additions are highlighted in Appendix B.

- *Site Description*

Information relating to the survey (such as date, recorders, site number, tributary name, type of site, whether or not tidal) are recorded. A location description for each site, including an access sketch, is provided so that the site, and each sample point where a cross-section survey has been done, can be relocated for follow-up surveys. A GPS is used to provide a grid reference for the site and each sample point.

A standard set of colour slides is taken at each site including upstream and downstream views, at each bank, along the reach environs and at other key features. These slides are numbered sequentially and are accompanied by an associated description.

- *Reach Environs and Site Features*

Reach environs are those lands immediately adjacent to the riparian zone along the reach and include the floodplain and valley flat. Local information is recorded about these lands including land use, local disturbance, land tenure, local vegetation/habitat type and floodplain features. This information is important for classification purposes and for identifying processes and potential causes of changes in condition in the stream. A subjective overall disturbance rating, based on the extent of clearing, and replacement of vegetation by exotic species in the riparian zone and adjacent land, is also recorded.

The water levels at the time of sampling is also recorded along with the local channel pattern (eg regular meanders, braided channel, *etc*).

- *Channel Habitat Types, Diversity and Dimensions*

The segments of the reach were categorised into the following channel habitat types: waterfall, cascade, rapid, riffle, glide, run, pool or backwater. The average reach length surveyed was recorded (ie average for study was 824m; range 17.5m to 5,000m). The pool chosen was usually the largest and deepest in the area. Longitudinal profile surveys, that is depth measurements along the streams' 'thalweg', assisted with determining the location of the four habitat types that would make up the reach (ie at least two complete pools and riffle/run habitats).

The length, percentage of the reach covered, depth and width of each channel habitat type present, along with a sketch, was recorded. This information allows for an assessment to be made of the diversity of habitat types present in the area, which is important ecologically. Two sample points were usually selected, one at a pool habitat and one at a shallow habitat-type like a riffle, run or rapid.

A cross-section survey was done across each sample point/habitat type at right angles to the bank. The survey was aimed to pass over the point of maximum depth and minimum flow in a pool section and maximum flow and minimum depth in a riffle/run habitat. The extremes were chosen in order to establish the range of substrates, depths and channel parameters within the reach.

The cross-section surveys also took into account the width, height and slope of the lower and upper bank on each side of the stream to the high bank. The slope and shape of the banks along the reach were also ranked. Up to three flow measurements were undertaken at some cross-sections.

A depth sounder and boat were used to measure cross-section depths and widths where water was present and boat access was available. The depth measurements made are dependent on the prevailing discharge at the time of the survey but are also referenced to the 'water mark'. If the river or creek bed was dry, or isolated pools were present, a tape measure and measuring pole were used to measure the depths and widths in relation to the 'water mark'.

The concept of a 'water mark' is used to provide a reference point for standardising the channel measurements and for defining the boundary between the lower and upper banks (refer to Glossary).

Cross-sections provide a basic picture of the channel size, shape and form. They also provide baseline information for follow-up surveys when changes in channel dimensions may be detected. The cross-sections have been presented diagrammatically in Part 2 of this report.

Boat and sediment grab equipment

Measuring bed sediments

- *Bank Condition and Stability*

The assessment of the banks is made in terms of the percentage of the bank length, for both lower and upper banks, that is recorded as being stable or unstable (eroding or aggrading). That is, the dominant process at the time of sampling is recorded. The location of the instability (for example at bends, obstacles, irregularly, *etc*) and the local factors affecting stability are also assessed to help to identify the processes involved. Overall subjective ratings of the condition of the bank stability is also made. The presence of artificial bank protection measures, such as tree planting and fencing off of river banks, is recorded.

- *Bed and Bar Condition and Stability*

The type of bar and its relative percentage of the total surface area of the bed, above water mark, is assessed. Overall subjective ratings of the stability of the bed and what is the dominant process at the time of sampling (ie whether stable, aggrading or eroding) is also made. Local factors affecting stability is assessed. Features relating to the gravel angularity and shape, bed compaction and the type of controls (eg rock outcrops, culverts, *etc*) stabilising the bed are also recorded.

- *Bed and Bank Sediments*

At the time of undertaking the cross-section surveys, the sediment composition of the bed, from three samples, and the lower and upper banks was also recorded. A grab-type sediment sampler was used to sample bed sediments. The contribution made by each sediment size class (ie fines, sands, gravels, cobbles, boulder and rocks), expressed as a percentage of the total volume, was determined by visual inspection. The sediment size classes are those of the Standards Association of Australia. From this data the mean size of the sediment has been determined for each of the major channel types.

Different bed sediment size classes

Stream invertebrate distribution and abundance is very much influenced by the type of substrate present and the relationship between flows, depths and substrates.

- *Riparian Vegetation*

Riparian vegetation was assessed in terms of percentage cover for the various structural groups: trees >30m, 10-30m, 2-10m; regenerating trees <2m; woody shrubs <2m; vines; rushes/sedges; phragmites; herbs; grasses; ferns; mangroves; and palms. The covers for native versus exotic species, within each structural category, are recorded separately. The total percentage cover of exotic species within the riparian zone for each bank is also assessed. The width of the riparian zone for each bank is recorded and is measured from 'water mark' to the edge of the distinct band of riparian vegetation.

The percentage of the lower and upper bank length that was bare of vegetation cover, separated into overstorey versus understorey cover, was also assessed. The overstorey comprised trees and shrubs (>1.3m tall) whereas the understorey included the remaining ground covers.

This project also undertook vegetation surveys or compiled vegetation lists of the major species for each site. A vegetation profile was not completed at every site. The 10m-wide belt transect was located at right angles to the water's edge and extended to the upper bank or edge of riverine vegetation. Measurements (such as diameter at 1.3m, bole and tree height, and crown width) for each tree, greater than 1.3m tall and located within the profile, was recorded. Ground covers, such as grasses and herbs, were recorded within this vegetation profile through the use of a $1m^2$ quadrat, usually located at 5m intervals along the profile length starting at the water's edge. Percentage covers for each species type located within the quadrat was recorded. The vegetation profiles have been represented diagrammatically (refer Part 2 of the report) in order to show the zonation of, and a typical cross-section through, the riverine vegetation.

Collecting vegetation samples for identification

- *Aquatic Vegetation*

Aquatic vegetation was divided into either submerged (eg Chara/Nitella, Vallisneria, *etc*), floating (eg water lilies, *etc*) or emergent (eg Phragmites, Typha, rushes/sedges, *etc*) groups and was assessed in terms of percentage cover for the various structural types. The presence of exotic species was also recorded. Identification of the major aquatic vegetation was also undertaken as part of this study.

- *Instream and Bank Habitats*

Instream cover for organic debris (such as logs, branches, leaves and twigs), emergent and aquatic vegetation, rocks and permanent pool habitats deeper than 1m was assessed in terms of percentage cover. Bank habitat types providing cover along the stream (such as canopy cover, low vegetation, root and bank overhang) were assessed in terms of percentage of bank length and average width provided by each type.

An overall aquatic rating for all aquatic life was subjectively assessed. The rating took into account the diversity of depths and substrates, level of disturbance, diversity and extent of cover, extent of canopy and other vegetation cover, and whether or not the stream dries up. Passage for fish and other organisms at the time of the survey and when the water is at its normal level was also assessed.

- *Additional Sources of Information*

Stream flow information collected at flow gauge stations throughout the Daly River catchment, and extracted from a database system called 'Hydsys', have been used to summarise flow volumes and monthly discharges. Cross-section surveys at flow gauge stations have also been extracted from 'Hydsys'.

Water quality information collected throughout the catchment for flow gauge stations and other water quality sampling points on rivers and creeks, that have been extracted from 'Hydsys', have been used to summarise results for the following parameters: Electrical conductivity, turbidity, water temperature, pH, total alkalinity and total phosphorus. Water quality information collected at Ausrivas (Australian River Assessment Scheme) project sites, have also been summarised.

Background information on the Daly River catchment has been gained through a literature review, as well as liaising with landowners/ managers (pastoralists, aboriginal groups), councils and other government departments.

Measuring stream flow

3.6 Data Analyses and Presentation of Information

Once collected, the raw data has been entered, verified and stored in an Access Relational Database that has been designed for the 'Top End Waterways Project'. This database can be used as an ongoing management tool to store and analyse the information collected over time. This database can be directly interfaced with the GIS package 'ArcView'.

Information from stream gauging sites, water quality sampling sites and Ausrivas project sites have been included as additional reference information within this database.

Data analysis or queries have been designed to provide summaries of the data for the entire catchment as well as for each sub-section. Only those sites where information has been collected on a particular field component are included in determining percentages for that component.

The raw data recorded for each of the components at a site is used to produce a series of condition or stability ratings for each site. The ratings developed by Anderson (1993b,c) were modified or completely altered by a NT Technical Working Group so that results would reflect Northern Territory conditions more closely. Appendix C summarises the condition and stability ratings, including the formulae, used for this project. Those that have been modified or completed altered have been highlighted in Appendix C. The condition or stability ratings include:

- state of the reach environs;
- channel type diversity;
- bank stability;
- bed stability;
- cover and structural diversity of riparian vegetation;
- cover of exotic riparian vegetation;
- cover and diversity of instream and bank habitats; and
- overall condition.

The overall condition is the result of combining equally the condition and stability ratings for the reach environs, bank and bed stability, riparian and exotic vegetation, and instream and bank habitats. **The derived rating for channel type diversity is not used to produce the overall condition rating**. Maps 10-26 shows the results for the condition and stability ratings and other attributes for each site (discussed in Section 4 'Catchment Results').

Each rating category for each site is scored as a percentage or a number, with 100% or 10 representing an ideal, undisturbed or natural state and 0% or 1 being very disturbed or unstable. A summary of the overall condition and stability rating categories used are outlined in Table 3.1.

Table 3.1 Condition & Stability Rating Categories

Condition and Stability Categories	Rating (%)	Rating (out of 10)
Extreme Modification (1) Extreme Instability (2) Severe Erosion or Aggradation (3) Very Low Cover/Diversity (4) & (6) Very High Cover for Exotics (5) Very Low Overall Condition (7)	0 - 20	1 - 2
Major Modification (1) Extensive Instability (2) Low Cover/Diversity (4) & (6) High Cover for Exotics (5) Low Overall Condition (7)	21 - 40	3 - 4
Moderate Modification (1) Moderate Instability (2) Moderate Erosion or Aggradation (3) Moderate Cover/Diversity (4) & (6) Moderate Cover for Exotics (5) Moderate Overall Condition (7)	41 - 60	5 - 6
Some Modification (1) Limited Instability (2) High Cover/Diversity (4) & (6) Low Cover for Exotics (5) High Overall Condition (7)	61 - 80	7 - 8
Essentially Natural (1) Stable (2) & (3) Very High Cover/Diversity (4) & (6) Exotics Absent (5) Very High Overall Condition (7)	81 - 100	9 - 10

(1) State of the reach environs
(2) Bank stability
(3) Bed stability
(4) Cover and structural diversity of riparian vegetation
(5) Cover of exotic riparian vegetation
(6) Cover and diversity of instream and bank habitats
(7) *Overall condition*

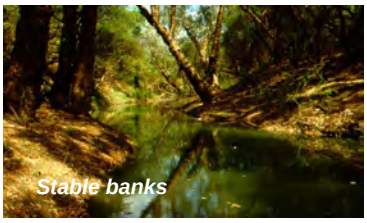
The results for each of the ratings are presented as the number or percentage of sites in each rating category. Even though this has not been directly related to the actual proportion of the river system in each of these categories, it is felt that these results provide an indication of the major condition and stability rating trends for each sub-section.

Presentation of maps have been done using ArcView GIS package. Catchment and sub-section boundaries were drawn and digitised off 1:50,000 topographic map sheets. Vegetation profiles, based on hand drawn and scanned trees, have been presented using Microstation (refer Part 2). Cross-sections have also been presented diagrammatically using Excel (refer Part 2).

Below are examples of a range of condition and stability ratings found throughout the Daly River catchment:

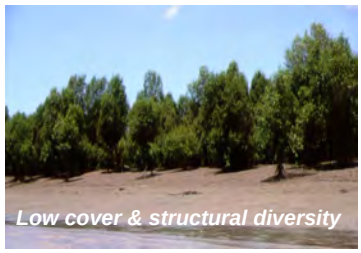
State of the reach environs:

Bank stability:



Bed stability:

Cover and structural diversity of riparian vegetation:



Cover and diversity of instream and bank habitats:

Overall condition:

4. CATCHMENT RESULTS

Maps 10-26 show the results for the condition and stability ratings and other attributes discussed in this section.

4.1 Reach Environs and Site Features

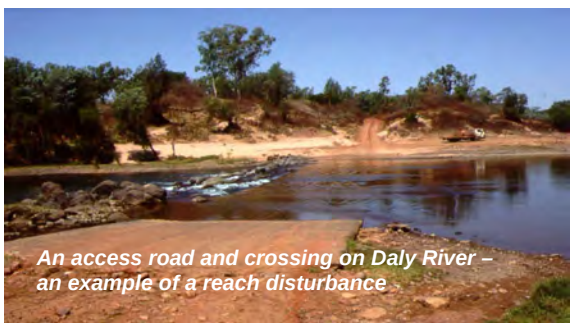
As shown on Map 10, the majority of the land adjacent to stream reaches studied was under either freehold or leasehold tenure (90% of sites). Other land tenure types included National Parks (8%), Reserves (6%) or Urban Reserves (1%).

The major land use recorded adjacent to the streams in the catchment was grazing. This consisted of grazing on thinned native pasture (70% of sites), grazing on virgin native pasture (50%) and grazing on cleared native pasture (24%). Parks or reserves occurred at 14% of sites. The dominant land uses in the catchment bordering the streams are recorded in Table 4.1.

Table 4.1 Land Use Adjacent to Reach Environs

Land Use Type	Percent of Sites (%)
Grazing - native - thinned	70
Grazing - native - virgin	50
Grazing - native - cleared	24
Park or Reserve	14
Grazing – sown pasture	11
Rural residential	6
Horticulture tree crops/fruit	3
Rainfed broadacre row crops	3
Irrigated broadacre row crops	2
Urban residential	1

The major types of disturbances likely to affect streams were recorded at each site and these are summarised in Table 4.2. The results indicate that grazing activity (recorded at 89% of sites) and roads or tracks (recorded at 52% of sites) were the two major disturbances to streams. At 3% of sites no local disturbance was recorded.



An access road and crossing on Daly River – an example of a reach disturbance

Table 4.2 Major Factors Contributing to the Disturbance of the Reach Environs

Disturbance Type	Percent of Sites (%)
Grazing	89
Road / track	52
Causeway / river crossing	34
People	19
Watering point for stock/ferals	10
Bridge / culvert	9
Boat ramp	4
Water extraction	3
Weir	3
Dredging	1
Other mine	1

Stock utilising rivers for grazing or as a watering point are major factors contributing to the disturbance of the reach environs

Subjective disturbance ratings indicated that nearly half the sites (48%) recorded a low disturbance level with respect to the reach environs (refer Table 4.3). A further 43.5% of sites were low to moderately disturbed. Few (2%) sites were highly disturbed and no sites were very highly to extremely disturbed.

Table 4.3 Disturbance Levels along Reach Environs based on Subjective Ratings

Disturbance Category	Percent of Sites (%)
Very Low	1
Very Low to Low	3
Low	48
Low to Moderate	16
Moderate	28
Moderate to High	2
High	2
Very High	0
Extreme	0

Sites recording a low disturbance rating had native vegetation present on both sides of the river with a virtually intact canopy that was in good condition and there were few introduced species. Any disturbance observed along the reach was minor.

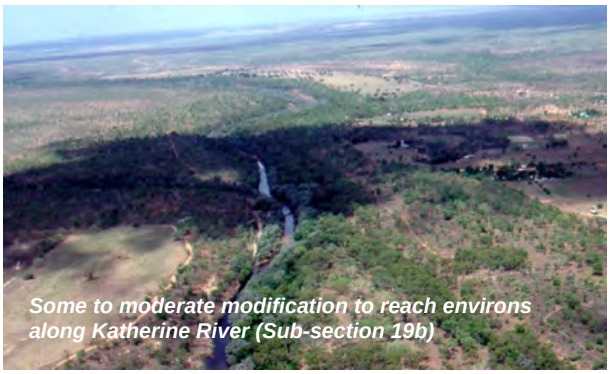
A moderate disturbance rating meant that the riparian vegetation was intact but there was clearing on the floodplain on one side of the river. Any disturbance observed along the reach was of moderate impact, including the presence of exotic species.

A summary of the state of the land corridor along the survey reach and on the floodplain adjacent to the reach (from derived ratings which take into account the land use and local disturbances) is shown in Table 4.4 and Map 11.

The results indicate that the majority of sites throughout the catchment were classified as having essentially natural reach environs (64%) or some modification to the reach environs (33%). Generally, these sites had relatively low impact land uses, undisturbed vegetation and few local disturbances. Those sites that recorded a moderate modification to the reach environs were mostly located near Katherine where land uses were more diverse and intensive.

Table 4.4 State of the Reach Environs

Reach Environs Category (Rating)	Number of Sites (%)
Extreme Modification (0-20%)	0 (0)
Major Modification (21-40%)	0 (0)
Moderate Modification (41-60%)	3 (3)
Some Modification (61-80%)	38 (33)
Essentially Natural (81-100%)	74 (64)



Some to moderate modification to reach environs along Katherine River (Sub-section 19b)

The floodplain features were recorded at each site. The major feature included billabongs/oxbows (43% of sites), prominent flood channels (32%), floodplain erosion and scouring (28%), floodplain deposits (7%) and remnant channels (1%).

4.2 Channel Habitat Types, Diversity and Dimensions

The mean reach length studied was 824m (range 17.5-5,000m). The channel habitat types recorded are listed in Table 4.5. The dominant habitat types that occurred were pools (97% of sites) and riffles (64%). Pools generally occurred in conjunction with a riffle, run or rapid (which occurred before or after a pool). Cascades and waterfalls were associated with areas of steeper topography (eg gorge systems, tufa formations). Rapids were mostly located along mid to upper sections of Daly River and along Katherine River where river gradients were steeper. Runs were mostly located along Daly, Katherine and Douglas Rivers.

Table 4.5 Channel Habitat Types

Channel Habitat Type	Number of Sites (%)
Pool	109 (97)
Run	25 (22)
Glide	3 (3)
Riffle	72 (64)
Rapid	14 (13)
Cascade	3 (3)
Waterfall	3 (3)
Backwater	0 (0)

As the majority of the surveys were conducted during the dry season, the rivers and creeks (not fed by springs) were either completely dry (21% of sites), had isolated pools or low flow (15%). The water level at sampling time at other sites was recorded as moderate but less than the normal level (15% of sites), normal at water mark (31%) or high (11%). Tidal influences (eg high tide, incoming/outgoing tides) were recorded at 7% of sites located along the tidal reaches of the Daly River.

The channel dimensions of each habitat type is shown in Table 4.6. To allow for the variation in water level at the time of survey, measurements of channel width and depth were taken at the water mark (the normal water level) and the water surface level. Only those recorded at the water mark are listed in Table 4.6 for each habitat type.

Pools dominated the reaches studied with an average of 74% of the reach covered by this habitat type. Pools had an average length of 509.4m (range 6-4,000m), an average depth of 2m (range 0.2-10.2m) and an average width of 58.2m (range 2.7-1,530m).

Table 4.6 Channel Dimensions for each Habitat Type

Channel Habitat Type	Mean Percent of Reach Covered by Habitat Type and Range (%)	Mean Length of Habitat Type and Range (m)	Mean Depth (D) or Height (H) at Water Mark and Range (m)	Mean Width at Water Mark and Range (m)
Pool	74.1 (26-100)	509.4 (6.0-4,000.0)	D 2.0 (0.2-10.2)	58.2 (2.7-1,530.0)
Run	27.4 (2-100)	150.7 (2.7-1,200.0)	D 1.4 (0.1-4.5)	32.2 (3.7-91.0)
Glide	13.8 (5-19)	8.2 (2.2-17.0)	D 0.2 (0.1-0.3)	3.6 (2.5-5.5)
Riffle	26.2 (2-74)	74.0 (3.0-600.0)	D 0.5 (0.1-2.4)	19.0 (2.0-74.0)
Rapid	20.3 (6-67)	163.5 (25.0-550.0)	D 0.5 (0.2-1.7)	27.5 (0.3-52.0)
Cascade	40.7 (5-100)	39.7 (4.0-100.0)	H 0.4 (0.2-0.6)	25.7 (2.0-39.0)
Waterfall	9.0 (4-17)	13.3 (10.0-15.0)	H 1.5 (1.2-1.8)	41.0 (2.0-80.0)


Pool habitat on Daly River

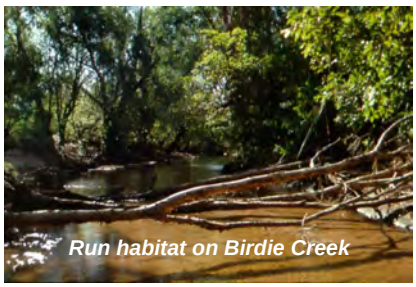

Dry riffle habitat on Bradshaw Ck


Rapids along Katherine Gorge


Isolated pool habitat on Scott Ck


Small riffle on Fergusson River


Cascade habitat on Flora River


Run habitat on Birdie Creek


Riffle habitat on Daly River


Cascade on upper Daly River


Glide habitat on Hayes Creek


Rapid habitat on Daly River


Waterfall on Flora River

The average upper bank dimensions for each channel habitat type are shown in Table 4.7. The upper bank, for all habitat types, had an average width of 18.2m, an average height of 6.6m and an average slope of 25.2^{o} (range 1.5-83.7^{o}). The lower bank (ie below water mark), for all habitat types, had an average width of 1.5m (range 0.1-18m); an average height of 0.6m (range 0.1-5.5m); and an average slope of 41.1^{o} (range 1.9-78.7^{o}).

Table 4.7 Upper Bank Dimensions for each Habitat Type

Channel Habitat Type	Upper Bank Mean Width and Range (m)	Upper Bank Mean Height and Range (m)
Pool	14.7 (0.4-160.0)	6.5 (0.3-50.0)
Run	19.0 (1.0-67.0)	8.3 (0.8-37.0)
Glide	5.4 (0.5-13.0)	2.4 (1.8-3.0)
Riffle	19.9 (0.4-155.0)	5.7 (0.2-50.1)
Rapid	37.0 (6.0-88.0)	8.9 (1.1-25.0)
Cascade	47.8 (15.0-116.0)	4.4 (3.5-5.5)
Waterfall	22.9 (10.0-42.5)	21.1 (2.0-40.0)
Overall Mean - All Habitats	18.2 (0.4-160.0)	6.6 (0.2-50.1)

The major bank slope recorded was moderate (30-60^{o}). The remainder of slopes recorded included low (10-30^{o}), steep (60-80^{o}), vertical (80-90^{o}) and flat (<10^{o}).

The major bank shape recorded was either convex or concave. Other bank shapes recorded included a wide lower bench, stepped, cliff and undercut.

The dimensions for most habitat types varied considerably throughout the catchment and are discussed in detail within each sub-catchment section of this report (refer Section 5). Cross-section surveys for each site (transects across each habitat type at a sample point) are shown in Part 2 of this report. The location of longitudinal profile surveys (depth measurements along rivers and creeks) are also shown in Part 2.

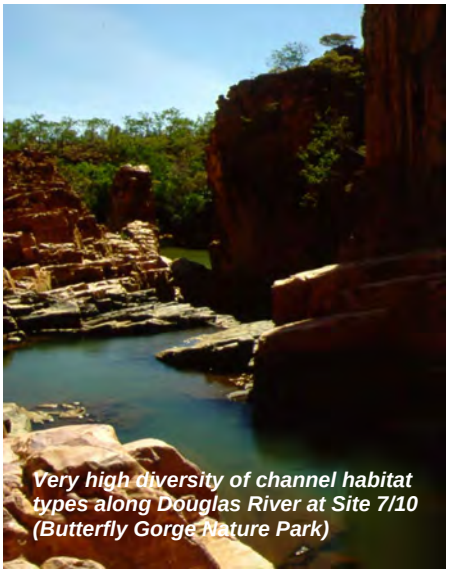
When the sites were assessed for their variability or diversity of channel habitat types, the majority (72%) of sites recorded a high diversity (refer Table 4.8 and Map 12). The diversity categories take into account the number of different channel habitat types present as well as the proportion of the reach occupied by pools versus other habitat types (ie riffles, rapids, runs, glides, cascades and waterfalls).

Table 4.8 Channel Type Diversity

Diversity Category (Rating)	Number of Sites (%)
Very Low Diversity (1-2)	2 (2)
Low Diversity (3-4)	7 (6)
Moderate Diversity (5-6)	16 (14)
High Diversity (7-8)	81 (72)
Very High Diversity (9-10)	6 (6)

Even though the site reaches were generally dominated by two channel habitat types (79% of sites), with only 13% of sites recording more than two habitat types present, the proportion of the reach occupied by pools versus other habitat types rated more highly. That is, 37% of sites recorded 10-30% of the reach being occupied by habitat types other than pools and 40% of sites recorded >30% of the reach being occupied by non-pool habitat types. When these two factors were combined to give an overall channel type diversity, the sites rated more highly.

Those streams recording reaches with a very high diversity of channel habitat types were Douglas River (2 sites), Daly River (1), Flora River (1), Fergusson River (1) and Hayes Creek (1). Low channel type diversity ratings were recorded for: sections of the Daly River estuary where pool habitats were very uniform; along other sections (ie Daly River upstream of Douglas River junction) where pools were very long and dominated the reach extensively; and where only one habitat type was recorded (ie a section of Katherine and Edith Rivers). Other sections recording very low diversity ratings were located on Birdie Creek and a tributary of Stray Creek where only one habitat type was noted and there was little or no variation in depths.



Very high diversity of channel habitat types along Douglas River at Site 7/10 (Butterfly Gorge Nature Park)

4.3 Bank Condition and Stability

A summary of the stability of river banks throughout the catchment, based on derived ratings, is shown in Table 4.9 and Map 13. Most sites had banks that were stable (87%) or had limited instability (11%). No river banks were suffering from extensive or extreme instability. However, some form of erosion processes along the river banks was recorded at 99% of sites.

Table 4.9 Bank Stability Ratings

Stability Category (Rating)	Number of Sites (%)
Extreme Instability (0-20%)	0 (0)
Extensive Instability (21-40%)	0 (0)
Moderate Instability (41-60%)	2 (2)
Limited Instability (61-80%)	12 (11)
Stable (81-100%)	95 (87)
Dominant Process Recorded	
Aggradation	1 (1)
Erosion	108 (99)

A subjective assessment of the stability of the banks indicated that most (84%) sites recorded minimal to low overall bank instability (refer Table 4.10). Whereas, 49% of sites had low-moderate to moderate bank instability, and few (6%) sites recorded a moderate to high overall bank instability. Similar percentages were recorded for the susceptibility of banks to erosion.

Table 4.10 Overall Bank Condition based on Subjective Ratings

Bank Stability Category	Percent of Sites (%)	
	Overall Instability	Susceptibility to Erosion
Minimal	7	6
Minimal to Low	9	6
Low	68	68
Low to Moderate	24	28
Moderate	25	22
Moderate to High	6	6
High	0	0

The location of instabilities along the banks, both lower and upper, is summarised in Table 4.11. As previously stated, erosion was the dominant process affecting bank stability throughout the catchment. Bank erosion was recorded mostly at obstacles and outside bends. Other locations where bank erosion occurred were at floodplain scours, irregularly or at seepage and runoff points. Aggradation occurred predominantly along inside bends and at obstacles.

Table 4.11 Location of Instability along Banks

Location of Instability	Percent of Sites (%)	
	Erosion	Aggradation
Bends - Outside	64	5
- Inside	0	17
Floodplain Scours	44	5
Obstacles	82	13
Seepage / Runoff Points	28	0
Irregular	31	7
All Along	3	4

Factors affecting bank stability are listed in Table 4.12. The instability recorded at survey sites was attributed predominantly to high flow, stock, infrastructure (ie roads, tracks, river crossings, bridges, *etc*), floodplain scours/breakouts and runoff.

Table 4.12 Factors Affecting Bank Stability

Factor	Percent of Sites (%)
High Flow	75
Stock	69
Roads, Crossings, Bridges	40
Floodplain Scours/Breakouts	36
Runoff	27
People Tracks	17
Vermin	16
Clearing of Vegetation	7
Tidal Influence	7
Seepage	6
Wash from Boats	2
Mining	2
Other	1

Lower banks were more stable than upper banks (Table 4.13). The average percent of the bank recorded as being stable was 91% for the lower bank and 87% for the upper bank. A large number of sites (75%) recorded ≥90% of the lower banks as being stable, compared to 59% of sites having upper banks ≥90% stable. The average percent of erosion occurring along the upper bank was 12%, though this varied from 0% to as high as 85%.

Table 4.13 Stability of Lower Banks Compared to Upper Banks

Stability Comparisons	Bank Location	
	Lower Bank	Upper Bank
Percent Sites (%) where:		
≥90% Stable	75	59
≥50% Stable	100	99
≥50% Eroding	1	2
≥50% Aggrading	<1	<1
Mean Percent Stable and Range (%)	91 (15-100)	87 (15-98)
Mean Percent Eroding and Range (%)	9 (0-85)	12 (0-85)
Mean Percent Aggrading and Range (%)	1 (0-60)	2 (0-50)

The only type of artificial bank protection measures recorded for all survey sites was fencing (along the river and/or at stock watering points). This type of bank protection was only recorded at 2% of sites.

Erosion due to an access track and crossing along King River (Site 21b/1)

Moderate bank instability on Aroona Creek (Site 18/5)

4.4 Bed and Bar Condition and Stability

A summary of the overall bed stability throughout the catchment, based on a subjective assessment made in the field of whether the river bed is stable, moderately eroding or aggrading, or severely eroding or aggrading, is shown in Table 4.14 and Map 14. The majority (65%) of sites had stable river beds. Few (6%) sites recorded moderate bed erosion, whereas, 29% of sites recorded moderate bed aggradation. No sites had beds that were severely eroding or aggrading.

The majority of sites recording moderate bed aggradation were located within the Daly River (10 sites), Fergusson River (7), Katherine River (5), Stray Creek (3) and Chilling Creek (2) sub-catchments.

Table 4.14 Overall Bed Stability Ratings

Stability Category (Rating)	Number of Sites (%)
Severe Erosion or Aggradation (2)	0 (0)
Moderate Erosion or Aggradation (6)	39 (35)
Stable (10)	71 (65)
Dominant Process Recorded	
Aggradation	32 (29)
Erosion	7 (6)
No process (bed stable)	71 (65)

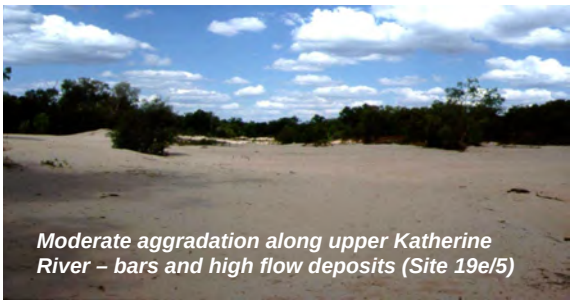
Bars were recorded at 83% of sites. At sites which recorded a bar, 46% of bar types were point bars (refer Table 4.15). The total percentage of bed surface along the reach protruding out of the water at water mark and forming a bar was also recorded. The mean size of these bars was 16% of the bed, ranging to as high as 70%.

Table 4.15 Bar Types Recorded

Bar Type	Percent of Sites (%)	Percent of Bar Types (%)
Point	38	46
Encroaching Vegetation	22	26
High Flow Deposits	21	25
Mid-channel Island	19	23
Alternate / Side Irregular	17	21
Channel Bar Plain	5	7
Around Obstacles	2	2

Gravel features recorded for the bed and bars showed that the gravel was mostly covered by algae or silt (81% of sites); and was composed of sub angular (63% of sites), rounded (33%) or angular (22%) material. The major shapes recorded for the gravel was spherical (58% of sites) or disc-shaped (51%). The bed compaction ranged from low (46% of sites), moderate (33%), packed but not armoured (25%), tightly packed and armoured (16%) or very low compaction (12%). Generally, those sites that had bar material that was armoured or well packed indicate that they would be only slightly mobile in times of moderate flow.

Moderate bed aggradation along Daly River - instream and point bars (reach at Site 1c/10)



Moderate aggradation along upper Katherine River – bars and high flow deposits (Site 19e/5)

The major factor that was considered to affect bed stability was agriculture or grazing (40% of sites). Other processes affecting bed condition are listed in Table 4.16. No factors were found to be affecting bed stability at 31% of sites.

Table 4.16 Factors Affecting Bed Stability

Factor	Percent of Sites (%)
Agriculture or Grazing	40
Instream Siltation	21
Bank Erosion	12
Channelisation / concentration of flows	5
Bed deepening / lowering	3

The major controls stabilising the bed were rock outcrops (60% of sites) and fallen trees (29%). No bed stabilising controls were recorded for 19% of sites.

4.5 Bed and Bank Sediments

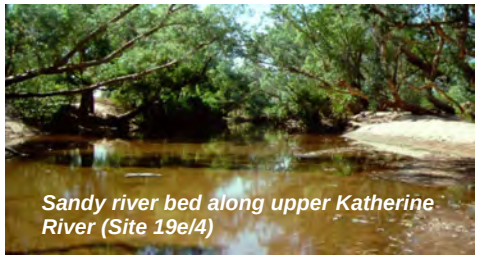
Table 4.17 shows the mean bed and bank sediment sizes recorded for all habitat types across the study area. From these results it can be noted that a range of size classes, from clays to boulders, was recorded for beds. Lower and upper banks consisted mainly of clays and small sand. Organic material was present in both bed and bank material ranging from 11-21%.

Table 4.17 Bed and Bank Sediments Recorded for all Habitat Types

Sediment Size Classes	Mean Composition of Sediment Types (%)		
	Bed	Lower Bank	Upper Bank
Fines / Clays (<0.06mm)	19	48	52
Small Sand (0.06-0.5mm)	19	28	34
Large Sand (0.5-2mm)	17	7	5
Small Gravel (2-5mm)	11	4	1
Medium Gravel (5-20mm)	4	2	<1
Large Gravel (20-60mm)	6	1	<1
Cobbles (60-300mm)	10	2	2
Boulders (>300mm)	14	8	5
Organic Material	21	15	11

Tables 4.18, 4.19 and 4.20 show the sediment sizes recorded for beds, lower banks and upper banks, respectively, for each habitat type. The data shows that pool, run and glide habitats have a higher proportion of smaller bed sediments; riffles have a range of bed sediment sizes; rapids have a higher proportion of larger bed sediments; and cascades and waterfalls have boulder beds. The sediments along the lower and upper banks for all habitat types consisted mainly of smaller sediment sizes, except waterfall habitats, which had a higher proportion of boulders.

Rock outcrops were recorded at 70 survey sites (64% of sites). At sites that recorded rock outcrops, 93% were located in the bed, 51-53% were located along the left and right lower banks respectively, and 41% along either the right or left upper banks.



Sandy river bed along upper Katherine River (Site 19e/4)

Table 4.18 Bed Sediments Recorded for Each Habitat Type

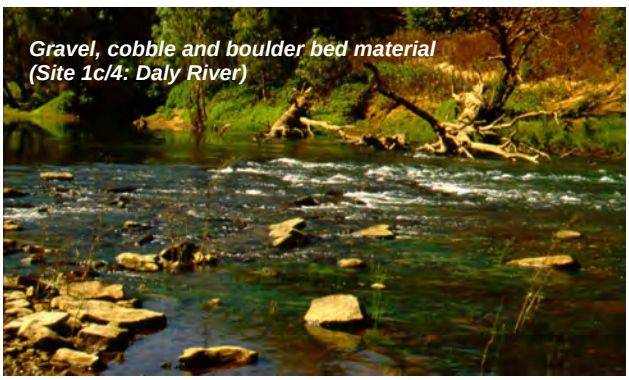
Sediment Size Classes		Mean Composition of Sediment Types for Beds (%)						
		Pool	Run	Glide	Riffle	Rapid	Cascade	Waterfall
Fines / Clays	(<0.06mm)	27	35	20	7	1	0	0
Small Sand	(0.06-0.5mm)	24	21	23	13	8	0	0
Large Sand	(0.5-2mm)	20	24	20	16	4	0	0
Small Gravel	(2-5mm)	11	9	10	12	5	0	0
Medium Gravel	(5-20mm)	3	2	7	7	3	0	0
Large Gravel	(20-60mm)	3	3	8	9	12	0	0
Cobbles	(60-300mm)	5	4	2	19	16	0	0
Boulders	(>300mm)	7	2	10	17	51	100	100

Table 4.19 Lower Bank Sediments Recorded for Each Habitat Type

Sediment Size Classes		Mean Composition of Sediment Types for Lower Banks (%)						
		Pool	Run	Glide	Riffle	Rapid	Cascade	Waterfall
Fines / Clays	(<0.06mm)	58	66	38	33	26	57	0
Small Sand	(0.06-0.5mm)	28	20	26	30	32	10	0
Large Sand	(0.5-2mm)	6	6	11	9	6	0	0
Small Gravel	(2-5mm)	2	2	12	6	5	0	0
Medium Gravel	(5-20mm)	1	<1	9	3	3	0	0
Large Gravel	(20-60mm)	<1	<1	4	3	5	0	0
Cobbles	(60-300mm)	<1	0	0	6	5	0	0
Boulders	(>300mm)	4	5	0	10	18	33	100

Table 4.20 Upper Bank Sediments Recorded for Each Habitat Type

Sediment Size Classes		Mean Composition of Sediment Types for Upper Banks (%)						
		Pool	Run	Glide	Riffle	Rapid	Cascade	Waterfall
Fines / Clays	(<0.06mm)	57	64	71	44	23	72	41
Small Sand	(0.06-0.5mm)	35	24	20	36	30	27	3
Large Sand	(0.5-2mm)	3	5	5	7	9	<1	2
Small Gravel	(2-5mm)	1	1	2	2	3	0	2
Medium Gravel	(5-20mm)	1	<1	2	1	2	0	2
Large Gravel	(20-60mm)	<1	0	0	1	5	0	0
Cobbles	(60-300mm)	<1	0	0	3	8	0	0
Boulders	(>300mm)	2	5	0	6	20	0	50



Gravel, cobble and boulder bed material (Site 1c/4: Daly River)

Boulder bed material on Fergusson River (above Site 13b/3)

4.6 Riparian Vegetation

Most sites (87%) had vegetation that was associated with freshwater streams. That is, these channels form corridors lined with a narrow belt of characteristic vegetation typified by *Melaleuca* and *Pandanus* species (Brock, 1993). This distinct corridor of vegetation along the edge of a stream or river is called the 'riparian zone'. This zone is inextricably linked with the stream both in providing litter, from leaves and branches, to the stream and being affected by the extra moisture that is available. Other vegetation types recorded included lowland monsoon vine-forest (7% of sites) and mangroves (3%).

A summary of the cover and structural diversity of riparian vegetation throughout the catchment is shown in Table 4.21 and Map 15. The ratings take into account the foliage cover or density provided by the overstorey, understorey and ground cover vegetation types or growth forms and the structural diversity or number of different growth forms present. A large proportion of the riparian vegetation was rated as having moderate cover and diversity (65% of sites), with a further 34% being rated has having high cover and diversity.

Table 4.21 Cover and Structural Diversity of Riparian Vegetation

Riparian Vegetation Category (Rating)	Number of Sites (%)
Very Low Cover/Diversity (1-2)	0 (0)
Low Cover/Diversity (3-4)	1 (1)
Moderate Cover/Diversity (5-6)	72 (65)
High Cover/Diversity (7-8)	37 (34)
Very High Cover/Diversity (9-10)	0 (0)

High cover and structural diversity rating for riparian vegetation (Site 1c/1: Daly River)

The average width of the riparian zone was 22m (range 1.5-155m). This width is similar to the mean width of the upper bank (18.2m, range 0.4-160m) and emphasises the importance of the upper bank as a 'refuge area' for riparian vegetation. Eleven (11%) of sites had a riparian zone width of <5m; 29% were between 5-10m; 29% between 11-20m; 32% between 21-40m; and 24% of sites had a riparian zone width of >40m. Map 16 shows the riparian vegetation width category for each site. Those sites that recorded a riparian zone width of >31m were mostly located on the Daly River and, to a lesser extent, the Katherine and lower sections of the Douglas, Flora and Fergusson Rivers.

The structural types recorded for the vegetation in the riparian zone, including both native and exotic species, are shown in Table 4.22. Grasses were present at all sites. Forbs, woody shrubs, regenerating trees, trees (2-30m) and vines were very prevalent and were present at >90% of the sites. Rushes and sedges (present at 43% of sites), phragmites (22%), ferns (17%) and trees taller than 30m (9%) were not as prevalent throughout the study area.

Table 4.22 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	9	0.3 (0-5)
Trees (10-30m)*	97	26.5 (0-75)
Trees (2-10m)*	99	21.4 (0-50)
Regen. Trees (<2m)*	99	6.3 (0-30)
Woody Shrubs (<2m)*	97	6.1 (0-30)
Vines	93	6.5 (0-25)
Rushes and Sedges*	43	1.9 (0-15)
Phragmites*	22	1.0 (0-12)
Forbs (or Herbs)*	99	8.1 (0-35)
Grasses*	100	22.9 (0-75)
Ferns*	17	0.8 (0-10)
Mangroves*	3	0.8 (0-40)
Salt Marsh	0	0
Palms	4	0.2 (0-8)

* Can be included as riparian and emergent aquatic vegetation

Assessment is also made in terms of the percentage cover of the surface area for each structural type (refer Table 4.22). Trees, within the category of 2-30m tall, and grasses provided a higher percentage of cover within the riparian zone than the other structural categories, totaling 48% and 23% covers respectively.

The percentage of the lower and upper bank length that was bare of vegetation cover was assessed. The overstorey (that is, trees and shrubs greater than 1.3m tall) provided a greater cover than the understorey (or ground cover) vegetation. The lower bank recorded an average of 92% bare (range 27-100%) for understorey vegetation cover and 86% bare (range 20-100%) for the overstorey. The upper bank, on the other hand, recorded an average of 71% bare (range 20-98%) for understorey vegetation cover and 54% bare (range 5-87%) for the overstorey.

Riparian vegetation dominated by grasses (Site 21b/1: King River)

Map 17 shows the cover of exotic riparian vegetation throughout the catchment as well as the number of different types of exotic species recorded at a site, if present. The rating takes into account the degree of invasion or percentage cover recorded for exotic species within the riparian zone. Exotic vegetation species were recorded at over three-quarters of the sites (refer Table 4.23). Nearly half (47%) the sites recorded relatively low covers for exotic riparian vegetation (between 1-5%), whereas 35% of sites recorded >5% and up to 32% cover for exotic riparian vegetation.

Table 4.23 Cover of Exotic Riparian Vegetation

% Cover Category (Rating)	**Number of Sites (%)
16 - 32* (2)	11 (10)
11 - 15 (4)	10 (9)
6 - 10 (6)	17 (16)
1 - 5 (8)	52 (47)
0 (10)	20 (18)

* The maximum % cover recorded for exotic riparian vegetation was 32%.

** If all sites where the dominant riparian vegetation was noted, but no covers documented, were to be included, 79% of sites would record the presence of exotic riparian vegetation.

The mean total cover of exotic species in the riparian zone was 6% (with a range of 0-33%). The structural types and percentage covers recorded for the exotic vegetation are shown in Table 4.24. The most common exotic structural types were vines and forbs. The average percent covers for the exotic vegetation was low with forbs averaging 4% and vines 2% cover. Exotic species that are declared as noxious within the Northern Territory were located at 56% of sites.

Table 4.24 Structural Categories Present in the Riparian Zone and Cover for Exotic Vegetation

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (10-30m)	1	0.04 (0-8)
Trees (2-10m)	5	0.2 (0-8)
Woody Shrubs (<2m)	5	0.2 (0-15)
Vines	60	2.0 (0-20)
Forbs (or Herbs)	58	3.6 (0-30)
Grasses	5	0.2 (0-12)

The more common native overstorey species, including trees, low trees and shrubs, recorded at greater than 10% of sites are shown in Table 4.25. Palm and mangrove species were not prevalent and were recorded at less than 2% of sites. Palm species consisted of *Livistona rigida* and *Carpentaria acuminata*. Mangrove tree and shrub species consisted of *Avicennia marina*, *Excoecaria agallocha*, *Excoecaria ovalis* and *Xylocarpus mekangensis*.

The major native understorey or ground cover species (including forbs, ferns, rushes, sedges, grasses and vines) are shown in Table 4.26.

Vegetation lists or vegetation profiles compiled for the survey sites are shown in Part 2.

Pandanus aquaticus, the most common native overstorey vegetation species

Table 4.25 More Common Native Riparian Overstorey Vegetation (trees, low trees and shrubs)

Plant Name – *Genus species*	Structural Type	Percent of Sites (%)
Pandanus aquaticus	Tree	64
Nauclea orientalis	Tree	56
Melaleuca leucadendra	Tree	49
Barringtonia acutangula	Low tree / shrub	48
Eucalyptus camaldulensis	Tree	45
Melaleuca argentea	Tree	40
Acacia holosericea	Low tree / shrub	40
Lophostemon grandiflorus	Tree	33
Casuarina cunninghamiana	Tree	31
Phyllanthus reticulatus	Low tree / shrub (or liane)	25
Strychnos lucida	Tree	25
Terminalia platyphylla	Tree	24
Flacourtia territorialis	Low tree / shrub (climbing)	21
Acacia auriculiformis	Tree	21
Ficus coronulata	Tree	21
Pandanus spiralis	Tree	19
Antidesma ghaesembilla	Low tree / shrub	19
Ficus racemosa	Tree	18
Ficus scobina	Low tree / shrub	18
*Eucalyptus papuana**	Tree	17
Cathormion umbellatum	Low tree / shrub	16
Carallia brachiata	Tree	14
Syzygium armstrongii	Tree	14
Canthium schultzii	Low tree / shrub	13
Diospyros calycantha	Tree	12
Canarium australianum	Tree	11
Syzygium forte	Tree	11
Excoecaria parvifolia	Tree	11
Atalaya hemiglauca	Low tree / shrub	10
Grevillea pteridifolia	Tree	10

* Now called *Eucalyptus bella*

Table 4.26 More Common Native Riparian Ground Cover Vegetation (forbs, ferns, grasses and vines)

Plant Name – *Genus species*	Structural Type	Percent of Sites (%)
Cynodon dactylon	Grass	34
Phragmites karka	Grass	19
Bambusa arnhemica	Grass (Bamboo)	16
Nelsonia campestris	Forb	15
Ampelopteris prolifera	Fern	14
Flagellaria indica	Vine (liane)	13
Paspalidium distans	Grass	12
Arundinella nepalensis	Grass	11
Heteropogon contortus	Grass	11
Mnesithea rottboellioides	Grass	11
Alternanthera nodiflora	Forb	10

The major exotic species recorded with their percentage covers, where present, are shown in Table 4.27**.** They included *Passiflora foetida,* a naturalised vine that was present at 56% of sites; *Hyptis suaveolens* (37%) and *Xanthium occidentale,* commonly known as Noogoora Burr, which was present at 23% of sites. Both *H. suaveolens* and *X. occidentale* are declared noxious weeds within the Northern Territory. One other noxious species recorded, but not shown in Table 4.27, was *Senna occidentalis,* present at 1% of sites.

Maps 18, 19 and 20 show the cover and distribution throughout the catchment of *Passiflora foetida*, *Hyptis suaveolens* and *Xanthium occidentale* (Noogoora Burr), respectively.

Passiflora foetida was widely distributed throughout the catchment with higher covers being recorded at one site on each of the following streams: Edith and King Rivers, Seventeen Mile and Stray Creeks. Of the noxious species, *Hyptis suaveolens* had a wide distribution and was recorded throughout the majority of sub-sections, although not at every site. The lower Flora River site recorded the highest cover (11-15%) for *Hyptis*. *Xanthium occidentale* was more confined in its distribution and was located at all non-tidal sites along the Daly River, one-third of sites in the tidal area and along the following tributaries that were generally close to the junction with Daly River: Chilling, Hayward, Dead Horse and Limestone Creeks and lower Fergusson and Katherine Rivers. Covers recorded for *Xanthium occidentale* along some sections of the Daly River were high (16-28% cover category).

Table 4.27 More Common Exotic Riparian Vegetation

Plant Name - *Genus species*	**Structural Type**	**Percent of Sites (%)**	**Mean Percent Cover and Range (%)**
Passiflora foetida	Vine (climber)	56	3.7 (1-20)
Hyptis suaveolens (Hyptis)*	Forb	37	4.2 (1-12)
Xanthium occidentale (Noogoora Burr)*	Forb / sub-shrub	23	10.5 (5-28)
Cardiospermum halicacabum	Vine (climber)	6	2.0 (1-4)
Sida acuta (Spinyhead Sida)*	Forb / sub-shrub	6	2.3 (1-5)
Melochia pyramidata	Forb	5	1.4 (1-2)
Pennisetum polystachion (Mission Grass)*	Grass	4	3.6 (1-6)
Parkinsonia aculeata (Parkinsonia)*	Low tree / shrub	3	5.4 (4-8)
Gossypium hirsutum (Wild Cotton)	Shrub	2	1.5 (1-2)
Jatropha gossypiifolia (Bellyache Bush)*	Shrub	2	9.0 (5-15)
Leonotis nepetifolia (Lion's Tail)*	Forb	2	1.0 (1-1)

* Declared Noxious Weed within the Northern Territory


Passiflora foetida (a naturalised vine)


Hyptis suaveolens


Xanthium occidentale (Noogoora Burr)

4.7 Aquatic Vegetation

Over half (65%) the sites recorded the presence of aquatic vegetation as either submerged, floating or emergent. The average percentage bare (that is, no aquatic vegetation) was 91% (range 55-100%). There was no aquatic vegetation species recorded that were exotic.

Most aquatic vegetation was present as emergent vegetation (61% of sites). It recorded an average of 11% cover (range 0-45%). Submerged vegetation was present at 22% of sites and recorded an average cover of 3% (range 0-25%). Floating vegetation was present at only 1% of sites. Table 4.28 shows the structural categories recorded for submerged, floating and emergent aquatic vegetation and their percentage covers.

Submerged aquatic vegetation (Site 19e/7: Tributary of Katherine River)

Table 4.28 Structural Categories and Cover for Vegetation in the Aquatic Zone

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Submerged:		
- Filamentous algae	8	0.6 (0-8)
- Chara / Nitella	12	1.9 (0-25)
- Vallisneria / strap like	4	0.3 (0-5)
- Myriophyllum	2	0.1 (0-4)
Floating:		
- Water lilies	1	0.1 (0-5)
Emergent:		
- Phragmites*	17	0.5 (0-10)
- Rushes / Sedges*	20	0.6 (0-15)
- Pandanus*	39	5.9 (0-15)
- Melaleuca*	20	7.3 (0-15)
- Other shrubs/trees*	7	0.6 (0-30)
- Other ground covers*	4	0.1 (0-5)

* Can be included as riparian and emergent aquatic vegetation

The cover and distribution of submerged and emergent aquatic vegetation throughout the catchment is presented in Maps 21 and 22, respectively. Emergent vegetation recorded a more widespread distribution than did submerged aquatic vegetation. Sites along the Daly, Flora, Katherine and Fergusson Rivers, and to a lesser extent the lower Douglas River, recorded the presence of both submerged and emergent aquatic vegetation.

Major species recorded (at greater than 1% of sites) for submerged, floating and emergent vegetation and their percentage covers, where present, are shown in Table 4.29. Floating aquatic vegetation species were recorded at 1% of sites and consisted of *Nymphoides hydrocharoides* and *Nymphaea violacea*.

Table 4.29 Major Species and Cover Recorded for Aquatic Vegetation

Plant Name / Aquatic Zone*	Percent of Sites (%)	Mean Percent Cover and Range (%)
Pandanus aquaticus (E)	39	7.2 (1-15)
Melaleuca sp. (includes M. argentea, M. leucadendra and M. viridiflora) (E)	20	7.3 (2-15)
Phragmites karka (E)	17	4.8 (1-10)
Chara sp. (S)	6	8.7 (4-15)
Schoenoplectus litoralis (E)	6	6.9 (5-10)
Nitella sp. (S)	6	5.5 (3-10)
*Vallisneria spiralis*** (S)	4	4.5 (4-5)
Fimbristylis pauciflora (E)	3	2.3 (2-3)
Eleocharis geniculata (E)	3	5.3 (3-8)
Barringtonia acutangula (E)	2	3.5 (2-5)
Cynodon dactylon (E)	2	4.0 (3-5)
Cyperus haspan (E)	2	5.5 (3-8)
Myriophyllum sp. (S)	2	3.0 (2-4)

* Zones include: S = Submerged F = Floating E = Emergent
** Now called *Vallisneria nana*

Phragmites karka – emergent aquatic vegetation

4.8 Instream and Bank Habitats

A summary of the cover and diversity of instream and bank habitats throughout the catchment, based on derived ratings, is shown in Table 4.30 and Map 23. The ratings are based on a combination of the cover and diversity provided by instream organic debris, aquatic vegetation and other habitat types on the bed, as well as the cover and diversity provided by the canopy and other habitats along the river banks. The majority of sites were rated as having high cover and diversity of instream and bank habitats (52% of sites) or moderate cover and diversity (43%). Sections on Dead Horse and Limestone Creeks rated the worst in the Daly River catchment. The few sites recording very high cover and diversity of instream and bank habitats were located on Flora and Douglas Rivers and Green Ant Creek.

Table 4.30 Cover and Diversity of Instream and Bank Habitats

Instream/Bank Habitat Category (Rating)	Number of Sites (%)
Very Low Cover/Diversity (0-20%)	0 (0)
Low Cover/Diversity (21-40%)	2 (2)
Moderate Cover/Diversity (41-60%)	47 (43)
High Cover/Diversity (61-80%)	56 (52)
Very High Cover/Diversity (81-100%)	3 (3)

Very high cover and diversity of instream and bank habitats (Site 17/2: Flora River)

The overall aquatic rating for all aquatic life was also subjectively assessed (refer Table 4.31). Nearly half (47%) the sites were subjectively rated as having a good to very high overall aquatic rating. Another 22% of sites had poor aquatic habitat and 31% of sites poor to good. The assessment took into account the diversity of depths and substrates, level of disturbance, diversity and extent of cover, extent of canopy and other vegetation cover, and whether the stream dries up completely.

Table 4.31 Overall Aquatic Condition based on Subjective Ratings

Condition Category	Percent of Sites (%)
Very Poor	0
Poor	22
Poor to Good	31
Good	35
Good to Very High	10
Very High / Pristine	2

Instream and bank habitat types are summarised in Tables 4.32 and 4.33. The most commonly occurring instream cover types included logs, leaves and twigs, branches, rock faces/boulders, and permanent pool habitats deeper than 1m. Stream bed cover provided from the banks was dominated by vegetation canopy cover (at 99% of sites) and vegetation overhang which was less than 1m from the water (at 98% of sites). The canopy cover provided a mean width of 2.6m and occurred along a mean of 63% of the bank length.

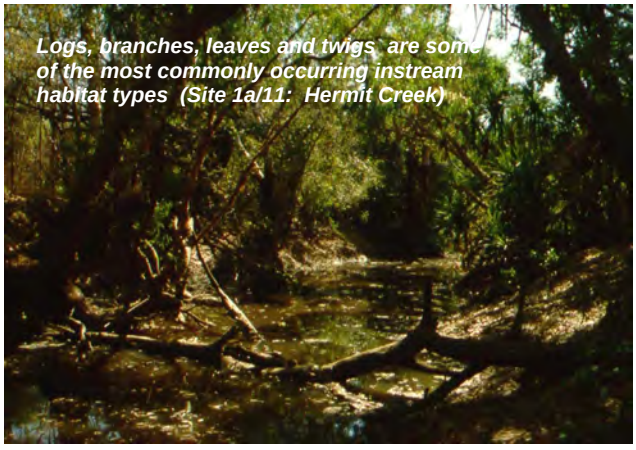
Table 4.32 Instream Habitat Types

Instream Habitat Type	Percent of Sites (%)	Mean Percent Cover and Range (%)
Logs	91	6.9 (0-25)
Log Jam - <50% dense - >50% dense	 22 11	 1.2 (0-20) 1.2 (0-75)
Branches	89	5.2 (0-15)
Branch Piles - <50% dense - >50% dense	 31 5	 2.0 (0-25) 0.3 (0-10)
Leaves and Twigs	91	12.1 (0-80)
Macrophyte Fragments	9	0.8 (0-50)
Algal Clumps	45	3.5 (0-50)
Large Submerged Plants - Freshwater	14	1.0 (0-18)
Mangroves	3	0.6 (0-30)
Floating Vegetation	1	0.1 (0-5)
Emergent Vegetation	33	2.4 (0-20)
Tree Roots	2	0.1 (0-8)
Rock Faces	72	19.9 (0-90)
Permanent Pool >1m Deep	62	35.6 (0-100)
Built Structures/ Debris	5	0.3 (0-10)

Table 4.33 Bank Habitat Types

Bank Cover	Percent of Sites (%)	Mean Bank Length and Range (%)	Mean Width of Type and Range (m)
Canopy	99	63.4 (0-95)	2.6 (0-10)
Vegetation Overhang	98	21.0 (0-80)	1.0 (0-5)
Root Overhang	87	8.6 (0-50)	0.2 (0-3)
Bank Overhang	38	2.6 (0-20)	0.1 (0-1)
Built Structures	3	0.1 (0-4)	0.2 (0-10)

Extensive riparian vegetation overhang along sections of Katherine River at Site 19b/4



Logs, branches, leaves and twigs are some of the most commonly occurring instream habitat types (Site 1a/11: Hermit Creek)

At the time of the survey, 32% of sites had no passage for fish and other aquatic organisms; 50% were partly to very restricted; and 17% had good or unrestricted passage. If the water level were normal or at 'water mark', no sites were totally restricted (that is, had no passage); 72% of sites had some form of restriction in place; and 28% of sites had good to unrestricted passage.

4.9 Overall Condition

The result of combining equally the ratings for the following six components is shown in Table 4.34:

- State of the Reach Environs
- Bank Stability
- Bed Stability
- Cover and Structural Diversity of Riparian Vegetation
- Cover of Exotic Riparian Vegetation
- Cover and Diversity of Instream and Bank Habitats

Table 4.34 Overall Condition Rating

Overall Condition Rating (%)	General Term Used to Describe Overall Condition	Number of Sites (%)
0-20	Very Low	0 (0)
21-40	Low	0 (0)
41-60	Moderate	1 (1)
61-80	High	91 (83)
81-100*	Very High	17 (16)

* 100% = Ideal, undisturbed or natural state

The results indicate that the majority (83%) of sites recorded a high overall condition rating with a further 16% of sites rating very highly. No sites were rated as being degraded overall. Map 24 shows the overall condition ratings for sites throughout the catchment. Reaches that rated very highly overall were located on Douglas River (5 sites), Daly River (3), Green Ant Creek (3), Flora River (2), Katherine River (2), Edith River (1) and Dry River (1). The only site to record a moderate overall condition (the poorest rating in the catchment) was located on Eight Mile Creek.

Very high overall condition rating (Site 7/1: Douglas River)

4.10 Stream Flow

The location of the flow gauge stations within the Daly River Catchment is shown on Map 25. The 16 operational stations are shown along with 11 closed stations. The location of the two High Flow Stations, located on the Daly and Katherine Rivers, are also shown. These two stations are part of the flood warning system and record high flow events. A Tide Station, which was located along the lower part of the Daly River estuary, was closed in 1986.

Map 25 also shows the location of monitoring bores within the Daly River catchment (refer Section 2.6.2). These bores were drilled in order to monitor groundwater levels on a regional basis. The majority of these bores are concentrated around Katherine, including rural surrounds, Douglas River area, mid Daly River region, at Pine Creek and Daly River township.

Table 4.35 summarises the stream flow information for the gauge stations, excluding the newly established station on upper Katherine River (G8140219). Gauge station G8140040, at Mt Nancar, is located the furthest downstream on the Daly River. This gauge station, with a catchment area of 47,100 km^2, records a mean annual flow volume of 5,720 million m^3 (ie 5,720,000 ML) or a mean annual discharge of 213.9m^3/sec.

The five major tributary systems (that is, Katherine, King-Dry, Fergusson, Flora and Douglas Rivers) vary considerably in stream flow contributions to the Daly River. The flow from the King-Dry River system on average has a small contribution despite a comparable catchment size to the Katherine River. Flows in the Katherine and Fergusson systems are similar when comparing flow volumes per unit of catchment area but the annual discharge figures for the Katherine River are nearly four times greater than those recorded for the Fergusson River. Discharge figures for the Flora and Fergusson River systems are comparable and are greater than those recorded for Douglas River.

Groundwater contributes to the stream flow in several sub-catchments, through seepage points located along the rivers and creeks (also refer Section 2.6). The contribution from groundwater becomes increasingly important as the dry season progresses because these rivers and creeks would otherwise become isolated pools or dry up completely. Map 25 shows the location of springs that have been recorded throughout the catchment, many of which are contributing to stream flow. The larger permanent springs are located along the Daly, Katherine, Flora, Douglas, Fergusson, Edith, King and Fish Rivers.

The mean monthly discharges for the Daly River and several tributaries are shown in Figures 4.1-4.5. As discussed in Section 2.6.1, the concentration of rainfall during the wet season, November to March, is reflected in marked seasonal changes in stream flows. Those gauge stations recording a minimum monthly discharge that is greater than zero, are located on the Daly, Douglas, Katherine, Flora, Edith and Fish Rivers and Seventeen Mile Creek. The baseflow, or minimum discharge, within these rivers and creeks is largely attributed to groundwater discharges thus emphasising the close interaction between ground and surface water systems.

The Daly River has a large perennial flow. Figure 4.1 shows the mean monthly discharge recorded at 4 gauge stations located on the Daly River. The highest mean monthly discharge along the Daly River occurs in February and March and ranges from 635.6–871.4m^3/sec. The lowest mean monthly discharge occurs in September and October and ranges from 5.2m^3/sec at G8140067 to 17.9m^3/sec at the Mt Nancar gauge station (G8140040). Minimum mean monthly discharges have been recorded in October for these Daly River gauge stations and range from 4.4m^3/sec at G8140067 to 16.2m^3/sec at G8140042.

The mean monthly discharge recorded at 3 gauge stations on the Katherine River and the Seventeen Mile Creek gauge station is shown in Figure 4.2. These stations recorded their highest mean monthly discharge in February and their lowest discharge in September. The mean monthly discharge recorded for Seventeen Mile Creek was 0.4-12.3m^3/sec. G8140001 on the Katherine River, at the old railway bridge, recorded a mean monthly discharge of between 1.9-274.3m^3/sec.

Flow in the Katherine River at the Gorge usually ceases to flow each dry season in July-August. The minimum mean monthly discharge recorded for G8140019 is 0.05m^3/sec. Seventeen Mile Creek maintains flows within the Katherine River downstream of the Gorge. Perennial flow occurs along the Katherine River within the town reach due to groundwater discharge from the Tindall Limestone aquifer.

Figure 4.3 shows the mean monthly discharge recorded for the Douglas, Edith, Fergusson and Flora Rivers. The highest mean monthly discharge in these rivers occurs in February and ranges from 19.5m^3/sec on the Douglas River to 110m^3/sec on the Flora River. The Fergusson River at G8140008 records no flows in August-September. The lowest mean monthly discharge for the other rivers occurs from July-September and ranges from 0.08m^3/sec on the Edith River to 3.2m^3/sec on the Flora River.

Table 4.35 Summary of Stream Flow Information for the Daly River Catchment

Gauge Station Number	Tributary	Catchment Area (km^2)	Mean Annual Flow Volume (m^3)	Mean Annual Discharge (m^3/sec)	Median Annual Discharge (m^3/sec)	Min – Max Monthly Discharge (m^3/sec)
G8140003	Daly River (High Flow Stn)	48,400	N/A	N/A	N/A	N/A
G8140040	Daly River	47,100	5,720,000,000	213.90	153.20	4.83-3,681.0
G8140042	Daly River	41,000	4,798,000,000	191.00	130.20	1.87-3,713.0
G8140067	Daly River	35,800	4,515,000,000	147.90	113.30	1.52-6,498.0
G8140063	Douglas River	842	148,800,000	6.07	3.37	0.14-887.7
G8140011	Dry River	6,290	163,300,000	10.95	6.65	0-2,671.0
G8140152	Edith River	590	220,100,000	8.55	5.71	0-1,396.0
G8140008	Fergusson River	1,490	415,600,000	23.49	16.02	0-1,183.0
G8140044	Flora River	5,900	762,300,000	30.80	20.26	0-3,510.0
G8140161	Green Ant Creek	435	71,259,117	2.76	2.30	0-434.9
G8140001	Katherine River	8,640	1,922,000,000	87.17	53.47	0.67-2,853.0
G8140023	Katherine River (High Flow Stn)	6,404	N/A	N/A	N/A	N/A
G8140218	Katherine River	3,700	956,300,000	33.12	27.32	0-875.0
G8140158	McAdden Creek	133	33,817,649	2.10	1.45	0-362.6
G8140159	Seventeen Mile Creek	619	102,700,000	2.99	2.12	0.09-461.3
G8140234*	Bradshaw Creek	240	18,161,705	1.17	0.96	0-395.6
G8140062*	Copperfield Creek	9.2	2,049,537	0.06	0.05	0-50.84
G8140041*	Daly River	46,300	3,559,000,000	175.10	149.90	5.66-4,691.0
G8140166*	Fish River	992	149,700,000	4.46	3.19	0.01-1,546.0
G8140005*	Flora River	829	139,300,000	3.92	2.12	0.001-564.5
G8140019*	Katherine River	6,390	1,152,000,000	57.09	47.29	0-3,549.0
G8140068*	King River	11,000	207,800,000	7.64	3.65	0-2,947.0
G8140086*	King River	484	41,812,011	1.62	1.01	0-326.20
G8140151*	Mathison Creek	725	10,844,798	0.29	0.05	0-201.50
G8140214*	Scott Creek	528	15411,067	0.62	0.38	0-224.9

* Closed Gauge Station
Source: Figures obtained from 'Hydsys' and were up-to-date at the time of extraction (1995-1997)

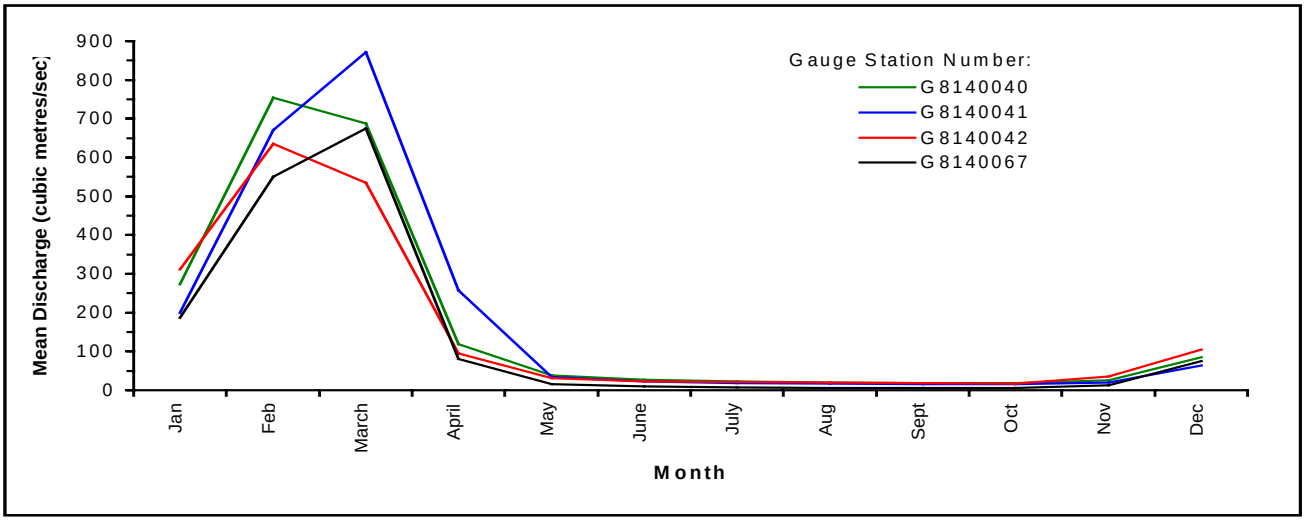


Figure 4.1 Mean Monthly Discharge Recorded for Daly River

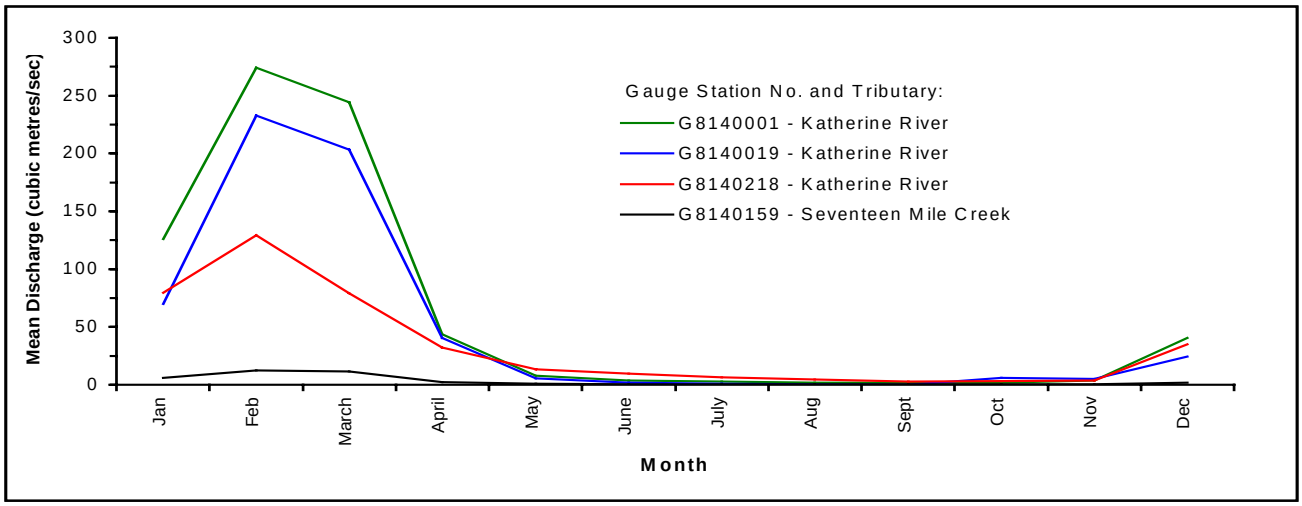


Figure 4.2 Mean Monthly Discharge Recorded for Katherine River and Seventeen Mile Creek

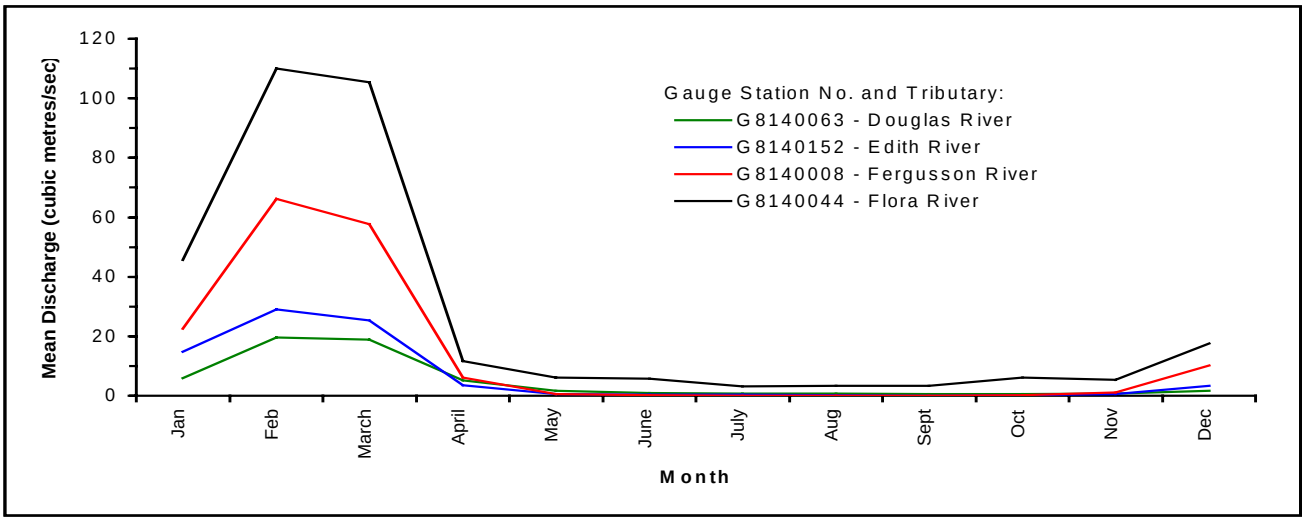


Figure 4.3 Mean Monthly Discharge Recorded for Several Major Tributaries of the Daly River

The mean monthly discharge recorded for the intermittent tributaries - Dry River, King River, Mathison Creek and Scott Creek, is shown in Figure 4.4. Flows within these rivers and creeks are not maintained by springs and they dry up during the dry season. The lowest mean monthly discharge for Scott Creek is 0.01m^3/sec though the mean minimum monthly flows for November and December are zero. The highest mean monthly discharge for these rivers and creeks occurs in March and ranges from 1.8m^3/sec on Mathison Creek to 51.4m^3/sec on King River.

Figure 4.5 shows the mean monthly discharge recorded for several smaller tributaries of the Daly River - Bradshaw Creek, Fish River and Green Ant Creek. At G8140166 on Fish River, flows are maintained throughout the year and the mean monthly discharge ranges from 0.1m^3/sec in September to 22.3m^3/sec in February. Green Ant Creek also maintains flows throughout the year (0.1-10.4m^3/sec). Bradshaw Creek records no mean monthly discharge for August because it is dry and in February records 6.6m^3/sec.

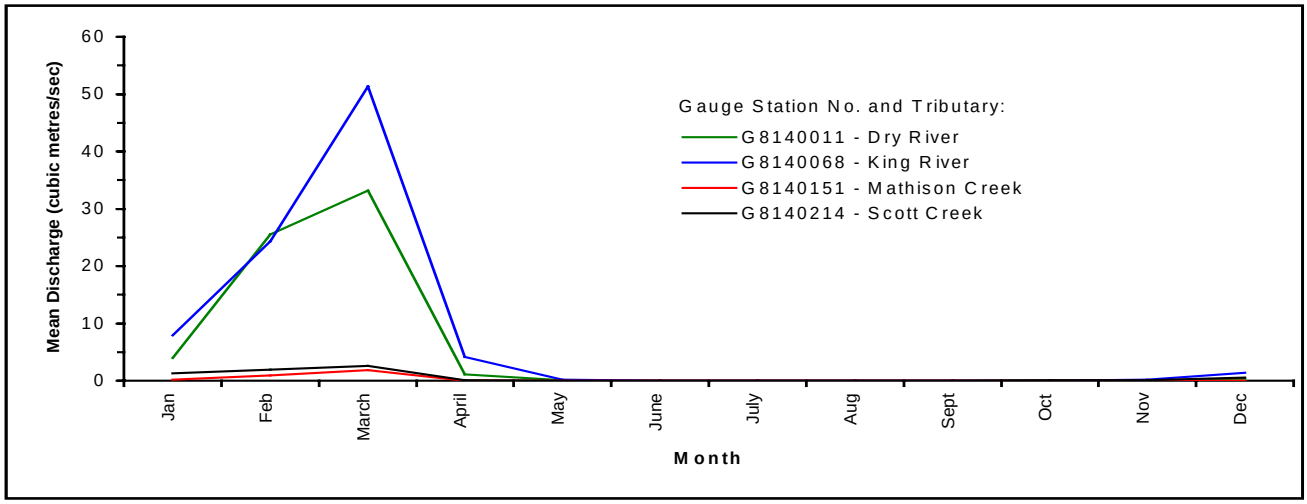


Figure 4.4 Mean Monthly Discharge Recorded for Intermittent Tributaries within the Daly River Catchment

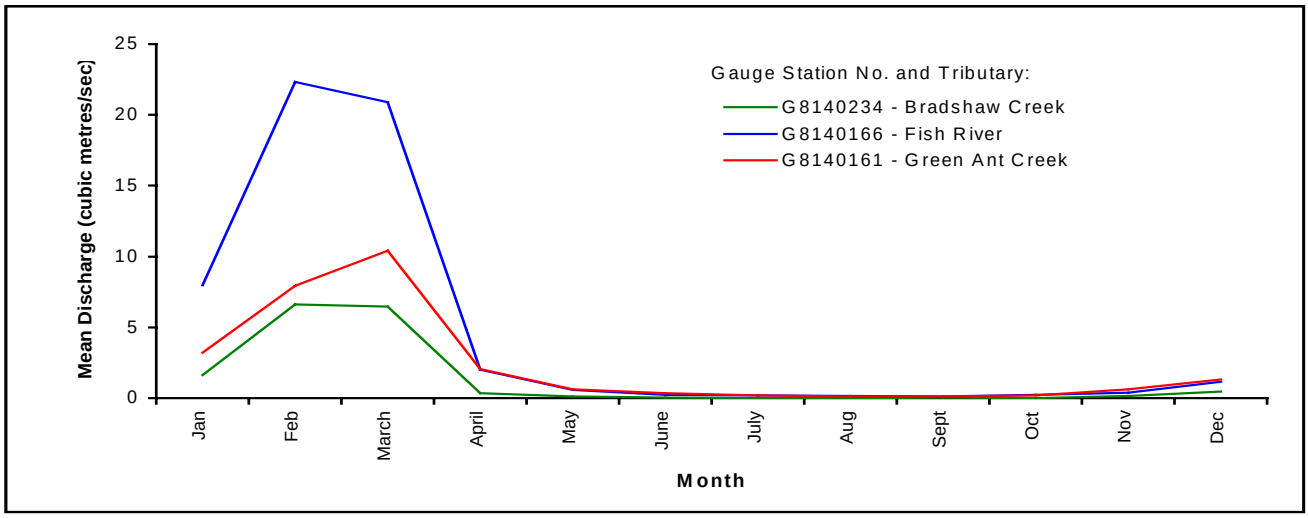


Figure 4.5 Mean Monthly Discharge Recorded for Several Smaller Tributaries of the Daly River

4.11 Water Quality

The location of 61 water quality sampling points throughout the Daly River catchment is shown on Map 26. These sampling points have been divided into 3 categories. That is, those located at a flow gauge station, away from a flow gauge station and at an 'Ausrivas' (Australian River Assessment Scheme) Project site.

Section 2.6.3 provides background information on water quality issues and monitoring within the Daly River catchment. Table 4.36 provides a summary of the quality guidelines for the protection of freshwater aquatic ecosystems, as defined by the 'Australian Water Quality Guidelines for Fresh and Marine Waters' (ANZECC, 1992). These guidelines have been used as a general comparison for the water quality results for the Daly River catchment.

Table 4.36 Quality Guidelines for the Protection of Freshwater Aquatic Ecosystems
(Source: ANZECC, 1992)

Indicator	Units	Quality Guidelines
Electrical Conductivity (EC)	µS/cm	<1,500 (1)
Turbidity	NTUs	<10% change seasonal mean concentration (2)
Water Temperature	^{o}C	<2^{o}C increase (3)
pH		6.5-9 (4)
Total Alkalinity (as $CaCO_3$)	mg/L	No figures available (5)
Total Phosphorus	mg/L	<0.01 – 0.1 (6)

(1) The EC concentration may need to be less depending on other uses of the water. For example, (a) raw water for drinking purposes: <1,500µS/cm recommended although levels in excess of 800µS/cm cause deterioration in taste; and (b) irrigation water: 0-800µS/cm classed as low to medium-salinity water for irrigation of most crops.

(2) Suspended solids may arise from point sources (eg industrial and sewage discharge) but by far the largest contribution in Australia comes from diffuse sources (eg soil and stream bank erosion). Levels of suspended solids in rivers may vary greatly with time – the concentration increases with discharge as sediment is washed into the river due to rainfall and deposited sediment is resuspended.

(3) In the Top End, water temperature in rivers fluctuates seasonally and is influenced by groundwater discharge that has elevated temperatures (such as at Douglas Hot Springs).

(4) Most natural freshwaters have a pH close to 7. In many waters the pH is controlled by the carbonate-bicarbonate buffer system. pH and salinity (EC) are largely determined by the geology and soils of the catchment. Water running off limestone areas would have relatively high pH levels. Increasing salinity also causes an increase in pH levels.

(5) The concentration of hardess (which, like total alkalinity, is also expressed as $CaCO_3$) in raw water for drinking water supply is recommended to not exceed 500mg/L. The principal hardness-causing ions in freshwater are calcium and magnesium. Hardness is mainly a problem in water supplies using groundwater. Total alkalinity levels are also influenced by groundwater discharge into rivers.

(6) The total phosphorus (TP) range of 0.01-0.1mg/L is provided only as an indication of levels at or above which nuisance algal problems (eutrophication) have been known to occur in Australian rivers. Site-specific studies are required to determine TP guidelines for specific waterbodies. High flows during the Top End's wet season would preclude any nuisance algal problems.

Tables 4.37-4.39 summarise the results for the 61 water quality sampling points shown in Map 26. The results, where available, are for the 6 water quality parameters that are shown in Table 4.36. The water quality results have not been analysed on a monthly basis, in order to show trends between the wet and dry season, due to the general scarcity of results and ad hoc nature of the data collection.

Table 4.37 summarises the water quality information for 15 open and 9 closed gauge stations. In general, Flora River recorded the highest EC and, to a lesser extent, the Daly and Douglas Rivers and Green Ant Creek, although the results were within the quality guidelines. Daly and King Rivers recorded turbidity levels greater than 100 NTUs although the majority of levels were less than 50 NTUs. Stations located on Edith, mid-upper Katherine, and King Rivers recorded pH levels of <6.5 which is below the quality guidelines. Higher total alkalinity levels were recorded for sites on Flora, Daly and Douglas Rivers and Green Ant Creek. Total phosphorus levels were within the quality guidelines.

Table 4.38 summarises the water quality information for 17 sampling points not located at a flow gauge station. Several points along Flora, Daly and Katherine Rivers recorded elevated EC levels compared to other points. Turbidity levels were generally low. Water temperature was high at Douglas Hot Springs (49.25^{o}C). Points along Douglas and Edith Rivers and Stray Creek recorded pH levels of <6.5.

Table 4.39 summarises the water quality information for 20 sampling points located at an 'Ausrivas' project site. Flora River recorded the highest EC levels, although Green Ant Creek, Daly, Douglas and a point on Katherine River also recorded elevated ECs. Turbidity levels were low. Water temperatures were generally <30^{o}C. Over half the sites recorded pH levels of <6.5. Higher total alkalinity levels were recorded for sites on Flora, Daly, Douglas and Katherine Rivers and Green Ant Creek. Total phosphorus levels were within the quality guidelines.

Table 4.37 Summary of Water Quality Information for Sampling Points Located at a Flow Gauge Station

Gauge Station Number	Tributary	Mean Electrical Conductivity – Lab (µS/cm) (No. of results)	Mean Turbidity – Lab (NTUs) (No. of results)	Mean Water Temp – Field (°C) (No. of results)	Mean pH – Lab (No. of results)	Mean Total Alkalinity – Lab (mg/L) (No. of results)	Mean Total Phosphorus – Lab (mg/L) (No. of results)
G8140003	Daly River	399 (21)	62.3 (4)	-	7.7 (19)	200 (20)	0.02 (1)
G8140040	Daly River	320 (51)	81.0 (90)	-	7.5 (49)	155 (49)	0.01 (3)
G8140042	Daly River	472 (9)	-	-	7.9 (7)	259 (9)	0.01 (3)
G8140067	Daly River	419 (27)	31.9 (17)	-	7.8 (24)	207 (24)	0.01 (3)
G8140063	Douglas River	334 (22)	5.3 (3)	-	7.5 (22)	187 (18)	-
G8140011	Dry River	65 (1)	-	-	6.7 (1)	32 (1)	-
G8140152	Edith River	26 (28)	40.7 (6)	27.0 (1)	6.4 (23)	10 (28)	0.03 (3)
G8140008	Fergusson River	30 (35)	21.0 (2)	-	6.6 (33)	14 (24)	0.03 (3)
G8140044	Flora River	668 (17)	8.0 (1)	-	7.6 (14)	338 (16)	0.01 (3)
G8140161	Green Ant Creek	340 (16)	22.9 (2)	-	7.3 (16)	182 (14)	0.01 (2)
G8140001	Katherine River	129 (102)	29.6 (139)	-	6.6 (87)	56 (87)	-
G8140023	Katherine River	28 (13)	18.7 (4)	25.8 (8)	6.6 (12)	11 (13)	0.00 (2)
G8140218	Katherine River	29 (7)	6.8 (3)	-	6.5 (7)	7 (6)	-
G8140158	McAdden Creek	40 (20)	30.9 (9)	-	6.6 (19)	17 (19)	-
G8140159	Seventeen Mile Creek	26 (71)	23.4 (19)	30.5 (1)	6.5 (66)	10 (70)	0.01 (3)
G8140062*	Copperfield Creek	41 (33)	8.8 (15)	20.0 (1)	6.6 (31)	17 (33)	0.03 (2)
G8140041*	Daly River	373 (25)	112.9 (78)	-	7.8 (25)	187 (24)	-
G8140166*	Fish River	101 (27)	11.7 (11)	-	7.3 (25)	49 (27)	0.02 (2)
G8140005*	Flora River	358 (6)	53.0 (1)	-	7.7 (6)	188 (6)	-
G8140019*	Katherine River	24 (10)	16.0 (3)	-	6.3 (10)	9 (10)	-
G8140068*	King River	70 (20)	103.3 (9)	-	6.7 (20)	29 (20)	-
G8140086*	King River	25 (12)	107.9 (14)	-	6.4 (12)	8 (12)	-
G8140151*	Mathison Creek	36 (1)	30.0 (1)	-	6.7 (1)	19 (1)	-
G8140214*	Scott Creek	69 (3)	52.7 (3)	-	7.3 (3)	35 (3)	-

* Closed Gauge Stations
Source: Figures obtained from 'Hydsys' and were up-to-date at the time of extraction (1997)

Table 4.38 Summary of Water Quality Information for Sampling Points Not Located at a Flow Gauge Station

Gauge Station Number	Tributary	Location Description	Mean Electrical Conductivity – Lab (µS/cm) (No. of results)	Mean Turbidity – Lab (NTUs) (No. of results)	Mean Water Temp – Field (^{o}C) (No. of results)	Mean pH – Lab (No. of results)
G8145241	Copperfield Creek	Recreation Dam At Pine Creek	39 (13)	4.4 (86)	28.2 (15)	6.74 (6)
G8145047	Daly River	At Point B1 (estuary)	803 (103)	-	-	-
G8145048	Daly River	At Point C (estuary)	480 (11)	-	-	-
G8145094	Daly River	At Pt. 26 Douglas/Daly	527 (7)	-	-	7.33 (3)
G8140325	Douglas River	At Lower Crossing	461 (6)	-	-	-
G8140376	Douglas River	At Road Crossing	232 (9)	-	-	7.00 (4)
G8145053	Douglas River	At Pt. C (Butterfly Gorge)	289 (14)	22.0 (1)	-	5.70 (2)
G8145054	Douglas River	At Pt. D (Crystal Falls)	159 (7)	-	-	7.65 (2)
G8145010	Douglas River	Douglas Hot Springs	78 (21)	-	49.3 (2)	6.17 (4)
G8140154	Edith River	At Edith Falls	21 (8)	-	-	5.97 (3)
G8145130	Flora River	At Point J	787 (3)	-	33.5 (2)	7.25 (2)
G8140002	Katherine River	Hospital (Knotts) Crossing	104 (132)	21.3 (101)	29.5 (2)	6.75 (59)
G8140030	Katherine River	D/s Sewerage Ponds Outflow	329 (54)	13.2 (45)	26.8 (5)	6.85 (2)
G8140301	Katherine River	At Galloping Jacks	510 (5)	-	-	7.65 (4)
G8140302	Katherine River	At Ballongilly	534 (6)	-	-	7.92 (4)
G8145222	Katherine River	At Low Level Bridge	282 (65)	19 (65)	26.2 (10)	7.08 (13)
G8145315	Stray Creek	Umbrawarra Gorge	160 (2)	-	-	5.95 (2)

Source: Figures obtained from 'Hydsys' and were up-to-date at the time of extraction (1997). These water quality sampling points had >10 results for a parameter and/or results >1985.

Table 4.39 Summary of Water Quality Information for Sampling Points Located at an 'Ausrivas' Project Site

Site Number	Tributary and Location Description	Mean Electrical Conductivity – Lab (µS/cm)	Mean Turbidity – Field (NTUs)	Mean Water Temp – Field (°C)	Mean pH – Lab	Mean Total Alkalinity – Lab (mg/L)	Mean Total Phosphorus – Lab (mg/L)
MR-DA-19	Copperfield Creek	54	23.1	26.2	6.1	19	0.05
MR-DA-01	Daly River at Dorisvale Crossing (upstream)	449	5.1	29.0	8.0	240	0.01
MR-DA-07	Daly River at Beeboom Crossing	518	4.0	28.6	8.1	288	0.01
MR-DA-08	Daly River at Mt Nancar	492	4.0	28.6	7.9	252	0.01
MR-DA-09	Daly River at Oolloo Crossing	491	1.7	28.2	7.6	274	0.01
MR-DA-10	Douglas River at Oolloo Road Crossing (upstream)	204	2.1	28.9	6.8	109	0.01
MR-DA-14	Douglas River at Butterfly Gorge	19	5.8	27.6	5.7	4	0.01
MR-DA-15	Douglas River at Crystal Falls	491	3.1	28.2	7.8	287	0.01
MR-DA-16	Douglas River at Douglas Hot Springs	52	2.3	42.0	6.1	21	0.05
MR-DA-11	Edith River – upstream of Mt Todd	18	2.8	27.4	6.0	5	0.01
MR-DA-12	Edith River – downstream of Mt Todd	42	5.4	29.0	6.3	17	0.02
MR-DA-02	Fergusson River at Stuart Hwy Crossing (downstream)	66	10.6	29.6	6.4	28	0.02
MR-DA-18	Fish River – upstream of road crossing	53	18.3	26.3	6.4	21	0.03
MR-DA-05	Flora River at Kathleen Falls	734	3.8	29.2	7.6	386	0.01
MR-DA-17	Green Ant Creek	548	1.3	23.1	8.2	303	0.01
MR-DA-03	Katherine River – downstream Gorge	22	1.9	28.1	6.1	6	0.01
MR-DA-06	Katherine River – downstream sewerage operations	514	2.8	28.6	7.3	298	0.01
MR-DA-20	Katherine River at Eva Valley road	31	4.0	27.4	6.2	11	0.01
MR-DA-04	Seventeen Mile Creek at crossing in Nitmiluk NP	18	1.6	26.4	5.9	4	0.01
MR-DA-13	Stray Creek (arm) at Umbrawarra Gorge	27	2.8	25.5	6.2	13	0.01

Source: Figures obtained from the 'Ausrivas' Project. Four to five water quality tests were carried out between 1994 and 1996 predominantly during the months of June/July, September and November.

5. SUB-CATCHMENT RESULTS

Maps 10-26 show the results for the condition and stability ratings and other attributes for the whole of the Daly River Catchment (refer Section 4).

5.1 Daly River

5.1.1 Results

5.1.1.1 Daly River Estuary

Sub-section 1a incorporates the tidal section of the Daly River, downstream of Daly River Crossing. Sites were located on the Daly River as well as on several small tributaries (4 sites). Of the 15 sites located in this sub-section, 11 of these were fully assessed.

- *Reach Environs and Site Features*

The sites in this sub-section were classified as having essentially natural reach environs (73%) or some modification to the reach environs (27%). Subjective ratings of disturbance of the reach environs indicated that 9% of sites had very low to low disturbance, 46% had low disturbance, 27% low to moderate disturbance and 18% were moderately disturbed.

All sites had land tenure that was either freehold or leasehold, while some sites (18%) had one side of the river as a Reserve. The major land use was grazing (73% of sites) which occurred predominantly on thinned native pastures (73% of sites), virgin timbered native pastures (55%), cleared native pastures (18%) or with sown pastures (9%). Other land uses included rural residential areas (18% of sites), Reserve (18%) or horticultural tree crops (9%).

Grazing activity was the major disturbance likely to affect stream reaches (91% of sites). Other disturbances included roads/tracks (37% of sites), people (27%), causeways/river crossings (18%) or a boat ramp (9%). There was no disturbance recorded at 9% of sites. All sites recorded billabongs/oxbows as the major floodplain feature.

- *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 1,995m (range 50-4,380m). These reaches were dominated by pools, which were present at 100% of sites. The pools, on average, covered 84% of the reach length (range 60-100%). Riffles (33% of sites) and runs (33%) were also present.

The diversity of channel habitat types in this sub-section ranged from high to low (refer Table 5.1).

Table 5.1 Channel Type Diversity

Diversity Category (Rating)	Percent of Sites (%)
Very Low Diversity (1-2)	0
Low Diversity (3-4)	33
Moderate Diversity (5-6)	17
High Diversity (7-8)	50
Very High Diversity (9-10)	0

The water level at the time of sampling was dominated by tidal influences at 73% of sites. The smaller creeks studied had isolated pools (18% of sites) or moderate water levels that were less than normal levels (9%). Table 5.2 presents the mean dimensions for the pool, riffle and run habitats. To allow for comparison between the various channel habitat types, regardless of the variation in water level at the time of the survey, only those recorded at the water mark are listed.

The pools located on the Daly River within this sub-section are the widest within the catchment and this was reflected in a very high width to depth ratio. The pools, at 3.7m deep and 1,863m long, are the deepest and longest compared to other sites, except those recorded in Sub-section 19c which takes in the Katherine Gorge. The lower banks were generally narrow and low, depending on the tides, with moderately steep slopes. The upper banks were quite low and narrow compared to other sections of the Daly River. Bank slopes along the reaches were generally moderate or low and bank shapes were either convex or concave.

- *Bank Condition and Stability*

The majority of reaches assessed in this sub-section were rated as having stable banks, while others had limited instability (refer Table 5.3). Subjective ratings indicated that the overall bank instability in this sub-section ranged from minimal (9% of sites), minimal to low (27%), low (45%), low to moderate (36%), moderate (27%) and moderate to high (9%). Similar percentages were recorded for the susceptibility of banks to erosion.

Table 5.2 Channel Dimensions for all Habitat Types Present

Dimension		Pool	Riffle	Run
Mean Percent of Reach Covered (%)		84.4 (60-100)	21.5 (9-30)	25.3 (2-40)
Mean Length (m)		1,863.0 (28.0-4,000.0)	262.8 (8.5-400.0)	463.3 (65.0-1,200.0)
Mean Depth at Water Mark (m)		3.7 (0.4-7.4)	1.1 (0.4-1.8)	3.5 (2.3-4.5)
Mean Width at Water Mark (m)		317.7 (6.8-1,530.0)	38.2 (5.8-74.0)	69.5 (55.0-91.0)
Width:Depth Ratio		68.9 (6.7-277.2)	30.8 (6.7-60.9)	20.9 (16.8-25.2)
Lower Bank	Width (m)	2.6 (0.1-8.0)	0.8 (0.2-1.5)	0.7 (0.1-1.0)
	Height (m)	1.7 (0.2-5.5)	0.3 (0.2-0.4)	1.0 (0.4-1.7)
	Slope (^{o})	46.1 (11.3-76.0)	32.3 (7.6-63.4)	59.0 (45.0-76.0)
Upper Bank	Width (m)	8.4 (2.5-15.0)	9.1 (2.5-13.0)	8.1 (7.0-9.0)
	Height (m)	3.8 (0.3 – 10.0)	5.8 (1.9-10.0)	4.8 (2.0-7.5)
	Slope (^{o})	22.3 (1.7-45.0)	31.4 (11.9-51.3)	29.6 (14.0-39.8)

The dominant bank process was erosion, being observed for all reaches within this sub-section (100% sites). The erosion was predominantly occurring at obstacles (91% of sites) or outside bends (82%). At 27% of sites erosion was occurring at irregular intervals or was found along most of the bank length. On average, 15% of the lower banks were eroding compared to 12% for the upper banks (though this ranged up to 50% for both banks). Some aggradation (36% of sites) was recorded along inside bends.

Table 5.3 Bank Stability Ratings

Stability Category (Rating)	Percent of Sites (%)
Extreme Instability (0-20%)	0
Extensive Instability (21-40%)	0
Moderate Instability (41-60%)	0
Limited Instability (61-80%)	18
Stable (81-100%)	82
Dominant Process Recorded	
Aggradation	0
Erosion	100

The major factors identified as affecting bank stability was tidal influences (73% of sites) and high flow (55% of sites). No artificial bank protection measures, such as fencing or tree planting, were recorded in this sub-section.

Those sites that recorded subjective bank stability ratings of moderate or moderate to high overall bank instability and susceptibility to erosion, were located on the Daly River (sites 1a/10, 1a/18 and 1a/19). Figure 5.1 shows the changes in channel location observed along the lower tidal section of the Daly River during field work in September 1995.

Downstream of site 1a/8 there were several outside bends that are migrating and the banks have eroding >1km since the topographic maps were produced in 1966. The banks along these sections are actively eroding and, as they collapse into the river, so does the riverine vegetation, which consists mostly of mangrove species. Refer Section 2.7 and Appendix A, which discusses the 'Evolution of the Daly River Estuarine Plains, noting how the river meanders along the tidal section of the Daly River are very actively migrating and the channel is "ever-changing".

Migrating river banks along lower Daly River

Limited bank instability (Site 1a/18: Daly River)

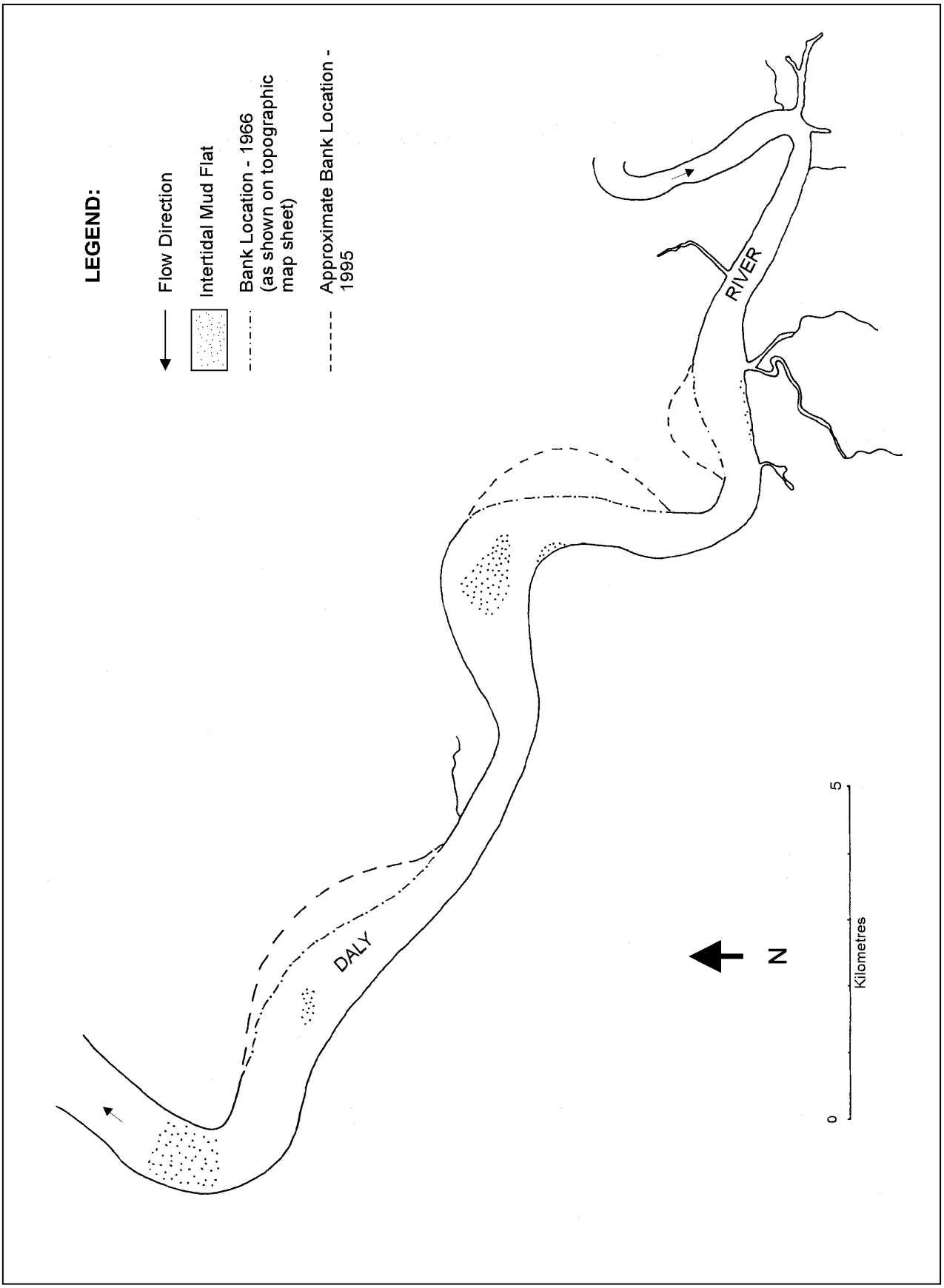


Figure 5.1 Changes in Channel Location along the Lower Tidal Section of Daly River

♦ *Bed and Bar Condition and Stability*

Subjectively, 55% of sites were rated as having beds that were stable, while 36% were moderately aggrading and 9% moderately eroding (refer Table 5.4).

Table 5.4 Overall Bed Stability Ratings

Stability Category (Rating)	Percent of Sites (%)
Severe Erosion or Aggradation (2)	0
Moderate Erosion or Aggradation (6)	45
Stable (10)	55
Dominant Process Recorded	
Aggradation	36
Erosion	9
No process (bed stable)	55

Sand and gravel bars were recorded at 55% of sites, occurring mostly as point bars, although a small proportion were alternate bars or channel bar plains. The mean size of these bars was 10% of the bed surface above water mark, ranging from 5-25%. The gravel forming the bed and bars, where present, was sphere-shaped and was generally rounded or sub-angular. As expected in an estuary, the bed compaction was low.

Bed stability was not affected by any factors at 73% of sites. Instream siltation, agriculture/grazing or bank erosion was affecting bed stability at 9% of sites. Some reaches had rock outcrops (27% of sites) and fallen trees (18%) which had a bed stabilising influence.

♦ *Bed and Bank Sediments*

Pool habitats had a high proportion of fine material (ie clays) along their beds, although some sands and a small amount of gravel were recorded. Pool banks were predominantly composed of fines. The riffle and run habitats, on the other hand, had beds that were composed of a range of sediment sizes (fines, sands, gravels and cobbles), although their banks were predominantly composed of fines. Organic matter was present in both bed and banks of all habitat types and ranged from 11-17%. Rock outcrops were not widespread (recorded at 9% of site cross-sections) and, where present, were located in the bed.

♦ *Riparian Vegetation*

The majority of the riparian vegetation was rated as having either moderate or high cover and structural diversity (refer Table 5.5).

Table 5.5 Cover and Structural Diversity of Riparian Vegetation

Riparian Vegetation Category (Rating)	Percent of Sites (%)
Very Low Cover/Diversity (1-2)	0
Low Cover/Diversity (3-4)	9
Moderate Cover/Diversity (5-6)	46
High Cover/Diversity (7-8)	45
Very High Cover/Diversity (9-10)	0

The major vegetation type recorded was lowland monsoon vine-forest (45% of sites), mangroves (27%) or vegetation associated with freshwater streams (27%). The average width of the riparian vegetation zone was 26m (range 5-50m), with 18% of sites recording riparian zones of between 5-10m, 17% between 11-20m, 36% between 21-30m, 18% between 31-40m and 9% >40m.

The structural types recorded are shown in Table 5.6. Small trees (2-10m) and grasses were present at all sites. Mangroves were present at 27% of sites. Covers ranged from 0-50%.

Table 5.6 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	0	0
Trees (10-30m)	73	20.9 (0-50)
Trees (2-10m)	100*	30.7 (8-50)
Regen. Trees (<2m)	91	8.5 (0-30)
Woody Shrubs (<2m)	91*	8.8 (0-30)
Vines	91*	10.5 (0-20)
Rushes and Sedges	36	1.5 (0-15)
Phragmites	55	3.6 (0-12)
Forbs (or Herbs)	91*	7.1 (0-30)
Grasses	100	6.1 (0-25)
Ferns	0	0
Mangroves	27	8.0 (0-40)
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

The overstorey provided a greater cover than the understorey vegetation. The upper bank recorded an average of 84% bare (range 70-98%) for understorey vegetation cover and 45% bare (range 25-72%) for the overstorey vegetation.

Exotic riparian vegetation species were recorded at over half of the sites (refer Table 5.7). Where present, most covers recorded were relatively low (between 1-5%), although one tidal site near Daly River Crossing recorded a high cover for 3 exotic species. The mean total cover of exotic species in the riparian zone was 5% (range 0-30%). Structural types included small trees 2-10m (18% of sites), shrubs (9%), vines (27%) and forbs (45%).

Table 5.7 Cover of Exotic Riparian Vegetation

% Cover Category (Rating)	**Percent of Sites (%)
16 - 32* (2)	9
11 - 15 (4)	0
6 - 10 (6)	9
1 - 5 (8)	46
0 (10)	36

* The maximum % cover recorded for exotic riparian vegetation within the catchment was 32%.

** If all sites where the dominant riparian vegetation was noted, but no covers documented, were to be included, 62% of sites would record the presence of exotic riparian vegetation.

The average percent covers for the exotic vegetation was low for all structural types except forbs and ranged up to 5%. Forbs had a mean cover of 3.6%, though they ranged up to 25%. Noxious species were present at 46% of sites. *Xanthium occidentale* (Noogoora Burr) was the most common noxious species (present at 31% of sites), and had the highest cover (mean of 18%). Other more prevalent noxious species included *Hyptis suaveolens* (23% of sites) and *Parkinsonia aculeata* (15%). *Passiflora foetida* (an exotic, naturalised vine) was present at 23% of sites.

An exotic species that has been recorded as widespread in the Daly floodplain estuary system (ANCA, 1993), but was not collected as part of this survey, is *Mimosa pigra*.

♦ *Aquatic Vegetation*

All sites recorded the presence of emergent aquatic vegetation which had a mean cover of 16% (range 4-45%). Submerged vegetation, as *Chara sp.,* was present at 9% of sites and recorded a mean cover of 5%.

The structural categories recorded for the emergent aquatic vegetation was Phragmites (36% of sites), rushes and sedges (36%), other shrubs and trees (27%), Pandanus (55%) and Melaleucas (9%). The major emergent species recorded included *Pandanus aquaticus* (55%), *Phragmites karka* (36%) and *Schoenoplectus litoralis* (18%).

♦ *Instream and Bank Habitats*

Sites assessed in this sub-section were rated as having either moderate (55% of sites) or high (45%) cover and diversity of instream and bank habitats. Subjectively, the aquatic habitat condition was rated as good (45% of sites), poor to good (45%) or poor (10%).

The dominant instream habitat types included permanent pools deeper than 1m (91% of sites), individual logs (91%), individual branches (73%), terrestrial leaves and twigs (64%) and emergent vegetation (45%). The extent of instream cover provided by these habitat types was generally less than 10%, although pools deeper than 1m recorded a mean cover of 76%.

Four different types of overhanging bank cover were represented in this sub-section. Vegetation canopy cover was found at all sites and occurred along 64% of the bank, with a mean width of 1.7m. Vegetation overhang was also found at all sites, although it occurred along 16% of the bank and had a mean width of 0.9m. Other bank covers included root overhang (91% of sites) and bank overhang (45%). Both these types of bank covers occurred over less than 10% of the bank length and had a width of <1m.

At the time of the survey, 55% of sites had unrestricted passage for fish and other aquatic organisms; 18% were partly restricted; and 9% had either good passage, were very restricted or had no passage. If the water level were normal, 64% of sites would have unrestricted passage, while 27% good passage and 9% would still be partly restricted.

♦ *Overall Condition*

The overall condition rating for sites assessed in this sub-section was high (82% of sites) or very high (18%).

Very high overall condition (Site 1a/16: Daly River)

5.1.1.2 Daly River – below Douglas River

Sub-section 1b encompasses the Daly River from Daly River Crossing upstream to Douglas River junction. Seven sites, located on the Daly River, were fully assessed in this sub-section.

♦ *Reach Environs and Site Features*

The majority of sites (86%) were rated as having essentially natural reach environs, while 14% of sites had some modification to the reach environs. Subjective disturbance ratings indicated that 72% of sites had low levels of disturbance, while 14% had low to moderate disturbance and 14% were moderately disturbed.

All sites had land tenure that was either freehold or leasehold. Grazing was the major land use which occurred predominantly on virgin timbered native pastures (100% of sites), thinned native pastures (86%) or cleared native pastures (14%).

Grazing activity was the major disturbance likely to affect stream reaches (100% of sites). Other disturbances included roads and tracks (43% of sites). All sites recorded billabongs/oxbows as the major floodplain feature. Other features included prominent flood channels (29% sites) and floodplain erosion and scouring (14%).

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 1,228m (range 225-3,774m). These reaches were dominated by pools, which were present at all sites. The pools, on average, covered 78% of the reach length (range 62-93%). Other habitat types were riffles (43% of sites), runs (43%) and a rapid (14%). The diversity of channel habitat types in this sub-section was rated as either high (71% of sites) or moderate (29%).

The water level at the time of sampling was at the water mark (normal water level) along all reaches assessed. Table 5.8 presents the mean dimensions for the pool, riffle and run habitats. Pools were deeper, averaging 2.7m, and longer than riffle or run habitats. Widths were quite high for all habitats, ranging from 43-59m. Riffles and runs recorded higher width to depth ratios than pools. No lower banks were recorded in this sub-section. Upper banks were wide, high and moderately steep for all habitats.

Bank slopes along the reaches were generally moderate, though others were steep, low or flat. Bank shapes were generally either convex or concave.

High riparian vegetation rating (Site 1b/1: Daly River)

Moderate instream and bank habitat rating; stable; high overall rating (Site 1b/8: Daly River)

Table 5.8 Channel Dimensions for Pool, Riffle and Run Habitat Types

Dimension		Pool	Riffle	Run
Mean Percent of Reach Covered (%)		77.6 (62-93)	11.7 (7-19)	28.0 (16-35)
Mean Length (m)		747.9 (90.0-2,000.0)	93.3 (60.0-135.0)	185.0 (75.0-400.0)
Mean Depth at Water Mark (m)		2.7 (1.5-4.3)	1.2 (0.3-2.4)	1.3 (0.7-2.2)
Mean Width at Water Mark (m)		56.7 (50.0-74.0)	43.3 (35.0-60.0)	59.3 (45.0-70.0)
Width:Depth Ratio		23.6 (15.7-39.4)	64.5 (25.0-129.6)	55.4 (31.8-70.0)
Upper Bank	Width (m)	20.9 (11.0-50.0)	29.8 (14.0-50.0)	18.2 (15.0-22.0)
	Height (m)	15.1 (8.0 – 45.0)	20.7 (11.0-45.0)	14.0 (8.0-25.0)
	Slope (^{o})	35.5 (21.5-52.1)	35.9 (14.6-52.0)	36.6 (24.0-48.7)

♦ *Bank Condition and Stability*

All reaches assessed in this sub-section (100% of sites) had stable banks. Subjective ratings indicated that the overall bank instability and the susceptibility of banks to erosion were either low (71% of sites) or minimal to low (29%).

Some form of erosion processes along the river banks was recorded for all reaches within this sub-section (100% sites). The erosion was predominantly occurring along outside bends (100% of sites), at obstacles (86%) or at seepage /runoff points (14%). The bank erosion was minor and, on average, 96% of the bank length was stable. Some aggradation (14% of sites) was recorded at irregular intervals along the river.

The major factors identified as affecting bank stability, although minor, were high flow and stock (100% of sites). Other factors included seepage, roads/bridges/crossings and people tracks (14% of sites). No artificial bank protection measures, such as fencing or tree planting, were recorded in this sub-section.

♦ *Bed and Bar Condition and Stability*

All reaches assessed in this sub-section (100% of sites) were subjectively rated as having stable beds.

Sand and gravel bars were recorded at all sites, occurring mostly as point bars (57% of types), mid-channel islands (57%), alternate bars (43%) or bars with encroaching vegetation (14%). The mean size of these bars was 11% of the bed surface above water mark, ranging from 5-25%. The gravel forming the bed and bars was either sphere-shaped or disc-shaped and had rounded or sub-angular material. The bed compaction ranged from low compaction (57% of sites), moderate compaction (57%), to being packed (29%).

Bed stability was not affected by any factors at 71% of sites. Factors identified as affecting bed stability were agriculture/grazing (29% of sites) or concentration of flow (14% of sites). Rock outcrops provided a degree of bed stabilising influence at 86% of sites.

♦ *Bed and Bank Sediments*

Pool habitats had a high proportion of fine material (ie clays) and sands along their beds, although gravels and boulders made up 22% of the bed material. Pool banks were predominantly composed of fines and sands, although boulders were present in the lower bank, making up 10% of the bank material. Run habitats had a high proportion of sands and small gravels making up the bed material and their banks were predominantly fines and small sands. Riffle habitats had a range of material making up their beds but was predominantly fines, sands and boulders. Riffle banks were predominantly fines and small sands, although boulders comprised 17% of the lower bank material.

Organic matter was present in both bed and banks of all habitat types and ranged from 8-27%. Rock outcrops were prevalent and were recorded at 86% of sites, mostly being located in the bed, although rock outcrops also occurred in the banks.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having either high (57% of sites) or moderate (43%) cover and structural diversity. The vegetation type recorded at all sites was vegetation associated with freshwater streams. The average width of the riparian vegetation zone was 40m (range 18-50m), with 14% of sites recording riparian zones of between 11-20m, 29% between 21-30m, 14% between 31-40m and 71% >40m.

The structural types recorded are shown in Table 5.9. There was a good range of structural types present, with medium-sized trees (10-30m tall), small trees (2-10m), regenerating trees, shrubs, vines, forbs, grasses and ferns recorded present at all sites. Covers ranged from 0-50%, though 34% was the highest mean cover recorded and this was for medium-sized trees.

The overstorey provided a greater cover than the understorey vegetation. The upper bank recorded an average of 66% bare (range 30-85%) for understorey vegetation cover and 47% bare (range 30-70%) for the overstorey vegetation.

The more common native overstorey species recorded at all sites were *Barringtonia acutangula, Casuarina cunninghamiana* and *Pandanus aquaticus*. Native ground cover vegetation that was present at all sites was a grass, *Cynodon dactylon*. Refer Part 2 for a more complete list of the vegetation species present.

All sites recorded the presence of exotic riparian vegetation, ranging from 1 to 6 different species at a site, including noxious species (refer Table 5.10). Covers recorded were generally high and ranged from 16-32% at nearly half the sites. The mean total cover of exotic species in the riparian zone was 17% (range 5-32%). Structural types included forbs (100% of sites), vines (57%) and shrubs (14%).

Table 5.9 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	29	1.0 (0-5)
Trees (10-30m)	100	34.0 (25-50)
Trees (2-10m)	100	22.9 (10-50)
Regen. Trees (<2m)	100	6.3 (5-8)
Woody Shrubs (<2m)	100*	6.7 (4-15)
Vines	100*	5.9 (3-10)
Rushes and Sedges	43	1.6 (0-5)
Phragmites	71	2.9 (0-5)
Forbs (or Herbs)	100*	18.6 (8-35)
Grasses	100	12.1 (4-50)
Ferns	100	5.0 (0-10)
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

Table 5.10 Cover of Exotic Riparian Vegetation

% Cover Category (Rating)	Percent of Sites (%)
16 - 32* (2)	43
11 - 15 (4)	14
6 - 10 (6)	29
1 - 5 (8)	14
0 (10)	0

* The maximum % cover recorded for exotic riparian vegetation within the catchment was 32%.

The mean percent cover for the exotic vegetation was low (up to 5%) for shrubs and vines. Forbs had a mean cover of 15% (range 5-30%). *Xanthium occidentale* (Noogoora Burr) was the most common noxious species (present at all sites), and it also had the highest mean cover of 13% (range 5-28%). Other more prevalent noxious species included *Hyptis suaveolens* (57% of sites) and *Leonotis nepetifolia* (29%). Other exotic vine species included *Passiflora foetida* (57% of sites) and *Cardiospermum halicacabum* (43%).

♦ *Aquatic Vegetation*

All sites recorded the presence of aquatic vegetation. Forms of aquatic vegetation recorded were emergent (86% of sites) or submerged (57%). Covers were low for both vegetation types (ie 6% and 3% respectively).

The structural categories recorded for the emergent aquatic vegetation were Phragmites (71% of sites), rushes and sedges (14%), Pandanus (43%) and Melaleucas (14%). The major emergent species recorded included *Phragmites karka* and *Pandanus aquaticus*. The submerged structural types included Chara/Nitella (29% of sites) and Vallisneria (43%). The species were *Nitella sp*. and *Vallisneria spiralis*.

♦ *Instream and Bank Habitats*

Nearly three-quarters of the sites (71%) were rated as having high cover and diversity of instream and bank habitats, while 29% recorded a moderate cover and diversity. Subjectively, the aquatic habitat condition was rated as good (86% of sites) or good to very high (14%).

The dominant instream habitat types that were present at all sites included individual logs, individual branches, terrestrial leaves and twigs, rock faces and permanent pools deeper than 1m. The extent of instream cover provided by these habitat types was generally less than 10%, although rock faces recorded a mean cover of 19% (range 4-50%) and pools deeper than 1m recorded a mean cover of 69% (range 40-95%).

Four different types of overhanging bank cover were represented in this sub-section. Vegetation canopy cover was found at all sites and occurred along 73% of the bank, with a mean width of 2.1m. Vegetation overhang was also found at all sites, although it only occurred along 20% of the bank and had a mean width of 0.6m. Other bank covers included root overhang (100% of sites) and bank overhang (29%). Both these types of bank covers occurred over less than 10% of the bank length and had a width of <1m.

At water mark (normal level), 29% of sites have unrestricted passage for fish and other aquatic organisms, 43% have good passage and 14% would still be either partly or moderately restricted.

♦ *Overall Condition*

All sites recorded a high overall condition rating.

Point bar on Daly River

5.1.1.3 Daly River – below Fergusson River

Sub-section 1c encompasses the Daly River from the junction with the Douglas River upstream to Fergusson River junction. Of the 8 sites in this sub-section, all of which are located on the Daly River, 7 were fully assessed.

♦ *Reach Environs and Site Features*

Sites were rated as either having essentially natural reach environs (50% of sites) or some modification to the reach environs (50%). Subjective disturbance ratings indicated that 63% of sites had low levels of disturbance, 13% had low to moderate disturbance and 25% were moderately disturbed.

All sites had land tenure that was either freehold or leasehold. Grazing was the major land use which occurred predominantly on thinned native pastures (63% of sites), virgin timbered native pastures (50%), cleared native pastures (38%) or with sown pastures (38%).

Grazing activity was the major disturbance likely to affect stream reaches (100% of sites). Other disturbances included people (50% of sites), causeway/river crossings (38%) or roads and tracks (13%). The major floodplain features recorded included billabongs/oxbows (88% of sites), prominent flood channels (50%) and floodplain erosion and scouring (13%).

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 1,702m (range 200-5,000m). The pools, on average, covered 68% of the reach length (range 33-100%). Although pools dominated the reaches (100% of sites), there was a range of habitat types. Other habitats present were riffles (63% of sites), rapids (38%) and runs (25%). The diversity of channel habitat types was mostly high (refer Table 5.11).

Table 5.11 Channel Type Diversity

Diversity Category (Rating)	Percent of Sites (%)
Very Low Diversity (1-2)	0
Low Diversity (3-4)	13
Moderate Diversity (5-6)	12
High Diversity (7-8)	62
Very High Diversity (9-10)	13

The water level at the time of sampling was at the normal water level (63% of sites), or was moderate but less than the water mark (38%). Table 5.12 presents the mean dimensions for the pool, riffle and rapid habitats. To allow for comparison of the dimensions between the various channel habitat types, regardless of the variation in water levels, only those recorded at the water mark are listed.

Pools were over three times deeper than riffles or rapids and were wider, particularly compared to rapids. Width:depth ratios were higher for rapids and riffles. The lower banks were generally narrow and low, with a moderate to steep slope. Upper banks were generally wide and high, with moderate slopes. Bank slopes along the reaches were mostly moderate and shapes were generally either convex or concave, although wide lower benches and stepped banks were also present.

♦ *Bank Condition and Stability*

All reaches assessed in this sub-section (100% of sites) had stable banks. Subjective ratings indicated that the overall bank instability was low (100% of sites), although at 14% of sites the instability was recorded as moderate. The susceptibility of banks to further degradation was subjectively rated as low (86% of sites), low to moderate (14%) or moderate (14%).

The dominant bank process identified was erosion and was recorded for all reaches within this sub-section (100% sites). The erosion was predominantly occurring at obstacles (100% of sites), along outside bends (57%), or at seepage /runoff points (29%). The bank erosion was relatively minor and, on average, 90% of the bank length was stable. Some aggradation was recorded at obstacles (29% of sites) or along outside bends (14%).

The major factors identified as affecting bank stability, although relatively minor, were high flow and stock (100% of sites). Other factors included seepage (43% of sites), roads/bridges/crossings (29%), people tracks (29%), floodplain scours (14%) or runoff (14%). No artificial bank protection measures, such as fencing and tree planting, were recorded in this sub-section.

♦ *Bed and Bar Condition and Stability*

The majority of sites (75%) were subjectively rated as having beds that were moderately aggrading, while 25% were stable.

Table 5.12 Channel Dimensions for Pool, Riffle and Rapid Habitat Types

Dimension		Pool	Riffle	Rapid
Mean Percent of Reach Covered (%)		67.6 (33-100)	22.8 (2-50)	30.7 (12-67)
Mean Length (m)		984.3 (140.0-2,600.0)	94.0 (60.0-120.0)	236.7 (120.0-460.0)
Mean Depth at Water Mark (m)		2.0 (1.0-3.0)	0.6 (0.3-0.9)	0.6 (0.5-0.6)
Mean Width at Water Mark (m)		54.1 (41.5-65.0)	41.0 (31.0-50.0)	28.3 (10.0-50.0)
Width:Depth Ratio		32.8 (13.8-63.2)	76.5 (44.4-140.0)	52.5 (16.7-91.0)
Lower Bank	Width (m)	0.2 (0.1-0.5)	0.2 (-)	0.7 (0.6-0.7)
	Height (m)	0.3 (0.2-0.4)	0.2 (-)	0.4 (0.3-0.4)
	Slope (^{o})	61.4 (21.8-76.0)	45.0 (-)	28.2 (26.2-29.7)
Upper Bank	Width (m)	21.3 (7.5-40.0)	27.0 (12.0-63.0)	30.0 (12.0-75.0)
	Height (m)	13.5 (9.0 – 22.0)	14.6 (11.0-21.0)	14.1 (12.0-16.5)
	Slope (^{o})	34.0 (15.5-54.5)	32.9 (12.1-52.7)	35.0 (11.3-54.0)

Sand and gravel bars were recorded at all sites. The five bar types recorded were mid-channel islands (63% of types), alternate/side irregular (50%), high flow deposits (25%), around obstacles (13%) and point bars (13%). The mean size of these bars was 22% of the bed surface above water mark, though this ranged from 5% to as high as 50%. The bar sizes were larger than for other sections of the Daly River.

All sites within Sub-section 1c (except 1c/2) recorded instream siltation. The Daly River was very shallow in places and was observed to be carrying a large amount of sediment. This was particularly evident between Claravale Crossing and Fergusson River junction, where the Daly River was very shallow and large, instream bars were observed, along with high flow deposits. Numerous 'bars' were observed along other sections (eg near Oolloo Crossing) but the majority were below the water mark level and, therefore, were not recorded as a 'bar'.

The gravel forming the bed and bars was either sphere-shaped or disc-shaped and had rounded or sub-angular material. The bed compaction ranged from low compaction (13% of sites), moderate compaction (50%) to being packed (63%).

Factors identified as affecting bed stability were instream siltation (75% of sites) and agriculture/ grazing (13%). Bed stability was not affected by any factors at 25% of sites. Rock outcrops provided a degree of bed stabilising influence at 75% of sites.

♦ *Bed and Bank Sediments*

Pool, riffle and rapid habitats had a full range of sediment sizes comprising the bed material. The bed material at pools was predominantly a mixture of sands, gravels, cobbles and boulders, with only 4% of material present as fines. The bed material at riffle and rapid habitats was predominantly gravels, cobbles and boulders. Fines and small sands were prevalent in the banks, although 5-6% of boulder material was present in the lower banks at pools and riffles.

Organic matter was present in both bed and banks of habitat types and ranged from 7-13%. Rock outcrops were recorded at 75% of sites, mostly being located in the bed or lower banks

♦ *Riparian Vegetation*

The riparian vegetation at all sites was rated as having high cover and structural diversity. The major vegetation type recorded was vegetation associated with freshwater streams (100% of sites). The average width of the riparian vegetation zone was 48m (range 45-50m). All sites, therefore, had riparian vegetation in the category of >40m.

The structural types recorded are shown in Table 5.13. There was a good range of structural types present, with medium trees (10-30m), small trees (2-10m), regenerating trees, shrubs, vines, forbs, and grasses recorded present at all sites. Covers ranged from 0-50%, though 31% was the highest mean cover recorded and this was for medium trees.

Table 5.13 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	29	1.0 (0-5)
Trees (10-30m)	100	29.0 (15-50)
Trees (2-10m)	100	31.1 (10-50)
Regen. Trees (<2m)	100	6.7 (5-10)
Woody Shrubs (<2m)	100	4.9 (4-5)
Vines	100*	7.0 (5-10)
Rushes and Sedges	29	1.4 (0-5)
Phragmites	57	2.7 (0-5)
Forbs (or Herbs)	100*	13.1 (8-20)
Grasses	100	8.6 (5-25)
Ferns	86	4.1 (0-8)
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

The overstorey provided a greater cover than the understorey vegetation. The upper bank recorded an average of 81% bare (range 70-95%) for understorey vegetation cover and 41% bare (range 20-75%) for the overstorey vegetation.

The more common native overstorey species recorded at all sites were *Barringtonia acutangula* and *Casuarina cunninghamiana*. The most common native ground cover species were *Ampelopteris prolifera* (a fern present at 75% of sites) and *Cynodon dactylon* (a grass present at 75% of sites). Refer to Part 2 for vegetation lists or vegetation profiles for sites in this sub-section.

Exotic riparian vegetation, including noxious species, was recorded at all sites, with between 1 and 3 species being found (refer Table 5.14). The mean total cover of exotic species in the riparian zone was 10% (range 0-22%). Structural types included forbs (100% of sites) and vines (43%).

Table 5.14 Cover of Exotic Riparian Vegetation

% Cover Category (Rating)	Percent of Sites (%)
16 - 32* (2)	14
11 - 15 (4)	29
6 - 10 (6)	28
1 - 5 (8)	29
0 (10)	0

* The maximum % cover recorded for exotic riparian vegetation within the catchment was 32%.

The mean percent covers for exotic vegetation was low (less than 10%) for forbs and vines, although forbs ranged up to 15% cover. *Xanthium occidentale* (Noogoora Burr) was the most common noxious species (100% sites), and also had the highest mean cover of 9% (range 5-15%). The only other noxious species present was *Hyptis suaveolens* (13% of sites). Other exotic vine species included *Passiflora foetida* (50% of sites) and *Cardiospermum halicacabum* (25%).

♦ *Aquatic Vegetation*

Aquatic vegetation was present at 86% of sites. Forms of vegetation recorded were emergent (71% of sites) and submerged (71%). Mean covers were low for both vegetation types (ie 5% and 6% respectively, ranging up to 10%).

The structural categories recorded for the emergent aquatic vegetation were Phragmites (29% of sites), rushes/sedges (43%) and Pandanus (29%). The emergent species recorded included *Phragmites karka*, *Pandanus aquaticus*, *Schoenoplectus litoralis* and *Eleocharis geniculata*. The submerged structural types included filamentous algae (57% of sites), Chara/Nitella (14%) and Vallisneria (14%). The species recorded were *Chara sp*. and *Vallisneria spiralis*.

♦ *Instream and Bank Habitats*

All sites were rated as having high cover and diversity of instream and bank habitats. Subjectively, the aquatic habitat condition was rated as good (43% of sites), good to very high (29%) or poor to good (29%).

The dominant instream habitat types present at all sites were permanent pools deeper than 1m, individual logs and terrestrial leaves and twigs. Other types included algal clumps (86% of sites), individual branches (86%), rock faces (86%) and branch piles<50% (57%). The extent of instream cover provided by these habitat types was less than 10%, although rock faces recorded a mean cover of 21% (range 0-40%) and permanent pools recorded a mean cover of 62% (range 25-90%).

Four different types of overhanging bank cover were recorded. Vegetation canopy cover (100% of sites) occurred along 70% of the bank, with a mean width of 2.0m. Vegetation overhang (100% of sites) only occurred along 21% of the bank and had a mean width of 1.0m. Other bank covers included root overhang (71% of sites) and bank overhang (43%). Both these types of bank covers occurred over less than 10% of the bank length and had a width of <1m.

At water mark (normal level), 14% of sites have unrestricted passage for fish and other aquatic organisms, 43% have good passage, 29% would be partly restricted and 14% moderately restricted.

♦ *Overall Condition*

The overall condition rating for sites assessed in this sub-section was high (86% of sites) or very high (14%).

Moderate bed aggradation (1c: Daly River)

Very high overall rating (Site 1c/2: Daly River)

5.1.1.4 Daly River – below Katherine River

Sub-section 1d encompasses the Daly River from Fergusson River junction upstream to the Katherine River junction. Of the 3 sites in this sub-section, all of which are located on the Daly River, 2 were fully assessed.

♦ *Reach Environs and Site Features*

Sites within this sub-section were rated as having some modification to their reach environs. Subjective disturbance ratings indicated that 50% of sites had low disturbance and 50% were moderately disturbed.

Both sites had land tenure that was either freehold or leasehold. Grazing was the major land use at all sites and occurred on thinned native pastures and virgin timbered native pastures. Other uses included rainfed broadacre crops (50% of sites) and irrigated broadacre crops (50%).

Grazing activity was the major disturbance likely to affect stream reaches (100% of sites). The major floodplain features recorded at all sites were billabongs/ oxbows.

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 667m (range 230-1,020m). These reaches were dominated by pools, which were present at 100% of sites. The pools, on average, covered 78% of the reach length (range 67-87%). Other habitat types present were rapids (67% of sites) and runs (33%). The diversity of channel habitat types in this sub-section was assessed as high for all sites.

The water level at the time of sampling was moderate but less than the water mark (100% of sites). Table 5.15 presents the mean dimensions for the pool, rapid and run habitats. To allow for comparison of the dimensions between the various channel habitat types, regardless of the variation in water levels, only those recorded at the water mark are listed.

Table 5.15 Channel Dimensions for Pool, Rapid and Run Habitat Types

Dimension		Pool	Rapid	Run
Mean Percent of Reach Covered (%)		77.7 (67-87)	27.5 (22-33)	12.0 (-)
Mean Length (m)		526.7 (180.0-900.0)	150.0 (50.0-250.0)	120.0 (-)
Mean Depth at Water Mark (m)		3.2 (2.4-4.4)	1.1 (0.5-1.7)	1.4 (-)
Mean Width at Water Mark (m)		43.3 (34.0-50.0)	28.5 (27.0-30.0)	46.0 (-)
Width:Depth Ratio		15.0 (7.7-21.3)	37.6 (17.7-57.5)	32.9 (-)
Lower Bank	Width (m)	0.1 (0.1-0.2)	0.2 (0.1-0.3)	0.2 (-)
	Height (m)	0.2 (0.1-0.3)	0.2 (0.1-0.3)	0.2 (-)
	Slope (^{o})	51.3 (45.0-71.6)	45.0 (-)	45.0 (-)
Upper Bank	Width (m)	17.3 (10.5-25.0)	46.5 (17.0-88.0)	16.5 (8.0-25.0)
	Height (m)	6.3 (5.5 – 7.0)	8.0 (4.5-10.5)	6.8 (6.0-7.5)
	Slope (^{o})	21.1 (14.6-27.7)	13.0 (6.8-24.7)	26.8 (17.0-37.0)

Pools were relatively deep at 3.2m, and were three times deeper then the rapid or run habitats. Widths for both pools and runs were similar, whereas rapids were narrower in comparison. Width:depth ratios were higher for rapid and run habitats. The lower banks were generally narrow and low, with moderate slopes. Upper banks were generally wider, particularly at rapids, and higher, with low to moderate slopes.

Bank slopes along the reach were mostly moderate and shapes were generally either convex or concave.

♦ *Bank Condition and Stability*

All reaches assessed in this sub-section (100% of sites) had stable banks. Subjective ratings indicated that the overall bank instability and the susceptibility of banks to further erosion were low to moderate (50% of sites) or moderate (50%).

Erosion was the dominant bank process recorded at all sites. The erosion was predominantly occurring at obstacles (100% of sites), along outside bends (50%) or at irregular intervals (50%). Some aggradation was recorded along inside bends (50% of sites). Lower banks were more stable than upper banks, with an average of 18% of the upper bank length eroding compared to 6% for the lower bank.

The major factors identified as affecting bank stability were high flow and stock (100% of sites), although runoff was also recorded (50%). No artificial bank protection measures, such as fencing, were recorded in this sub-section.

♦ *Bed and Bar Condition and Stability*

Subjectively, 50% of sites were rated as having stable beds, while 50% were moderately eroding.

Sand and gravel bars were recorded at all sites, occurring as both high flow deposits and point bars. The mean size of these bars was 7% of the bed surface above water mark (range 5-8%). The gravel forming the bed and bars was either disc-shaped (100% of sites) or sphere-shaped (50%) and had sub-angular (100%) or rounded (50%) material. The bed compaction ranged from low compaction (100% of sites) to being packed (50%).

Factors identified as affecting bed stability were agriculture/grazing (50% of sites) and bank erosion (50%). Bed stability was not affected by any factors at 25% of sites. Rock outcrops and fallen trees provided a degree of bed stabilising influence at all sites.

♦ *Bed and Bank Sediments*

The bed material at pools was predominantly sand, whilst the bank material was fines and small sand. Rapids had a full range of sediment sizes (excluding boulders) comprising the bed and bank material, although cobbles made up 73% of the bed material. The bed material at run habitats was predominantly a mixture of sands and small gravels, while the bank material was mostly fines. Organic matter was present in both bed and banks of all habitat types and ranged from 4-15%. Rock outcrops were recorded at 67% of sites, mostly being located in the bed or upper banks.

♦ *Riparian Vegetation*

The riparian vegetation for all sites was rated as having moderate cover and structural diversity. The major vegetation type recorded was vegetation associated with freshwater streams (100% of sites). The average width of the riparian vegetation zone was 45m (range 40-50m), with 50% of sites recording riparian zones of between 31-40m and 50% >40m.

The structural types recorded are shown in Table 5.16. There was a good range of structural types present, with 8 of the 13 represented at all sites. Covers ranged from 0-25%, though 23% was the highest mean cover recorded and this was for medium-sized trees.

The overstorey provided a slightly greater cover than the understorey vegetation. The upper bank recorded an average of 77% bare (range 75-78%) for understorey vegetation cover and 63% bare (range 60-65%) for the overstorey vegetation.

The more common native overstorey species recorded at all sites were *Barringtonia acutangula Casuarina cunninghamiana, Eucalyptus camaldulensis, Melaleuca argentea, M. leucadendra, Pandanus aquaticus* and *Nauclea orientalis*. The most common native ground cover species was *Cynodon dactylon* (a grass present at all sites). Refer to Part 2 for vegetation lists or vegetation profiles for sites in this sub-section.

Exotic riparian vegetation, including noxious species, was recorded at all sites, with between 2 and 4 species being found at a site. The sites rated as having a high invasion by exotics with the mean total cover of exotic species in the riparian zone being 12% (range 10-16%). Structural types included forbs (100% of sites) and vines (100%).

Table 5.16 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	0	0
Trees (10-30m)	100	22.5 (20-25)
Trees (2-10m)	100	13.5 (12-15)
Regen. Trees (<2m)	100	5.0 (-)
Woody Shrubs (<2m)	100	5.5 (4-7)
Vines	100*	8.8 (8-10)
Rushes and Sedges	0	0
Phragmites	100	4.5 (4-5)
Forbs (or Herbs)	100*	16.3 (15-20)
Grasses	100	17.0 (15-20)
Ferns	50	1.0 (0-2)
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

Xanthium occidentale (Noogoora Burr) was the only noxious species recorded (100% of sites), and had a mean cover of 8%. Other more common exotic species included *Passiflora foetida*, a naturalised vine, present at 67% of sites (mean cover of 3%).

♦ *Aquatic Vegetation*

Aquatic vegetation was present at all sites in the form of emergent vegetation. Mean cover for this type was low, averaging 6% (range 4-7%).

The structural categories recorded for the emergent aquatic vegetation were Phragmites (50% of sites) and Pandanus (100%). The emergent species recorded included *Phragmites karka* and *Pandanus aquaticus*.

♦ *Instream and Bank Habitats*

All sites were rated as having high cover and diversity of instream and bank habitats. Subjectively, the aquatic habitat condition was rated as good for all sites.

The dominant instream habitat types present at all sites were permanent pools deeper than 1m, rock faces, individual logs, terrestrial leaves and twigs, individual branches, emergent vegetation, algal clumps and log jams. The extent of instream cover provided by these habitat types was less than 10%, although individual logs recorded a mean cover of 13%, rock faces recorded 19% (range 10-28%) and pools deeper than 1m recorded a mean cover of 68% (range 65-70%).

Four different types of overhanging bank cover were recorded. Vegetation canopy cover (100% of sites) occurred along 76% of the bank, with a mean width of 2.4m. Vegetation overhang (100% of sites) only occurred along 8% of the bank and had a mean width of 1.0m. Other bank covers included root overhang (100% of sites) and bank overhang (50%). Both these types of bank covers occurred over less than 5% of the bank length and had a width of <1m.

At water mark (normal level), 50% of sites have good passage for fish and other aquatic organisms, while 50% would be partly restricted.

♦ *Overall Condition*

The overall condition rating for sites assessed in this sub-section was high (100% of sites).

Moderate riparian vegetation (1d: Daly River)

5.1.1.5 Comparison of Daly River Sub-sections

The *reach environs* for sections of the Daly River were rated as either essentially natural or having some modification. Subjective disturbance ratings indicated a generally low level of reach environs disturbance in the mid-catchment and low to moderate levels in the tidal and upper Daly River section. Grazing was identified as the major land use and disturbance factor likely to affect stream reaches, which were predominantly located on freehold or leasehold land.

Channel type diversity ranged although was generally high. Lower diversity ratings were recorded along the lower sections of the Daly River estuary where pools were very uniform and along other sections (eg upstream of Douglas River junction) where pools were very long. Pools dominated all reaches along the Daly River and were particularly deep and wide in the estuary. Upper banks were narrower and lower along the tidal section and upper section of the Daly River.

Bank stability – Reaches along the Daly River were rated as having stable banks except for sections along the estuary, where banks were actively eroding and migrating and were rated as having limited instability. Tides, within the estuary, high flows and stock were identified as the major factors affecting bank stability, although minor in places.

Bed and bar stability – Just over half of the reaches along the Daly River had stable beds. A lower tidal site and the most upper Daly River site recorded moderate bed erosion (2 of 7 sites in the Daly River catchment to do so). The lower reaches of the Daly River estuary were moderately aggrading along with most reaches within Sub-section 1c, where instream siltation was identified as affecting bed stability. Bars were common along all non-tidal reaches and were larger in reaches between Douglas and Fergusson River junctions.

The *riparian vegetation* was generally rated as having either moderate or high cover and structural diversity, except for a lower Daly River estuary site. Higher ratings relied on a range of structural types being present, with relatively good covers. The vegetation types ranged from mangrove communities and monsoon vine-forest along lower sections of the Daly River to vegetation associated with freshwater streams along mid to upper sections. The width of the riparian zone was greater in the mid- to upper parts of the Daly River, with greater variation in widths in the lower section. The overstorey vegetation (>1.3m tall) tended to dominate the structural categories and native herbs and grasses, in particular, had covers which were often <10%.

Over half the riparian zones were rated as having a moderate to very high invasion by exotic species. Covers for exotic riparian species was low or absent in the lower parts of the Daly River estuary. *Xanthium occidentale* (Noogoora Burr) was present at all Daly River sites in non-tidal areas and one-third of sites in the tidal area. It recorded the highest average covers amongst exotic species and where present, covers between 5-28% were recorded. *Hyptis suaveolens* was another notable noxious species along the Daly River, being present at one-fifth of sites. Other noxious species included scattered *Parkinsonia aculeata* along the tidal section of Daly River and *Leonotis nepetifolia* within sub-section 1b. *Passiflora foetida*, a vine, was recorded at nearly half the sites.

Although *aquatic vegetation* was present at the majority of sites along the Daly River, more commonly as emergent vegetation and, to a much lesser extent, submerged vegetation, the covers were generally low. No floating aquatic vegetation was recorded.

The cover and diversity of *instream and bank habitats* along the Daly River was high for nearly three-quarters of the reaches, particularly in the non-tidal sections. Instream habitat covers were generally <10%, except for rocks, permanent pools and, on occasions, individual logs. Canopy cover along the banks was generally good, being recorded along 64-76% of bank length.

The *overall condition* of reaches along the Daly River was predominantly high.

5.1.2 Discussion

While some differences between the Daly River sub-sections were observed, the general condition of most attributes examined was similar. Overall, the reaches rated highly or very highly.

Over one-third of sites had reach environs that were somewhat modified. The river banks were generally stable even though the reaches studied along the Daly River were mostly located on freehold or leasehold land, and grazing activity was identified as the major disturbance affecting stream reaches, river banks (along with high flow) and, in a few instances, river bed stability. On the other hand, the river bed was not as stable as the river banks and was showing signs of moderate aggradation, particularly between Oolloo Crossing and Fergusson River junction where sand and gravel bars were large and instream siltation was identified as affecting river bed stability. As expected, the lower parts of the estuary were also moderately aggrading.

The mid to lower sections of the Daly River, in particular, had riparian vegetation that had a good range of structural types with covers up to 50%. The riparian vegetation was generally wider than other areas in the catchment. Invasion of the riparian zone by exotic species, particularly by the noxious species *Xanthium occidentale* (Noogoora Burr), may be of concern, particularly if it is displacing other native ground covers. Control of problematic weed species should be considered to maintain or to improve the condition of the riparian zone and to prevent the spread of exotic species like *Xanthium occidentale* into other tributaries. The spread of problematic weed species from high use recreational areas along the Daly River into other areas should be targeted as one control measure. Aquatic vegetation was widespread.

The channel type diversity rating reflected the number of different habitat types present and the extent to which pools dominated reaches. Instream and bank habitats were relatively diverse although the cover provided ranged.

5.2 Chilling Creek

Sub-section 2 includes the catchment area of Chilling and Muldiva Creeks. Three sites, located on both creeks, were fully assessed.

5.2.1 Results

♦ *Reach Environs and Site Features*

Sites were rated as having essentially natural reach environs. Subjective disturbance ratings indicated that 67% of sites had low disturbance and 33% were low to moderately disturbed.

All sites had land tenure that was either freehold or leasehold. Grazing was the major land use that occurred predominantly on thinned native pastures (67% of sites) and virgin timbered native pastures (67%).

Grazing activity was the major disturbance likely to affect stream reaches at all sites. Other disturbances included roads/tracks (67% of sites) and causeways/river crossings (33%). The major floodplain features recorded were billabongs/ oxbows (67% of sites).

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 54m (range 21-99m). These reaches were dominated by pools, which were present at all sites. The pools, on average, covered 72% of the reach length. Other habitat types present were riffles (67% of sites) and runs (33%). The diversity of channel habitat types was rated as high for all sites.

The water level at the time of sampling was either isolated pools (67% of sites), or moderate but less than the normal level (33%).

Table 5.17 presents the mean dimensions for the pool, riffle and run habitats. The habitats, including the pools, were relatively shallow and narrow. Width:depth ratios were generally moderate. Lower banks were recorded only for pools and were generally low and relatively narrow, with gentle slopes. Upper banks were generally wider, higher and had moderate slopes.

♦ *Bank Condition and Stability*

All reaches assessed in this sub-section (100% of sites) had stable banks. Subjective ratings indicated that the overall bank instability was minimal to low (67% of sites) or low (67%). The susceptibility of banks to further erosion was minimal (33% of sites), minimal to low (33%) or low (67%).

Erosion was the dominant bank process recorded at all sites. The erosion was mostly occurring along outside bends (100% of sites) or at seepage/runoff points (67%). The bank erosion was minor and on average >95% of the bank length was stable. Some aggradation was recorded along inside bends (33% of sites) and at obstacles (33%).

The major factors identified as affecting bank stability, although minor, were stock (100% of sites) and floodplain scours (67%). No artificial bank protection measures were recorded.

♦ *Bed and Bar Condition and Stability*

Subjectively, 67% of sites were rated as having moderately aggrading beds, while 33% were stable. Sand and gravel bars were recorded at 67% of sites, occurring as alternate/side irregular bars or point bars. The mean size of these bars was 30% of the bed surface above water mark (range 20-40%).

Table 5.17 Channel Dimensions for Pool, Riffle and Run Habitat Types

Dimension		Pool	Riffle	Run
Mean Percent of Reach Covered (%)		71.7 (67-79)	26.0 (21-31)	33.0 (-)
Mean Length (m)		21.7 (14.0-34.0)	10.0 (4.5-15.5)	7.0 (-)
Mean Depth at Water Mark (m)		0.8 (0.4-1.4)	0.2 (0.2-0.3)	0.5 (-)
Mean Width at Water Mark (m)		7.9 (6.8-8.5)	7.1 (5.0-9.2)	4.5 (-)
Width:Depth Ratio		12.3 (5.9-21.5)	32.0 (30.7-33.3)	9.0 (-)
Lower Bank	Width (m)	3.5 (2.0-5.0)	-	-
	Height (m)	0.7 (0.7-0.8)	-	-
	Slope (^{o})	13.9 (8.5-19.3)	-	-
Upper Bank	Width (m)	7.8 (1.3-16.0)	4.8 (3.0-8.0)	13.0 (10.0-16.0)
	Height (m)	4.8 (1.4-10.5)	1.8 (1.4-2.0)	9.8 (9.0-10.5)
	Slope (^{o})	32.7 (15.6-66.6)	22.2 (14.0-28.1)	37.6 (33.3-42.0)

The gravel forming the bed and bars was sphere-shaped and sub-angular. The bed compaction was low at all sites. Factors identified as affecting bed stability were agriculture/grazing (33% of sites) and instream siltation (33%). Fallen trees provided a degree of bed stabilising influence at 67% of sites.

♦ *Bed and Bank Sediments*

The bed and bank material at pools and runs was predominantly fines and small sands. The bed material at riffle habitats was predominantly a mixture of sands and small gravels, whilst the bank material was mostly fines and small sand. Organic matter was present in both bed and banks of all habitat types and ranged from 14-21%. Rock outcrops were recorded at 33% of sites, and was located in the lower banks.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having either moderate (67% of sites) or high (33%) cover and structural diversity. The average width of the riparian vegetation zone was 19.5m (range 3-50m), with 33% of sites recording riparian zones of <5m, 33% between 5-10m and 33% >40m. The site that recorded a high cover and structural diversity for its riparian vegetation was also the narrowest.

The vegetation structural types recorded in the riparian zone are shown in Table 5.18. There were 6 of the 13 structural types present at all sites. Covers ranged from 0-50%. The highest mean cover was 38% and was recorded for medium-sized trees (10-30m).

The overstorey provided a greater cover than the understorey vegetation. The upper bank recorded an average of 67% bare (range 45-80%) for understorey vegetation cover and 42% bare (range 25-72%) for the overstorey vegetation. The more common native overstorey species recorded at all sites were *Barringtonia acutangula, Cupaniopsis anacardioides* and *Melaleuca argentea*.

Exotic vegetation, including noxious species, was recorded at 33% of sites (refer Table 5.19). Where present, covers recorded were moderate (between 6-10%). The mean total cover of exotic species in the riparian zone was 2% (range 0-7%). Structural types included forbs (33% of sites) and vines (33%). *Xanthium occidentale* (Noogoora Burr) was the only noxious vegetation recorded (33% of sites), and had a mean cover of 5%. The only other exotic species recorded was *Passiflora foetida*, a naturalised vine, present at 33% of sites (mean cover of 4%).

Table 5.18 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	0	0
Trees (10-30m)	100	37.7 (25-50)
Trees (2-10m)	100	31.7 (20-50)
Regen. Trees (<2m)	100	7.0 (5-8)
Woody Shrubs (<2m)	100	11. 0 (3-25)
Vines	67*	3.0 (0-5)
Rushes and Sedges	0	0
Phragmites	0	0
Forbs (or Herbs)	100*	5.3 (4-8)
Grasses	100	27.7 (8-50)
Ferns	0	0
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

Table 5.19 Cover of Exotic Riparian Vegetation

% Cover Category (Rating)	Percent of Sites (%)
16 - 32* (2)	0
11 - 15 (4)	0
6 - 10 (6)	33
1 - 5 (8)	0
0 (10)	67

* The maximum % cover recorded for exotic riparian vegetation within the catchment was 32%.

♦ *Aquatic Vegetation*

Aquatic vegetation was present at 33% of sites in the form of emergent vegetation. The only structural category present was Pandanus, which had a mean cover of 15%. The emergent species recorded was *Pandanus aquaticus*.

♦ *Instream and Bank Habitats*

Sites in this sub-section were rated as having either moderate (67% of sites) or high (33%) cover and diversity of instream and bank habitats. Subjectively, the aquatic habitat condition was rated as poor to good (67% of sites) or good (33%).

Nine instream habitat types were recorded. The dominant types present at all sites were individual logs and individual branches. Other types included leaves and twigs (67% of sites), algal clumps

(67%) and pools deeper than 1m (67%). The extent of instream cover provided by these habitat types was <10%, although leaves and twigs recorded a mean cover of 33% (range 0-75%).

Four different types of overhanging bank cover were recorded. Vegetation canopy cover (100% of sites) occurred along 77% of the bank and had a mean width of 2.3m. Vegetation overhang (100% of sites) only occurred along 13% of the bank and had a mean width of 0.7m. Other bank covers included root overhang (67% of sites) and bank overhang (67%). Both these types of bank covers occurred over less than 10% of the bank length and had a width of <1m.

At water mark (normal level), 67% of sites have moderately restricted passage for fish and other aquatic organisms, while 33% would be partly restricted.

♦ *Overall Condition*

The overall condition rating for sites assessed in this sub-section was high.

5.2.2 Discussion

The overall condition of sites was high. All reach environs were essentially natural even though they were located on freehold or leasehold land and grazing activity was identified as the major disturbance likely to affect reaches and river banks, although minor. The river banks were very stable. River beds were showing signs of moderate aggradation within upper sub-catchment sites, where bars averaged 30% of the bed surface. Grazing and instream siltation were identified as factors affecting bed stability.

Even though pools dominated reaches, the channel habitat diversity was rated highly. The cover and diversity of instream and bank habitats was mostly moderate, with one-third being assessed as high. Even though a variety of instream covers were present, covers were generally <10%. Vegetation canopy cover along the banks was generally good, averaging 77% of the bank length.

Even though the riparian vegetation zone was narrow (<10m) at the upper catchment sites, the cover and structural diversity was mostly moderate, with one-third of sites being assessed as high. Trees (2-10m tall) dominated the overstorey, though grass and shrub cover was higher. A noxious weed, in the form of *Xanthium occidentale* (Noogoora Burr), was present at one-third of the sites, and it had a cover of 5%. Aquatic emergent vegetation was very scattered in its distribution.

Moderate bed aggradation and instream / bank habitats (Site 2/2: Chilling Creek)

5.3 Hayward Creek

Sub-section 3 includes the catchment of Hayward Creek. Two sites were fully assessed in this sub-section.

5.3.1 Results

♦ *Reach Environs and Site Features*

The sites in this sub-section were rated as having essentially natural reach environs. Subjective disturbance ratings indicated that 50% of sites had low disturbance and 50% were highly disturbed.

All sites had land tenure that was either freehold or leasehold. Grazing was the major land use that occurred predominantly on thinned native pastures (50% of sites) and virgin timbered native pastures (50%).

Grazing activity was the major disturbance likely to affect stream reaches (100% of sites). Other disturbances included roads/tracks (50% of sites) and causeways/river crossings (50%). The major floodplain features recorded at all sites were billabongs/ oxbows.

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 30m (range 18-42m). These reaches were dominated by pools, which were present at all sites. The pools, on average, covered 70% of the reach length. Other habitat types present were riffles (50% of sites) and runs (50%). The diversity of channel habitat types was rated as high.

The water level at the time of sampling was either low (50% of sites), or moderate but less than the normal level (50% of sites).

Table 5.20 presents the mean dimensions for the pool, riffle and run habitats. The pools, at 1.2m deep, were two to three times deeper than riffle and run habitats. The width:depth ratios were low to moderate. All habitats were generally narrow. The lower banks were narrow and low while the upper banks varied in heights and widths for all habitat types.

♦ *Bank Condition and Stability*

The reaches assessed in this sub-section were rated as having either stable banks (50% of sites) or limited instability (50%). Subjective ratings indicated that the overall bank instability and the susceptibility of banks to further erosion were minimal (50% of sites), moderate (50%) or moderate to high (50%). An upper catchment site was experiencing localised bank erosion as a result creek widening and deepening due to an eroding creek crossing and access track.

Erosion was the dominant bank process recorded at all sites. The erosion was occurring along outside bends (100% of sites), at seepage/runoff points (50%), floodplain scours (50%) or at obstacles (50%). Both lower and upper banks were equally stable, with an average of 12% of the bank length recorded as eroding (range of 2-30%). There was no aggradation recorded along the banks.

The major factors identified as affecting bank stability were stock and high flow (100% of sites), roads/crossings (50%), floodplain scours (50%) and runoff (50%). No artificial bank protection measures were recorded at these sites.

♦ *Bed and Bar Condition and Stability*

Subjectively, 50% of sites were rated as having stable beds, while 50% were moderately eroding.

Sand and gravel bars were recorded at 50% of sites, occurring as point bars. The mean size of these bars was 4% of the bed surface above water mark. The gravel forming the bed and bars was disc-shaped (50% of sites) and was sub-angular (50%). The bed compaction ranged from low compaction (100% of sites) to moderate compaction (50%).

Factors identified as affecting bed stability were bank erosion and bed deepening (50% of sites). An upper catchment site was experiencing active bed lowering and creek widening due to a creek crossing that was eroding. Bed stability was not affected by any factors at 50% of sites. Fallen trees provided a degree of bed stabilising influence at 50% of sites.

♦ *Bed and Bank Sediments*

The bed and bank material at pools was predominantly fines and small sands, though up to 14% of the material in the bed and lower banks were cobbles. The predominant material comprising the bed and banks at run habitats was fine material (clays). The bed and bank material at riffle habitats was predominantly sands and cobbles, although boulders made up 40% of the upper bank material. Organic matter was present in both bed and banks of all habitat types and ranged from 21-55%. Rock outcrops were recorded at 50% of sites in the bed and banks.

Table 5.20 Channel Dimensions for Pool, Riffle and Run Habitat Types

Dimension		Pool		Riffle		Run	
Mean Percent of Reach Covered (%)		70.0	(69-71)	29.0	(-)	31.0	(-)
Mean Length (m)		10.5	(6.0-15.0)	10.0	(-)	2.7	(-)
Mean Depth at Water Mark (m)		1.2	(0.4-2.0)	0.4	(-)	0.6	(-)
Mean Width at Water Mark (m)		6.9	(5.7-8.0)	6.8	(-)	3.7	(-)
Width:Depth Ratio		11.4	(2.9-20.0)	19.4	(-)	6.2	(-)
Lower Bank	Width (m)	0.2	(-)	0.5	(0.4-0.5)	-	
	Height (m)	0.2	(-)	0.2	(-)	-	
	Slope (^{o})	45.0	(-)	24.2	(21.8-26.6)	-	
Upper Bank	Width (m)	8.4	(4.5-12.0)	4.5	(4.0-5.0)	11.5	(11.0-12.0)
	Height (m)	3.6	(1.0-6.0)	0.6	(0.2-1.1)	6.5	(6.0-7.0)
	Slope (^{o})	19.8	(11.3-26.6)	8.6	(1.7-15.4)	29.5	(26.6-32.5)

♦ *Riparian Vegetation*

The riparian vegetation was rated as having either high (50% of sites) or moderate (50%) cover and structural diversity. The major vegetation type recorded was vegetation associated with freshwater streams (100% of sites). The average width of the riparian vegetation zone was 11m (range 8-15m), with 50% of sites recording riparian zones of between 5-10m, and 50% 11-20m.

The structural types recorded are shown in Table 5.21. There were 7 of the 13 structural types present at all sites. Covers ranged from 0-50%. The highest mean cover was 38% and was recorded for small trees (2-10m).

The overstorey provided a greater cover than the understorey vegetation. The upper bank recorded an average of 75% bare (range 70-80%) for understorey vegetation cover and 42% bare (range 38-45%) for the overstorey vegetation.

Table 5.21 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	0	0
Trees (10-30m)	100	25.0 (-)
Trees (2-10m)	100	37.5 (25-50)
Regen. Trees (<2m)	100	5.0 (-)
Woody Shrubs (<2m)	100	7.0 (5-10)
Vines	100*	8.8 (4-15)
Rushes and Sedges	50	2.0 (0-4)
Phragmites	0	0
Forbs (or Herbs)	100*	10.5 (7-14)
Grasses	100*	9.0 (3-15)
Ferns	50	2.0 (0-4)
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

Exotic vegetation, including noxious species, was recorded at all sites (refer Table 5.22). The mean total cover of exotic species in the riparian zone was 9% (range 2-15%), with between 2 and 3 species being recorded at a site. Structural types recorded were forbs (100% of sites), vines (50%) and grasses (50%).

Noxious weeds included *Xanthium occidentale*, (Noogoora Burr), present at 50% of sites, *Hyptis suaveolens* (50%) and *Pennisetum polystachion* (50%). Exotic vine species were *Passiflora foetida* (50% of sites) and *Cardiospermum halicacabum*. Of these exotic species, covers generally ranged from 2-3%, although *Xanthium occidentale* had the highest mean cover of 10%.

Table 5.22 Cover of Exotic Riparian Vegetation

% Cover Category (Rating)	Percent of Sites (%)
16 - 32* (2)	0
11 - 15 (4)	50
6 - 10 (6)	0
1 - 5 (8)	50
0 (10)	0

* The maximum % cover recorded for exotic riparian vegetation within the catchment was 32%.

♦ *Aquatic Vegetation*

Aquatic vegetation was present at 50% of sites in the form of emergent vegetation. Cover was low for this vegetation type (mean of 8% cover). Structural types present were rushes/ sedges (50% of sites) and Pandanus (50%), each recording a mean cover of 3% and 5% respectively. The emergent species recorded were *Cyperus haspan* and *Pandanus aquaticus*.

♦ *Instream and Bank Habitats*

The instream and bank habitats were rated as having either high (50% of sites) or moderate (50%) cover and diversity. Subjectively, the aquatic habitat condition was rated as good (50% of sites) or poor (50%).

The dominant instream habitat types present (100% of sites) were individual logs, individual branches, leaves and twigs, branch pile <50% and permanent pools deeper than 1m. The extent of instream cover provided by these habitat types was less than 13%, although pools recorded a mean cover of 28% (range 5-50%).

Three different types of overhanging bank cover were recorded. Vegetation canopy cover (100% of sites) occurred along 58% of the bank, with a mean width of 2.3m. Vegetation overhang (100% of sites) only occurred along 8% of the bank and had a mean width of 0.9m. A small amount of root overhang cover was also recorded.

At water mark (normal level), all sites would have a partly restricted passage for fish and other aquatic organisms.

♦ *Overall Condition*

The overall condition rating for sites assessed in this sub-section was high.

5.3.2 Discussion

When the six components that make up the overall condition rating were taken into account, both sites rated as having a high overall condition although they varied in their diversity and stability.

Of the two sites surveyed, the upper catchment site was experiencing moderate bed erosion (one of 7 sites in the Daly River catchment to do so) and limited bank instability due to an eroding creek crossing and access track. These instability problems may have also impacted on the moderate rating for cover and diversity of instream and bank habitats. This site also had moderate cover and structural diversity of the narrow, 5-10m wide, riparian zone, which recorded only a low invasion by exotic species. Emergent vegetation was present at the site. The reach environs were essentially natural and high channel habitat type diversity was recorded.

The lower catchment site was essentially natural, relatively diverse and stable. The riparian zone was moderately invaded by exotic species, in particular the noxious species *Xanthium occidentale* (Noogoora Burr), which dominated the forbs and had the highest cover of 10%. This site was relatively close to the junction with the Daly River and therefore closer to the population of Noogoora Burr that was present along its length. No aquatic vegetation was recorded at this lower catchment site.

The riparian zone was quite narrow throughout the sub-section, averaging 11m. Trees (2-10m tall) dominated the overstorey vegetation, while forbs were the only other structural type to exceed 10% cover.

Poor creek crossing and track design and maintenance, or lack thereof, can influence the condition of creeks at a local scale, as has been shown in the upper catchment site. This emphasises the importance of properly locating creek crossings, avoiding outside bends or steep banks, and targeting areas where the creeks are shallower and have larger sediments along the bed like gravels, cobbles or boulders. As little riparian vegetation should be disturbed as possible when constructing creek crossings. Tracks should be maintained on a regular basis and should not concentrate flows along their lengths as was occurring in this upper catchment site.

Moderate bed erosion; bank instabilities (Site 3/3: Hayward Creek – upper catchment)

High overall condition (Site 3/1: Hayward Creek – lower catchment)

5.4 Fish River

Sub-section 4 includes the catchment of Fish River. Of the 5 sites located in this sub-section, 3 of these were fully assessed.

5.4.1 Results

♦ *Reach Environs and Site Features*

Sites were rated as having reach environs that were essentially natural (80% of sites) or had moderate modification (20%). Subjective disturbance ratings indicated that 20% of sites had very low to low levels of disturbance, 60% moderate and 20% high levels of disturbance.

All sites had land tenure that was either freehold or leasehold. Grazing was the major land use that occurred predominantly on thinned native pastures (100% of sites), virgin timbered native pastures (40%) and cleared native pastures (40%).

Grazing activity was the major disturbance likely to affect stream reaches (80% of sites). Other disturbances included roads/tracks (60% of sites) and causeways/river crossings (60%). The major floodplain features recorded were prominent flood channels (40% of sites) and floodplain erosion (20%).

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 202m (range 57-394m). The reaches were dominated by pool habitats (100% of sites) which, on average, covered 62% of the reach length. Other habitat types present were riffles (67% of sites) and runs (33%). The diversity of channel habitat types was rated as high for all sites.

The water level at the time of sampling was at normal levels (20% of sites), was dry (40%) or had isolated pools (40%).

Table 5.23 presents the mean dimensions for the pool, riffle and run habitats. Pools and riffles were similar in length, though pools were deeper and wider. Water levels were reduced by over 50% along some pools, where beds were not dry. Upper banks at pools were moderately wide and high. At run habitats the upper banks were particularly wide and high, these being located within Fish River Gorge. Riffles had narrow, low and relatively steep upper banks.

Banks along the reaches were mostly steep and were convex shaped, though a cliff and a wide lower bench was recorded at one site in Fish River Gorge.

♦ *Bank Condition and Stability*

The reaches assessed in this sub-section were rated as having banks that were either stable (67% of sites) or had limited instability (33%). Subjective ratings indicated that the overall bank instability and the susceptibility of banks to further erosion were low (67% of sites) or moderate (33%).

Erosion was the dominant bank process recorded at all sites. The erosion was mostly occurring along outside bends (67% of sites), at floodplain scours (67%) or at obstacles (67%). Both lower and upper banks were equally stable, with an average of 15% of the bank length recorded as eroding (range of 2-30%). There was some aggradation recorded at floodplain scours (33% of sites).

The major factors identified as affecting bank stability were high flow (100% of sites), stock (67%) and floodplain scours (67%). Crossings, runoff, vermin, clearing and mining were other minor factors (33% of sites). No artificial bank protection measures were recorded at these sites.

♦ *Bed and Bar Condition and Stability*

Subjectively, 67% of sites were rated as having stable beds, while 33% were moderately aggrading.

Sand and gravel bars were recorded at all sites, predominantly occurring as point bars (67% of sites). Other types included mid-channel islands, alternate/side irregular bars and high flow deposits. The mean size of these bars was 29% of the bed surface above water mark (range 18-35%).

Table 5.23 Channel Dimensions for Pool, Riffle and Run Habitat Types

Dimension		Pool		Riffle		Run	
Mean Percent of Reach Covered (%)		62.2	(44-72)	42.0	(28-56)	29.0	(-)
Mean Length (m)		54.0	(21.0-87.0)	59.0	(8.0-110.0))	15.0	(-)
Mean Depth at Water Mark (m)		1.0	(0.5-1.5)	0.4	(0.3-0.5)	0.6	(-)
Mean Width at Water Mark (m)		14.1	(5.7-26.0)	8.9	(4.7-13.0)	17.6	(-)
Width:Depth Ratio		9.2	(7.0-11.4)	20.8	(15.7-26.0)	29.3	(-)
Lower Bank	Width (m)	4.0	(1.0-7.0)	-		-	
	Height (m)	1.7	(-)	-		-	
	Slope (^{o})	23.0	(-)	-		-	
Upper Bank	Width (m)	11.9	(1.0-50.0)	2.4	(0.7-6.0)	42.0	(22.0-62.0)
	Height (m)	12.8	(2.0-38.0)	2.9	(2.2-4.5)	28.5	(20.0-37.0)
	Slope (^{o})	59.0	(26.6-68.5)	57.1	(22.6-74.4)	38.6	(17.9-59.1)

The gravel forming the bed and bars was either disc-shaped (67% of sites) or spherical (67%); and was either sub-angular (67% of sites) or rounded (67%). The bed compaction was moderate or packed.

Factors identified as affecting bed stability were agriculture/grazing (67% of sites). Bed stability was not affected by any factors at 33% of sites. Rock outcrops (67% of sites) and fallen trees (33%) provided a degree of bed stabilising influence.

♦ *Bed and Bank Sediments*

The bed material at pools ranged in size from fines, sands, gravels and cobbles. The bank material at pools was mostly fines and small sand, though boulders comprised 18% of the total material. The predominant material comprising the bed at riffle and run habitats was large gravels and cobbles, though boulders made up 40% of the material at run habitats. The bank material at riffle habitats was predominantly fines and small sand. Boulders made up the bank material at run habitats. Organic matter was present in both bed and banks of all habitat types and ranged from 5-6%. Rock outcrops were recorded at 67% of sites in the bed and banks.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having moderate cover and structural diversity for all sites. The major vegetation type recorded was vegetation associated with freshwater streams (100% of sites). The average width of the riparian vegetation zone was 11m (range 2-60m), with 75% of sites recording riparian zones of <5m, 25% between 11-20m, and 25% >40m.

The structural types recorded are shown in Table 5.24. There were 6 of the 13 structural types present at all sites. Covers ranged from 0-75%. The highest mean cover was 57% and was recorded for grasses. The higher proportion of grass cover corresponded to a lower tree and shrub cover.

The understorey provided a greater cover than the overstorey vegetation. The upper bank recorded an average of 46% bare (range 25-88%) for understorey vegetation cover and 60% bare (range 30-75%) for the overstorey vegetation.

The most common native species recorded at all sites was *Lophostemon grandiflorus*.

Table 5.24 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	0	0
Trees (10-30m)	100	17.5 (5-38)
Trees (2-10m)	100	17.5 (7-38)
Regen. Trees (<2m)	100	6.9 (5-10)
Woody Shrubs (<2m)	100	7.7 (4-25)
Vines	50*	2.3 (0-5)
Rushes and Sedges	50	2.0 (0-4)
Phragmites	0	0
Forbs (or Herbs)	100*	6.5 (4-8)
Grasses	100	57.3 (4-75)
Ferns	0	0
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

Exotic vegetation, including noxious species, was recorded at 80% of sites. Where present, the mean total cover of exotic species in the riparian zone was 4% (range 0-5%) and, therefore, these sites rated as having a low invasion by exotics. Structural types recorded were forbs (75% of sites) and vines (25%). The only noxious weed recorded was *Hyptis suaveolens* (80% of sites). Other exotic species were *Passiflora foetida* (20% of sites) and *Hibiscus sabdariffa* (20%). Covers for these exotic species was <5%.

♦ *Aquatic Vegetation*

There was no aquatic vegetation at sites assessed within this sub-section.

♦ *Instream and Bank Habitats*

The instream and bank habitats were rated as having either high (50% of sites) or moderate (50%) cover and diversity. Subjectively, the aquatic habitat condition was rated as poor (67% of sites) or good (33%).

The dominant instream habitat types recorded were individual logs (67% of sites), individual branches (67%) and leaves and twigs (67%). The extent of instream cover provided by these habitat types was generally less than 5%, although rock faces (33% of sites) recorded a mean cover of 30% (range 0-90%), and pools deeper than 1m (33% of sites) recorded 27% cover (range 0-80%).

Four different types of overhanging bank cover were recorded. Vegetation canopy cover (67% of sites) occurred along 21% of the bank, with a mean width of 1.5m. Vegetation overhang (67% of sites) occurred along 23% of the bank and had a mean width of 0.2m. A small amount of root and bank overhang cover was also recorded.

At water mark (normal level), 33% of sites would have good passage for fish and other aquatic organisms, although 67% would be moderately restricted.

♦ *Overall Condition*

The overall condition rating for sites assessed in this sub-section was high.

5.4.2 Discussion

Reach environs were essentially natural except for the upper catchment site that was located near a disused mine area. River banks were mostly stable throughout the sub-section, except for limited instability problems in the upper catchment site. Reaches recorded some disturbance to river banks by high flow, stock activity and floodplain scours. River beds were also mostly stable, with stock causing disturbance in some areas, although the site in Fish River Gorge was assessed as moderately aggrading.

Even though pools dominated reach lengths, the diversity of channel habitat types was high for all reaches assessed within this sub-section. Instream and bank covers were reduced for some reaches and contributed to a moderate cover and diversity rating for the upper catchment site. The water level varied greatly at the time of the survey from being at normal levels to being dry, or having isolated pools present.

The riparian zone was quite narrow throughout the sub-section, averaging 11m, although the majority of sites recorded widths of <5m. Grasses dominated the vegetation structural types. The higher proportion of grasses corresponded to a lower tree cover. A moderate rating for the cover and diversity of the riparian vegetation was due to the decreased diversity and cover for the majority of structural types. Most sites recorded some degree of disturbance to the riparian zone by noxious species, though covers were generally <5%. *Hyptis suaveolens*, the only noxious species, was widespread. No aquatic vegetation was recorded throughout the sub-section.

Overall, the sites were assessed as having a high overall condition rating.

High overall condition (Site 4/2: Fish River Gorge)

5.5 Bamboo (Moon Boon) Creek

Sub-section 5 includes the catchment of Bamboo (Moon Boon) Creek. Two sites were fully assessed in this sub-section.

5.5.1 Results

♦ *Reach Environs and Site Features*

Sites were rated as having reach environs that were essentially natural (50% of sites) or had some modification (50%). Subjective disturbance ratings indicated that all sites had moderate levels of disturbance.

All sites had land tenure that was either freehold or leasehold. Grazing was the major land use that occurred predominantly on thinned native pastures (100% of sites) or virgin timbered native pastures (50%).

Grazing activity and causeways/crossings were the major disturbances likely to affect stream reaches (100% of sites). The major floodplain features recorded were prominent flood channels (50% of sites) and billabongs (20%).

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 61m (range 47-74m). The reaches were dominated by both pool and riffle habitats (100% of sites), although pools averaged 66% of the reach length. The diversity of channel habitat types was rated as high for all sites. Table 5.25 presents the mean dimensions for the pool and riffle habitats. The creeks were dry at the time of sampling and no lower banks were recorded.

Table 5.25 Channel Dimensions for Habitat Types

Dimension	Pool	Riffle
Reach Covered (%)	65.5 (58-73)	34.5 (27-42)
Mean Length (m)	19.5 (14.0-25.0)	8.4 (8.0-8.7)
Mean Depth (m)**	0.9 (-)	0.7 (0.6-0.7)
Mean Width (m)**	5.3 (4.5-6.0)	5.4 (5.3-5.5)
Width:Depth Ratio	5.8 (5.0-6.7)	8.4 (7.9-8.8)
*UB: Width (m)	2.1 (0.4-4.5)	2.3 (0.4-7.0)
Height (m)	2.9 (1.2-6.0)	2.5 (1.1-6.0)
Slope (^{o})	56.2 (50-72)	55.6 (41-75)

* UB = Upper Bank; ** Measured from the water mark.

Both pools and riffles were shallow, narrow and had a low width:depth ratio. The upper banks were narrow and low, with a steep slope. Banks along the reach were mostly moderate or steep and were convex or concave in shape.

♦ *Bank Condition and Stability*

The reaches assessed in this sub-section were rated as having stable banks (100% of sites). Subjective ratings indicated that the overall bank instability and the susceptibility of banks to further erosion were low (50% of sites), low to moderate (100%) or moderate (50%).

Erosion was the dominant bank process recorded at all sites. The erosion was mostly occurring along outside bends (100% of sites), at seepage/runoff points (100%), floodplain scours (50%) or at obstacles (50%). Both lower and upper banks were equally stable, with an average of 14% of the bank length recorded as eroding (range of 5-20%). No aggradation was recorded.

The major factors identified for all sites as affecting bank stability were crossings, high flow, stock and runoff. Floodplain scours were also recorded for 50% of sites. No artificial bank protection measures were recorded at these sites.

♦ *Bed and Bar Condition and Stability*

Subjectively, all sites were rated as having moderately eroding beds. Factors identified as affecting bed stability were bank erosion (100% of sites) and agriculture/grazing (50%). Rock outcrops and fallen trees provided a degree of bed stabilising influence.

Sand and gravel bars were recorded at all sites, occurring as point bars. The mean size of these bars was 9% of the bed surface above water mark (range 8-10%). The gravel forming the bed and bars was disc-shaped and either angular or sub-angular. The bed material was compacted.

♦ *Bed and Bank Sediments*

The bed material at pools and riffles ranged in size, although sands, gravels and cobbles comprised the majority of the material. The bank material at both these habitats was predominantly fines and small sand. Organic matter was present in both bed and banks of all habitat types and ranged from 5-8%. Rock outcrops were recorded at all sites and were mostly located in the bed.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having either high (50% of sites) or moderate (50%) cover and structural diversity. The vegetation type recorded for all sites was vegetation associated with freshwater streams. The riparian vegetation zone was narrow and had an average width of 3m (range 1.5-4m). All sites, therefore, had riparian zones within the <5m category.

The structural types recorded are shown in Table 5.26. There were 7 of the 13 structural types present at all sites. Covers ranged from 0-75%. The highest mean cover was 52% and was recorded for grasses. Tree cover was also moderate although the riparian zone was very narrow. The understorey provided an equal cover with the overstorey vegetation, both recording an average of 47% cover.

Table 5.26 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	0	0
Trees (10-30m)	100	37.5 (25-50)
Trees (2-10m)	100	22.5 (20-25)
Regen. Trees (<2m)	100	11.0 (10-12)
Woody Shrubs (<2m)	100	10.0 (-)
Vines	100	4.0 (-)
Rushes and Sedges	0	0
Phragmites	0	0
Forbs (or Herbs)	100*	6.5 (5-8)
Grasses	100	51.5 (28-75)
Ferns	0	0
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

Exotic/noxious vegetation was recorded at all sites. The mean total cover of exotic species in the riparian zone was 3% (range 2-4%) and, therefore, these sites rated as having a low invasion by exotics. The only structural type recorded was forbs. The only exotic (noxious) species recorded was *Hyptis suaveolens*.

The most common native species recorded at all sites was *Acacia auriculiformis, Flacourtia territorialis, Ixora klanderana* and *Terminalia platyphylla.*

♦ *Aquatic Vegetation*

There was no aquatic vegetation at sites assessed within this sub-section.

♦ *Instream and Bank Habitats*

The instream and bank habitats were rated as having either high (50% of sites) or moderate (50%) cover and diversity. Subjectively, the aquatic habitat condition was rated as poor for all sites.

The dominant instream habitat types recorded were leaves and twigs (100% of sites) and rock faces (100%). Individual logs and log jams were also present at 50% of sites, though they provided <5% cover. Rock faces provided a mean cover of 65% (range 40-90%) and leaves and twigs recorded a mean cover of 42% (range 4-80%). There was no permanent pool habitats recorded.

Four different types of overhanging bank cover were recorded for all sites. Vegetation canopy cover occurred along 44% of the bank, with a mean width of 3m. Vegetation overhang occurred along 38% of the bank and had a mean width of 1m. Root and bank overhang cover were also recorded along <15% of the bank (mean width <1m).

At water mark, 50% of sites would have good passage for fish and other aquatic organisms, although 50% would be partly restricted.

♦ *Overall Condition*

The overall condition rating for sites assessed in this sub-section was high.

5.5.2 Discussion

Overall, the sites rated highly. All reaches were on freehold or leasehold land and were essentially natural, although some modification to the mid-catchment sites was recorded. Grazing was the major landuse.

River banks were stable throughout the sub-section, although some disturbances were caused by crossings, high flow, stock activity and runoff. These disturbances were reflected in the low to moderate overall instability and susceptibility of banks to further erosion subjective ratings. The river beds were assessed as moderately eroding with localised bank erosion and stock causing disturbances in some areas. Of the 7 sites recording moderate bed erosion in the Daly River catchment, 2 of these were located on Bamboo Creek.

The creeks were dry at the time of the survey and even though pools dominated reaches the channel habitat type diversity was high. The cover and diversity of instream and bank habitats ranged from moderate in the upper catchment to high in the mid-catchment, though it was subjectively rated as poor. Canopy overhang occurred over less than half of the river lengths.

The riparian zone was very narrow throughout the sub-section, averaging only 3m. Grass covers dominated the vegetation structural types. Tree cover was also moderate, although the vegetation was confined to the very narrow riparian zone. A moderate rating for the cover and diversity of riparian vegetation in the mid-catchment was due to the decreased diversity and cover for the majority of structural types. Most sites recorded some degree of disturbance to the riparian zone by noxious species, namely *Hyptis suaveolens*, though covers were low, averaging 3%. No aquatic vegetation was recorded throughout the sub-section.

Moderate cover and diversity of riparian vegetation (Site 5/3: Bamboo Creek)

5.6 Green Ant Creek

Sub-section 6 includes the catchment of Green Ant Creek. Of the 5 sites located in this sub-section, 4 of these were fully assessed.

5.6.1 Results

♦ *Reach Environs and Site Features*

Reach environs were rated as being essentially natural at all sites. Subjective disturbance ratings indicated that 25% of sites had very low to low levels of disturbance, 25% low to moderate and 50% moderate levels of disturbance.

All sites had land tenure that was either freehold or leasehold. Grazing was the major land use that occurred predominantly on cleared native pastures (100% of sites), improved pastures (75%), thinned native pastures (25%) or virgin timbered native pastures (25%).

Grazing activity, roads/tracks and causeways/ crossings were identified as the major disturbances likely to affect stream reaches at 75% of sites. No disturbances were recorded at 25% of sites.

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 412m (range 29-715m). The reaches were dominated by pool habitats (100% of sites), that averaged 82% of the reach length. Other habitat types present where riffles (50% of sites), runs (50%) and rapids (25%). The diversity of channel habitat types was rated as either high (75% of sites) or moderate (25%). The water level at the time of sampling was moderate (75% of sites) or at water mark (25%).

Table 5.27 presents the mean dimensions for the pool, riffle and run habitats. Pools and runs were deeper and wider compared to riffles. All habitats recorded moderate width:depth ratios. Lower banks were generally low and narrow. Upper banks had low to moderate widths, heights and slopes. Banks along the reaches were mostly moderate or steep and were convex, concave or had a wide lower bench .

♦ *Bank Condition and Stability*

The reaches assessed in this sub-section were rated as having stable banks (75% of sites) or banks with limited instability (25%). Subjective ratings indicated that the overall bank instability and the susceptibility of banks to further erosion were low (100% of sites) or moderate (25%).

Erosion was the dominant bank process recorded at all sites. The erosion was occurring along outside bends (75% of sites), at obstacles (75%), floodplain scours (25%) or at irregular intervals (25%). The lower and upper banks were equally stable. On average, 11% of the upper bank length was recorded as eroding (range 4-40%) compared to 10% erosion for the lower banks (range 4-25%). Some aggradation was recorded along inside bends (25% of sites).

The major factors identified for all sites as affecting bank stability were stock (75% of sites), crossings (50%), high flow (25%) and floodplain scours (25%). No artificial bank protection measures were recorded at these sites.

♦ *Bed and Bar Condition and Stability*

Subjectively, all sites were rated as having stable beds.

Table 5.27 Channel Dimensions for Pool, Riffle and Run Habitat Types

Dimension		Pool	Riffle	Run
Mean Percent of Reach Covered (%)		82.3 (76-96)	17.0 (14-20)	14.0 (4-24)
Mean Length (m)		233.6 (10.5-475.0)	21.7 (3.3-40.0))	82.5 (15.0-150.0))
Mean Depth at Water Mark (m)		1.6 (1.2-2.4)	0.6 (0.4-0.8)	1.2 (0.4-2.0)
Mean Width at Water Mark (m)		17.3 (2.7-35.0)	5.0 (2.0-8.0)	21.5 (8.0-35.0)
Width:Depth Ratio		10.9 (2.3-21.9)	11.3 (2.5-20.0)	18.8 (17.5-20.0)
Lower Bank	Width (m)	0.7 (0.1-2.5)	4.2 (0.2-12.0)	0.2 (0.1-0.3)
	Height (m)	0.8 (0.2-0.6)	0.5 (0.3-0.8)	0.2 (-)
	Slope (^{o})	45.6 (13.5-71.6)	24.4 (1.9-76.0)	48.6 (33.7-63.4)
Upper Bank	Width (m)	6.7 (3.0-11.0)	7.3 (2.0-15.0)	7.0 (3.0-9.0)
	Height (m)	5.0 (1.5-13.0)	2.3 (0.5-5.0)	5.5 (1.0-10.0)
	Slope (^{o})	33.5 (16.7-49.8)	17.0 (9.5-21.8)	33.7 (8.0-48.0)

Sand and gravel bars were recorded at 75% of sites, occurring as point bars (100% of types) and mid-channel islands (33%). The mean bar size was 7% of the bed surface above water mark (range 1-15%). The gravel forming the bed and bars was disc-shaped and mostly rounded, though there was sub-angular material. Bed compaction ranged from low compaction (25% of sites), moderate compaction (25%) to being packed (50%).

Factors identified as affecting bed stability were agriculture/grazing (50% of sites) and bank erosion (25%). At 50% of sites there were no factors affecting bed stability. Fallen trees (75% of sites) and rock outcrops (25%) provided a degree of bed stabilising influence.

♦ *Bed and Bank Sediments*

The bed material at pools ranged in size, although fines, cobbles and boulders comprised the majority of the material. The bank material at pools was predominantly fines, sands and boulders. The bed and bank material at riffle habitats was predominantly cobbles and boulders, although fines made up 42% of the material in the upper banks. The bed at run habitats was all fines and the banks were predominantly fines, although sand contributed up to 39% of the material. Organic matter was present in both bed and banks of all habitat types and ranged from 24-37%. Rock outcrops were recorded at 50% of sites.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having either moderate (75% of sites) or high (25%) cover and structural diversity. The major vegetation type recorded was vegetation associated with freshwater streams (100% of sites). The average width of the riparian vegetation zone was 17m (range 10-25m), with 25% of sites recording riparian zones of 5-10m, 75% between 11-20m and 50% between 21-30m.

The structural types recorded are shown in Table 5.28. There were 5 of the 13 structural types present at all sites. Covers ranged from 0-75%. The highest mean cover was 42% and was recorded for medium-sized trees (10-30m). Grass cover was low.

The overstorey provided a much greater cover than the understorey vegetation. The upper bank recorded an average of 90% bare (range 85-95%) for understorey vegetation cover and 34% bare (range 15-55%) for the overstorey vegetation.

Table 5.28 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	50	1.3 (0-5)
Trees (10-30m)	100	41.9 (25-75)
Trees (2-10m)	75	16.4 (0-30)
Regen. Trees (<2m)	100	5.8 (5-8)
Woody Shrubs (<2m)	75	3.5 (0-5)
Vines	100	5.4 (5-8)
Rushes and Sedges	25	0.6 (0-3)
Phragmites	0	0
Forbs (or Herbs)	100*	6.3 (4-15)
Grasses	100*	9.1 (0-30)
Ferns	0	0
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

Exotic vegetation, including noxious species, was recorded at 50% of sites. The mean total cover of exotic species in the riparian zone was 2% (range 0-10%). As a result, the sites with exotics rated as having a low invasion by exotic species and those without rated very highly. Structural types recorded were forbs (50% of sites) and grasses (25%). The noxious species recorded were *Hyptis suaveolens* (40% of sites), *Sida acuta* (20%) and *Pennisetum polystachion* (20%). Covers for these exotic species were 2-5%.

♦ *Aquatic Vegetation*

Aquatic vegetation was present at 50% of sites in the form of emergent vegetation. Cover was low for this vegetation type (mean of 6% cover). Structural types present were rushes/ sedges (25% of sites), Pandanus (25%) and Melaleucas (50%).

♦ *Instream and Bank Habitats*

The cover and diversity of instream and bank habitats ranged from moderate to very high (refer Table 5.29). Subjectively, the aquatic habitat condition was rated as poor to good (50% of sites), good (25%) and good to very high (25%).

There were 11 instream habitat types identified. The dominant types recorded at all sites included individual logs and branches, leaves/twigs. Other types included branch piles, log jams, macrophytes algal clumps, emergent vegetation, roots, rock

faces and pools deeper than 1m. Permanent pools provided a mean cover of 48% (range 0-90%). The mean covers provided by the other types ranged from 5-31%.

Table 5.29 Cover and Diversity of Instream and Bank Habitats

Instream/Bank Habitat Category (Rating)	Percent of Sites (%)
Very Low Cover/Diversity (0-20%)	0
Low Cover/Diversity (21-40%)	0
Moderate Cover/Diversity (41-60%)	25
High Cover/Diversity (61-80%)	50
Very High Cover/Diversity (81-100%)	25

Three different types of overhanging bank cover were recorded for all sites. Vegetation canopy cover occurred along 89% of the bank, with a mean width of 5.8m. Vegetation overhang occurred along 46% of the bank and had a mean width of 2.2m. Root overhang cover was recorded along 5% of the bank and had a mean width 0.8m.

At water mark, all sites would have good passage for fish and other aquatic organisms.

♦ *Overall Condition*

The overall condition rating for sites assessed in this sub-section was either very high (75% of sites) or high (25%).

5.6.2 Discussion

Overall, the majority of sites within this sub-section rated very highly, compared to most other sub-sections.

The reach environs were essentially natural although all sites were on freehold or leasehold land where grazing was the major landuse and disturbances were identified (eg grazing activity, roads, tracks and crossings). River banks were predominantly stable throughout the sub-section and all river beds were assessed as being stable.

The diversity of channel habitat types was predominantly high. The cover and diversity of instream and bank habitats ranged throughout the sub-section from moderate to an above average very high rating, reflecting the variety of instream covers and the very good canopy cover (ie occurring along 89% of the bank length).

The riparian zone averaged 17m wide throughout the sub-section. Trees (10-30m tall) dominated the vegetation structural types. Ground covers had low covers, averaging <10%. The riparian vegetation was predominantly rated moderately reflecting the decreased diversity and cover for the majority of structural types. Less than half the sites recorded some degree of disturbance to the riparian zone by noxious species, though covers were low, averaging 2%. *Hyptis suaveolens* was the more common species. Half the sites recorded the presence of aquatic vegetation in the form of emergents, though covers were low.

Very high instream and bank habitat rating; very high overall rating (Site 6/2: Green Ant Creek)

Very high overall rating (Site 6/3: Green Ant Creek)

5.7 Douglas River

The Douglas River sub-catchment includes Douglas River, Hayes Creek and Middle Creek sub-sections.

5.7.1 Results

5.7.1.1 Douglas River

Sub-section 7 encompasses the Douglas River, excluding the catchment area of Hayes and Middle Creeks. Of the 9 sites located in this sub-section, 7 were fully assessed.

♦ *Reach Environs and Site Features*

Sites were rated as having reach environs that were essentially natural (71% of sites) or had some modification (29%). Subjective disturbance ratings indicated that 57% of sites had a low level of disturbance, 29% low to moderate and 14% moderate levels of disturbance.

Land tenure, at 86% of sites, was either freehold or leasehold, while 29% of sites where located within Reserves. Grazing was the major land use that occurred predominantly on thinned native pastures (71% of sites), on virgin timbered native pastures (43%), on cleared native pastures (43%) or on improved pastures (29%). Other land uses included rainfed broadacre farming (29% of sites) or Parks/Reserves (29%).

The major disturbances likely to affect stream reaches were grazing (71% of sites), causeways/ crossings (43%), people (43%) and roads/tracks (43%). The major floodplain features recorded were billabongs (43% of sites), floodplain deposits (29%) and floodplain scours (14%).

- *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 628m (range 27-2,785m). The reaches were dominated by pool habitats (100% of sites) which averaged 77% of the reach length. Other habitat types present where riffles (57% of sites), runs (43%), rapids (14%), glides (14%) and a waterfall (14%). The diversity of channel habitat types in this sub-section ranged from moderate to very high (refer Table 5.30).

Table 5.30 Channel Type Diversity

Diversity Category (Rating)	Percent of Sites (%)
Very Low Diversity (1-2)	0
Low Diversity (3-4)	0
Moderate Diversity (5-6)	14
High Diversity (7-8)	57
Very High Diversity (9-10)	29

Moderate bank instability and bed erosion (Site 7/8: Depot Creek)

Table 5.31 presents the mean dimensions for the pool and riffle habitats. Pools were moderately deep at 2.9m (though this ranged up to 8.6m) and wide compared to the shallower and narrower riffles. Width:depth ratios were generally moderate to high. Lower banks were narrow, low and moderately steep. Upper banks were relatively wide and high; though at riffles the banks were not as tall. Banks along the reaches were mostly moderate, vertical, low, steep or flat and were convex, concave or had a wide lower bench, were undercut or had a cliff.

Table 5.31 Channel Dimensions for Habitat Types

Dimension		Pool	Riffle
Reach Covered (%)		67.7 (46-797)	19.8 (3-47)
Mean Length (m)		560.0 (11-2,700)	51.0 (3-85)
Mean Depth (m)**		2.9 (0.2-8.6)	0.4 (0.1-0.6)
Mean Width (m)**		29.4 (3.4-80.0)	8.8 (5.0-16.0)
Width:Depth Ratio		14.6 (6.8-46.7)	27.2 (12.0-50.0)
♦LB:	Width (m)	0.2 (0.1-0.4)	1.3 (0.1-2.5)
	Height (m)	0.2 (0.2-0.3)	0.2 (-)
	Slope (°)	54.6 (26.6-78.7)	34.0 (4.6-63.4)
∗UB:	Width (m)	17.9 (4.0-45.0)	22.3 (9.0-45.0)
	Height (m)	11.2 (2.5-50.0)	5.0 (1.5-7.0)
	Slope (°)	30.9 (8.0-76.5)	15.9 (4.3-35.8)

♦LB = Lower Bank ∗UB = Upper Bank
** Measured from the water mark.

The water level at the time of sampling was at the water mark or normal level (57% of sites), or was moderate (29%) or dry (14%).

Very high habitat type diversity; very high overall condition (Site 7/10: Douglas River)

♦ *Bank Condition and Stability*

The reaches assessed in this sub-section were rated as having stable banks (86% of sites) or moderate instability (14%). Subjective ratings indicated that the overall bank instability was minimal (29% of sites), low (57%), low to moderate (29%) or moderate to high (14%). Similar results were recorded for the susceptibility of banks to further erosion.

Erosion was the dominant bank process recorded at all sites. The erosion was occurring at floodplain scours (43% of sites), along outside bends (29%), at obstacles (29%), at irregular intervals (29%) or at seepage/runoff points (14%). The lower and upper banks were equally stable. On average, 11% of the bank length, for both upper and lower banks, was recorded as eroding, though this ranged to as high as 85%. Some aggradation was recorded along bends (14% of sites).

The major factors identified as affecting bank stability were high flow (57% of sites), people tracks (57%) roads/crossings/bridges (43%) and stock (43%). Other factors recorded included runoff, floodplain scours and clearing.

♦ *Bed and Bar Condition and Stability*

Subjectively, 71% of sites were rated as having stable beds, while 14% were moderately aggrading and 14% moderately eroding (refer Table 5.32).

Table 5.32 Overall Bed Stability Ratings

Stability Category (Rating)	Percent of Sites (%)
Severe Erosion or Aggradation (2)	0
Moderate Erosion or Aggradation (6)	28
Stable (10)	72
Dominant Process Recorded	
Aggradation	14
Erosion	14
No process (bed stable)	72

Sand and gravel bars were recorded at all sites, predominantly occurring as point bars (43% of sites) or mid-channel islands (43%). Other types included bars with encroaching vegetation, alternate/side irregular bars and channel bar plain. The mean size of these bars was 12% of the bed surface (range 4-25%). The gravel forming the bed and bars was predominantly sphere-shaped (71% of sites) or disc-shaped (43%); and was mostly sub-angular (71% of sites) or rounded (43%). The bed compaction was poor (86% of sites), moderate (29%) or tightly packed (43%).

Factors identified as affecting bed stability were agriculture/grazing (29% of sites), bank erosion (14%), bed deepening (14%) and instream siltation (14%). Bed stability was not affected by any factors at 43% of sites. Rock outcrops (71% of sites) and fallen trees (43%) provided a degree of bed stabilising influence.

♦ *Bed and Bank Sediments*

The bank material at all habitats consisted predominantly of fine clay material and sands, although boulders were prevalent in rapid and waterfall habitats. The bed material at pools was mostly fines and sands. The beds at riffles recorded a range of sediment sizes, although gravels and boulders made up the majority of material. The bed material as rapids and waterfalls was predominantly cobbles and boulders. Sand made up the majority of the bed at glides. Organic matter was present in both bed and banks of all habitat types and ranged from 11-16%. Rock outcrops were recorded at 67% of sites.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having either high (57% of sites) or moderate (43%) cover and structural diversity. The major vegetation type recorded was vegetation associated with freshwater streams (72% of sites), although monsoon vine-forests were also recorded. The average width of the riparian vegetation zone was 18m (range 5-50m), with 57% of sites recording riparian zones of 5-10m, 14% between 11-20m, 29% between 31-40m and 14% >40m.

The structural types recorded are shown in Table 5.33. There were 6 of the 13 structural types present at all sites, although the majority of types were represented throughout the sub-section. Covers ranged from 0-75%. The highest mean cover was 49% and was recorded for medium trees (10-30m). Palms were also present (14% of sites).

The overstorey provided a much greater cover than the understorey vegetation. The upper bank recorded an average of 70% bare (range 20-82%) for understorey vegetation cover and 32% bare (range 5-77%) for the overstorey vegetation.

Exotic vegetation was recorded at 57% of sites. If all sites where the dominant vegetation was noted, but no covers documented, were to be included in the assessment, 75% of sites would record the presence of exotic riparian vegetation and those

declared noxious would be present at 50% of these sites. Where exotic species were present in the riparian zone, the sites rated as having a low invasion by exotics with the mean total cover averaging 2% (range 0-5%). Structural types recorded were forbs, vines and grasses. The exotic/noxious species recorded were *Hyptis suaveolens* (38% of sites), *Sida acuta* (13%) and *Pennisetum polystachion* (13%). Other exotic species included *Passiflora foetida* (38% of sites).

Table 5.33 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	14	0.7 (0-5)
Trees (10-30m)	100	48.8 (15-75)
Trees (2-10m)	100	22.7 (10-50)
Regen. Trees (<2m)	100	6.8 (4-12)
Woody Shrubs (<2m)	100	5.2 (4-10)
Vines	88*	3.9 (0-5)
Rushes and Sedges	71	2.9 (0-5)
Phragmites	14	0.7 (0-5)
Forbs (or Herbs)	100*	5.6 (4-10)
Grasses	100*	21.3 (4-75)
Ferns	43	2.2 (0-8)
Mangroves	0	0
Salt Marsh	0	0
Palms	14	0.6 (0-4)

* Contains exotic species

♦ *Aquatic Vegetation*

Aquatic vegetation was present at 43% of sites. Forms of vegetation recorded were emergent (43% of sites) or submerged (14%). Mean covers recorded for emergent vegetation was 14% (range 5-28%). Covers for submerged vegetation was low, recording an average of 0.7% cover (range 0-2%).

The structural categories recorded for the emergent aquatic vegetation were Phragmites (14% of sites), rushes/sedges (43%), Pandanus (14%) and Melaleucas (14%). The emergent species recorded included *Phragmites karka*, *Eleocharis geniculata, Schoenoplectus litoralis*, *Pandanus aquaticus* and *Melaleuca leucadendra*. The submerged structural type was filamentous algae (14% of sites).

♦ *Instream and Bank Habitats*

The cover and diversity of instream and bank habitats ranged from moderate (29% of sites), high (57%) to very high (14%). Subjectively, the aquatic habitat condition was rated as poor (29% of sites), good (14%) and good to very high (57%).

There were 11 instream habitat types identified. The dominant types recorded included individual logs (86% of sites), branches (100%), leaves/twigs (100%), algal clumps (86%), rock faces (72%), pool habitats deeper than 1m (71%) and branch piles (43%). Other types included log jams and emergent/freshwater vegetation. The extent of instream cover provided by these habitat types was generally <10%, although pools deeper than 1m provided a mean cover of 46% (range 0-80%).

Two different types of overhanging bank cover were recorded for all sites. Vegetation canopy cover occurred along 63% of the bank, with a mean width of 1.6m. Vegetation overhang occurred along 27% of the bank and had a mean width of 1.1m. Other bank covers included root overhang (86% of sites) and bank overhang (71%). Both these types of bank covers occurred over less than 15% of the bank length and had a width of <1m.

At water mark, 57% of sites would have partly restricted passage for fish and other aquatic organisms, 29% moderately restricted and 14% very restricted passage.

♦ *Overall Condition*

The overall condition rating for sites assessed in this sub-section was very high (71% of sites) or high (29%).

5.7.1.2 Hayes Creek

Sub-section 8 includes the catchment area of Hayes Creek. Two sites were fully assessed within this sub-section.

♦ *Reach Environs and Site Features*

Reach environs were rated as being essentially natural at all sites. Subjective disturbance ratings indicated that 50% of sites had low levels of disturbance and 50% moderate to high levels of disturbance.

Both sites had land tenure that was either freehold or leasehold. Grazing was the major land use that occurred predominantly on thinned native pastures (100% of sites) or cleared native pastures (100%).

Grazing activity, roads/tracks and causeways/ crossings were identified as the major disturbances likely to affect stream reaches at all sites. Other factors included bridges/culverts (50% of sites). The major floodplain features recorded at 50% of sites were billabongs and prominent flood channels.

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 94m (range 88-101m). Pool and glide habitats were the dominant habitat types (100% of sites). Pools dominated the reaches though, averaging 79% of the reach length. Other habitat types present where riffles (50% of sites). The diversity of channel habitat types was rated as either very high (50% of sites) or moderate (50%). The water level at the time of sampling was moderate (50% of sites) or isolated pools were present (50%).

Table 5.34 presents the mean dimensions for the pool and glide habitats. Both pools and glides were similar in width, although pools were deeper and had a lower width:depth ratio. Upper banks were relatively narrow and low, with moderate to steep slopes. Banks along the reach were moderate or steep and were convex or concave in shape.

Table 5.34 Channel Dimensions for Habitat Types

Dimension		Pool	Glide
Reach Covered (%)		79.0 (63-95)	12.0 (5-19)
Mean Length (m)		53.0 (11.0-95.0)	11.3 (5.5-17.0)
Mean Depth (m)**		1.0 (0.7-1.3)	0.2 (0.1-0.3)
Mean Width (m)**		5.3 (4.5-6.0)	4.2 (2.8-5.5)
Width:Depth Ratio		6.0 (3.5-8.6)	26.1 (17.2-35.0)
♦LB:	Width (m)	1.4 (0.2-4.8)	1.1 (0.1-2.0)
	Height (m)	0.5 (0.2-0.8)	0.2 (-)
	Slope (°)	43.9 (9.5-76.0)	34.6 (5.7-63.4)
∗UB:	Width (m)	2.5 (1.5-5.0)	5.4 (0.5-13.0)
	Height (m)	2.2 (2.1-2.5)	2.2 (1.8-2.5)
	Slope (°)	46.0 (22.8-59.0)	36.7 (8.3-78.7)

♦LB = Lower Bank ∗UB = Upper Bank
** Measured from the water mark.

♦ *Bank Condition and Stability*

The reaches assessed in this sub-section were rated as having stable banks (50% of sites) or banks with limited instability (50%). Subjective ratings indicated that the overall bank instability was low (50% of sites), moderate (50%) or moderate to high (50%). Similar results were recorded for the susceptibility of banks to further erosion.

Erosion was the dominant bank process recorded at all sites. The erosion was occurring along outside bends (100% of sites), at obstacles (100%) or at irregular intervals (50%). Both upper and lower banks were eroding, with an average of 24% of the lower bank length eroding (range 5-40%), compared to 22% for the upper bank (range 8-30%). No aggradation was recorded.

The major factors identified as affecting bank stability were high flow (100% of sites), roads/ crossings/bridges (100%), floodplain scours (50%), stock (50%) and clearing (50%).

♦ *Bed and Bar Condition and Stability*

Subjectively, all sites were rated as having stable beds. Factors identified as affecting bed stability were agriculture/grazing (50% of sites) and bed deepening (50%). At 50% of sites there were no factors affecting bed stability. Rock outcrops (100% of sites) and culverts (50%) provided a degree of bed stabilising influence.

Sand and gravel bars were recorded at 50% of sites, occurring as point bars. Bars were small, averaging 5% of the bed surface above water mark. The gravel forming the bed and bars was sphere-shaped (100% of sites) or disc-shaped (50%) and was sub-angular (50%) or angular (50%). Bed compaction was low (50% of sites) or packed (50%).

♦ *Bed and Bank Sediments*

The bed material at pools and glides ranged in size, although fines, sands, large gravels and cobbles comprised the majority of the material. Glides also recorded 15% of boulder-sized material in the bed. The bank material at pools and glides was predominantly fines/clays, although sands, gravels and cobbles were present. Organic matter was present in both bed and banks of habitat types and ranged from 10-29%. Rock outcrops were recorded at all sites and were located in the bed and banks.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having either high (50% of sites) or moderate (50%) cover and structural diversity. The vegetation types recorded were vegetation associated with freshwater streams (50% of sites) and monsoon vine-forests (50%). The riparian vegetation zone was narrow, averaging 4.5m (range 4-5m), with 50% of sites recording riparian zones of <5m and 50% between 5-10m.

The structural types recorded are shown in Table 5.35. There were 7 of the 13 structural types present at all sites. Covers ranged from 0-46%. The highest mean cover was 37% and was recorded for medium-sized trees (10-30m). The more common native species recorded at all sites, included *Acacia auriculiformis*, *Breynia cernua* and *Carallia brachiata*.

Table 5.35 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	0	0
Trees (10-30m)	100*	37.0 (22-46)
Trees (2-10m)	100*	16.0 (10-24)
Regen. Trees (<2m)	100	6.5 (5-8)
Woody Shrubs (<2m)	100	5.0 (5-5)
Vines	100*	6.5 (3-10)
Rushes and Sedges	50	1.5 (0-3)
Phragmites	0	0
Forbs (or Herbs)	100*	7.0 (4-10)
Grasses	100	10.5 (5-20)
Ferns	0	0
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

The overstorey provided a much greater cover than the understorey vegetation. The upper bank recorded an average of 87% bare (range 80-90%) for understorey vegetation cover and 53% bare (range 45-72%) for the overstorey vegetation.

Exotic vegetation was recorded at all sites and noxious vegetation at half the sites. Of the two sites assessed, one site rated as having a low invasion by exotics (1-5% cover) and the other as having a very high invasion (16-32% cover). The mean total cover of exotic species in the riparian zone was 9% (range 1-22%). Structural types recorded were medium trees (50% of sites) small trees (50%), vines (100%) and forbs (50%). The noxious species, present at 50% of sites, was *Hyptis suaveolens* (mean cover of 5%). Other exotic species included *Mangifera indica*, common mango, recorded at 50% of sites (mean cover of 12%); and *Passiflora foetida,* a naturalised vine, recorded at all sites (mean cover of 3%).

♦ *Aquatic Vegetation*

There was no aquatic vegetation at sites assessed within this sub-section.

♦ *Instream and Bank Habitats*

The instream and bank habitats were rated as having a high cover and diversity at all sites. The subjective ratings for the condition of the aquatic habitat were poor (50% of sites) and good (50%).

Eight instream habitat types were recorded. Those listed for all sites were individual branches, leaves and twigs, branch piles and rock faces. Individual logs, pool habitats deeper than 1m, log jams and man-made structures were also present at 50% of sites. The covers provided by these habitat types were generally <10%, though leaves/twigs provided a mean cover of 43% (range 30-55%), and rock faces provided a mean cover of 38% (range 1-75).

Three different types of overhanging bank cover were recorded for all sites. Vegetation canopy cover occurred along 79% of the bank, with a mean width of 2.8m. Vegetation overhang occurred along 18% of the bank and had a mean width of 0.9m. Root and bank overhang cover were also recorded along <5% of the bank (mean width <1m).

At water mark, 50% of sites would have a moderately restricted passage for fish and other aquatic organisms and 50% very restricted passage.

♦ *Overall Condition*

The overall condition rating for sites assessed in this sub-section was high.

Very high channel habitat type diversity; stable channel; high overall condition rating (Site 8/4: Hayes Creek)

5.7.1.3 Middle Creek

Sub-section 9 includes the catchment area of Middle Creek. Two sites were fully assessed within this sub-section.

♦ *Reach Environs and Site Features*

Sites were rated as having reach environs that were essentially natural (50% of sites) or had some modification (50%). Subjective disturbance ratings indicated that 50% of sites had moderate levels of disturbance and 50% moderate to high levels.

Both sites had land tenure that was either freehold or leasehold. Grazing was the major land use at both sites and occurred predominantly on thinned native pastures, virgin timbered native pastures and cleared native pastures.

Grazing activity was identified as the major disturbance likely to affect stream reaches at both sites. Other factors included roads/tracks, a bridge/culvert and a weir. The major floodplain feature recorded at 50% of sites was billabongs.

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 158m (range 98-217m). Pool and riffle habitats were the dominant habitat types (100% of sites). Pools dominated the reaches though, averaging 73% of the reach length. Even though there were no other habitat types recorded in this sub-section, the channel type diversity rating was high. The water level at the time of sampling was at water mark (50% of sites) or isolated pools (50%).

Table 5.36 presents the mean dimensions for the pool and riffle habitats. Pools and riffles were similar in width, though pools were over four times deeper and had a much lower width:depth ratio. Lower banks were narrow, low with a steep slope. Upper banks were relatively narrow, with moderate slopes and varying heights. Banks along the reach were mostly moderate or steep and were convex or concave in shape.

♦ *Bank Condition and Stability*

The reaches assessed in this sub-section were rated as having stable banks (50% of sites) or limited instability (50%). Subjective ratings indicated that the overall bank instability and the susceptibility of banks to further erosion was low (50% of sites) or moderate (50%).

Table 5.36 Channel Dimensions for Habitat Types

Dimension		Pool	Riffle
Reach Covered (%)		73.0 (60-86)	27.0 (14-40)
Mean Length (m)		62.0 (30-94)	17.0 (15-19)
Mean Depth (m)**		1.3 (1.0-1.6)	0.3 (0.1-0.4)
Mean Width (m)**		6.3 (6.0-6.5)	5.5 (4.0-7.0)
Width:Depth Ratio		5.0 (4.1-6.0)	28.8 (17.5-40.0)
♦LB:	Width (m)	0.4 (0.3-0.4)	-
	Height (m)	0.6 (-)	-
	Slope (°)	59.9 (56.3-63.4)	-
∗UB:	Width (m)	5.5 (2.0-9.0)	7.4 (3.5-14.0)
	Height (m)	5.4 (3.5-8.0)	5.4 (3.0-9.0)
	Slope (°)	46.8 (29.7-63.4)	40.2 (12.1-61.0)

♦LB = Lower Bank ∗UB = Upper Bank
** Measured from the water mark.

Erosion was the dominant bank process recorded at all sites. The erosion was occurring at seepage/runoff points (100% of sites), along outside bends (50%), at obstacles (50%) or at floodplain scours (50%). Lower banks were more stable than upper banks, with an average of 11% of the lower bank length eroding (range 5-20%), compared to 20% for the upper bank (range 10-35%). No aggradation was recorded.

The major factors identified at all sites as affecting bank stability were floodplain scours, runoff, and stock. Other factors included roads/crossings/ bridges, people tracks, clearing and vermin.

♦ *Bed and Bar Condition and Stability*

Subjectively, all sites were rated as having stable beds. A minor factor identified as affecting bed stability was agriculture/grazing at one site. Rock outcrops (50% of sites) provided a degree of bed stabilising influence.

Sand and gravel bars were recorded at all sites, occurring as either point bars or alternate/side irregular bars. The mean size of the bars was relatively high, averaging 33% of the bed surface above water mark (range 15-50%). The gravel forming the bed and bars was disc-shaped (100% of sites), sub-angular (50%) or rounded (50%). Bed compaction was low (50% of sites) or moderate (50%).

♦ *Bed and Bank Sediments*

The bed and bank material at pools was predominantly small sand and fines. The bed material at riffles ranged in size, although boulders were the dominant sediment size recorded. The bank material at riffles was mostly fines and small

sand, although boulders made up 50% of the lower bank sediments. Organic matter was present in both bed and banks of habitat types and ranged from 5-15%. Rock outcrops were recorded at 50% of sites and were located in the bed and banks.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having a moderate cover and structural diversity at all sites. The vegetation type recorded was vegetation associated with freshwater streams. The riparian vegetation zone was narrow, averaging 4m (range 2-6m), with 50% of sites recording riparian zones of <5m and 50% between 5-10m.

The structural types recorded are shown in Table 5.37. There were 7 of the 13 structural types present at all sites. Covers ranged from 0-30%. The highest mean cover was 24% and was recorded for small trees (2-10m). Grass covers were moderate, averaging 23%.

Table 5.37 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	0	0
Trees (10-30m)	100	21.3 (12-25)
Trees (2-10m)	100	23.8 (15-30)
Regen. Trees (<2m)	100	6.5 (5-7)
Woody Shrubs (<2m)	100	5.0 (4-7)
Vines	100*	5.3 (4-7)
Rushes and Sedges	0	0
Phragmites	0	0
Forbs (or Herbs)	100*	6.8 (6-8)
Grasses	100	22.5 (15-25)
Ferns	0	0
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

The upper bank recorded an average of 68% bare (range 65-75%) for understorey vegetation cover compared to 51% bare (range 40-65%) for the overstorey vegetation.

Exotic vegetation, including noxious species, was recorded at all sites, with between 1 and 3 different species being found. The mean total cover of exotic species in the riparian zone was low, averaging 5% (range 4-6%) and, therefore, these sites rated as having a low invasion by exotics.

Structural types recorded were forbs (100% of sites) and vines (50%). The noxious species included *Hyptis suaveolens* (100% of sites) and *Sida acuta* (50%). One other exotic species included *Passiflora foetida,* a naturalised vine (50% of sites).

♦ *Aquatic Vegetation*

There was no aquatic vegetation at sites assessed within this sub-section.

♦ *Instream and Bank Habitats*

The cover and diversity of instream and bank habitats rated as either high (50% of sites) or moderate (50%). Subjectively, the condition of the aquatic habitat was rated as poor (100% of sites).

Seven instream habitat types were recorded. Those listed for all sites were individual branches, individual logs and leaves/twigs. Branch piles, algal clumps, rock faces and permanent pools deeper than 1m, were also present at 50% of sites. The covers provided by these habitat types were generally <10%, though leaves/twigs provided a mean cover of 23% (range 15-30%) and permanent pools provided a mean cover of 28% (range 0-55).

Four different types of overhanging bank cover were recorded for all sites. Vegetation canopy cover occurred along 48% of the bank, with a mean width of 2.3m. Vegetation, root and bank overhang cover were also recorded along 10% of the bank and had a mean width <1m. Man-made structures were recorded at 50% of sites.

At water mark, all sites would have a moderately restricted passage for fish and other aquatic organisms.

♦ *Overall Condition*

The overall condition rating for sites assessed in this sub-section was high.

Stable; moderate riparian vegetation and instream / bank habitat ratings; high overall rating (Site 9/4: Middle Creek)

5.7.1.4 Comparison between Douglas River, Hayes Creek and Middle Creek Sub-sections

The *reach environs* for Douglas River, Hayes Creek and Middle Creek sub-sections were in similar condition and were rated as predominantly being essentially natural, although a site on the Douglas-Daly Research Farm and a section of Middle and Depot Creeks were assessed as having some modification to their reach environs. Subjective disturbance ratings indicated a generally low to moderate level of reach environs disturbance throughout the sub-sections, except for a mid-section site on Hayes Creek and also on Middle Creek. Outside of the Nature Parks (eg Douglas Hot Springs and Butterfly Gorge), grazing was identified as the major land use and disturbance factor likely to affect stream reaches, which were predominantly located on freehold or leasehold land. Other disturbances included roads/tracks, causeways/crossings and bridges/ culverts. People tracks were identified as a disturbance within the Nature Parks.

Channel type diversity ranged from moderate, high to very high. A greater range of diversity ratings was recorded along the Douglas River. A section of Douglas River near the Douglas-Daly Research Farm recorded a moderate diversity, due to a very long pool which dominated the reach; half the other reaches rated a high diversity; and areas like Butterfly Gorge were very highly diverse. Sections along Middle Creek recorded high diversity ratings. Hayes Creek was rated moderately mid-section, while the upper section rated very highly with regards to its diversity of habitat types. Although pools dominated all reach lengths, there were a variety of habitat types recorded, including riffles, runs, rapids, glides and waterfalls.

Water levels experienced at sampling ranged from being at normal levels, moderate (but less than normal), isolated pools or being dry.

Bank stability – reaches located along Douglas River were rated as having stable banks. Depot Creek, a small tributary of Douglas River, rated only moderate bank stability due to the fact that up to 85% of the bank length was eroding. This site was also subjectively rated as having a moderate to high overall instability and susceptibility to erosion. A mid section along Hayes Creek and lower Middle Creek recorded limited instability problems along the banks, while other sections were stable. The factors recorded as affecting bank stability ranged widely and included high flows, roads, crossings, runoff, stock, floodplain scouring, people tracks, clearing and vermin.

Bed and bar stability – All reaches along Douglas River had stable beds except for an upper catchment site that was moderately aggrading and recorded instream siltation as a factor affecting the stabiltiy of the river bed. All reaches along Hayes and Middle Creeks had stable beds. Depot Creek, a small tributary of Douglas River, recorded a moderately eroding bed because the bed was showing signs of deepening, including exposed clay material along the bed and eroding banks. Bars were present along the majority of reaches, averaging between 5-33% of the bed surface. The smallest-sized bars were recorded along Hayes Creek. Factors identified as affecting bed stability included grazing activity and bed deepening.

The *riparian vegetation* along Hayes and Middle Creeks was very narrow, averaging 4-5m, and its cover and structural diversity was predominantly moderate, except for an upper Hayes Creek site which rated more highly. The riparian vegetation along the Douglas River and Depot Creek ranged in widths, averaging 18m. Two sections along Douglas River recorded wider riparian vegetation (>31m). The cover and diversity of structural types ranged from moderate to high along Douglas River with sections near Douglas Hot Springs, Depot Creek and within the upper catchment not rating as highly. In all sub-sections, trees (2-30m tall) provided the major cover, though grasses ranged from 11-23% cover. The remaining structural types recorded <10% covers.

Exotic vegetation was located throughout the sub-catchment, being recorded at three-quarters of the sites. Covers were generally low, and as a result the sites that recorded exotic species rated a low level of invasion of the riparian zone, while sites without exotic species rated more highly. The upper catchment site on Hayes Creek did record a high invasion by exotics. Noxious species were present along at least half the reaches and *Hyptis suaveolens* was the most widespread. Other noxious species, with a scattered distribution, included *Sida acuta* and *Pennisetum polystachion*. *Passiflora foetida* was quite widespread.

Only three reaches along Douglas River recorded the presence of *aquatic vegetation* in the form of emergents. Submerged aquatic vegetation was only observed along one reach. No floating aquatic vegetation was recorded. Covers for aquatic vegetation were generally low.

The cover and diversity of the *instream and bank habitats* varied. An upper Douglas River catchment site and Depot Creek, a small tributary of Douglas River, rated as having moderate cover and diversity, while a section of Douglas, upstream of Bond Bridge, rated very highly.

Hayes Creek and the lower section of Middle Creek recorded high cover and diversity of instream and bank habitats, while the mid-section on Middle Creek rated only moderately. Instream habitat types were quite diverse, although the covers were generally <10%, except for permanent pools, leaves/twigs and, occasionally, rock faces. Canopy cover along the banks was better along Douglas River and Hayes Creek than along Middle Creek.

The *overall condition* of reaches throughout the Douglas River sub-catchment was predominantly high, although nearly three-quarters of reaches in Douglas River sub-section rated very highly.

5.7.2 Discussion

Overall, Douglas River sub-catchment rated highly. Of the 17 sites that rated very highly overall within the Daly River catchment, 5 of these were located on Douglas River itself.

The river banks and beds were predominantly stable, except on Depot Creek and upper Douglas River. Depot Creek was one of only two sites in the Daly River catchment to record moderate bank stability, the lowest recording. It was experiencing not only bank erosion but also bed erosion upstream of an old creek crossing. Upper Douglas River was also somewhat unstable, suffering from moderate aggradation (ie shallow, uniform channel) and localised problems due to a badly eroding access track into a river crossing. Disturbances ranged widely over the sub-catchment. Nature Parks still recorded disturbances to the river banks, for example, people tracks.

Four sections along Douglas River and an upper Hayes Creek reach had a greater cover and diversity of riparian vegetation, although the overstorey dominated structurally and the widths varied from 5-40m. Invasion of the riparian zone by exotic species was occurring although the covers were generally low. Aquatic vegetation was confined to a few sections along Douglas River.

The channel type diversity was generally higher within the Douglas River sub-catchment compared to other sub-catchments within the Daly River catchment. That is, there were only 6 sites throughout the Daly River catchment that rated a very high habitat type diversity and 3 of these sites were located within the Douglas River sub-catchment – 2 being located on Douglas River and 1 on upper Hayes Creek.

The cover and diversity of instream and bank habitats varied considerably throughout the Douglas River sub-catchment.

5.8 Stray Creek

Sub-section 10 includes the catchment area of Stray Creek. Three sites were fully assessed within this sub-section.

5.8.1 Results

♦ *Reach Environs and Site Features*

All sites were rated as having reach environs that were essentially natural. Subjective disturbance ratings indicated that 67% of sites had low levels of disturbance and 33% moderate levels.

Land tenure was predominantly freehold or leasehold (67% of sites), although 33% of sites were located in Parks/Reserves. Grazing was the major land use and occurred predominantly on virgin timbered native pastures (67% of sites) or thinned native pastures (33%). Other land uses included Parks/Reserves (33% of sites).

The major disturbances likely to affect stream reaches were causeway/crossing (100% of sites), roads/tracks (100%), people (100%) and grazing (67%). The major floodplain features recorded were floodplain scours (67% of sites), prominent flood channels (33%) and billabongs (33%).

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 140m (range 50-260m). Pools were the dominant habitat types (100% of sites), averaging 83% of the reach length. Riffles were present at 67% of sites. The diversity of channel habitat types ranged from high diversity (67% of sites) to very low diversity (33%). The water levels recorded were moderate (33% of sites), isolated pools (33%) or the bed was dry (33%).

Table 5.38 presents the mean dimensions for the pool and riffle habitats. Pools were slightly deeper and narrower compared to riffles. Width:depth ratios were generally high. Upper banks varied in widths and heights. Banks along the reaches were mostly moderate in slope and convex in shape.

♦ *Bank Condition and Stability*

The reaches assessed in this sub-section were rated as having stable banks (67% of sites) or banks with limited instability (33%). Subjective ratings indicated that the overall bank instability and the susceptibility of banks to further erosion was low (67% of sites) or low to moderate (33%).

Table 5.38 Channel Dimensions for Habitat Types

Dimension		Pool	Riffle
Reach Covered (%)		83.3 (62-100)	25.0 (12-38)
Mean Length (m)		70.7 (22-110)	26.5 (3-50)
Mean Depth (m)**		0.6 (0.4-0.8)	0.5 (0.2-0.8)
Mean Width (m)**		10.9 (3.5-15.2)	11.9 (3.0-20.7)
Width:Depth Ratio		21.9 (4.4-38.0)	53.6 (3.8-103.5)
♦LB:	Width (m)	11.0 (4.0-18.0)	8.8 (0.5-17.0)
	Height (m)	0.6 (0.5-0.7)	0.5 (0.4-0.6)
	Slope (°)	4.7 (2.2-7.1)	20.3 (2-38.7)
∗UB:	Width (m)	5.6 (1.0-15.0)	7.4 (1.4-20.0)
	Height (m)	2.3 (0.6-7.0)	3.4 (1.3-6.5)
	Slope (°)	25.3 (11.0-35.0)	33.1 (18.0-52.0)

♦LB = Lower Bank ∗UB = Upper Bank
** Measured from the water mark.

Erosion was the dominant bank process recorded at all sites. The erosion was predominantly occurring at obstacles (100% of sites), along outside bends (67%) or at irregular intervals (67%). The lower and upper banks were equally stable, with an average of 8% of the lower bank length eroding (range 5-15%), compared to 11% for the upper bank (range 5-20%). At 33% of sites aggradation was recorded along inside bends, at obstacles or all along. On average, 9% of the lower banks were aggrading (range of 0-30%).

The major factors identified as affecting bank stability were roads/crossings/bridges (100% of sites), high flow (67%), people tracks (67%) and stock (67%).

♦ *Bed and Bar Condition and Stability*

Subjectively, all sites were rated as having moderately aggrading beds. The major factor identified as affecting bed stability was instream siltation (100% of sites). Culverts (67% of sites), fallen trees (33%) and rock outcrops (33%) provided a degree of bed stabilising influence.

Sand and gravel bars were recorded at all sites, occurring predominantly as bars with encroaching vegetation (100% of sites). Other bar types recorded were mid-channel islands, channel bar plains or high flow deposits. The mean size of the bars was relatively high, averaging 29% of the bed surface above water mark (range 5-70%). The gravel forming the bed and bars was mostly disc-shaped (67% of sites), and was sub-angular, angular or rounded. Bed compaction was low (67% of sites) or moderate (67%).

♦ *Bed and Bank Sediments*

The bed and bank material at pools was predominantly sand and small gravel, although the bank material also consisted of 21-33% fines/clays. The bed material at riffles ranged in size, although the predominant material was large sand and gravel. The banks at riffles were mostly composed of fines and sand. Organic matter was present in both bed and banks of habitat types and ranged from 10-19%. Rock outcrops were recorded at 67% of sites and was mostly located in the bed.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having either moderate (67% of sites) or high (33%) cover and structural diversity. The vegetation types recorded were vegetation associated with freshwater streams (67% of sites) and monsoonal-type vegetation (33%). The riparian vegetation zone was narrow, averaging 5.8m (range 5-7m), with all sites recording riparian zones of between 5-10m.

The structural types recorded are shown in Table 5.39. There were 7 of the 13 structural types present at all sites. Covers ranged from 0-50%. The highest mean cover was 33% and was recorded for grasses. Understorey vegetation provided similar covers to overstorey vegetation. The upper bank recorded an average of 66% bare (range 50-88%) for understorey vegetation cover compared to 65% bare (range 60-75%) for the overstorey vegetation.

Table 5.39 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	0	0
Trees (10-30m)	100	21.3 (15-28)
Trees (2-10m)	100	16.3 (15-20)
Regen. Trees (<2m)	100	5.2 (4-8)
Woody Shrubs (<2m)	100	4.7 (4-5)
Vines	100*	10.2 (5-18)
Rushes and Sedges	33	1.7 (0-5)
Phragmites	0	0
Forbs (or Herbs)	100*	8.0 (4-10)
Grasses	100	32.5 (5-50)
Ferns	0	0
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

Exotic vegetation, including noxious species, was recorded at all sites to differing degrees, with 2 exotic species at each site being found (refer Table 5.40). The mean total cover of exotic species in the riparian zone was 8% (range 3-12%). Structural types recorded were forbs (100% of sites) and vines (100%). The only noxious species recorded was *Hyptis suaveolens* (mean cover of 4%). *Passiflora foetida,* an exotic vine, was also recorded (mean cover of 5%).

Table 5.40 Cover of Exotic Riparian Vegetation

% Cover Category (Rating)	Percent of Sites (%)
16 - 32* (2)	0
11 - 15 (4)	33
6 - 10 (6)	34
1 - 5 (8)	33
0 (10)	0

* The maximum % cover recorded for exotic riparian vegetation within the catchment was 32%.

♦ *Aquatic Vegetation*

All sites recorded aquatic emergent vegetation. It had a mean cover of 16% (range 8-25%). The structural categories present were Melaleucas (100% of sites), Pandanus (33% of sites) and other shrubs/trees. The covers for these structural types was generally <5%, although Melaleucas recorded a mean cover of 11% (range 8-15%).

♦ *Instream and Bank Habitats*

The cover and diversity of instream and bank habitats rated as either moderate (67% of sites) or high (33%). Subjectively, the condition of the aquatic habitat was rated as poor to good (100% of sites).

Eight instream habitat types were recorded. Those listed for all sites were individual branches, individual logs, leaves/twigs and rock faces. Other types included log jams, branch piles, algal clumps and man-made infrastructure. There were no permanent pools deeper than 1m recorded. The covers provided by these habitat types were generally <10%, though leaves/twigs provided a mean cover of 18% (range 15-25%).

Two different types of overhanging bank cover were recorded for all sites. Vegetation canopy cover occurred along 78% of the bank, with a mean width of 2.6m. Vegetation overhang occurred along 24% of the bank, with a mean width of 1m. Some root and bank overhang cover was also recorded.

At water mark, 67% of sites would have a moderately restricted passage for fish and other aquatic organisms and 33% would be partly restricted.

♦ *Overall Condition*

The overall condition rating for sites assessed in this sub-section was high.

Moderate bed aggradation (Site 10/3: Stray Creek)

5.8.2 Discussion

Of the sites surveyed, the lower sub-section site was experiencing localised bank stability problems. Roads and crossings were identified as the major disturbance to river banks. All river beds sampled within the sub-section were subjectively rated as moderately aggrading and instream siltation was identified as the major factor affecting bed stability, particularly at the lower sub-section site. Bars were relatively large within this sub-section, averaging 29% of the bed surface, though this ranged to as high as 70% for the lower sub-section site.

Even though pools dominated reaches, the sites on Stray Creek rated a high diversity of habitat types, while the site on a tributary of Stray Creek, above Umbrawarra Gorge, rated a very low diversity due to the channel being so uniform and having no variation in depth. There were only 2 sites that recorded very low channel type diversity in the Daly River catchment. Even though a variety of instream habitat types were present, covers were generally <10% and this was reflected in moderate instream/bank cover and diversity ratings for two-thirds of the reaches. Vegetation canopy cover along the banks was good though, averaging 78% of the bank length.

Reaches were essentially natural. Outside of Umbrawarra Gorge Nature Park, grazing was identified as the major land use and disturbance factor likely to affect stream reaches, although all sites recorded causeways/crossings, roads and people as disturbances.

The riparian zone was narrow throughout the sub-section, averaging only 6m. Understorey covers were dominated by grasses and vines and provided similar overall covers to that provided by trees (2-30m tall). Other structural types each provided <10% cover. Moderate riparian vegetation ratings for two-thirds of the reaches was due to the lack of diversity and cover provided by the majority of structural types.

All sites recorded some degree of disturbance to the riparian zone by exotic and noxious vegetation. *Hyptis suaveolens* was the only noxious species recorded and was present at all sites, although covers were low. *Passiflora foetida*, a naturalised vine, also had a wide distribution being present at all sites, although the covers were moderately high at the upper Stray Creek site. Even though aquatic vegetation, in the form of emergents, was present at all sites, there was a lack of structural diversity and covers ranged.

According to DPI&F, an exotic species, declared noxious in the Northern Territory, that was not collected as part of this survey but is known to be present on Stray Creek (below Site 10/3), is *Mimosa pigra*. DPI&F have a control program in place to combat this exotic species in order to stop it spreading downstream to the Daly River.

Stable bed and banks; high overall rating (Site 11/2: Bradshaw Creek)

Moderate riparian vegetation and instream/ bank habitat ratings (Site 11/2: Bradshaw Creek)

5.9 Bradshaw Creek

Sub-section 11 includes the catchment area of Bradshaw Creek. Of the 2 sites located in this sub-section, 1 site was fully assessed.

5.9.1 Results

♦ *Reach Environs and Site Features*

All sites were rated as having reach environs that had some modification. Subjective disturbance ratings indicated that 50% of sites had moderate levels of disturbance and 50% moderate to high levels.

Both sites had land tenure that was freehold or leasehold. Grazing was the major land use and occurred predominantly on thinned native pastures. Grazing was identified as the major disturbance likely to affect stream reaches and to a lesser extent, a watering point for stock/ferals. Channel patterns where braided at 50% of sites.

♦ *Channel Habitat Types, Diversity and Dimensions*

The reach length studied was 406m. Pools and riffles were recorded at the site studied. Pools were the dominant habitat type, taking up 94% of the reach length. As a result of the lack of diverse habitat types present, the channel type diversity rating was moderate. The water level at the time of sampling was either isolated pools (50% of sites) or the bed was dry (50%).

Table 5.41 presents the dimensions for the pool and riffle habitats recorded at one site. Pools, at 1.2m, were four times deeper than riffles and were slightly wider. Width:depth ratios for riffles was very high. Upper banks were <10m wide and were low, with a low slope. Banks along the reach were moderate in slope and convex or concave-shaped.

♦ *Bank Condition and Stability*

The site assessed in this sub-section was rated as having stable banks. Subjectively, the overall bank instability and the susceptibility of banks to further erosion were rated as moderate.

Erosion was the dominant bank process recorded. The erosion was predominantly occurring along outside bends, at floodplain scours or seepage/ runoff point. The lower bank was slightly more stable than the upper banks, with 90% of the lower bank being recorded as stable, compared to 82% for the upper bank. No aggradation along the banks was recorded.

Table 5.41 Channel Dimensions for Habitat Types

Dimension		Pool	Riffle
Reach Covered (%)		94.0	6.0
Mean Length (m)		192.0	11.0
Mean Depth (m)**		1.2	0.3
Mean Width (m)**		47.0	44.0
Width:Depth Ratio		40.9	146.7
♦LB:	Width (m)	8.3 (5.5-11.0)	-
	Height (m)	1.0 (-)	-
	Slope (°)	7.8 (5-10)	-
∗UB:	Width (m)	8.0 (6.0-10.0)	5.0 (4.0-6.0)
	Height (m)	1.3 (1.2-1.3)	1.9 (1.1-2.6)
	Slope (°)	9.4 (7-11)	19.4 (15-23)

♦LB = Lower Bank ∗UB = Upper Bank
** Measured from the water mark.

The major factors identified as affecting bank stability were stock and vermin.

♦ *Bed and Bar Condition and Stability*

Subjectively, the site assessed in this sub-section was rated as having a stable bed. The major factor identified as affecting bed stability was agriculture/grazing.

A sand and gravel bar was recorded at this site. The size of the encroaching vegetation bar was 15% of the bed surface above water mark. The gravel forming the bed and bar was blade-shaped and angular. Bed compaction was low along the pool and compacted at the riffle.

♦ *Bed and Bank Sediments*

The bed and bank material at the pool habitat was predominantly fines/clays. The bed material at the riffle habitat was predominantly cobbles and boulders, while the banks where predominantly fines. Organic matter was present in both bed and banks and ranged from 9-10%. Rock outcrops were also present.

♦ *Riparian Vegetation*

The riparian vegetation at this site was rated as having moderate cover and structural diversity. The vegetation types recorded were vegetation associated with freshwater streams (50% of sites) and Melaleuca Woodland (50%). The riparian vegetation zone was very narrow, averaging 3.5m (range 3-4m).

The structural types recorded included trees 2-30m, regenerating trees, vines, forbs and grasses. Covers ranged from 0-35%. The highest cover (35%) was recorded for small trees. The remaining covers where 10% or less. Overstorey vegetation provided much greater cover than understorey vegetation.

Exotic/noxious vegetation, in the form of *Hyptis suaveolens* (a forb), was recorded at one site. This site rated a low overall invasion by exotics (1-5% cover) when covers for both river banks were averaged. A mean cover of 8% for *Hyptis* was recorded along one river bank.

♦ *Aquatic Vegetation*

The site recorded aquatic emergent vegetation, in the form of *Pandanus aquaticus*. It had a mean cover of 5%.

♦ *Instream and Bank Habitats*

For the site surveyed, the cover and diversity of instream and bank habitats rated as moderate. Subjectively, the site was rated as having a poor overall aquatic condition.

Five instream habitat types were recorded. They included individual branches, individual logs, leaves/twigs, emergent vegetation and rock faces. There were no permanent pools deeper than 1m recorded. The covers provided by these habitat types were generally 5% or less, though rock faces provided cover of 50%.

Three different types of overhanging bank cover were recorded. Vegetation canopy overhang occurred along 78% of the bank, with a mean width of 2.5m. Vegetation and root overhang occurred along <10% of the bank and had a width of 0.2-1.5m.

At water mark, the site would have a partly restricted passage for fish and other aquatic organisms.

♦ *Overall Condition*

The overall condition of the site assessed in this sub-section was high.

5.9.2 Discussion

Reach environs along Bradshaw Creek were somewhat modified. The creek banks and bed along lower Bradshaw Creek were stable, even though the reaches were located on freehold or leasehold land, and grazing activity was identified as the major disturbance affecting stream reaches, banks and river bed stability. Vermin were also identified as having some impact on bank stability.

Only pool and riffle habitats were recorded within this sub-section. Pools dominated the reaches to a very high extent resulting in a moderate rating for the channel habitat type diversity. The cover and diversity of instream and bank habitats was also moderate although it was subjectively assessed as being in poor condition. Instream covers were not as diverse as other sub-sections and covers were quite low, although a very good canopy cover along the creek banks was recorded.

The riparian vegetation was very narrow, averaging only 3-4m. The moderate cover and structural diversity rating for the riparian vegetation was due to the low diversity and cover provided by the majority of structural types. Only six structural types were present, with small trees providing the greatest cover. Except for small trees, the remaining structural types each provided <10% cover.

Half the sites recorded some degree of disturbance to the riparian zone by noxious species. *Hyptis suaveolens* was the only exotic/noxious species present and it recorded a moderate cover along one river bank compared to other forbs.

Only emergent aquatic vegetation was recorded present throughout the Bradshaw Creek sub-section.

When all six components that make up the overall condition were considered, the site surveyed rated highly.

Limited bank instability (Site 12/1: Dead Horse Creek)

Moderate riparian vegetation and instream/bank habitat ratings (Site 12/1: Dead Horse Creek)

5.10 Dead Horse Creek

Sub-section 12 includes the catchment area of Stray Creek. Two sites were fully assessed within this sub-section.

5.10.1 Results

♦ *Reach Environs and Site Features*

All sites were rated as having reach environs that had some modification. Subjective disturbance ratings indicated that all sites had moderate levels of disturbance.

Land tenure was freehold or leasehold at all sites. Grazing was the major land use and occurred predominantly on thinned native pastures (100% of sites) and virgin timbered native pastures (50%).

The major disturbances likely to affect stream reaches were grazing (100% of sites); causeways/crossings (50%) and a watering point for stock/ferals (50%). The major floodplain features recorded were floodplain scours (50% of sites) and billabongs (50%).

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 134m (range 132-135m). Pools and riffles occurred at 100% of sites, although pools dominated the reach, averaging 69% of the reach length. The channel type diversity rating was high for all sites. The water level at the time of sampling was isolated pools (50% of sites) or the bed was dry (50%).

Table 5.42 presents the mean dimensions for the pool and riffle habitats. Pools were nearly twice the length, width and depth compared to riffles. Both habitat types had similar width:depth ratios. Only pools recorded a lower bank because riffles were dry at the time of sampling. Upper banks were moderately wide and high, with a low to moderate slope. Banks along the reach were mostly moderate in slope and concave in shape.

♦ *Bank Condition and Stability*

The reaches assessed in this sub-section were rated as having stable banks (50% of sites) or limited instability (50%). Subjective ratings indicated that at 50% of sites the overall bank instability and the susceptibility of banks to further erosion was low, low to moderate, moderate or moderate to high.

Table 5.42 Channel Dimensions for Habitat Types

Dimension		Pool	Riffle
Reach Covered (%)		69.0 (57-81)	31.0 (19-43)
Mean Length (m)		37.5 (37-38)	21.0 (13-29)
Mean Depth (m)**		0.5 (-)	0.3 (-)
Mean Width (m)**		7.8 (7.5-8.0)	4.5 (2.0-7.0)
Width:Depth Ratio		15.5 (15.0-16.0)	15.0 (6.7-23.3)
♦LB:	Width (m)	1.3 (1.2-1.4)	-
	Height (m)	0.4 (-)	-
	Slope (°)	17.2 (16.0-18.0)	-
∗UB:	Width (m)	14.8 (4.0-25.0)	14.4 (3.5-25.0)
	Height (m)	5.2 (2.5-11.0)	4.8 (1.8-10.5)
	Slope (°)	23.6 (10.2-34.0)	23.1 (10.2-32.0)

♦LB = Lower Bank ∗UB = Upper Bank
** Measured from the water mark.

Erosion was the dominant bank process recorded at all sites. The erosion was predominantly occurring at floodplain scours (100% of sites), obstacles (100%), seepage/runoff points (100%) or along outside bends (50%). The lower and upper banks both recorded erosion, with an average of 21% of the lower bank length eroding (range 10-35%), compared to 25% for the upper bank (range 10-50%). No aggradation along the banks was recorded.

The major factors identified as affecting bank stability were stock (100% of sites), floodplain scours (100%) and runoff (50%).

♦ *Bed and Bar Condition and Stability*

Subjectively, all sites were rated as having stable beds. The major factors identified as affecting bed stability at 50% of sites were agriculture/grazing, concentration of flows and bank erosion.

Sand and gravel bars were present at all sites, occurring predominantly as bars with encroaching vegetation (50% of sites) or forming at obstacles (50%). The mean size of the bars was 18% of the bed surface above water mark (range 5-30%). The gravel forming the bed and bars was disc-shaped and angular. Bed compaction was low (100% of sites) or moderate (50%). Fallen trees (50% of sites) and rock outcrops (50%) provided a degree of bed stabilising influence.

♦ *Bed and Bank Sediments*

The bed material at pool and riffle habitats was predominantly fines/clays, although sands and gravels were also present. The bank material at pools and riffles was mostly fines and clays, although boulders were recorded in the upper bank at the riffle habitat.

Organic matter was present in both bed and banks of habitat types and ranged from 7-13%. Rock outcrops were recorded at 50% of sites.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having moderate cover and structural diversity at all sites. The vegetation types recorded were vegetation associated with freshwater streams (50% of sites) and eucalypt wet sclerophyl forest (50%). The mean width of the riparian vegetation zone was 19.8m (range 3-45m), with 50% of sites recording riparian zones <5m wide, 50% between 21-30m and 50% >40m.

The structural types recorded are shown in Table 5.43. There were 7 of the 13 structural types present at all sites. Covers ranged from 0-50%. The highest mean cover was 39% and was recorded for grasses.

Table 5.43 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	0	0
Trees (10-30m)	100	23.8 (15-50)
Trees (2-10m)	100	13.8 (10-15)
Regen. Trees (<2m)	100	8.8 (5-15)
Woody Shrubs (<2m)	100	5.0 (-)
Vines	100*	4.8 (0-10)
Rushes and Sedges	50	2.0 (0-4)
Phragmites	0	0
Forbs (or Herbs)	100*	10.0 (5-20)
Grasses	100	38.8 (15-50)
Ferns	0	0
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

Understorey vegetation provided greater cover than overstorey vegetation. The upper bank recorded an average of 54% bare (range 40-75%) for understorey vegetation cover compared to 65% bare (range 40-85%) for the overstorey vegetation.

Exotic vegetation, including noxious species, was recorded at 50% of sites and the mean total cover of exotic species in the riparian zone for this sub-section was 6% (range 0-17%). The lower sub-section site rated a high invasion by 3 exotic

species (11-15% cover). Structural types recorded were forbs and vines. The only noxious species recorded was *Xanthium occidentale* (mean cover of 8%). Exotic vines included *Passiflora foetida* (mean cover of 4%) and *Cardiospermum halicacabum* (mean cover of 4%).

♦ *Aquatic Vegetation*

Aquatic vegetation was recorded at 50% of sites, in the form of emergent and submerged vegetation. Emergent vegetation (as ground covers) had a mean cover of 5%, whereas submerged aquatic vegetation (in the form of Chara/Nitella) had a mean cover of 15%. Species recorded were *Cynodon dactylon* and *Chara sp*..

♦ *Instream and Bank Habitats*

The cover and diversity of instream and bank habitats rated as either moderate (50% of sites) or low (50%). Subjectively, the condition of the aquatic habitat was rated as poor (100% of sites).

Seven instream habitat types were recorded. The only type listed for all sites was leaves/twigs, which had the highest mean cover of 15% (range 5-25%). Other types included individual branches, individual logs, log jams, branch piles and rock faces. There were no permanent pools deeper than 1m recorded. The covers provided by these habitat types was generally <10%.

Two different types of overhanging bank cover were recorded. Vegetation canopy overhang occurred along 40% of the bank and had a mean width of 3.2m. Vegetation overhang occurred along 8% of the bank and had a mean width of 0.3m.

At water mark, 50% of sites would have a partly restricted passage for fish and other aquatic organisms and 50% would be very restricted.

♦ *Overall Condition*

The overall condition rating for sites assessed in this sub-section was high.

Low cover & diversity of instream & bank habitats (Site12/2: Dead Horse Creek)

5.10.2 Discussion

Reach environs were showing signs of being somewhat modified. All sites were on freehold or leasehold land where grazing was the major land use activity. River banks were generally stable throughout the sub-section, although floodplain scours, a log jam and stock were causing localised instability problems at a site near Daly River junction. At this site up to half the length of the upper bank was eroding in places. River beds were stable throughout the sub-section, with grazing, bank erosion and concentration of flows causing some disturbances to bed stability.

Although only two habitat types were recorded within Dead Horse Creek sub-section, the channel type diversity was rated as high because riffles occupied between 10-30% and >30% of the reach length. The cover and diversity of instream and bank habitats ranged from moderate lower in the sub-section to low in the upper sub-section reach. Only 2 sites recorded a low instream and bank habitat rating in the Daly River catchment, the lowest recording, and the upper sub-section site was one of those. All sites were subjectively assessed as having a poor overall aquatic habitat condition. There was generally a range of instream habitat types present, although the covers were often <10%, and less than half the banks had vegetation canopy cover overhanging the stream.

The moderate rating for riparian vegetation extended throughout the sub-section. The rating reflected the lower structural diversity and covers provided by the riparian vegetation. Understorey vegetation, in particular grasses and forbs, provided better cover than did trees (2-30m). Other structural types where present, provided low covers. There was a noticeable variation in riparian zone widths throughout the sub-section. The site located near the Daly River junction had much wider vegetation, averaging 31-40m, compared to the upper sub-section site, which was very narrow at <5m wide. Aquatic vegetation was restricted to the upper sub-section reach, where submerged *Chara* sp. provided moderate covers.

Only the lower sub-section site recorded some degree of disturbance to the riparian zone by exotic/noxious species. *Xanthium occidentale* (Noogoora Burr) was the only noxious species recorded and was notable by its moderate cover of 8% compared to other forbs. Other exotic species, *Passiflora foetida* and *Cardiospermum halicacabum*, provided only low covers. This site was near the Daly River junction and therefore close to a source of exotic species like Noogoora Burr.

5.11 Fergusson River

The Fergusson River sub-catchment includes Fegusson River (below and above Edith River), Edith River, Eight Mile Creek and Cullen River/ Copperfield Creek sub-sections.

5.11.1 Results

5.11.1.1 Fergusson River – below Edith River

Sub-section 13a encompasses the Fergusson River, downstream of the junction with Edith River. Two sites were fully assessed in this sub-section.

♦ *Reach Environs and Site Features*

All sites were rated as having reach environs that had some modification. Subjective disturbance ratings indicated that all sites had low levels of disturbance.

Land tenure was freehold or leasehold. Grazing was the major land use and occurred on thinned native pastures (100% of sites). The major disturbance likely to affect stream reaches was grazing (100% of sites). The major floodplain features recorded were prominent flood channels, remnant channels and billabongs. Braided channels were present at 50% of sites.

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 304m (range 250-358m). Pools and riffles occurred at all sites, although pools dominated the reach, averaging 73%. The channel type diversity rating in this sub-section was either high (50% of sites) or moderate (50%). The water level at the time of sampling was moderate but less then normal (100% of sites).

Table 5.44 presents the mean dimensions for the pool and riffle habitats. Although pools were similar in depth and width to riffles, they were much longer. Upper banks varied considerably in widths, although heights were moderate. Banks were mostly low-moderate in slope and were either concave-shaped or had a wide lower bench.

♦ *Bank Condition and Stability*

All reaches assessed were rated as having stable banks. Subjective ratings indicated that the overall bank instability and the susceptibility of banks to further erosion were low at all sites. The major factors identified as affecting bank stability at all sites were stock and high flow.

Table 5.44 Channel Dimensions for Habitat Types

Dimension		Pool	Riffle
Reach Covered (%)		73.0 (50-96)	27.0 (4-50)
Mean Length (m)		373.5 (172-575)	15.0 (-)
Mean Depth (m)**		0.5 (-)	0.5 (0.4-0.6)
Mean Width (m)**		24.2 (8.3-40.0)	24.9 (4.8-45.0)
Width:Depth Ratio		16.6 (-)	44.2 (13.3-75.0)
♦LB:	Width (m)	0.2 (0.1-0.5)	-
	Height (m)	0.2 (0.1-0.3)	-
	Slope (^{o})	46.1 (11.3-71.6)	-
∗UB:	Width (m)	68.3 (13-160)	14.4 (3.5-25.0)
	Height (m)	6.0 (4.5-10.0)	4.8 (1.8-10.5)
	Slope (^{o})	9.8 (1.6-21.0)	23.1 (10.2-32.0)

♦LB = Lower Bank ∗UB = Upper Bank
** Measured from the water mark.

Erosion was the dominant bank process recorded at all sites. At 50% of sites the erosion was occurring at floodplain scours, obstacles, seepage/ runoff points, irregularly or along outside bends. The banks were quite stable, with only 4-7% recorded as eroding. Aggradation, which averaged 14% along the upper bank (range 0-40%), was recorded along inside bends (50% of sites) and all along the banks (50%).

♦ *Bed and Bar Condition and Stability*

Subjectively, all sites were rated as having beds that were moderately aggrading. The major factors identified as affecting bed stability were instream siltation (100% of sites) and agriculture/grazing (50%).

Sand and gravel bars were recorded at all sites, occurring predominantly as bars with encroaching vegetation (50% of sites), as channel bar plains (50%) or high flow deposits (50%). The mean size of the bars was large, averaging 33% of the bed surface above water mark (range 25-40%). The gravel forming the bed and bars was sphere-shaped, sub-angular or rounded. Bed compaction was low (50% of sites) or moderate (50%). Fallen trees (50% of sites) provided a degree of bed stabilising influence.

♦ *Bed and Bank Sediments*

The bed material at pool habitats was predominantly fines/clays and small gravel. The riffles on the other hand had bed material that was predominantly gravels and cobbles. Bank material at both habitat types was mostly fines/clays and small sand. Organic matter was present in both bed and banks of habitat types and ranged from 12-23%. Rock outcrops were recorded at 50% of sites.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having moderate cover and structural diversity at all sites. The vegetation type recorded was vegetation associated with freshwater streams (100% of sites). The mean width of the riparian vegetation zone was 55.8m (range 18-155m), with 100% of sites recording riparian zones between 11-20m, 50% between 21-30m and 50% >40m.

The structural types recorded are shown in Table 5.45. There were 7 of the 13 structural types present at all sites. Covers ranged from 0-50%. The highest mean cover was 30% and was recorded for medium-sized trees (10-30m). Overstorey vegetation provided much greater cover than understorey vegetation. The upper bank recorded an average of 90% bare for understorey vegetation cover compared to 53% bare (range 40-75%) for the overstorey vegetation.

Table 5.45 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	0	0
Trees (10-30m)	100	30.0 (10-50)
Trees (2-10m)	100	21.3 (15-25)
Regen. Trees (<2m)	100	5.5 (4-8)
Woody Shrubs (<2m)	100	4.5 (4-5)
Vines	100*	7.5 (5-10)
Rushes and Sedges	0	0
Phragmites	0	0
Forbs (or Herbs)	100*	5.8 (4-10)
Grasses	100	6.0 (4-10)
Ferns	0	0
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

Exotic vegetation was recorded at all sites, while noxious vegetation was present at half the sites. The mean total cover of exotic species in the riparian zone was low, averaging 3% (range 0-8%) and, as a result, the sites rated as having a low invasion by exotic species. Structural types recorded at all sites were forbs and vines. The only noxious species recorded was *Xanthium occidentale* or Noogoora Burr (mean cover of 5%). Other exotic species included *Passiflora foetida* (mean cover of 3%) and *Melochia pyramidata* (mean cover of 1%).

♦ *Aquatic Vegetation*

Aquatic vegetation was recorded at all sites, in the form of emergent and/or submerged vegetation. Emergent vegetation (as Pandanus) was present at 50% of sites and had a mean cover of 8%. Submerged aquatic vegetation (in the form of Chara/Nitella) was present at 100% of sites and had a mean cover of 10%. Species recorded were *Pandanus aquaticus* and *Chara sp*..

♦ *Instream and Bank Habitats*

The cover and diversity of instream and bank habitats rated as either high (50% of sites) or moderate (50%). Subjectively, the condition of the aquatic habitat was rated as good (100% of sites).

Ten instream habitat types were recorded. The types listed for all sites were individual logs, individual branches, leaves/twigs and freshwater submerged vegetation. Other types included log jams, branch piles, algal clumps, emergent vegetation and permanent pools deeper than 1m. The covers provided by these habitat types was generally <10%, although pool habitats provided a mean cover of 20% (range 0-40%).

Two different types of overhanging bank cover were recorded at all sites. Vegetation canopy overhang occurred along 50% of the bank and had a mean width of 3.6m. Vegetation overhang occurred along 21% of the bank and had a mean width of 0.8m. Root and bank overhang were also recorded at 50% of sites and occurred along 15% and 5% of the bank respectively, with a width of <0.5m.

At water mark, 50% of sites would have unrestriced passage for fish and other aquatic organisms and 50% would be partly restricted.

♦ *Overall Condition*

The overall condition rating for sites assessed in this sub-section was high.

Moderate bed aggradation (Site 13a/1: Fergusson River)

5.11.1.2 Fergusson River – above Edith River

Sub-section 13b encompasses the Fergusson River, upstream of the junction with Edith River (excluding Edith River, Eight Mile Creek and Cullen River catchment areas). Two sites were fully assessed in this sub-section.

♦ *Reach Environs and Site Features*

Sites were rated as having reach environs that were essentially natural (50% of sites) or had some modification (50%). Subjective disturbance ratings indicated that reach environs had low levels of disturbance (50% of sites) or moderate levels (50%).

Land tenure was freehold or leasehold (100% of sites). Grazing was the major land use and occurred on thinned native pastures (50% of sites) and virgin timbered native pastures (50%). The disturbances likely to affect stream reaches at 50% of sites were bridges/culverts, people, roads/tracks and grazing. The major floodplain features recorded were floodplain scours (100% of sites) and prominent flood channels (50%).

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 207m (range 164-250m). The dominant habitat type was pools (100% of sites), which averaged 54% of the reach length. Other habitat types included: rapids (50% of sites), riffles (50%) and runs (50%). The channel type diversity rating in this sub-section was either very high (50% of sites) or high (50%). The water level at the time of sampling was moderate but less than the normal level (50% of sites) or at water mark (50%).

Table 5.46 presents the mean dimensions for the pool and rapid habitats. The pools were twice as long as rapids, were wider and over five times deeper. Pools recorded a low width:depth ratio compared to rapids. Lower banks were quite narrow and low, with a low to moderate slope. Upper banks were relatively wide and averaged 3-4m in height, with a low slope. Banks along the reach were mostly low or moderate in slope and were either concave-shaped or had a wide lower bench.

♦ *Bank Condition and Stability*

All reaches assessed in this sub-section were rated as having stable banks. Subjective ratings indicated that the overall bank instability at all sites was low. The susceptibility of banks to further erosion was rated as either low (50% of sites) or low to moderate (50%).

Table 5.46 Channel Dimensions for Habitat Types

Dimension		Pool	Rapid
Reach Covered (%)		53.5 (31-76)	24.0
Mean Length (m)		120.0 (50-190)	60.0
Mean Depth (m)**		2.1 (1.5-2.8)	0.4
Mean Width (m)**		19.8 (18.0-21.5)	12.0
Width:Depth Ratio		9.9 (7.8-12.0)	34.3
♦LB:	Width (m)	0.5 (0.4-0.5)	0.6 (0.2-1.0)
	Height (m)	0.1 (-)	0.2 (0.2-0.3)
	Slope (^{o})	12.7 (11.3-14.0)	25.5 (14.0-36.9)
∗UB:	Width (m)	13.3 (7.5-16.0)	25.0 (20.0-30.0)
	Height (m)	3.5 (2.1-6.0)	3.4 (2.7-4.0)
	Slope (^{o})	14.8 (8.7-20.6)	8.2 (5.0-11.0)

♦LB = Lower Bank ∗UB = Upper Bank
** Measured from the water mark.

Erosion was the dominant bank process recorded at all sites. The erosion was occurring at floodplain scours (100% of sites), obstacles (100%), seepage/runoff points (50%), irregularly (50%) or along outside bends (50%). The banks were stable, with only 3-9% of the bank length recorded as eroding. Minor aggradation was recorded at floodplain scours (50% of sites).

The major factor identified as affecting bank stability was high flow (100% of sites). Other factors included roads/bridges/crossings, floodplain scours, people tracks, seepage points and stock.

♦ *Bed and Bar Condition and Stability*

Subjectively, the sites assessed were rated as having stable beds (50% of sites) or moderately aggrading beds (50%).

Sand and gravel bars were recorded at all sites, occurring predominantly as high flow deposits (100% of sites) or alternate/side irregular bars (50%). The mean size of the bars was 17% of the bed surface above water mark (range 8-25%). The gravel forming the bed and bars was sphere-shaped, sub-angular or angular. Bed compaction was low (50% of sites), moderate (50%) or tightly packed (50%).

The major factor identified as affecting bed stability was agriculture/grazing (50% of sites). Rock outcrops (100% of sites) provided a degree of bed stabilising influence.

♦ *Bed and Bank Sediments*

The bed material at pool habitats was predominantly sands, small gravel and boulders. Rapids had bed material that was mostly boulders and cobbles. Riffles, on the other hand, had bed material composed of sands and small gravel. Bank material at pool and riffle habitats was predominantly composed of sand and small gravel. The banks at rapids were mostly boulder, cobble and gravel materials. Organic matter was present in both bed and banks of habitat types and ranged from 5-29%. Rock outcrops were recorded at all sites.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having moderate cover and structural diversity at all sites. The vegetation type recorded was vegetation associated with freshwater streams (100% of sites). The mean width of the riparian vegetation zone was 15m (range 7-25m), with 50% of sites recording riparian zone widths between 5-10m, 100% between 11-20m and 50% between 21-30m.

The structural types recorded are shown in Table 5.47. There were 7 of the 13 structural types present at all sites. Covers were reduced and ranged from 0-25%. The highest mean cover was 17% and was recorded for medium trees (10-30m tall).

Table 5.47 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	0	0
Trees (10-30m)	100	17.0 (10-25)
Trees (2-10m)	100	13.0 (10-15)
Regen. Trees (<2m)	100	5.0 (-)
Woody Shrubs (<2m)	100	7.0 (5-8)
Vines	100*	6.3 (5-10)
Rushes and Sedges	50	1.0 (0-2)
Phragmites	50	1.5 (0-3)
Forbs (or Herbs)	100*	7.0 (4-10)
Grasses	100	9.3 (5-13)
Ferns	0	0
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

Overstorey vegetation provided much greater cover than understorey vegetation. The upper bank recorded an average of 85% bare (range 76-90%) for understorey vegetation cover compared to 68% bare (range 47-80%) for the overstorey vegetation.

Exotic vegetation was recorded at all sites, while noxious vegetation was present at 50% of sites. The mean total cover of exotic species in the riparian zone for the sub-section was low, averaging 5% (range 2-10%), although one site rated a moderate invasion from 2 exotic species with a cover between 6-10% being recorded. Structural types recorded were vines (100% of sites) and forbs (50%). The only noxious species recorded was a forb, *Hyptis suaveolens* (mean cover of 5%). The exotic vine species was *Passiflora foetida* (mean cover of 3%).

♦ *Aquatic Vegetation*

Aquatic vegetation was recorded at all sites in the form of emergent vegetation. The cover provided by this vegetation was low, averaging 5%. The structural types present included Pandanus (100% of sites) and Melaleucas (50%). Species recorded were *Pandanus aquaticus*, *Melaleuca leucadendra* and *M. nervosa.*

♦ *Instream and Bank Habitats*

The cover and diversity of instream and bank habitats was high for all sites. Subjectively, the overall aquatic habitat condition was rated as good (50% of sites) or poor to good (50%).

Seven instream habitat types were recorded. The types listed for all sites were individual logs, leaves/twigs, algal clumps, emergent vegetation, rock faces and pools deeper than 1m. One other type recorded was individual branches (50% of sites). The covers provided by these habitat types was <10%, although rock faces provided a mean cover of 48% (range 45-50%) and permanent pool habitats provided a mean cover of 28% (range 25-30%).

Three different types of overhanging bank cover were recorded at all sites. Vegetation canopy cover occurred along 45% of the bank and had a mean width of 3.1m. Vegetation overhang occurred along 15% of the bank and had a mean width of 1.6m. Root (100% of sites) and bank overhang (50%) occurred along <10% of the bank and recorded a mean width of <0.5m.

At water mark, 50% of sites would have partly restricted passage for fish and other aquatic organisms and 50% would be moderately restricted.

♦ *Overall Condition*

The overall condition rating for sites assessed in this sub-section was high.

Some modification to river banks and bed along Edith River following high flood flows in early 1995 (Site 14/3)

5.11.1.3 Edith River

Sub-section 14 includes the catchment of Edith River. Of the 4 sites located within this sub-section, 3 sites were fully assessed.

♦ *Reach Environs and Site Features*

Sites were rated as having reach environs that were essentially natural (67% of sites) or had some modification (33%). Subjective disturbance ratings indicated that sites had low levels of reach environs disturbance (67% of sites) or moderate levels (33%).

Land tenure was freehold or leasehold at all sites. Grazing was the major land use and occurred on virgin timbered native pastures (67% of sites) and thinned native pastures (33%). The major disturbances likely to affect stream reaches were grazing (67% of sites), roads/tracks (67%), people (33%) or watering points (33%). The major floodplain features recorded were floodplain scours (67% of sites) and floodplain deposits (33%).

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 174m (range 40-348m). The dominant habitat type was pools (100% of sites), which averaged 90% of the reach length. The only other habitat type recorded was riffles (67% of sites). The channel type diversity rating ranged from high diversity (67% of sites) to low diversity (33%). The water level at the time of sampling was moderate but less than the normal level at all sites.

Table 5.48 presents the mean dimensions for the pool and riffle habitats. Pools were over three times longer than riffles. Pools and riffles were relatively shallow at 0.6m and 0.1m respectively. Widths were also generally low for both habitat types. Riffles recorded a much higher width:depth ratio. Lower banks were narrow and low, with moderate to high slopes. Upper banks were much wider than they were tall, with a low slope. Banks along the reach were mostly moderate or low in slope and were either concave-shaped, convex-shaped or had a wide lower bench.

Table 5.48 Channel Dimensions for Habitat Types

Dimension		Pool	Riffle
Reach Covered (%)		90.0 (80-100)	15.0 (10-20)
Mean Length (m)		122.5 (60-185)	37.5 (7-68)
Mean Depth (m)**		0.6 (0.5-0.8)	0.1 (0.1-0.2)
Mean Width (m)**		10.6 (6.0-18.0)	6.7 (3.0-10.3)
Width:Depth Ratio		16.6 (12.0-22.5)	49.5 (49.1-50.0)
♦LB:	Width (m)	0.2 (-)	0.2 (-)
	Height (m)	0.2 (-)	0.1 (-)
	Slope (^{o})	45.0 (-)	26.6 (-)
∗UB:	Width (m)	20.3 (3.5-57.0)	34.9 (6.0-58.0)
	Height (m)	3.7 (2.0-5.5)	4.4 (1.7-8.3)
	Slope (^{o})	20.6 (5.5-31.8)	8.9 (4.5-15.8)

♦LB = Lower Bank ∗UB = Upper Bank
** Measured from the water mark.

♦ *Bank Condition and Stability*

The reaches assessed in this sub-section were rated as having stable banks (67% of sites) or banks with limited instability (33%). Subjective ratings indicated that the overall bank instability and the susceptibility of banks to further erosion were minimal to low (33% of sites), low (33%) or moderate (67%).

Erosion was the dominant bank process recorded at all sites. The erosion was occurring at floodplain scours (67% of sites), irregularly (33%) or along outside bends (33%). The lower banks were more stable than the upper banks, with only 6% (range 2-10%) of the bank length recorded as eroding. The upper banks, on the other hand, recorded erosion along an average of 12% of the bank length (range 5-20%). Aggradation was also recorded, occurring at obstacles (67% of sites), floodplain scours (33%) and irregularly (33%). A mean of 8% of the upper bank was recorded as aggrading (range 0-15%).

The major factor identified as affecting bank stability was high flow (100% of sites). Other factors included roads/bridges/crossings, floodplain scours and vermin.

♦ *Bed and Bar Condition and Stability*

The reaches assessed in this sub-section were subjectively rated as having beds that were stable, moderately aggrading or eroding (refer Table 5.49).

Table 5.49 Overall Bed Stability Ratings

Stability Category (Rating)	Percent of Sites (%)
Severe Erosion or Aggradation (2)	0
Moderate Erosion or Aggradation (6)	67
Stable (10)	33
Dominant Process Recorded	
Aggradation	34
Erosion	33
No process (bed stable)	33

Sand and gravel bars were present at 67% sites, occurring predominantly as high flow deposits (67% of sites) or bars with encroaching vegetation (33%). The mean size of the bars was relatively large, averaging 20% of the bed surface above water mark. The gravel forming the bed and bars was sphere-shaped (100% of sites) or disc-shaped (33%); and was sub-angular (67%) or angular (67%). Bed compaction was either poor (33% of sites), moderate (33%) or packed (33%).

At 33% of sites, the major factor identified as affecting bed stability was agriculture/grazing. No factors were recorded at 33% of sites. Rock outcrops (67% of sites) and fallen trees (33%) provided a degree of bed stabilising influence.

♦ *Bed and Bank Sediments*

The bed material at pool and riffle habitats recorded a full range of sizes, although large sand, gravels, cobbles and boulders dominated the material. The lower banks recorded a similar range in sediment sizes although the pool habitats recorded a greater amount of fines/clays and small sands. At pool habitats, the upper bank was mostly fines and sand, whereas at riffles, they were predominantly sands, gravels and cobbles. Organic matter was present in both bed and banks of habitat types and ranged from 12-25%. Rock outcrops were recorded at 67% of sites and were mostly located in the bed.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having either high (67% of sites) or moderate (33%) cover and structural diversity.

The vegetation type recorded was vegetation associated with freshwater streams (100% of sites). The mean width of the riparian vegetation zone was 14m (range 8-30m), with 67% of sites recording riparian zone widths between 5-10m, 33% between 11-20m and 33% between 21-30m.

The structural types recorded are shown in Table 5.50. There were 8 of the 13 structural types present at all sites. Covers ranged from 0-55%. The highest mean cover was 30% and was recorded for grasses. Small trees dominated the overstorey vegetation and recorded a mean cover of 21%.

Table 5.50 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	0	0
Trees (10-30m)	100	14.0 (10-20)
Trees (2-10m)	100	21.2 (10-30)
Regen. Trees (<2m)	100	6.5 (5-8)
Woody Shrubs (<2m)	100	5.5 (4-8)
Vines	100*	12.5 (4-25)
Rushes and Sedges	100	7.0 (5-8)
Phragmites	0	0
Forbs (or Herbs)	100*	7.0 (4-12)
Grasses	100	30.0 (5-55)
Ferns	0	0
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

Overstorey vegetation provided a similar cover to that provided by understorey vegetation. The upper bank recorded an average of 65% bare (range 30-88%) for understorey vegetation cover compared to 63% bare (range 60-65%) for the overstorey vegetation.

Exotic vegetation was recorded at all sites, while those declared noxious were present at 33% of sites. Two sites rated a low disturbance from exotic species (covers 1-5%), while one site rated a very high invasion (covers 16-32%) caused by 2 exotic species. Overall, the mean total cover of exotic species in the riparian zone was 10% (range 0-24%). Structural types recorded were vines (100% of sites) and forbs (33%). The only noxious species recorded was a forb, *Hyptis suaveolens*

(mean cover of 4%). The exotic vine species was *Passiflora foetida,* which had a mean cover of 10% (range 3-20%). This vine recorded a high cover at a site located on Edith River that was disturbed by large flooding in early 1995.

♦ *Aquatic Vegetation*

Aquatic vegetation was recorded at 67% of sites, in the form of emergent vegetation. The cover provided by the emergent vegetation was 12%. The structural categories present were rushes/sedges (33% of sites), Pandanus (33%) and other ground covers (33%). Pandanus recorded the highest mean cover of 15%. Species recorded were *Pandanus aquaticus*, *Goodenia purpurascens, Fimbristylis pauciflora* and *Lipocarpa microcephala.*

♦ *Instream and Bank Habitats*

The cover and diversity of instream and bank habitats was rated as high (67% of sites) or moderate (33%). Subjectively, the overall aquatic habitat condition was rated as good (67% of sites) or poor to good (33%).

Nine instream habitat types were recorded. The types listed for all sites were individual branches and leaves/twigs. Other types included individual logs, branch piles, algal clumps, rock faces, log jams, emergent vegetation and pools deeper than 1m. The covers provided by these habitat types was generally <10%, although rock faces provided a mean cover of 38% (range 0-65%) and permanent pool habitats provided a mean cover of 20% (range 0-55%).

Two different types of overhanging bank cover were recorded at all sites. Vegetation canopy cover occurred along 67% of the bank and had a mean width of 2.6m. Root overhang occurred along 29% of the bank and had a mean width of 0.2m. Vegetation overhang was also present at 67% of sites, occurring along 39% of the bank, with a mean width of 0.7m. Some bank overhang was also recorded.

At water mark, 33% of sites would have partly restricted passage for fish and other aquatic organisms, 33% would be moderately restricted and 33% would be very restricted.

♦ *Overall Condition*

The overall condition rating for sites assessed in this sub-section was high (67% of sites) or very high (33%).

5.11.1.4 Eight Mile Creek

Sub-section 15 includes the catchment of Eight Mile Creek. One site was fully assessed within this sub-section.

♦ *Reach Environs and Site Features*

The site assessed in this sub-section was rated as having some modification to the reach environs. A subjective disturbance rating indicated that this site had low to moderate levels of disturbance.

Land tenure was recorded as freehold or leasehold. Grazing was the major land use and occurred predominantly on cleared native pastures and virgin timbered native pastures. Grazing, roads/tracks and a watering point for stock/ferals were identified as the major disturbances likely to affect stream reaches. The channel pattern recorded for this site was braided.

♦ *Channel Habitat Types, Diversity and Dimensions*

The reach length studied was 180m. Pools and riffles were recorded at the site studied. Pools slightly dominated the reach length, taking up 56%. The diversity of channel types was rated as high for this site. Isolated pools were present at the time of sampling.

Table 5.51 presents the dimensions for the pool and riffle habitats. Pools and riffles were of similar widths, although pools were slightly deeper. Both types recorded low-moderate width:depth ratios. Lower banks varied. Pools had narrower upper banks compared to riffles, although both were generally low. Banks along the reach recorded a low slope and were convex or concave in shape.

Table 5.51 Channel Dimensions for Habitat Types

Dimension		Pool	Riffle
Reach Covered (%)		56.0	44.0
Mean Length (m)		100.0	80.0
Mean Depth (m)**		0.9	0.6
Mean Width (m)**		16.0	16.0
Width:Depth Ratio		17.8	27.6
♦LB:	Width (m)	0.4 (-)	6.5 (4.0-9.0)
	Height (m)	0.3 (-)	0.7 (0.5-0.8)
	Slope (^{o})	40.9 (37-45)	6.1 (5-7)
∗UB:	Width (m)	1.8 (1.5-2.0)	7.5 (7.0-8.0)
	Height (m)	1.2 (0.8-1.5)	1.0 (-)
	Slope (^{o})	32.5 (28-37)	7.6 (7-8)

♦LB = Lower Bank ∗UB = Upper Bank
** Measured from the water mark.

♦ *Bank Condition and Stability*

The site assessed in this sub-section was rated as having banks with limited instability. Subjectively, the overall bank instability and the susceptibility of banks to further erosion were rated as either low or moderate.

Erosion was the dominant bank process recorded. The erosion was predominantly occurring along outside bends, at floodplain scours or obstacles. Both lower and upper banks were eroding, with 23% (range 10-35%) of the lower bank recorded as eroding, compared to 28% (range 15-40%) for the upper bank. Aggradation was also recorded along 14% of the upper bank, being located along inside bends.

The major factors identified as affecting bank stability were high flow, runoff, stock and floodplain scours.

♦ *Bed and Bar Condition and Stability*

The site assessed in this sub-section was subjectively rated as having a river bed that was moderately aggrading.

A sand and gravel bar was recorded at this site. The size of the encroaching vegetation bar and high flow deposits were very large, covering 45% of the bed surface above water mark. The gravel forming the bed and bar was sphere-shaped and sub-angular. Bed compaction was recorded as being packed.

The major factors identified as affecting bed stability were agriculture/grazing, bank erosion and instream siltation.

♦ *Bed and Bank Sediments*

The bed material at the pool habitat was predominantly fines/clays and boulders, whereas the bank was mostly fines and sand-sized material. The riffle recorded a range of sediment sizes in both the bed and banks including gravels, cobbles and boulders. Organic matter was present in both bed and banks and ranged from 12-15%. Rock outcrops were also present.

♦ *Riparian Vegetation*

The riparian vegetation at this site was rated as having a high cover and structural diversity. The vegetation type recorded was vegetation associated with freshwater streams. The riparian vegetation zone was very narrow, averaging 5m.

The structural types recorded included trees 2-30m, regenerating trees, shrubs, vines, herbs rushes/sedges and forbs. Covers ranged from 0-60%. The highest cover (60%) was recorded for grasses. The remaining covers where 10% or less, except for small trees, which provided 15% cover. Understorey vegetation provided much greater cover than overstorey vegetation.

Exotic vegetation, including noxious species, was recorded. The mean total cover of exotic species in the riparian zone was very high, averaging 18% (range 17-19%) and as a result this site rated a very high invasion level by exotic species. Structural types recorded were vines, grasses and forbs. The noxious species recorded were *Hyptis suaveolens* (cover of 5%) and a grass species, *Pennisetum polystachion*, which had a cover of 6%. Other exotic species included *Passiflora foetida* (cover of 2%) and a grass species, *Melinis repens*, which recorded a cover of 6%.

♦ *Aquatic Vegetation*

The site recorded aquatic emergent vegetation in the form of rushes/sedges, which had a mean cover of 5%. The species recorded was *Cyperus viscidulus*.

♦ *Instream and Bank Habitats*

The cover and diversity of instream and banks habitats was rated as high. Subjectively, the site was rated as having a poor overall aquatic condition.

Five instream habitat types were recorded. They included individual branches, leaves/twigs, algal clumps, rock faces and permanent pools deeper than 1m. The covers provided by these habitat types were 10% or less, though rock faces provided cover of 50%.

Four types of overhanging bank cover were recorded for all sites. Vegetation canopy cover occurred along 19% of the bank, with a mean width of 3m. Vegetation, root and bank overhang occurred along <10% of the bank and had a width of 0.2-1.0m.

At water mark, the site would have a partly restricted passage for fish and other aquatic organisms.

♦ *Overall Condition*

The overall condition rating for the site assessed in this sub-section was rated as moderate.

5.11.1.5 Cullen River and Copperfield Creek

Sub-section 16 includes the catchment of Cullen River. Three sites were fully assessed within this sub-section. The sites were located on the Cullen River (1) and it's tributary, Copperfield Creek (2).

♦ *Reach Environs and Site Features*

All sites were rated as having essentially natural reach environs. Subjective disturbance ratings indicated that sites had low levels of reach environs disturbance (100% of sites).

Land tenure was freehold or leasehold at all sites. Grazing was the major land use and occurred on thinned native pastures (100% of sites) and cleared native pastures (67%). The major disturbances likely to affect stream reaches were grazing (100% of sites), roads/tracks (100%), causeways/ crossings (67%) or bridges/culverts (33%). The major floodplain features recorded were floodplain scours (33% of sites) and floodplain deposits (33%). Braided channels were recorded at 33% of sites.

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 212m (range 100-410m). Pools and riffles were the only habitat types recorded for all sites. Pools slightly dominated the reach length recording an average of 57%. The diversity of channel types was rated high for all sites. The channels were either dry (67% of sites) or had isolated pools (33%) at the time of sampling.

Table 5.52 presents the mean dimensions for the pool and riffle habitats. Riffles were slightly wider than pools, although they were not as deep. Both habitats were relatively shallow though and recorded very high width:depth ratios. Upper banks were generally wider than they were tall and recorded low slopes. Banks along the reach were mostly moderate or low in slope and either concave-shaped, convex-shaped or had a wide lower bench.

♦ *Bank Condition and Stability*

The reaches assessed in this sub-section were rated as having stable banks (67% of sites) or limited instability (33%). Subjective ratings indicated that the overall bank instability was low (100% of sites) or moderate (33%). The susceptibility of banks to further erosion was rated as being low (100% of sites).

Table 5.52 Channel Dimensions for Habitat Types

Dimension	Pool	Riffle
Reach Covered (%)	57.0 (51-65)	43.0 (35-49)
Mean Length (m)	148.5 (32-265)	73.7 (31-145)
Mean Depth (m)**	0.5 (0.3-0.7)	0.3 (0.2-0.3)
Mean Width (m)**	32.8 (9.0-74.0)	37.2 (12.0-71.0)
Width:Depth Ratio	70.8 (13-148)	180.7 (125-237)
∗UB: Width (m)	7.3 (4.0-16.0)	10.9 (4.0-20.0)
Height (m)	2.0 (1.4-2.5)	1.9 (1.0-2.7)
Slope (^{o})	19.0 (8.9-24.2)	16.5 (2.9-31.0)

∗UB = Upper Bank ** Measured from the water mark.

Erosion was the dominant bank process recorded at 67% of sites, while aggradation was dominant at 33% of sites. The erosion was occurring at obstacles (100% of sites), floodplain scours (33%), irregularly (33%) or along outside bends (33%). Both the lower and upper banks were recorded as being greater than 85% stable. Aggradation was recorded, occurring all along the banks at 33% of sites. A mean of 8% of the upper bank was recorded as aggrading (range 0-50%).

The major factor identified as affecting bank stability was stock (100% of sites). Other factors included roads/bridges/crossings, floodplain scours and high flow.

♦ *Bed and Bar Condition and Stability*

Subjectively, the reaches assessed in this sub-section were rated as having moderately aggrading beds (67% of sites) or beds that were stable (33%).

Sand and gravel bars were present at 67% sites, occurring as bars with encroaching vegetation (100% of types), mid-channel islands (100%), high flow deposits (50%) or as a channel bar plain (50%). The mean size of the bars was relatively large, averaging 27% of the bed surface above water mark (range 5-50%). The gravel forming the bed and bars was sphere-shaped or disc-shaped; and was sub-angular, angular or rounded. Bed compaction ranged from poor compaction through to being tightly packed.

The major factors identified as affecting bed stability were instream siltation (67% of sites) and agriculture/grazing (33%). Rock outcrops (100% of sites) and culverts (67%) provided a degree of bed stabilising influence.

♦ *Bed and Bank Sediments*

The pool habitat recorded a range of sediment sizes making up the bed, although sand and small gravel dominated the material. The banks were

predominantly fines and small sand, although 13% of boulders were recorded in the upper bank. At riffle habitats, the bed was comprised of a range of sediment sizes, although boulders, cobbles, small gravel and large sand dominated the material. Boulders and cobbles were also recorded in the banks at riffles, along with fines and sand. Organic matter was present in both bed and banks of habitat types and ranged from 4-9%. Rock outcrops were recorded at all sites.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having moderate cover and structural diversity at all sites. The vegetation type recorded was that associated with freshwater streams (100% of sites). The width of the riparian vegetation zone was narrow, averaging 6m (range 2-10m), with 33% of sites recording riparian zone widths of <5m and 67% between 5-10m.

The structural types recorded are shown in Table 5.53. There were 7 of the 13 structural types present at all sites. Covers ranged from 0-50%. The highest mean cover was 43% and was recorded for grasses. Medium-sized trees (10-30m) dominated the overstorey vegetation and recorded a mean cover of 17%.

Table 5.53 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	0	0
Trees (10-30m)	100	17.0 (15-20)
Trees (2-10m)	100	13.0 (10-18)
Regen. Trees (<2m)	100	6.5 (4-10)
Woody Shrubs (<2m)	100	4.8 (4-5)
Vines	100*	7.2 (5-10)
Rushes and Sedges	67	1.3 (0-4)
Phragmites	0	0
Forbs (or Herbs)	100*	7.7 (5-10)
Grasses	100	43.3 (35-50)
Ferns	0	0
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

Understorey vegetation provided a greater cover than overstorey vegetation. The upper bank recorded an average of 55% bare (range 50-60%) for understorey vegetation cover compared to 74% bare (range 65-80%) for the overstorey vegetation.

Exotic vegetation, including noxious species, was recorded at all sites. One site rated a low disturbance from exotic species (covers 1-5%), while two sites rated a moderate invasion (covers 6-10%). Overall, the mean total cover of exotic species in the riparian zone was 6% (range 3-10%). Structural types recorded at all sites were vines and forbs. The only noxious species recorded was a forb, *Hyptis suaveolens*. The exotic vine species was *Passiflora foetida.*

♦ *Aquatic Vegetation*

Aquatic vegetation was recorded at all sites in the form of emergent vegetation. The mean cover provided by the emergent vegetation was 15% (range 10-25%). The structural categories present were Pandanus (67% of sites) and Melaleucas (100%). Species recorded were *Pandanus aquaticus* and *Melaleuca argentea.*

♦ *Instream and Bank Habitats*

The cover and diversity of instream and bank habitats was rated as moderate for all sites. Subjectively, the overall aquatic habitat condition was rated as poor to good (100% of sites).

Four instream habitat types were recorded. The types recorded for all sites were individual branches, leaves/twigs and rock faces. Other types included individual logs. There were no permanent pool habitats deeper than 1m. The covers provided by these habitat types was generally <15%, although rock faces provided a mean cover of 28% (range 8-50%).

Two different types of overhanging bank cover were recorded at all sites. Vegetation canopy cover occurred along 58% of the bank and had a mean width of 2.3m. Vegetation overhang occurred along 11% of the bank and had a mean width of 1.4m. Some root overhang was also recorded.

At water mark, 33% of sites would have good passage for fish and other aquatic organisms, 33% would be partly restricted and 33% would be moderately restricted.

♦ *Overall Condition*

The overall condition of sites assessed in this sub-section was rated as high.

Moderate bed aggradation; moderate riparian vegetation & instream/bank habitat ratings (Site 16/1: Cullen River)

5.11.1.6 Comparison of Fergusson River Sub-sections

The *reach environs* for the mid to upper sites in Fergusson River sub-sections were rated as being essentially natural, while those sections along Eight Mile Creek, lower Edith and Fergusson Rivers had some modification. Grazing was identified as the major land use and disturbance factor likely to affect the majority of stream reaches, which were located on freehold or leasehold land. Roads and tracks were another major disturbance of the reach environs.

Channel type diversity was predominantly high, although the diversity rating ranged from low to very high. A reach along lower Fergusson River recorded moderate channel habitat type diversity while a reach upstream of its junction with Edith River was one of only 6 sites throughout the Daly River catchment to record a very high diversity. An upper Edith River site recorded low habitat type diversity, which was a poorer rating then numerous other sites. Pools and riffles were the only 2 habitat types recorded in all sub-sections except along Fergusson River (above the junction with Edith River), where rapids and runs were also present. Pools generally dominated all reaches. Water levels varied greatly at the time of the survey ranging from moderate levels along Fergusson and Edith Rivers to being dry or having isolated pools along Eight Mile Creek, Cullen River and Copperfield Creek.

Bank stability – reaches along Fergusson River were rated as having stable banks. Sites located on Edith River (near Gauge Station 8140152), Eight Mile Creek and Copperfield Creek (site 16/2) recorded banks with limited instability, while other sections were stable. At the more unstable sites, an average of 12-28% of the upper banks was recorded as eroding. Erosion was the dominant bank process along all reaches except for the Copperfield Creek site, where aggradation was dominant (the only site to record this in the catchment). High flows, particularly those occurring in early 1995, and stock were identified as the major factors affecting bank stability.

Bed and bar stability – only 3 reaches within the Fergusson River sub-sections were rated as having stable beds. The remaining reaches were subjectively assessed as having moderately aggrading beds, although a reach on Edith River (near Gauge Station 8140152) was one of only 7 sites within the Daly River catchment to record a moderately eroding bed. Bars were present along the majority of reaches and where quite large in places, averaging 17-45% of the bed surface. High flow deposits were common. Nearly half the reaches recorded instream siltation and/or agriculture/grazing as factors affecting bed stability.

The cover and diversity of *riparian vegetation* was rated as predominantly moderate throughout the sub-sections, though some reaches rated highly. Mid Edith and Eight Mile Creek rated a better riparian vegetation condition than did reaches assessed along Fergusson River, lower Edith River, Cullen River and Copperfield Creek. Structural categories were dominated by overstorey vegetation (>1.3m tall) along Fergusson River; had similar overstorey and understorey covers along Edith River; and were dominated by grasses along Eight Mile Creek and Cullen River/Copperfield Creek. The riparian vegetation was wider along lower Edith and Fergusson Rivers (ranging from 11m to >40m), while the remaining upper sub-section sites had vegetation that was <10m wide.

All reaches throughout the sub-sections recorded the presence of exotic vegetation. Covers ranged from 3-18%. Higher covers, and therefore lower ratings, were recorded for reaches along Eight Mile Creek, Edith River, mid Fergusson and Cullen Rivers, and upper Copperfield Creek. *Passiflora foetida*, a naturalised vine, was present at all sites and recorded generally low covers except for a site on Edith River, were a very high cover of 20% (the highest in the catchment) was recorded. Species declared noxious were present at over half the reaches. *Hyptis suaveolens* was the most widespread noxious species, present at over half the reaches, although covers were low. Other noxious species, with a scattered distribution, included *Pennisetum polystachion* and *Xanthium occidentale* (Noogoora Burr).

Aquatic vegetation was present at the majority of sites, most commonly as emergent vegetation, although covers were generally low (ie <15%). Submerged vegetation, in the form of *Chara* sp., was only recorded along lower Fergusson River. No floating aquatic vegetation was recorded.

The cover and diversity of *instream and bank habitats* was rated as mostly high, although sections along lower Fergusson, Edith and Cullen Rivers and along Copperfield Creek, recorded only moderate cover and diversity within the river channel and along the banks. Subjectively, over half the sites rated poor to good with regard to the overall aquatic condition. Instream covers were generally <10%, except where permanent pools or rock faces were present. Canopy cover along the banks was higher within Fergusson, Edith and Cullen River sub-sections (ranging from 45-67% of bank length). Canopy cover along Eight Mile Creek was low, averaging only 19% of the bank length.

The *overall condition* of reaches assessed throughout the Fergusson River sub-sections was rated as predominantly high, although the most upper site on Edith River was one of only 17 in the Daly River catchment to rate very highly overall. Eight Mile Creek was the only reach to record a moderate overall condition, the poorest rating within the Daly River catchment.

Moderate overall condition rating - poorest rating within Daly River Catchment (Site 15/2: Eight Mile Ck)

Fergusson River above Stuart Highway (Site 13b/1) High overall condition

5.11.2 Discussion

The reaches within Fergusson River sub-catchment ranged quite widely for many of the attributes assessed. Though overall the condition of reaches rated predominantly highly, Eight Mile Creek rated the poorest within Daly River catchment and, to the other extreme, a reach on Edith River was one of 17 to rate the highest overall.

Several reach environs were showing signs of some modification. A higher proportion of sites within this sub-catchment had unstable river banks or beds compared to other Daly River sub-catchments. High flood flows in early 1995 and localised problems contributed to the higher levels of bank erosion levels (and in one instance bed erosion) recorded within Edith River, Eight Mile Creek and Cullen River/Copperfield Creek sub-sections.

Many reaches were subjectively assessed as moderately aggrading and this was reflected in the presence of large bars within the river channel and also as high flow deposits along the banks. These river channels were generally shallow, uniform in cross-sectional shape and lacked diversity of depths. As a result, the subjective overall aquatic rating was poor to good for over half the reaches.

The moderate rating for the cover and diversity of instream and bank habitats for reaches on lower Fergusson, Edith and Cullen Rivers, and along Copperfield Creek, reflected the low variety and covers provided by the instream habitat types and generally lower canopy cover along several reaches.

Although the channel type diversity ratings were predominantly high, the lower ratings for sections on Edith River and lower Fergusson River tended to reflect the fact that pools dominated reaches and in most cases only two habitat types were recorded. The site that recorded a higher diversity of habitat types of relatively equal proportions (ie Fergusson River above the junction with Edith River) rated, along with 5 other sites in the Daly River catchment, the highest rating category.

The moderate riparian vegetation condition rating for several sites was due to the decreased diversity and cover for the majority of structural vegetation types. All sites recorded some degree of disturbance to the riparian zone by exotic species, in particular *Passiflora foetida*, and for a site on both Edith River and Eight Mile Creek the level of disturbance was very high and, as a result, this was reflected in very low ratings.

5.12 Flora River

The Flora River sub-catchment includes the sub-sections encompassing Flora River/Hayward Creek and Mathison and Aroona Creeks.

5.12.1 Results

5.12.1.1 Flora River and Hayward Creek

Sub-section 17 encompasses the Flora River and its tributary, Hayward Creek (excluding Mathison Creek catchment area). Five sites were fully assessed in this sub-section. One of these sites is located on Hayward Creek, whilst the remaining sites are on Flora River.

♦ *Reach Environs and Site Features*

Sites were rated as having reach environs that were essentially natural (60% of sites) or had some modification (40%). Subjective disturbance ratings indicated that reach environs had low levels of disturbance (100% of sites).

Land tenure was freehold or leasehold at 60% of sites, and was within a Reserve/Park at 40% of sites (ie Flora River Nature Park). Grazing was the major land use and occurred on thinned native pastures (60% of sites). Other land uses included Nature Reserve/Park (40% of sites). The disturbances likely to affect stream reaches were grazing (80% of sites), roads/tracks (60%), people (20%), causeway/crossing (20%) and a boat ramp (20%). The major floodplain features recorded were floodplain scours (80% of sites) and prominent flood channels (80%).

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 1,070m (range 68-4,700m). Pools were the dominant habitat type within this sub-section (100% of sites). They occupied, on average, 79% of the reach. Other habitat types were riffles (60% of sites), cascades (40%) and waterfalls (40%). The channel type diversity rating in this sub-section ranged from moderate (20% of sites), high (60%) to very high diversity (20%). The water level at the time of sampling was moderate but less than the normal level (20% of sites), at water mark (60%) or dry (20%).

Table 5.54 presents the mean dimensions for the pool and riffle habitats. Riffles were very shallow and narrow compared to pool habitats. Width to depth ratios were moderate for both habitat types.

Lower banks were low and narrow, with steep slopes. Upper banks were generally much wider than they were tall and recorded lower slopes. Banks along the reach were mostly moderate in slope and were convex-shaped, concave-shaped or had a wide lower bench.

Table 5.54 Channel Dimensions for Habitat Types

Dimension		Pool	Riffle
Reach Covered (%)		78.8 (59-96)	21.0 (7-41)
Mean Length (m)		725.6 (20-3,100)	12.3 (5-18)
Mean Depth (m)**		2.6 (0.7-8.4)	0.4 (0.1-0.6)
Mean Width (m)**		29.4 (5.0-67.0)	4.2 (2.5-7.0)
Width:Depth Ratio		13.6 (4.6-39.1)	16.1 (4.2-30.0)
♦LB:	Width (m)	0.2 (0.1-0.3)	0.4 (0.2-0.5)
	Height (m)	0.4 (-)	0.4 (0.3-0.4)
	Slope (°)	64.6 (53.1-76.0)	47.5 (38.7-56.3)
∗UB:	Width (m)	16.0 (5.0-42.5)	16.8 (7.0-34.0)
	Height (m)	3.3 (2.0-6.0)	3.8 (2.5-6.0)
	Slope (°)	16.9 (3.1-29.4)	15.5 (5.4-24.8)

♦LB = Lower Bank ∗UB = Upper Bank
** Measured from the water mark.

♦ *Bank Condition and Stability*

The reaches assessed in this sub-section were rated as having stable banks (100% of sites). Subjective ratings indicated that the overall bank instability and susceptibility of banks to further erosion was minimal (20% of sites), low (80%), low to moderate (20%) or moderate (60%).

Erosion was the dominant bank process recorded at all sites. The erosion was predominantly occurring at floodplain scours (100% of sites), obstacles (100%), along outside bends (60%) or irregularly (20%). The banks were relatively stable, with 9-13% (range 2-25%) of the bank length recorded as eroding. Aggradation was recorded along inside bends (20% of sites). An average of 2% (range 0-15%) of the bank was aggrading.

The major factors identified as affecting bank stability at 80% of sites were stock and floodplain scours. Other factors included roads/crossings, high flow, vermin, runoff and people tracks.

♦ *Bed and Bar Condition and Stability*

The sites assessed in this sub-section were subjectively rated as having stable beds (80% of sites) or moderately aggrading beds (20%).

Sand and gravel bars were recorded at 80% of sites, occurring predominantly as bars with encroaching vegetation (50% of types), point bars (25%) or alternate/side irregular bars (25%). The mean size of the bars was 16% of the bed surface above water mark (range 15-19%). The gravel forming the bed and bars was mostly disc-shaped and had sub-angular, angular or rounded material. Bed compaction ranged from low (20% of sites), moderate (60%) to packed (60%).

The major factor identified as affecting bed stability was agriculture/grazing (80% of sites). No factors were affecting stability at 20% of sites. Rock outcrops (100% of sites) and fallen trees (20%) provided a degree of bed stabilising influence.

♦ *Bed and Bank Sediments*

The bed material at pool habitats had a full range of sediment sizes, though fines, small sands, cobbles and boulders dominated the material. Riffle habitats recorded a range of sediment sizes, although they were predominantly composed of large gravel and cobbles. Waterfall and cascade habitats had boulder beds. The bank material at all habitats was predominantly fines and small sand, though larger sizes were recorded in riffle and waterfall habitats. Organic matter was present in both bed and banks of all habitat types and ranged from 8-28%. Rock outcrops were present at all sites.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having either moderate (60% of sites) or high (40%) cover and structural diversity. The vegetation type recorded was vegetation associated with freshwater streams (100% of sites). The mean width of the riparian vegetation zone was 22m (range 5-56m), with 40% of sites recording riparian zone widths between 5-10m, 20% between 11-20m, 20% between 21-30m, 20% between 31-40m and 20% >40m.

The structural types recorded are shown in Table 5.55. There were 7 of the 13 structural types present at all sites. Covers ranged from 0-50%. The highest mean cover was 27% and was recorded for grasses. The dominant overstorey structural type was medium-sized trees (10-30m), which recorded 24% cover. Palms and Phragmites were present at 40% of sites.

Overstorey vegetation provided a greater cover than understorey vegetation. The upper bank recorded an average of 72% bare (range 50-90%) for understorey vegetation cover compared to 62% bare (range 45-85%) for the overstorey vegetation.

Table 5.55 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	20	0.6 (0-3)
Trees (10-30m)	100	24.2 (10-35)
Trees (2-10m)	100	19.9 (5-25)
Regen. Trees (<2m)	100	6.9 (4-10)
Woody Shrubs (<2m)	100	5.8 (4-8)
Vines	100*	4.3 (0-10)
Rushes and Sedges	80	3.2 (0-5)
Phragmites	40	1.4 (0-5)
Forbs (or Herbs)	100*	8.4 (4-22)
Grasses	100	26.5 (5-50)
Ferns	0	0
Mangroves	0	0
Salt Marsh	0	0
Palms	40	2.6 (0-8)

* Contains exotic species

Exotic vegetation was recorded at 80% of sites, while noxious vegetation was present at 40% (refer Table 5.56). The mean total cover of exotic species in the riparian zone was low at 5% (range 0-18%), and therefore 60% of sites rated a low level of invasion. The site on lower Flora River that rated the highest level of invasion (16-32% cover) recorded three types of exotic species. Structural types recorded were vines (80% of sites) and forbs (40%).

Table 5.56 Cover of Exotic Riparian Vegetation

% Cover Category (Rating)	Percent of Sites (%)
16 - 32* (2)	20
11 - 15 (4)	0
6 - 10 (6)	0
1 - 5 (8)	60
0 (10)	20

* The maximum % cover recorded for exotic riparian vegetation within the catchment was 32%.

Noxious species recorded were *Hyptis suaveolens* (40% of sites) and *Sida acuta* (20%). The overall mean covers for the forbs were 9% and 5% respectively. The site on lower Flora River recorded a high level of invasion of the riparian zone from *Hyptis* (11-15% cover category). The exotic vine species was *Passiflora foetida* and it was widespread in its distribution, though covers were low (averaging 3%).

♦ *Aquatic Vegetation*

Aquatic vegetation was recorded at 80% of sites as both emergent and submerged vegetation types. Emergent vegetation recorded a mean cover of 18% (range 7-32%) and submerged vegetation recorded a mean cover of 13% (range 6-25%).

The emergent structural types present included Phragmites (40% of sites), rushes/sedges (80%) and Pandanus (80%). Species recorded were *Phragmites karka* (8% mean cover), *Fimbristylis pauciflora* (3% cover), *Schoenoplectus litoralis* (9% cover) and *Pandanus aquaticus* (8% cover).

The submerged structural types present were Chara/Nitella (80% of sites) and Myriophyllum (40%). Species recorded were *Chara sp*. (11% mean cover), *Nitella sp*. (6% cover) and *Myriophyllum sp*. (3% cover).

♦ *Instream and Bank Habitats*

The cover and diversity of instream and bank habitats rated as predominantly high (refer Table 5.57). Subjectively, the overall aquatic habitat condition was rated as very high (40% of sites), good (40%) or poor to good (20%).

Table 5.57 Cover and Diversity of Instream and Bank Habitats

Instream/Bank Habitat Category (Rating)	Percent of Sites (%)
Very Low Cover/Diversity (0-20%)	0
Low Cover/Diversity (21-40%)	0
Moderate Cover/Diversity (41-60%)	20
High Cover/Diversity (61-80%)	60
Very High Cover/Diversity (81-100%)	20

Twelve instream habitat types were recorded. The types recorded for all sites were individual logs, individual branches, leaves/twigs and rock faces. Other types recorded were branch piles, log jams, algal clumps, emergent vegetation, macrophyte fragments, freshwater submerged vegetation and permanent pools deeper than 1m. The covers provided by these habitat types was generally <10%, although rock faces provided a mean cover of 31% (range 10-80%) and permanent pool habitats provided a mean cover of 35% (range 0-75%).

Two different types of overhanging bank cover were recorded at all sites. Vegetation canopy cover occurred along 71% of the bank and had a mean width of 2.6m. Vegetation overhang occurred along 34% of the bank and had a mean width of 1.6m. Root and bank overhang also were recorded and occurred along <10% of the bank and recorded a mean width of <0.5m.

At water mark, 20% of sites would have unrestricted passage for fish and other aquatic organisms, 20% would be partly restricted and 60% very restricted.

♦ *Overall Condition*

The overall condition rating for sites assessed in this sub-section was high (60% of sites) or very high (40%).

Very high instream/bank habitat; stable and very high overall condition rating (Site 17/2: Flora River)

Very high overall condition rating (Site 17/6: upper Flora River)

5.12.1.2 Mathison and Aroona Creeks

Sub-section 18 includes the catchment of Mathison and Aroona Creeks. Three sites were fully assessed in this sub-section.

♦ *Reach Environs and Site Features*

Sites were rated as having reach environs that were essentially natural (67% of sites) or had some modification (33%). Subjective disturbance ratings indicated that sites had low to moderate levels of reach environs disturbance (67% of sites) or moderate levels (33%).

Land tenure was freehold or leasehold at all sites. Grazing was the major land use and occurred on virgin timbered native pastures (100% of sites), thinned native pastures (100%) and cleared native pastures (33%). The major disturbances likely to affect stream reaches were grazing (100% of sites), roads/tracks (100%), causeway/crossings (67%) or bridge/culverts (33%). The major floodplain features recorded were floodplain scours (67% of sites) and prominent flood channels (67%). Braided channels were recorded at 33% of sites.

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 217m (range 140-265m). Pools and riffles were present at all sites, though pools slightly dominated the reach lengths, averaging 56%. The channel type diversity rating in this sub-section was high for all sites. The creeks were dry at the time of sampling.

Table 5.58 presents the mean dimensions for the pool and riffle habitats. Pools and riffles were similar in length and width, although pools were twice as deep as riffles at 0.4m. Width:depth ratios were very high. Upper banks were of low to moderate width, height and slope. Generally banks were mostly moderate or low in slope and where either concave-shaped, convex-shaped or stepped.

Table 5.58 Channel Dimensions for Habitat Types

Dimension		Pool	Riffle
Reach Covered (%)		55.7 (42-64)	44.3 (36-58)
Mean Length (m)		76.6 (45-110)	76.0 (25-155)
Mean Depth (m)**		0.4 (0.3-0.6)	0.2 (0.2-0.3)
Mean Width (m)**		14.9 (11.3-20.5)	13.8 (13.5-14.0)
Width:Depth Ratio		40.0 (34.2-45.2)	64.7 (41.2-77.8)
∗UB:	Width (m)	9.5 (3.0-20.2)	12.4 (7.0-22.0)
	Height (m)	2.8 (1.8-5.0)	2.5 (0.4-5.0)
	Slope (^{o})	19.8 (9.8-33.7)	12.3 (1.5-22.6)

∗UB = Upper Bank ** Measured from the water mark.

♦ *Bank Condition and Stability*

The reaches assessed in this sub-section were rated as having stable banks (67% of sites) or banks with moderate instability (33%). Subjective ratings indicated that the overall bank instability and the susceptibility of banks to further erosion were low (67% of sites), low to moderate (67%) or moderate to high (33%).

Erosion was the dominant bank process recorded at all sites. The erosion was occurring at all sites along outside bends, irregularly, at obstacles or seepage/runoff points. Erosion at floodplain scours was occurring at 67% of sites. The lower banks were significantly more stable than the upper banks, with only 7% (range 5-10%) of the bank length recorded as eroding. The upper banks, on the other hand, recorded erosion along an average of 25% of the bank length (range 8-70%). No aggradation along the banks was recorded.

The major factors identified as affecting bank stability at all sites were roads/bridges/crossings, high flow, runoff and stock. Other factors included floodplain scours and vermin.

♦ *Bed and Bar Condition and Stability*

All sites assessed in this sub-section were subjectively rated as having stable beds.

Sand and gravel bars were present at 67% sites, occurring predominantly as bars with encroaching vegetation (67% of sites) and point bars (33%). The mean size of the bars was 10% of the bed surface above water mark (range 8-12%). The gravel forming the bed and bars was disc-shaped or sphere-shaped; and was angular or sub-angular. Bed compaction was either poor (67% of sites), moderate (100%) or packed (33%).

At 33% of sites, the major factor identified as affecting bed stability was agriculture/grazing, bank erosion and concentration of flows. No factors were recorded at 33% of sites. Rock outcrops (67% of sites) and fallen trees (33%) provided a degree of bed stabilising influence.

♦ *Bed and Bank Sediments*

The bed and bank material at pool habitats was predominantly fines and sands. A range of material was recorded at riffle habitats, although fines, gravels and cobbles dominated the bed material. The banks at riffles were predominantly fines and sands, though cobbles were recorded in the lower banks. Organic matter was present in both bed and banks of habitat types and ranged from 5-16%. Rock outcrops were recorded at 33% of sites and were located in the bed.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having moderate cover and structural diversity at all sites. The vegetation type recorded was vegetation associated with freshwater streams (100% of sites). The mean width of the riparian vegetation zone was 16m (range 13-18m), with all sites, therefore, fitting into the riparian zone width category of between 11-20m.

The structural types recorded are shown in Table 5.59. There were 6 of the 13 structural types present at all sites. Covers ranged from 0-55%. The highest mean cover was 49% and was recorded for grasses. Small trees dominated the overstorey vegetation and recorded a mean cover of 23%.

Table 5.59 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	0	0
Trees (10-30m)	100	19.0 (5-28)
Trees (2-10m)	100*	22.5 (20-25)
Regen. Trees (<2m)	100	5.0 (-)
Woody Shrubs (<2m)	100*	11.5 (5-20)
Vines	33*	1.7 (0-5)
Rushes and Sedges	33	1.7 (0-5)
Phragmites	0	0
Forbs (or Herbs)	100*	7.2 (5-13)
Grasses	100*	49.2 (45-55)
Ferns	0	0
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

Understorey vegetation provided a greater cover than overstorey vegetation. The upper bank recorded an average of 52% bare (range 45-57%) for understorey vegetation cover compared to 71% bare (range 63-77%) for the overstorey vegetation.

Exotic vegetation, including noxious species, was recorded at all sites. The mean total cover of exotic species in the riparian zone was relatively high at 15% (range 5-25%). As a result, one site rated a moderate level of invasion, while the remaining two sites recorded a very high level of invasion by exotic species, and therefore a very low rating, with up to four different species being found at each site. Structural types recorded were small trees (67% of sites), shrubs (67%), vines (33%), forbs (33%) and grasses (67%).

Noxious species recorded were *Parkinsonia aculeata* (6% mean cover), *Jatropha gossypiifolia* or Bellyache Bush (9% cover), *Hyptis suaveolens* (7% cover) and *Pennisetum polystachion* (1% cover). Other exotic species recorded were *Passiflora foetida* (5% mean cover) and *Echinochloa colona* (4% cover).

♦ *Aquatic Vegetation*

Aquatic vegetation was recorded at 33% of sites, in the form of emergent vegetation. The cover provided by the emergent vegetation was 8%. The structural categories present were rushes/sedges (4% cover) and other shrubs/trees (4% cover). Species recorded were *Fimbristylis littoralis, Cyperus holoschoenus and Flacourtia territorialis.*

♦ *Instream and Bank Habitats*

The cover and diversity of instream and bank habitats was rated as moderate for all sites. Subjectively, the overall aquatic habitat condition was rated as poor to good (67% of sites) or poor (33%).

Six instream habitat types were recorded. The types listed for all sites were individual branches, individual logs, branch piles and leaves/twigs. Other types recorded were rock faces and log jams. There were no permanent pools deeper than 1m. The covers provided by these habitat types was generally <10%, although rock faces provided a mean cover of 33% (range 0-75%) and leaves/ twigs provided a mean cover of 22% (range 10-45%).

Three different types of overhanging bank cover were recorded at all sites. Vegetation canopy cover occurred along 66% of the bank and had a mean width of 2.4m. Vegetation overhang occurred along 13% of the bank, with a mean width of 0.6m. Root overhang occurred along 4% of the bank and had a mean width of 0.2m.

At water mark, 67% of sites would have moderately restricted passage for fish and other aquatic organisms and 33% would be partly restricted.

♦ *Overall Condition*

The overall condition rating for sites assessed in this sub-section was high.

Moderate riparian vegetation and instream/bank habitat ratings; stable; high overall condition (Site 18/3: Mathison Creek)

5.12.1.3 Comparison of Flora River and Mathison Creek Sub-sections

The *reach environs* for the two sub-sections were in similar condition and were predominantly rated as being essentially natural, although reaches on mid Mathison Creek, Hayward Creek and upper Flora River had some modification. Subjectively, the reach environs along Flora River and Hayward Creek rated lower levels of disturbance compared to Mathison Creek sub-section. Outside of the Flora River Nature Park area, grazing was identified as the major land use and disturbance factor likely to affect stream reaches, which were located on freehold or leasehold land. Grazing activities were also identified as affecting the reach environs at one site located within the Nature Park. Roads and tracks were also identified as disturbing the majority of reach environs, including both sites located within the Nature Park.

Channel type diversity was predominantly high, except for two lower Flora River sites. The Flora River site closest to the junction with Daly River was one of only 6 sites in the Daly River catchment to rate a very high diversity of habitat types. Another Flora River site further upstream rated only moderately due to the reach being dominated to a very large extent by pool habitats (cascades <10% of reach). Only two habitat types were recorded within the Mathison Creek sub-section. Whereas along Flora River, particularly within the Nature Park, there were a greater variety of habitat types recorded, including tufa cascades and waterfalls. Pool habitats dominated all reach lengths though. The Flora River recorded moderate to normal water levels at the time of the surveys whereas Hayward, Mathison and Aroona Creeks were dry.

Bank stability – The only reach that was not rated as having stable banks, was located on Aroona Creek. This site was experiencing moderate bank erosion where up to 70% of an upper bank was unstable due to localised problems (ie high flows being concentrated, inflow points, runoff and stock activity). Some bank erosion was occurring at all sites within the sub-catchment, although relatively minor in places. Subjective bank stability assessments ranged widely from minimal to high overall instability and susceptibility to erosion. The factors recorded as affecting bank stability ranged widely, although stock activity was identified at the majority of sites.

Bed and bar stability – All reaches recorded stable beds except for an upper Flora River site which was experiencing some aggradation. Bars were present at three-quarters of the sites, averaging 10-16% of the bed surface. The factor identified as affecting bed stability at over half the sites was stock activity, including feral animals.

Understorey vegetation, in the form of grasses, dominated the structural *riparian vegetation* categories along Mathison and Aroona Creeks, whereas tree cover (including trees 2-10m tall and palms) dominated the vegetation types along Flora River. All sites though recorded the highest cover for grasses ranging from 27-49%. The majority of structural types, except for trees 2-30m and grasses, recorded <10% covers. As a result of the diversity and density of the structural types, only the lower and upper Flora River reaches recorded a high rating for the cover and structural diversity of the riparian vegetation. The remaining reaches were rated as having a moderate riparian vegetation condition. The vegetation was wider along the lower sections of Flora River compared to the mid- to upper sections of the sub-catchment.

Exotic vegetation was located throughout the sub-catchment, being recorded at the majority of sites. Covers for exotic species were higher within the Mathison Creek sub-section compared to the Flora River sub-section. As a result, the reaches within Mathison Creek sub-section rated much more poorly, along with a lower Flora River site that rated a very high level of invasion by 3 exotic species, particularly *Hyptis suaveolens*. Noxious species were present along at least half the reaches. *Hyptis suaveolens*, *Parkinsonia aculeata* and *Jatropha gossypiifolia* (Bellyache Bush) were the most widespread noxious species being present at two to three sites. Other exotic species, with a scattered distribution, included *Sida acuta*, *Pennisetum polystachion* and *Passiflora foetida*.

Aquatic vegetation was located at all sites on Flora River as both emergent and submerged vegetation. Only one site on Mathison Creek recorded the presence of emergent aquatic vegetation. Covers and diversity of structural types were higher along Flora River and ranged up to 25-32% along some reaches, although the average covers were 13-15%. No floating vegetation was recorded.

Sites on Flora River rated highly with regard to the cover and diversity of *instream and bank habitats*. In particular, a site within Flora River Nature Park was one of only 3 in the Daly River catchment to rate very highly. Sites on Mathison, Aroona and Hayward Creeks rated only moderately. Instream types were quite diverse, although the covers were generally <10%, except for rock faces and permanent pools. Canopy cover along the banks was moderate for all reaches averaging 66-71% of the bank length.

The overall condition rating for reaches throughout the Flora River sub-catchment was high, although a lower and an upper Flora River reach rated very highly overall.

5.12.2 Discussion

A lower Flora River reach, located within Flora River Nature Park, and an upper Flora River reach were two of 17 sites throughout the Daly River catchment to rate very highly overall. The factors contributing to the overall condition were an essentially natural or somewhat modified reach environs, stable banks and bed, moderate to high cover and diversity of riparian vegetation, low invasion by exotic species and a high to very high cover and diversity recorded for the instream and bank habitats.

Other reaches within the Flora River sub-catchment rated highly overall. Generally these sites were stable, except for Aroona Creek which rated the worst level of localised bank erosion, along with Depot Creek, within the Daly River catchment, and an upper Flora River site which was suffering from moderate bed aggradation. All these sites had reach environs that were essentially natural or had some modification. The cover and diversity of both the riparian vegetation and the instream and bank habitats was predominantly moderate.

Invasion of the riparian zone by exotic species was occurring to varying degrees and covers for noxious species along Mathison and Aroona Creeks, and lower Flora River (within the Nature Park) was moderate to very high. As both Mathison and Aroona creeks are tributaries of Flora River and are located upstream of the Flora River Nature Park, control of these noxious species should be considered to prevent their spread downstream.

An exotic species, declared noxious in the NT, that was not collected as part of this survey, but is known by DPI&F to be present on Mathison and Aroona Creeks, is *Martynia annua* (Devil's Claw).

Moderate bank instability (Site 18/5: Aroona Creek)

5.13 Katherine River

5.13.1 Results

5.13.1.1 Katherine River – below King River

Sub-section 19a encompasses the Katherine River from the junction with Daly River upstream to King River (excluding the catchment area of Limestone and Scott Creeks). Two sites, located on the Katherine River, were fully assessed in this sub-section.

- *Reach Environs and Site Features*

Sites were rated as having reach environs that were essentially natural (50% of sites) or had some modification (50%). Subjective disturbance ratings indicated that reach environs had low levels of disturbance (50% of sites) or moderate levels (50%).

Land tenure was freehold or leasehold at all sites. Grazing was the major land use and occurred on thinned native pastures (100% of sites), cleared native pastures (50%) and improved pastures (50%). The disturbances likely to affect stream reaches were grazing (100% of sites) and roads/tracks (50%). The major floodplain features recorded were billabongs and floodplain scours.

- *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 303m (range 100-505m). Pools, rapids, riffles and cascades were recorded at 50% of sites. In fact, pools were located at all sites but were not measured at 50% of sites. Pools dominated reach lengths, averaging 75% of the reach. The channel type diversity rating in this sub-section was high for all sites.

The water level at the time of sampling was higher than water mark (approximately by 0.5m) due to recent rains.

Table 5.60 presents the mean dimensions for the pool and rapid habitats. There are no lower bank measurements because of the raised water level. Pools were slightly narrower than rapids and were deeper. Width:depth ratios were high, particularly for rapids. Upper banks were wide and tall, particularly at rapid habitats, and had moderate slopes. Banks along the reach were moderate in slope and were concave or convex-shaped.

Table 5.60 Channel Dimensions for Habitat Types

Dimension	Pool	Rapid
Reach Covered (%)	75.0	10.0
Mean Length (m)	90.0	50.0
Mean Depth (m)**	1.3	0.8
Mean Width (m)**	37.0	40.0
Width:Depth Ratio	28.5	50.0
∗UB: Width (m)	16.0 (15.0-17.0)	42.5 (40.0-45.0)
Height (m)	7.3 (7.0-7.5)	21.5 (18.0-25.0)
Slope (°)	24.4 (23.8-25.0)	26.9 (21.8-32.0)

∗UB = Upper Bank ** Measured from the water mark.

♦ *Bank Condition and Stability*

The reaches assessed in this sub-section were rated as having stable banks (100% of sites). Subjective ratings indicated that the overall bank instability and susceptibility of banks to further erosion was low (100% of sites), low to moderate (50%) or moderate (50%).

Erosion was the dominant bank process recorded at all sites. The erosion was predominantly occurring at floodplain scours or break out points along the river (100% of sites). Other erosion (50% of sites) was occurring along outside bends, at obstacles, seepage/runoff points or irregularly. The lower banks were very stable, with only 4% (range 0-7%) of the bank length recorded as eroding. The upper banks were not as stable, with an average of 17% (range 12-22%) of the bank length recorded as eroding.

Aggradation was recorded along inside bends (50% of sites). An average of 2-3% (range 0-10%) of both the lower and upper banks were aggrading.

The major factors identified as affecting bank stability at all sites were high flow and floodplain scours or break out points. Other factors included roads/ bridges/crossings, vermin, runoff, stock and clearing.

♦ *Bed and Bar Condition and Stability*

All sites assessed in this sub-section were subjectively rated as having stable beds. The major factor identified as affecting bed stability at all sites was agriculture/grazing. Rock outcrops provided a degree of bed stabilising influence at all sites.

Sand and gravel bars were recorded at all sites, occurring as point bars. The mean bar size was low, averaging 5% of the bed surface above water mark. The gravel forming the bed and bars was disc or sphere-shaped and had sub-angular material.

Bed compaction ranged from low (50% of sites) to being packed (60%).

♦ *Bed and Bank Sediments*

The bed material at pool habitats consisted predominantly of sand and small gravel. The upper bank was mostly small sand. The bed at rapid habitats was predominantly small sand and boulders, while the bank material was fines and small sand. Cascades recorded boulders in the bed and lower bank, while the upper banks consisted mostly of fines/clays. Organic matter was present in both bed and banks of habitat types and ranged from 2-14%. Rock outcrops were present at all sites.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having moderate cover and structural diversity at all sites. The vegetation type recorded was vegetation associated with freshwater streams (100% of sites). The mean width of the riparian vegetation zone was 41m (range 37-45m), with 50% of sites recording riparian zone widths between 31-40m and 50% >40m.

The structural types recorded are shown in Table 5.61. There were 7 of the 13 structural types present at all sites. Covers ranged from 0-38%, though the majority was <10%. The highest mean cover was 35% and was recorded for medium sized trees (10-30m).

Table 5.61 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	0	0
Trees (10-30m)	100	35.3 (28-38)
Trees (2-10m)	100	16.0 (12-22)
Regen. Trees (<2m)	100	4.8 (4-5)
Woody Shrubs (<2m)	100	6.3 (5-10)
Vines	100*	5.8 (5-8)
Rushes and Sedges	0	0
Phragmites	50	1.0 (0-2)
Forbs (or Herbs)	100*	9.5 (5-13)
Grasses	100	7.3 (5-10)
Ferns	0	0
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

Overstorey vegetation provided a much greater cover than understorey vegetation. The upper bank recorded an average of 89% bare (range 88-90%) for understorey vegetation cover compared to 48% bare (range 35-60%) for the overstorey vegetation.

Exotic vegetation was recorded at all sites while noxious vegetation was present at half the sites. Overall the mean total cover of exotic species in the riparian zone was 7% (range 0-11% cover), with one site rating a low disturbance from exotics (1-5%) and the other a high level of invasion (11-15% cover). Structural types recorded were vines (100% of sites) and forbs (100%). The only noxious species recorded was *Xanthium occidentale* or Noogoora Burr (mean cover of 8%). Other exotic species were *Passiflora foetida* (mean cover of 3%) and *Melochia pyramidata* (2% cover).

♦ *Aquatic Vegetation*

Aquatic vegetation was recorded at all sites, in the form of emergent vegetation. The mean cover for this vegetation type was 15% (range 7-22%). The structural types present included Phragmites (50% of sites), Pandanus (50%) and Melaleucas (100%). Covers for these structural types averaged 2%, 10% and 9% respectively.

♦ *Instream and Bank Habitats*

The cover and diversity of instream and bank habitats rated as either high (50% of sites) or moderate (50%). Subjectively, the overall aquatic habitat condition was rated as good (50% of sites) or poor to good (50%).

Six instream habitat types were recorded. The types listed for all sites were individual logs, individual branches, emergents and rock faces. Other types recorded were leaves/twigs and permanent pools deeper than 1m. The covers provided by these habitat types was generally <10%, although rock faces provided a mean cover of 38% (range 5-70%) and permanent pool habitats provided a mean cover of 40% (range 0-80%).

Three different types of overhanging bank cover were recorded at all sites. Vegetation canopy cover occurred along 84% of the bank and had a mean width of 3.4m. Vegetation overhang occurred along 21% of the bank and had a mean width of 0.9m. Root overhang also was recorded and occurred along 6% of the bank and had a mean width of 0.2 m.

At water mark, 50% of sites would have partly restricted passage for fish and other aquatic organisms and 50% very restricted passage.

♦ *Overall Condition*

The overall condition rating for all sites assessed in this sub-section was high.

High instream & bank habitat rating; high overall condition (Site 19a/3: Katherine River)

5.13.1.2 Katherine River – below Seventeen Mile Creek

Sub-section 19b encompasses the Katherine River from the junction with King River upstream to Seventeen Mile Creek. This sub-section includes the Katherine Township urban and rural residential areas. Six sites, located on the Katherine River, were fully assessed in this sub-section.

♦ *Reach Environs and Site Features*

Sites were rated as having reach environs that predominantly had some or moderate levels of modification (refer Table 5.62). Subjective disturbance ratings indicated that reach environs had low to moderate levels of disturbance (33% of sites) or moderate levels (67%).

Table 5.62 State of the Reach Environs

Reach Environs Category (Rating)	Percent of Sites (%)
Extreme Modification (0-20%)	0
Major Modification (21-40%)	0
Moderate Modification (41-60%)	33
Some Modification (61-80%)	50
Essentially Natural (81-100%)	17

Land tenure was freehold or leasehold at 100% of sites. Urban reserves were present at 17% of sites. Grazing was the major land use and occurred on thinned native pastures (100% of sites), cleared native pastures (100%) or on improved pastures (33%). Other land uses recorded were rural residential (50% of sites), tree crops (50%), rainfed and irrigated broad acre cropping (17%) and urban residential (17%).

The major disturbances likely to affect stream reaches were grazing (83% of sites), roads/tracks (67%) and water extraction points (50%). Other factors contributing to the disturbance of the reaches (occurring at <35% of sites) were boat ramps, weirs, people, dredging and bridges/ crossings.

The major floodplain features recorded were prominent flood channels (50% of sites), floodplain scours (33%) and billabongs (17%).

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 1,486m (range 150-4,270m). Pools were the dominant habitat type and were recorded at 83% of reaches. Pools also dominated reach lengths, averaging 81% of the reach. Other habitat types recorded were riffles (67% of sites), rapids (17%) and runs (17%). The channel type diversity rating in this sub-section ranged from high (50% of sites), moderate (33%) to low (17%). The water level at the time of sampling was higher than water mark (approximately by 0.5m) due to recent rains.

Table 5.63 presents the mean dimensions for the pool and riffle habitats. There are no lower bank measurements because of the raised water level. Pools, at 3.1m, were significantly deeper than riffles, which averaged 0.8m deep. Both habitats were of similar width. The width:depth ratios were much lower for pools than for riffles. Upper banks were very wide and of moderate height, with low slopes. Banks along the reach were moderate or low in slope and were concave-shaped, convex-shaped or were stepped.

♦ *Bank Condition and Stability*

The reaches assessed in this sub-section were rated as having stable banks (100% of sites). Subjective ratings indicated that the overall bank instability and susceptibility of banks to further erosion was low (83% of sites), low to moderate (33%) or moderate (33%).

Erosion was the dominant bank process recorded at all sites. The erosion was predominantly occurring at obstacles (100% of sites) or at floodplain scours / break out points along the river (83% of sites). Areas along outside bends and at seepage points were also recorded as eroding.

The lower banks were very stable, with only 5% (range 0-15%) of the bank length recorded as eroding. The upper banks were not as stable, with an average of 11% (range 0-20%) of the bank length recorded as eroding.

Aggradation was also recorded along inside bends (33% of sites), at obstacles (17%) and along outside bends (17%). An average of 1-2% (range 0-10%) of both the lower and upper banks were aggrading.

The major factors identified as affecting bank stability were high flow (100% of sites), floodplain scours or break out points (67%), runoff (50%) or stock (50%). Other factors included roads/ bridges/crossings, people tracks and seepage.

Table 5.63 Channel Dimensions for Habitat Types

Dimension		Pool	Riffle
Reach Covered (%)		81.4 (61-91)	18.3 (9-39)
Mean Length (m)		722 (295-1,950)	126.3 (55-195)
Mean Depth (m)**		3.1 (2.0-5.1)	0.8 (0.4-1.8)
Mean Width (m)**		26.7 (4.6-42.0)	27.6 (19.0-31.2)
Width:Depth Ratio		10.2 (0.9-13.9)	44.1 (16.7-62.4)
∗UB:	Width (m)	28.6 (8.0-87.0)	38.1 (18.3-71.0)
	Height (m)	5.0 (3.0-6.0)	4.5 (2.7-6.0)
	Slope (^{o})	14.7 (2.4-32.0)	8.2 (2.2-13.2)

∗UB = Upper Bank ** Measured from the water mark.

♦ *Bed and Bar Condition and Stability*

All reaches assessed in this sub-section were subjectively rated as having stable beds. The major factor identified as affecting bed stability was agriculture/grazing (67% of sites). Bank erosion and concentration of flows were also recorded. Rock outcrops (67% of sites), structures (50%) and fallen trees (33%) provided a degree of bed stabilising influence.

Sand and gravel bars were present at 83% of sites, occurring as high flow deposits, bars with encroaching vegetation or point bars. The mean bar size was low, averaging 9% of the bed surface above water mark (range 5-15%). The gravel forming the bed and bars was sphere-shaped or disc-shaped and had sub-angular or rounded material. Bed compaction ranged from low (67% of sites), moderate (33%) to being packed (34%).

♦ *Bed and Bank Sediments*

The bed material at pool and run habitats consisted mostly of sand, although larger gravels were also recorded for the run habitat, and the bank material was mostly fines/clays and small sand. At rapids, the bed material was mostly large gravel and boulders, while the lower bank was composed mostly of gravels and the upper bank was sand and small gravel. Riffles had beds that consisted mostly of cobbles and boulders and banks that were composed of fines and/or sand.

Organic matter was present in both bed and banks of habitat types and ranged from 6-36%. Rock outcrops were present at 67% of sites.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having either moderate (83% of sites) or high (17%) cover and structural diversity. The vegetation type recorded was vegetation associated with freshwater streams (100% of sites). The mean width of the riparian vegetation zone was 30m (range 15-65m), with 33% of sites recording riparian zone widths between 11-20m, 50% between 21-30m, 33% between 31-40m and 16% >40m.

The structural types recorded are shown in Table 5.64. There were 7 of the 13 structural types present at all sites. Covers ranged from 0-38%, though the majority was <10%. The highest mean cover was 23% and was recorded for medium sized trees (10-30m). Small trees also dominated the structural types, recording a mean cover of 21%.

Table 5.64 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	0	0
Trees (10-30m)	100	23.2 (10-38)
Trees (2-10m)	100	20.6 (15-25)
Regen. Trees (<2m)	100	5.2 (5-7)
Woody Shrubs (<2m)	100	6.2 (4-10)
Vines	100*	6.9 (5-10)
Rushes and Sedges	33	1.3 (0-5)
Phragmites	33	1.7 (0-5)
Forbs (or Herbs)	100*	5.8 (3-10)
Grasses	100	9.7 (5-20)
Ferns	0	0
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

Overstorey vegetation provided a much greater cover than understorey vegetation. The upper bank recorded an average of 79% bare (range 65-85%) for understorey vegetation cover compared to 43% bare (range 25-62%) for the overstorey vegetation. The more common native overstorey species present at all sites included *Barringtonia acutangula*, *Eucalyptus camaldulensis* and *Pandanus aquaticus.*

Exotic vegetation was recorded at 83% of sites, while noxious species were present at only 17% of sites. The overall mean total cover of exotic species in the riparian zone was low, averaging 3% (range 0-9%). For 66% of sites a low cover rating for exotics (1-5%) was recorded, but one site had a moderate cover rating (6-10%). Structural types recorded were vines (83% of sites) and forbs (17%). The only noxious species recorded was *Hyptis suaveolens* (mean cover of 4%). Other exotic species were *Passiflora foetida, Merremia aegyptia* and *Melochia pyramidata*. Covers for these species ranged from 2-4%.

♦ *Aquatic Vegetation*

Aquatic vegetation was recorded at all sites. Emergent vegetation was present at all sites and had an overall mean cover of 14% (range 8-25%). The structural types present included Phragmites (33% of sites), Pandanus (100%), Melaleucas (83%) and other trees/shrubs (17%). Covers for these structural types were between 5-8%. Submerged vegetation was also present (33% of sites) in the form of filamentous algae. The cover for this vegetation type was low, averaging 2%.

♦ *Instream and Bank Habitats*

The cover and diversity of instream and bank habitats rated as either high (83% of sites) or moderate (17%). Subjectively, the overall aquatic habitat condition was rated as poor to good (67% of sites) or good (33%).

Nine instream habitat types were recorded. The major types recorded were individual logs, individual branches, emergent vegetation, leaves/ twigs, rock faces and permanent pools deeper than 1m. Other types recorded were algal clumps, log jams, and rubbish. The covers provided by these habitat types was generally <10%, although permanent pool habitats provided a mean cover of 51% (range 0-80%) and rock faces provided a mean cover of 23% (range 0-75%).

Three different types of overhanging bank cover were recorded at all sites. Vegetation canopy cover occurred along 76% of the bank and had a mean width of 3.3m. Vegetation overhang occurred along 36% of the bank (mean width 1.4m). Root overhang occurred along 24% of the bank and had a mean width of 0.2 m.

At water mark, 17% of sites would have partly restricted passage for fish and other aquatic organisms, 67% moderately restricted and 17% very restricted passage.

♦ *Overall Condition*

The overall condition rating for all sites assessed in this sub-section was high.

High riparian vegetation and instream / bank habitat ratings (Site 19b/3: Katherine River)

Knotts Crossing Weir on Katherine River - an example of a reach disturbance factor

5.13.1.3 Katherine River – below Grace and Fanny Creeks

Sub-section 19c encompasses the Katherine River from the junction with Seventeen Mile Creek (not including this creek) upstream to Grace Creek junction. This sub-section includes the Katherine Gorge. Two sites, located on the Katherine River, were fully assessed in this sub-section. A photographic site was also located on Emu Creek, a small tributary of the Katherine River.

♦ *Reach Environs and Site Features*

All sites were rated as having essentially natural reach environs as most of these sites were located within a National Park and the disturbance level was low. Subjective disturbance ratings indicated that reach environs had low levels of disturbance (100% of sites).

Land tenure was National Park status (100% of sites) or freehold/leasehold (50%), since the river was the border of the National Park at one site. As a result, the major land use was National Park, although grazing on virgin timbered country was also recorded (50% of sites). The major disturbances likely to affect stream reaches at 50% of sites were the presence of a boat ramp, people and grazing.

The major floodplain features recorded at 50% of sites were billabongs, flood channels and floodplain scours.

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 3,190m (range 2,890-3,490m). Pools and riffle habitats were recorded at all sites, although pools dominated the reach length (averaging 93%). Rapids were also present (50% of sites). The channel type diversity rating in this sub-section was either high (50% of sites) or moderate (50%). The water level at the time of sampling was higher than water mark (approximately by 0.2-0.3m) due to recent rains.

Table 5.65 presents the mean dimensions for the pool and riffle habitats. There are no lower bank measurements because of the raised water level. The pools, particularly those located along the Katherine Gorge, were the deepest within the Daly River catchment. Riffles were relatively shallow. Pools were significantly wider than riffles, and recorded a much lower width:depth ratio. Upper banks were much wider at riffles than at pools and were twice as tall. Banks along the reaches ranged in slope from low, moderate, steep to vertical. Bank shape also ranged from being concave in shape, to convex, stepped, cliff-shaped or having a wide lower bench.

Table 5.65 Channel Dimensions for Habitat Types

Dimension		Pool	Riffle
Reach Covered (%)		93.0 (88-98)	3.5 (2-5)
Mean Length (m)		2350 (1275-3425)	107.5 (65-150)
Mean Depth (m)**		5.9 (1.5-10.2)	0.4 (0.2-0.5)
Mean Width (m)**		58.0 (46.0-70.0)	37.3 (28.5-46.0)
Width:Depth Ratio		18.8 (7-31)	117.3 (92-143)
∗UB:	Width (m)	13.3 (5.0-27.0)	76.5 (42.5-111)
	Height (m)	21.2 (2.0-45.8)	42.6 (35.1-50.1)
	Slope (^{o})	42.4 (7.6-83.8)	32.0 (24.4-39.6)

∗UB = Upper Bank ** Measured from the water mark.

♦ *Bank Condition and Stability*

All reaches were rated as having stable banks. Subjective ratings indicated that the overall bank instability and susceptibility to further erosion was minimal to low. Erosion was the dominant bank process recorded at all sites. The erosion was occurring at obstacles (100% of sites), along outside bends (50%), at floodplain scours / break out points along the river (50%) or irregularly (50%). Both the lower and upper banks were very stable, with only 3-8% (range 2-10%) of the bank length recorded as eroding.

Aggradation was recorded at 50% of sites along inside bends, at obstacles, irregularly and along outside bends. An average of 1-5% (range 0-10%) of both the lower and upper banks were aggrading.

The major factor identified as affecting bank stability was high flow (100% of sites). Other factors (at 50% of sites) were people tracks, stock/vermin and wash from boats. The feral animals recorded included buffaloes, donkeys, wild horses and pigs. Fencing off of the river corridor was recorded at 50% of sites.

♦ *Bed and Bar Condition and Stability*

All reaches assessed in this sub-section were subjectively rated as having stable beds.

Sand and gravel bars were present at all sites, occurring as high flow deposits, bars with encroaching vegetation, alternate or point bars. The mean bar size was 12% of the bed surface above water mark (range 8-15%). The gravel forming the bed and bars was sphere-shaped or disc-shaped and had sub-angular or rounded material. Bed compaction ranged from low to being tightly packed.

The major factors identified as affecting bed stability were agriculture/grazing (50% of sites) or concentration of flow (50%). Rock outcrops (100% of sites), especially through Katherine Gorge, provided a large degree of bed stabilising influence.

♦ *Bed and Bank Sediments*

The bed material at pool and run habitats consisted predominantly of sand and boulders. The bank material at pools was mostly fines/clays and small sand. The bed material at rapid habitats was predominantly large gravel, cobbles and boulders, as was the upper bank material. Riffles had bed and bank material that consisted mostly of boulders. Organic matter was present in both bed and banks of habitat types and ranged from 6-47%.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having moderate cover and structural diversity at all sites. The vegetation type recorded was vegetation associated with freshwater streams (100% of sites). The mean width of the riparian vegetation zone was 15m (range 5-32m), with 50% of sites recording riparian zone widths between 5-10m, 50% between 11-20m and 50% between 31-40m.

The structural types recorded are shown in Table 5.66. There were 8 of the 13 structural types present at all sites. Covers were generally low and ranged from 0-30%, though the majority was <10%. The highest mean cover was 19% and was recorded for medium sized trees (10-30m). Palms were recorded.

Table 5.66 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	0	0
Trees (10-30m)	100	18.8 (10-30)
Trees (2-10m)	100	12.0 (8-15)
Regen. Trees (<2m)	100	5.0 (-)
Woody Shrubs (<2m)	100	5.0 (-)
Vines	100*	4.5 (1-7)
Rushes and Sedges	100	4.0 (3-5)
Phragmites	0	0
Forbs (or Herbs)	100	4.5 (4-5)
Grasses	100	8.0 (5-12)
Ferns	0	0
Mangroves	0	0
Salt Marsh	0	0
Palms	50	2.5 (0-5)

* Contains exotic species

Overstorey vegetation provided greater cover than understorey vegetation. The upper bank recorded an average of 80% bare (range 73-85%) for understorey vegetation cover compared to 64% bare (range 50-78%) for the overstorey vegetation.

Exotic vegetation was recorded at all sites assessed. There were no noxious species. The mean total cover of exotic species in the riparian zone was low, averaging 3% (range 1-4%) and therefore the sites rated quite highly. *Passiflora foetida*, a vine, was the only exotic species recorded.

♦ *Aquatic Vegetation*

Aquatic vegetation was recorded at all sites. Emergent vegetation was present at all sites and had an overall mean cover of 10% (range 4-15%). The structural types present included Pandanus (100% of sites) and Melaleucas (50%). Covers for these structural types were between 4-10%. Submerged vegetation was also present (50% of sites) in the form of filamentous algae. The cover for this vegetation type was low, averaging 2%.

♦ *Instream and Bank Habitats*

The cover and diversity of instream and bank habitats rated as moderate for all sites. Subjectively, the overall aquatic habitat condition was rated as good (100% of sites).

Seven instream habitat types were recorded. The major types recorded were individual logs, rock faces and permanent pools deeper than 1m. Other types included leaves/twigs, algal clumps, emergent vegetation and man-made structures. The covers provided by these habitat types was generally <10%, although permanent pool habitats provided a mean cover of 70% (range 60-80%) and rock faces provided a mean cover of 63% (range 50-75%).

The main types of overhanging bank cover were canopy cover, which occurred along 53% of the bank and had a mean width of 2.6m, and vegetation overhang, which occurred along 18% of the bank (mean width 1.0m). Root overhang and man-made structures were also present.

At water mark, all sites would have moderately restricted passage for fish and other aquatic organisms.

♦ *Overall Condition*

The overall condition rating for sites assessed in this sub-section was either very high (50% of sites) or high (50%).

Very high overall condition (Site 19c/3: Katherine River within Nitmiluk National Park)

Katherine Gorge in Nitmiluk National Park (upstream of Site 19c/3) which recorded the deepest pool habitats

5.13.1.4 Katherine River – below Birdie Creek

Sub-section 19d encompasses the Katherine River from the junction with Grace Creek upstream to Birdie Creek junction. This sub-section includes the catchment area of Grace and Fanny Creeks. Of the 5 sites within this sub-section, 3 were fully assessed. Two sites were located on Katherine River and 1 on Grace Creek. The 2 photographic sites were located on Ironbark and Snake Creeks.

♦ *Reach Environs and Site Features*

Sites were rated as having either some modification to their reach environs (67% of sites) or reach environs that were essentially natural (33%). Subjective disturbance ratings indicated that reach environs had low levels of disturbance (67% of sites) or moderate levels (33%).

Land tenure was mostly freehold or leasehold (100% of sites), although 33% of sites had National Park status. The major land use was grazing which occurred on virgin timbered pasture (100% of sites) and cleared pasture (33%). National Park was also the major land use at 33% of sites. The major disturbances likely to affect stream reaches were grazing (100% of sites), watering points (33%), crossings (33%) or tracks (33%). The major floodplain features recorded were prominent flood channels. Braided channels were recorded at 67% of sites.

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 646m (range 144-1,100m). Pools were recorded at all sites and dominated the reach length (averaging 76%). Other habitat types included riffles (67% of sites), rapids (33%) and runs (33%). The habitat type diversity rating in this sub-section was high for all sites.

The water level at the time of sampling was higher than water mark (by 0.15m) at 67% of sites, due to recent rains, or was at water mark (33% of sites).

Table 5.67 presents the mean dimensions for the pool and riffle habitats. There are no lower bank measurements because of the raised water level. Pools, at 1.6m, were nearly three times deeper than riffles. Both pools and riffles recorded similar widths, though riffles had a much higher width:depth ratio. Upper banks were moderately wide and tall, with relatively low slopes. Banks along the reaches ranged in slope from low, moderate to flat. Bank shape also ranged from being concave in shape, convex or having a wide lower bench.

Table 5.67 Channel Dimensions for Habitat Types

Dimension		Pool	Riffle
Reach Covered (%)		75.7 (60-86)	23.5 (7-40)
Mean Length (m)		172.0 (62-282)	50.0 (-)
Mean Depth (m)**		1.6 (0.3-2.9)	0.6 (0.3-0.9)
Mean Width (m)**		30.0 (11.0-49.0)	34.0 (20.0-48.0)
Width:Depth Ratio		24.1 (17.2-36.7)	64.0 (56.5-71.4)
∗UB:	Width (m)	19.2 (8.0-44.0)	11.5 (6.0-17.0)
	Height (m)	3.7 (1.8-4.5)	2.4 (2.0-2.7)
	Slope (°)	13.2 (5.2-20.0)	15.5 (6.7-24.2)

∗UB = Upper Bank ** Measured from the water mark.

♦ *Bank Condition and Stability*

The reaches assessed in this sub-section were rated as having stable banks (100% of sites). Subjective ratings indicated that the overall bank instability was low (67% of sites), minimal to low (33%) or moderate (33%). Similar figures were recorded for the susceptibility of banks to further erosion.

Erosion was the dominant bank process recorded at all sites. The erosion was occurring at obstacles (100% of sites), at floodplain scours/break out points along the river (67%), along outside bends (33%) or irregularly (33%). The lower banks were very stable, with only 3% (range 2-5%) of the bank length recorded as eroding. The upper banks were not as stable, with 11% (range 5-15%) of the bank length recorded as eroding. No aggradation was recorded.

The major factors identified as affecting bank stability at all sites were high flow and vermin. Other factors were floodplain scours/break out points (67% sites) and stock (33%). The feral animals recorded included buffaloes, donkeys, wild horses and pigs. Fencing off of the river corridor was recorded at 33% of sites.

♦ *Bed and Bar Condition and Stability*

The reaches assessed in this sub-section were rated as having stable beds (67% of sites) or moderately aggrading beds (33%).

Sand and gravel bars were present at all sites, occurring as bars with encroaching vegetation, channel bar plains, mid-channel islands, alternate or point bars. The mean bar size was relatively high, averaging 18% of the bed surface above water mark (range 5-40%). The gravel forming the bed and bars was sphere-shaped and had sub-angular material. Bed compaction was mostly low.

The major factors identified as affecting bed stability were agriculture/grazing (100% of sites) or instream siltation (33%). Rock outcrops and fallen trees provided a degree of bed stabilising influence at 67% of sites.

♦ *Bed and Bank Sediments*

The bed material at pool and run habitats consisted predominantly of sand. The bank material at these habitat types was mostly fines/clays and small sand. Boulders made up the majority of bed material at rapid habitats, and also the upper bank material (although sand was also present). Riffles had bed and bank material that consisted mostly of sand. Organic matter was present in both bed and banks of habitat types and ranged from 29-41%.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having moderate cover and structural diversity at all sites. The vegetation type recorded was vegetation associated with freshwater streams (100% of sites). The mean width of the riparian vegetation zone was 26m (range 15-66m), with 67% of sites recording riparian zone widths between 11-20m, 33% between 21-30m and 33% >40m.

The structural types recorded are shown in Table 5.68. There were 8 of the 13 structural types present at all sites. Covers were generally low and ranged from 0-25%, though the majority was <10%. The highest mean cover was 24% and was recorded for medium sized trees (10-30m). Large trees and ferns were recorded at 33% of sites.

Overstorey vegetation provided a much greater cover than understorey vegetation. The upper bank recorded an average of 87% bare (range 85-90%) for understorey vegetation cover compared to 52% bare (range 45-58%) for the overstorey vegetation.

Overall, exotic vegetation was recorded at 60% of sites, while noxious species were present at 40%. The mean total cover of exotic species in the riparian zone was low, averaging 1% (range 0-6%), and therefore the sites recording the presence of exotic species were rated as having a low level of invasion. The structural types recorded were vines (67% of sites) and forbs (33%). Noxious species included *Hyptis suaveolens* (40% of sites) and *Sida acuta* (20%). One other exotic species was *Passiflora foetida*, a naturalised vine.

Table 5.68 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	33	1.7 (0-5)
Trees (10-30m)	100	24.2 (20-25)
Trees (2-10m)	100	15.0 (-)
Regen. Trees (<2m)	100	5.0 (-)
Woody Shrubs (<2m)	100	6.3 (4-10)
Vines	100*	3.3 (2-4)
Rushes and Sedges	100	3.3 (2-4)
Phragmites	0	0
Forbs (or Herbs)	100*	4.8 (2-7)
Grasses	100	7.7 (5-10)
Ferns	100	0
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

♦ *Aquatic Vegetation*

Aquatic vegetation was recorded at 67% of sites, in the form of emergent vegetation. The cover for this type was 13% (range 12-13%). The structural types present included Pandanus (67% of sites), Melaleucas (67%) and other shrubs/trees (33%). Covers for the structural types were between 2-8%.

♦ *Instream and Bank Habitats*

The cover and diversity of instream and bank habitats rated as either moderate (67% of sites) or high (33%). Subjectively, the overall aquatic habitat condition was rated as poor to good (67% of sites) or good (33% of sites).

Eight instream habitat types were recorded. The major types listed were individual logs, individual branches, rock faces, leaves/twigs, emergent vegetation and permanent pools deeper than 1m. Other types included log jams and algal clumps. The covers provided by these habitat types was generally <10%, although permanent pool habitats provided a mean cover of 38% (range 5-70%) and leaves/twigs provided a mean cover of 15% (range 0-40%).

The main types of overhanging bank cover were canopy cover, which occurred along 56% of the bank and had a mean width of 2.6m; and vegetation overhang, which occurred along 19% of the bank (mean width 1.3m). Some root overhang was also recorded.

At water mark, 67% of sites would have moderately restricted passage for fish and other aquatic organisms and 33% would be very restricted.

♦ *Overall Condition*

The overall condition rating for all sites assessed in this sub-section was high.

High instream & bank habitat rating; stable channel; moderate riparian vegetation (Site 19d/1: Katherine River)

5.13.1.5 Upper Katherine River – includes Birdie, Gimbat and Snowdrop Creeks

Sub-section 19e encompasses the Katherine River from the junction with Birdie Creek to the top of the catchment. This sub-section includes the Arnhem Land Plateau. Of the 9 sites located within this sub-section, 6 were fully assessed (4 being located on the Katherine River).

♦ *Reach Environs and Site Features*

Sites assessed in this sub-section were rated as having reach environs that were essentially natural (71% of sites) or had some modification (29%). Subjective disturbance ratings indicated that reach environs had very low to low levels of disturbance (86% of sites) or low to moderate levels (14%).

Land tenure was National Park status (71% of sites) or freehold/leasehold (29%). As a result, the major land use was National Park, although grazing on virgin timbered pasture (29% of sites) and on native thinned pasture (14%) was also recorded. The major disturbances likely to affect stream reaches were grazing (86% of sites) and roads/tracks (57%). Other minor disturbances included watering points for stock/ferals, causeways/crossings and people. No disturbances were recorded at 14% of sites.

The major floodplain features recorded were billabongs, floodplain scours and flood channels. Braided channels were recorded at 29% of sites.

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 1,212m (range 100-2,920m). Pools were recorded at 83% of sites and dominated the reach length (averaging 79%). Other habitat types present were riffles (67% of sites), runs (33%) and rapids (17%). The channel type diversity rating in this sub-section ranged from high (50% of sites), moderate (33%) to very low (17%).

Table 5.69 presents the mean dimensions for the pool and riffle habitats. Pools were moderately deep at 2.6m compared to the shallow riffles, which averaged 0.2m. Pools were also over twice the width of riffles and recorded a much lower width to depth ratio. Upper banks were wide, particularly at riffles and were taller along pool habitats. Bank slopes were generally low. Banks along the reaches ranged in slope from low, moderate to vertical. Bank shape also ranged from being concave in shape, convex, stepped, cliff-shaped to having a wide lower bench.

Table 5.69 Channel Dimensions for Habitat Types

Dimension		Pool	Riffle
Reach Covered (%)		78.8 (54-94)	24.5 (5-46)
Mean Length (m)		939.6 (38-1,700)	234.0 (16-600)
Mean Depth (m)**		2.6 (0.9-4.0)	0.2 (0.1-0.3)
Mean Width (m)**		27.8 (9.0-44.0)	10.3 (5.9-18.1)
Width:Depth Ratio		11.3 (8-14)	70.2 (20-113)
∗UB:	Width (m)	21.0 (5.5-65.5)	41.7 (8.0-81.0)
	Height (m)	6.1 (0.9-35.0)	3.3 (1.8-6.4)
	Slope (^{o})	16.5 (1.8-68.2)	6.2 (2.0-12.7)

∗UB = Upper Bank ** Measured from the water mark.

The water level at the time of sampling was mostly at water mark (86% of sites), though at some sites (14%) the level was higher (by 0.15m) due to recent rains.

♦ *Bank Condition and Stability*

All reaches assessed in this sub-section were rated as having stable banks. Subjective ratings indicated that the overall bank instability was minimal (33% of sites), low (67%) or low to moderate (33%). The susceptibility of banks to further erosion recorded similar percentages.

Erosion was the dominant bank process recorded at all sites. The erosion was occurring at obstacles (100% of sites), at floodplain scours/break out points along the river (83%), irregularly (83%) or along outside bends (33%). Both the lower and upper banks were stable, with only 5-10% (range 3-15%) of the bank length recorded as eroding.

Aggradation was also recorded. An average of 13% (range 0-38%) of the upper bank was aggrading. It was occurring at irregular intervals (83% of sites), at obstacles (67%), along inside bends (33%), at floodplain scours (33%) and along outside bends (17%).

The major factor identified as affecting bank stability was high flow (100% of sites). Other factors were vermin, roads/crossings, floodplain scours/break out points, stock and people tracks. The feral animals recorded included buffaloes, donkeys, wild horses and pigs.

♦ *Bed and Bar Condition and Stability*

The reaches assessed in this sub-section were subjectively rated as having moderately aggrading beds (67% of sites) or stable beds (33%).

Sand and gravel bars were present at all sites, occurring as high flow deposits (83% of sites), mid-channel islands (50%), bars with encroaching vegetation (33%), alternate (33%) or point bars (33%). The mean bar size was relatively high, averaging 23% of the bed surface above water mark (range 15-40%). The gravel forming the bed and bars was sphere-shaped or disc-shaped and had sub-angular or angular material. Bed compaction was mostly low (84% of sites), although 66% of sites recorded packed beds.

The major factors identified as affecting bed stability were instream siltation (50% of sites) or agriculture/grazing (17%). No factors were recorded at 33% of sites. Rock outcrops (67% of sites) and fallen trees (17%) provided a degree of bed stabilising influence.

♦ *Bed and Bank Sediments*

The bed material at pool and run habitats consisted predominantly of sand material, although boulders comprised 19% of the pool bed. The bank material at pools was mostly fines/clays, small sand and 10% boulder material, whereas at runs sand dominated the bank material. The bed material at riffle habitats was predominantly sand, cobbles and boulders, whereas the bank material was mostly sand. Rapids recorded predominantly boulders and cobbles within the bed and bank. Organic matter was present in both bed and banks of habitat types and ranged from 8-31%.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having either high (67% of sites) or moderate (33%) cover and structural diversity. The vegetation type recorded was vegetation associated with freshwater streams (100% of sites). The mean width of the riparian vegetation zone was 25m (range 10-73m), with 17% of sites recording riparian zone widths between 5-10m, 67% between 11-20m, 33% between 21-30m, 16% between 31-40m and 33% >40m.

The structural types recorded are shown in Table 5.70. There were 8 of the 13 structural types present at all sites. Covers ranged from 0-70%, though the majority was <10%. The highest mean cover was 32% and was recorded for grasses. Medium-sized trees and small trees dominated the overstorey, averaging 25% cover each.

Table 5.70 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	17	0.3 (0-2)
Trees (10-30m)	100	25.0 (10-40)
Trees (2-10m)	100	25.1 (10-38)
Regen. Trees (<2m)	100	4.9 (4-5)
Woody Shrubs (<2m)	100	4.8 (4-5)
Vines	100*	8.0 (5-11)
Rushes and Sedges	100	6.2 (1-10)
Phragmites	0	0
Forbs (or Herbs)	100*	6.9 (5-15)
Grasses	100	32.3 (8-70)
Ferns	0	0
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

Overstorey vegetation provided greater cover than understorey vegetation. The upper bank recorded an average of 64% bare (range 22-88%) for understorey vegetation cover compared to 53% bare (range 20-80%) for the overstorey vegetation.

The more common overstorey native species included *Acacia holosericea, Carallia brachiata*, *Eucalyptus camaldulensis, Pandanus aquaticus* and *Syzygium armstrongii*.

Exotic vegetation was recorded at all sites, while species declared noxious were present at 43%. The mean total cover of exotic species in the riparian zone was 5% (range 1-10%). Therefore, the majority of sites (67%) rated a low level of invasion by exotic species (1-5% cover), while 33% rated a moderate level (6-10% cover). The structural types recorded were vines (100% of sites) and forbs (50%). The only noxious species recorded was *Hyptis suaveolens* (mean cover of 4%). The only other exotic species recorded was *Passiflora foetida* (mean cover of 3%).

♦ *Aquatic Vegetation*

Aquatic vegetation was recorded at 33% of sites. Emergent vegetation, present at 17% of sites, had an overall mean cover of 8%. Submerged vegetation was recorded at 33% of sites and had an overall cover of 14% (range 5-23%). Floating vegetation was also present within the sub-section at 17% of sites and was the only recording for the Daly River catchment. The cover for the floating vegetation was 5%.

The structural type present for the emergent vegetation was rushes/sedges (8% cover). Submerged vegetation consisted of Chara/Nitella (23% cover) and filamentous algae (5%). Floating vegetation structural types were water lilies (5% cover).

Aquatic vegetation species recorded were *Cyperus haspan* (emergent), *Chara sp*. or *Nitella sp*. (submerged), *Nymphoides hydrocharoides* (floating) and *Nymphaea violacea* (floating).

♦ *Instream and Bank Habitats*

The cover and diversity of instream and bank habitats rated as either high (67% of sites) or moderate (33%). Subjectively, the overall aquatic habitat condition was rated as good to high (50% of sites), good (33%) and poor to good (17%).

Twelve instream habitat types were recorded. The major types recorded were individual logs, individual branches, leaves/twigs, permanent pools deeper than 1m, rock faces and log jams. The covers provided by these habitat types was generally <10%, although permanent pool habitats provided a mean cover of 48% (range 0-80%) and rock faces provided a mean cover of 17% (range 0-60%).

The main types of overhanging bank cover were canopy cover, which occurred along 63% of the bank and had a mean width of 3.1m; vegetation overhang, which occurred along 28% of the bank

(mean width 1.0m); and root overhang which occurred along 17% of the bank (mean width 0.2m). Some bank overhang was also present.

At water mark, 33% of sites would have partly restricted passage for fish and other aquatic organisms, 50% moderately restricted and 17% very restricted.

♦ *Overall Condition*

The overall condition rating for sites assessed in this sub-section was either high (83%) or very high (17%).

Moderate aggradation occurring predominantly as high flow deposits along upper Katherine River (downstream of Centipede Dreaming Gorge)

Very high overall condition (Site 19e/6: Katherine River within Centipede Dreaming Gorge)

5.13.1.6 Comparison of Katherine River Sub-sections

The *reach environs* for sections of the Katherine River ranged from being essentially natural, having some modification to having moderate modification to the reach environs. Those sites located within Nitmiluk and Kakadu National Park and Arnhem Land Aboriginal Land, generally rated a better reach environs condition than those sites located along the rural and urban areas of Katherine (sub-section 19b). Along the latter reach, the types of land uses (eg cropping, urban residential, *etc*) and disturbances (eg roads, boat ramps, people, dredging, *etc*) varied much more widely and were more intensive. Outside of National Parks and Aboriginal Land, grazing was identified as the major land use. Along the majority of sections, grazing was identified as the major disturbance factor to the reach environs.

Channel type diversity was predominantly high throughout the sub-sections. The 12 reaches that rated a high level of diversity recorded 2 to 3 different habitat types, with >10% and up to >30% of the reach being occupied by riffles (or other non-pool habitats). The 5 reaches that recorded a moderate diversity recorded only 2 habitat types of which <10% of the reach was dominated by riffles (or non-pools). A reach on Katherine River and Birdie Creek that rated low and very low diversity ratings, respectively, recorded only one habitat type with little or no variation in depths. Overall, pools dominated all reaches along the Katherine River and, at Katherine Gorge, were the deepest within the Daly River catchment. Water levels were generally high at the time of sampling due to recent rains or were at water mark.

Bank stability – all reaches assessed along the Katherine River and small tributaries were rated as having stable banks. Erosion was the dominant bank process along all reaches, although generally minor. Nearly half the sites recorded some aggradation along the banks. Although the factors affecting bank stability ranged widely, all reaches recorded high flows as the major factor. Other factors included floodplain scours / breakout points along the river, vermin (including donkeys, buffaloes, wild pigs and horses), stock, runoff, roads/bridges/crossings and people tracks.

Bed and bar stability – The majority of reaches assessed were subjectively rated as having stable beds. All reaches on upper Katherine River downstream of Centipede Dreaming Gorge to Snake Creek junction and a reach on Birdie Creek were assessed as moderately aggrading. Bars were present along the majority of reaches and increased in size from 5% cover along lower Katherine River to 23% cover (range 15-40%) along upper Katherine River. Instream siltation was identified as affecting bed stability along those upper sections subjectively assessed as moderately aggrading. In many cases, these channels were described as being uniform in cross-sectional shape, had many side channels and were carrying a large amount of sediment. High flow deposits were very common along these reaches. Grazing activity was also recorded as a major factor affecting bed and bar stability at over half the reaches.

The *riparian vegetation* was predominantly rated as having moderate cover and structural diversity, although 4 of the upper catchment reaches and one below Katherine rated highly. In all sub-sections, trees (2-30m tall) provided the major cover averaging 12-35%, though grasses ranged from 7-32% cover and provided the highest cover

of all structural types along the upper section of Katherine River. The remaining structural types each recorded <10% covers for all sub-sections. The width of the riparian zone ranged throughout the sub-sections but was >11m wide for all reaches except for a site along Katherine Gorge where the vegetation was confined to sandy benches at the base of cliff walls.

Exotic vegetation was located throughout the sub-sections, being recorded at all except 2 sites. Covers were generally low and as a result the majority of sites rated a low level of invasion by exotic species (1-5% cover), although 4 reaches scattered throughout the sub-sections recorded a moderate to high level. *Passiflora foetida*, a naturalised vine, was the most widespread exotic species being present along all but 2 reaches, averaging 1-5% cover. Exotic species, listed as noxious, were recorded at less than one-third of the reaches. *Hyptis suaveolens* was the most widespread noxious species. *Xanthium occidentale* (Noogoora Burr) was located along a lower sub-section reach and *Sida acuta* was located along an upper sub-section reach.

Although *aquatic vegetation* was present at over three-quarters of the reaches, the covers for each structural type was generally low, not exceeding 15%. Emergent vegetation was the most common structural type. Submerged vegetation was more scattered throughout the sub-section, being observed along one-quarter of the reaches. Floating vegetation was observed along a tributary of the upper Katherine River and was the only recording for the Daly River catchment.

The cover and diversity of *instream and bank habitats* was rated as either moderate or high. Instream habitat types were more diverse at sites recording a slightly better rating, although the covers were generally <10%, except for permanent pools deeper than 1m and rock faces. Canopy cover along the river banks was more extensive along the lower sections than the upper sections of Katherine River.

The *overall condition* rating for reaches within the Katherine River sub-catchment was predominantly high although 2 reaches, both of which were located within gorge systems, were rated very highly.

5.13.2 Discussion

While some differences between the Katherine River sub-sections and the attributes examined were observed, the overall condition was high. Of the 17 sites to record a very high overall condition rating in the Daly River catchment, 2 of these were located within the Katherine River sub-catchment.

River instability problems were confined to moderate bed aggradation along an upper section of Katherine River (below Centipede Dreaming Gorge) and lower Birdie Creek. River banks were stable. Disturbances ranged widely over the sub-catchment, although high flows and grazing activities (including feral animals) were the major factors identified as affecting bank and bed/bar stability, respectively. Control of feral animals, particularly within National Park areas, would be beneficial to the stability of the rivers and creeks. Instream siltation was also identified as a bed stability issue affecting nearly half the reaches along the upper sections of the Katherine River.

Only 3 sites in Daly River catchment rated a moderate modification to their reach environs, and 2 of these were located on the Katherine River near the urban area. Other rural areas along the Katherine River near the township that recorded more diverse land uses and types of disturbances to elsewhere in the Daly River catchment also rated some modification to their reach environs. These results reflect the more intensive and diverse use of land and, as a result, more disturbances likely to impact on rivers, around a major population centre like Katherine.

The riparian vegetation throughout Katherine River sub-catchment rated similarly and reflected the diversity and density of the structural types. The riparian vegetation along several of the upper sections of the Katherine River and a reach downstream of Katherine was relatively denser and therefore rated more highly than other sections which rated moderately. The diversity of structural types was similar along the reaches and was dominated by overstorey vegetation. Invasion of the riparian zone by exotic species was occurring at the majority of sites although covers were generally low and less than one-third of sites recorded the presence of noxious species. The occurrence of the noxious species *Hyptis suaveolens* in the more remote upper sub-catchment areas could indicate their spread is assisted by motor vehicles.

The cover and diversity of instream and bank habitats generally reflected the diversity of the instream habitats (eg logs, branches, leaves, aquatic vegetation, *etc*) rather than their covers, which were predominantly <10%, except for permanent pools and rock faces. The 7 reaches that rated below average channel type diversity was due to the fact that one habitat dominated the reach extensively and that riffles (or non-pool habitats) made up <10% of the reach.

5.14 Limestone Creek

Sub-section 20 includes the catchment area of Limestone and Scott Creeks. Three sites have been fully assessed in this sub-section, of which 2 are located on Limestone Creek and 1 on Scott Creek.

5.14.1 Results

♦ *Reach Environs and Site Features*

Sites were rated as having reach environs that were essentially natural (67% of sites) or had some modification (33%). Subjective disturbance ratings indicated that sites had moderate levels of disturbance along the reach environs (100% of sites).

Land tenure was freehold or leasehold at all sites. Grazing was the major land use and occurred on thinned native pastures (100% of sites), cleared native pastures (33%) and improved pastures (33%). The major disturbances likely to affect stream reaches were grazing (100% of sites), roads/tracks (67%) or bridge/culverts (33%). The major floodplain features recorded at 67% of sites were floodplain scours and prominent flood channels.

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 165m (range 51-338m). Pools and riffles were present at all sites, although pools dominated the reach lengths, averaging 67%. The channel type diversity rating in this sub-section was high (100% of sites). The creeks had either isolated pools (67% of sites) or were dry at the time of sampling (33%).

Table 5.71 presents the mean dimensions for the pool and riffle habitats. Pools were three times deeper than riffles but recorded similar widths. The width:depth ratio for riffles was very high. Riffles had wider and taller upper banks compared to pools, though slopes were similar. Banks were mostly moderate in slope and convex-shaped.

♦ *Bank Condition and Stability*

The reaches assessed in this sub-section were rated as having stable banks (100% of sites). Subjective ratings indicated that the overall bank instability and susceptibility of banks to further erosion ranged from low to moderate.

Table 5.71 Channel Dimensions for Habitat Types

Dimension		Pool	Riffle
Reach Covered (%)		67.3 (51-83)	32.7 (17-49)
Mean Length (m)		63.0 (13-140)	19.7 (13-29)
Mean Depth (m)**		1.2 (0.9-1.6)	0.4 (0.1-1.0)
Mean Width (m)**		10.5 (10.0-11.0)	10.6 (9.0-13.5)
Width:Depth Ratio		9.6 (6.1-12.9)	68.1 (9.4-135.0)
♦LB:	Width (m)	1.5 (0.3-4.2)	-
	Height (m)	1.0 (0.4-1.5)	-
	Slope (°)	43.3 (19.7-61.9)	-
∗UB:	Width (m)	8.5 (4.0-24.0)	15.8 (4.0-52.0)
	Height (m)	3.4 (2.0-6.0)	4.6 (2.0-9.0)
	Slope (°)	25.2 (14.0-30.1)	22.6 (9.5-32.0)

♦LB = Lower Bank ∗UB = Upper Bank
** Measured from the water mark.

Erosion was the dominant bank process recorded at all sites. The erosion was mostly occurring along inside bends (100% of sites) and seepage and runoff points (67%), although some erosion was recorded at obstacles, floodplain scours/breakout points and irregularly. The lower banks were slightly more stable than the upper banks, with 10% (range 5-15%) of the bank length recorded as eroding. The upper banks, on the other hand, recorded erosion along an average of 16% (range 8-25%) of the bank length. No aggradation along the banks was recorded.

The major factors identified as affecting bank stability at all sites were runoff and stock. Other factors included clearing (67% of sites) and roads/bridges/crossings (33%).

♦ *Bed and Bar Condition and Stability*

The reaches assessed in this sub-section were subjectively rated as having stable beds (100% of sites).

Sand and gravel bars were present at all sites, occurring as point bars. The mean size of the bars was low, averaging 7% of the bed surface above water mark (range 5-10%). The gravel forming the bed and bars was disc-shaped and contained sub-angular or rounded material. Bed compaction was either moderate or packed.

The major factors identified as affecting bed stability was agriculture/grazing (67% of sites) or bank erosion (33%). Rock outcrops (67% of sites) and fallen trees (33%) provided a degree of bed stabilising influence.

♦ *Bed and Bank Sediments*

The bed and bank material at pool habitats was predominantly sand and gravel, while the upper banks consisted mostly of fines/clays and small sand. Large gravel, cobbles and boulders dominated the bed material at riffle habitats, while the banks consisted mostly of fines, with some larger material present as well. Organic matter was present in both bed and banks of habitat types and ranged from 7-9%. Rock outcrops were recorded at 67% of sites and were located mostly in the bed.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having moderate cover and structural diversity at all sites. The vegetation type recorded was vegetation associated with freshwater streams (100% of sites). The mean width of the riparian vegetation zone was 13m (range 4-40m), with 33% of sites recording riparian zone widths of <5m, 67% between 5-10m, 33% between 11-20m and 33% between 31-40m.

The structural types recorded are shown in Table 5.72. There were 7 of the 13 structural types present at all sites. Covers ranged from 0-65%. The highest mean cover was 28% and was recorded for grasses. Medium-sized trees (10-30m tall) dominated the overstorey vegetation and recorded a mean cover of 18%.

Table 5.72 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	0	0
Trees (10-30m)	100	17.5 (10-35)
Trees (2-10m)	100	9.2 (5-15)
Regen. Trees (<2m)	100	4.3 (3-5)
Woody Shrubs (<2m)	100	4.3 (4-5)
Vines	100*	4.8 (3-6)
Rushes and Sedges	0	0
Phragmites	0	0
Forbs (or Herbs)	100*	9.2 (4-15)
Grasses	100	28.3 (15-65)
Ferns	0	0
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

Understorey vegetation provided a greater cover than overstorey vegetation. The upper bank recorded an average of 70% bare (range 30-85%) for understorey vegetation cover compared to 76% bare (range 50-87%) for the overstorey vegetation.

Exotic vegetation, including noxious species, was recorded at all sites. Overall, the mean total cover of exotic species in the riparian zone was 7% (range 4-14%). Most sites (67%) rated a moderate level of invasion by exotics (6-10% cover), while 33% rated a low level of disturbance (1-5% cover). Structural types included vines and forbs. Noxious species recorded were *Hyptis suaveolens* (100% of sites), *Xanthium occidentale* (33%) and *Sida acuta* (33%). The covers provided by these noxious species ranged from 1-8%. *Passiflora foetida*, an exotic vine, was also recorded at all sites.

♦ *Aquatic Vegetation*

Aquatic vegetation was recorded at only 33% of sites, in the form of submerged vegetation. The species recorded was *Chara sp.* (4% cover).

♦ *Instream and Bank Habitats*

The rating for the cover and diversity of instream and bank habitats ranged from high (33% of sites), moderate (34%) to low (33%). Subjectively, the overall aquatic habitat condition was rated as poor (67% of sites) or poor to good (33%).

Six instream habitat types were recorded. The types listed for all sites were individual branches, individual logs, leaves/twigs and rocks. Other types recorded were individual logs, log jams and algal clumps. There were no permanent pools deeper than 1m. The covers provided by these habitat types was generally <10%, although rock faces provided a mean cover of 18% (range 10-25%) and leaves/ twigs provided a mean cover of 12% (range 10-15%). Two different types of overhanging bank cover were recorded at all sites. Vegetation canopy cover occurred along 33% of the bank and had a mean width of 1.9m. Vegetation overhang occurred along 8% of the bank and had a mean width of 0.7m. Some root and bank overhang was also recorded.

At water mark, 33% of sites would have good passage for fish and other aquatic organisms, 33% would be moderately restricted and 33% would be very restricted.

♦ *Overall Condition*

The overall condition rating for all sites assessed in this sub-section was high.

5.14.2 Discussion

The general condition of most attributes examined was similar and resulted in a high overall condition rating.

All reaches were located on freehold or leasehold land and had essentially natural or some modification to the reach environs, even though these reach environs were subjectively rated as having moderate levels of disturbance. Grazing activity was identified as the major disturbance likely to affect all reaches (along with roads) and river banks (along with runoff and clearing), and the majority of river beds. River banks and beds were rated as stable throughout the sub-section though.

Even though only two habitat types, pools and riffles, were recorded throughout the sub-section, a higher proportion of the reach was comprised of riffles and as a result all sites rated a high diversity of habitat types. Instream habitat types (eg logs, branches, *etc*) were not particularly diverse and covers were generally low. Canopy cover along the banks was relatively poor, averaging only one-third of the bank length. As a result, a site on Limestone Creek was one of only 2 throughout the Daly River catchment to record a low cover and diversity rating for instream and bank habitats (the worst rating for this attribute in the catchment).

The riparian zone was relatively narrow for those reaches furthest from the Katherine River junction. Grasses dominated the structural categories. All other structural types each provided <10% cover. A moderate riparian vegetation rating reflected the lack of diversity and cover provided by the majority of structural types. All sites recorded the presence of exotic species, with two reaches recording moderate levels of invasion (6-10% cover). *Hyptis suaveolens* and *Passiflora foetida* were present at all sites. Other problematic species, present at one-third of sites, included *Xanthium occidentale* (Noogoora Burr) and *Sida acuta*. An exotic/noxious species that was not collected as part of this survey, but is known by DPI&F to be present on Limestone Creek, is *Mimosa pigra*. Aquatic vegetation was only present at one third of sites and covers were low.

Low cover & diversity of instream & bank habitats; very narrow riparian vegetation (Site 20/2: Limestone Creek)

5.15 King and Dry Rivers

This sub-catchment includes King River (below and above Dry River), Dry River and Durrinyan Creek sub-sections.

5.15.1 Results

5.15.1.1 King River – below Dry River

Sub-section 21a includes the catchment area of King River, downstream of the junction with Dry River. Of the 4 sites within this sub-section, 3 sites have been fully assessed and are located on King River.

- *Reach Environs and Site Features*

All sites were rated as having essentially natural reach environs. Subjective disturbance ratings indicated that sites had low levels of disturbance along the reach environs (75% of sites) or moderate levels (25%).

Land tenure was freehold or leasehold at all sites. Grazing was the major land use and occurred on thinned native pastures (100% of sites) and virgin timbered native pastures (75%). The major disturbances likely to affect stream reaches were grazing (100% of sites), roads/tracks (100%), causeways/crossings (75%) or bridge/culverts (25%). The major floodplain features recorded at 50% of sites were prominent flood channels and floodplain scours.

- *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 238m (range 101-435m). Pools and riffles were present at all sites, though pools dominated the reach lengths, averaging 61%. The channel type diversity rating in this sub-section was high (100% of sites). The creeks were dry at the time of sampling (75% of sites) or had isolated pools (25%).

Table 5.73 presents the mean dimensions for the pool and riffle habitats. Pools, on average, were three times deeper than riffles but recorded similar widths. The width:depth ratio was much higher for riffles than for pools. Riffles had slightly wider and taller upper banks compared to pools, though slopes were similar. Banks along the reaches were mostly moderate in slope and convex-shaped.

Table 5.73 Channel Dimensions for Habitat Types

Dimension		Pool	Riffle
Reach Covered (%)		60.7 (26-84)	39.3 (16-74)
Mean Length (m)		75.7 (37-115)	116.0 (14-320)
Mean Depth (m)**		2.1 (1.5-3.2)	0.7 (0.2-1.0)
Mean Width (m)**		15.0 (11.3-16.9)	15.3 (13.0-19.0)
Width:Depth Ratio		8.7 (4-11)	49.7 (13-119)
♦LB:	Width (m)	2.4 (1.0-3.8)	-
	Height (m)	2.2 (-)	-
	Slope (°)	47.8 (30.1-65.6)	-
∗UB:	Width (m)	9.1 (3.3-18.0)	12.9 (5.0-20.0)
	Height (m)	3.2 (1.7-6.5)	3.6 (1.6-6.0)
	Slope (°)	24.7 (8.8-47.3)	20.1 (4.7-38.2)

♦LB = Lower Bank ∗UB = Upper Bank
** Measured from the water mark.

♦ *Bank Condition and Stability*

The reaches assessed in this sub-section were rated as having stable banks (100% of sites). Subjective ratings indicated that the overall bank instability was low (100% of sites), low to moderate (33%) or moderate (33%). The susceptibility of banks to further erosion was subjectively rated as low (100% of sites) or low to moderate (67%).

Erosion was the dominant bank process recorded at all sites. The erosion was mostly occurring along outside bends and at obstacles (67% of sites). The lower banks were slightly more stable than the upper banks, with 12% (range 6-20%) of the bank length recorded as eroding. The upper banks, on the other hand, recorded erosion along an average of 16% (range 10-25%) of the bank length. No aggradation along the banks was recorded.

The major factors identified as affecting bank stability at all sites were stock and roads/bridges/ crossings. Other factors included high flow (67% of sites) and runoff points (33%).

♦ *Bed and Bar Condition and Stability*

The reaches assessed in this sub-section were subjectively rated as having stable beds (100% of sites).

Sand and gravel bars were present at 67% of sites, occurring as either bars with encroaching vegetation or point bars. The mean size of the bars averaged 17% of the bed surface above water mark (range 15-18%). The gravel forming the bed and bars was mostly disc-shaped and contained sub-angular or angular material. Bed compaction was either moderate or packed.

The major factor identified as affecting bed stability was agriculture/grazing (67% of sites). Rock outcrops (33% of sites) and fallen trees (67%) provided a degree of bed stabilising influence.

♦ *Bed and Bank Sediments*

The bed and bank material at pool habitats was predominantly fines/clays and sand, although boulders made up 33% of the bed material. Cobbles and boulders dominated the bed material at riffle habitats, while the banks consisted mostly of fines and sand, with a small percentage of boulder material. Organic matter was present in both bed and banks of habitat types and ranged from 7-9%. All sites had rock outcrops.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having moderate cover and structural diversity at all sites. The vegetation type recorded was vegetation associated with freshwater streams (100% of sites). The mean width of the riparian vegetation zone was 16m (range 8-26m), with 33% of sites recording riparian zone widths of between 5-10m, 33% between 11-20m and 67% between 21-30m.

The structural types recorded are shown in Table 5.74. There were 7 of the 13 structural types present at all sites. Covers ranged from 0-50%. The highest mean cover was 45% and was recorded for grasses. Medium-sized trees dominated the overstorey vegetation and recorded a mean cover of 21%.

Understorey vegetation provided a greater cover than overstorey vegetation. The upper bank recorded an average of 53% bare (range 50-60%) for understorey vegetation cover compared to 69% bare (range 60-85%) for the overstorey vegetation.

Exotic vegetation was recorded at 67% of sites. There were no noxious species recorded. The mean total cover of exotic species in the riparian zone was generally low, averaging 4% (range 0-7%), though one site rated a moderate level of weed invasion (6-10% cover). The only structural type present was vines in the form of *Passiflora foetida*.

♦ *Aquatic Vegetation*

Aquatic vegetation was recorded at 67% of sites, in the form of emergent vegetation. It had a mean cover of 10% (range 5-15%). The structural types present were Pandanus (67% of sites) and other shrubs/trees (namely *Casuarina cunninhamiana*), present at 33% of sites.

Table 5.74 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	0	0
Trees (10-30m)	100	21.0 (15-28)
Trees (2-10m)	100	15.0 (10-22)
Regen. Trees (<2m)	100	4.8 (4-5)
Woody Shrubs (<2m)	100	4.8 (4-8)
Vines	100*	11.0 (5-15)
Rushes and Sedges	0	0
Phragmites	0	0
Forbs (or Herbs)	100	4.7 (4-5)
Grasses	100	45.0 (40-50)
Ferns	0	0
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

♦ *Instream and Bank Habitats*

The cover and diversity of instream and bank habitats was rated as either moderate (67% of sites) or high (33%). Subjectively, the overall aquatic habitat condition was rated as poor to good (67% of sites) or poor (33%).

Eight instream habitat types were recorded. The major types listed were individual branches, individual logs, leaves/twigs, rocks and log jams. The covers provided by these habitat types was generally <10%, although rock faces provided a mean cover of 58% (range 4-90%).

Three different types of overhanging bank cover were recorded at all sites. Vegetation canopy cover occurred along 43% of the bank and had a mean width of 2.6m. Vegetation overhang occurred along 13% of the bank and had a mean width of 1.5m. Some root and bank overhang was also recorded.

At water mark, 67% of sites would have partly restricted passage for fish and other aquatic organisms, and 33% would be moderately restricted.

♦ *Overall Condition*

The overall condition rating for all sites assessed in this sub-section was high.

Moderate riparian vegetation; high instream & bank habitat rating; stable channel (Site 21a/3, King River)

5.15.1.2 King River – above Dry River

Sub-section 21b includes the catchment area of King River, upstream of the junction with Dry River. Of the 3 sites located on King River within this sub-section, 2 sites have been fully assessed.

♦ *Reach Environs and Site Features*

All sites were rated as having essentially natural reach environs. Subjective disturbance ratings indicated that sites had low levels of disturbance along the reach environs (50% of sites) or low to moderate levels (50%).

Land tenure was freehold or leasehold at all sites. Grazing was the major land use and occurred on thinned native pastures (100% of sites) and virgin timbered native pastures (100%). The major disturbances likely to affect stream reaches were grazing (100% of sites), roads/tracks (100%), causeways/crossings (50%) or bridge/culverts (50%). The major floodplain features recorded at 50% of sites were floodplain scours.

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 94m (range 58-130m). Pools and riffles were present at all sites, though pools dominated the reach lengths, averaging 62%. The channel type diversity rating in this sub-section was high (100% of sites). The creeks were dry at the time of sampling.

Table 5.75 presents the mean dimensions for the pool and riffle habitats. Pools were shallow, averaging only 0.4m deep. Riffles averaged only 0.2m deep. Pools were slightly wider than riffles and recorded a lower width:depth ratio. Upper banks were quite narrow and low, with low-moderate slopes. Banks along the reaches were mostly moderate in slope and convex-shaped.

Table 5.75 Channel Dimensions for Habitat Types

Dimension	Pool	Riffle
Reach Covered (%)	61.5 (50-73)	38.5 (27-50)
Mean Length (m)	38.5 (29-48)	16.0 (14-18)
Mean Depth (m)**	0.4 (0.35-0.4)	0.2 (0.1-0.3)
Mean Width (m)**	8.0 (6.0-10.0)	5.2 (5.0-5.3)
Width:Depth Ratio	21.8 (15-29)	34.8 (20-50)
∗UB: Width (m)	3.9 (2.2-5.2)	5.2 (3.0-7.3)
Height (m)	1.9 (1.4-2.4)	2.6 (2.1-3.0)
Slope (°)	28.5 (15.1-47.5)	28.3 (19.5-36.9)

∗UB = Upper Bank ** Measured from the water mark.

♦ *Bank Condition and Stability*

The reaches assessed in this sub-section were rated as having stable banks (100% of sites). Subjective ratings indicated that the overall bank instability and susceptibility of banks to further erosion was low to moderate (100% of sites) or low (50%).

Erosion was the dominant bank process recorded at all sites. The erosion was mostly occurring at obstacles (100% of sites), along outside bends (50%), at breakout points (50%) or irregularly (50%). The lower banks were stable, with 5% (range 4-8%) of the bank length recorded as eroding. The upper banks, on the other hand, recorded erosion along an average of 14% (range 8-20%) of the bank length. Some aggradation was recorded along inside bends.

The major factors identified as affecting bank stability at all sites were stock, high flow, floodplain scours and roads/bridges/crossings.

♦ *Bed and Bar Condition and Stability*

The reaches assessed in this sub-section were subjectively rated as having stable beds (50% of sites) or moderately aggrading beds (50%).

Sand and gravel bars were present at all sites, occurring as either alternate bars or point bars. The mean size of the bars was low, averaging 4% of the bed surface above water mark. The gravel forming the bed and bars was mostly disc-shaped or sphere-shaped and contained sub-angular or angular material. Bed compaction was either moderate (100% of sites) or low (50%).

The only factor identified as affecting bed stability was instream siltation (50% of sites). No factors were recorded at 50% of sites. There were no bed stabilising influences, such as rocks, recorded.

♦ *Bed and Bank Sediments*

The bed material at pool habitats was predominantly sand, while the banks were composed mostly of fines/clays and small sand. Sand and boulders dominated the bed material at riffle habitats, while the banks consisted mostly of fines, sand and boulders. Organic matter was present in both bed and banks of habitat types and ranged from 5-17%. Rock outcrops were recorded in the bed and banks.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having moderate cover and structural diversity at all sites. The vegetation type recorded was vegetation associated with freshwater streams (100% of sites). The mean width of the riparian vegetation zone was 9m (range 6.5-11m), with 100% of sites recording riparian zone widths of between 5-10m and 50% between 11-20m.

The structural types recorded are shown in Table 5.76. There were 7 of the 13 structural types present at all sites. Covers ranged from 0-60%. The highest mean cover was 50% and was recorded for grasses. Medium-sized trees dominated the overstorey vegetation and recorded a mean cover of 22%.

Table 5.76 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	0	0
Trees (10-30m)	100	22.0 (18-25)
Trees (2-10m)	100	12.8 (8-18)
Regen. Trees (<2m)	100	4.8 (4-5)
Woody Shrubs (<2m)	100	4.3 (4-5)
Vines	100*	6.8 (4-10)
Rushes and Sedges	0	0
Phragmites	0	0
Forbs (or Herbs)	100	4.0 (-)
Grasses	100	50.0 (30-60)
Ferns	0	0
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

Understorey vegetation provided a much greater cover than overstorey vegetation. The upper bank recorded an average of 50% bare (range 40-70%) for understorey vegetation cover compared to 76% bare (range 72-78%) for the overstorey vegetation.

Exotic vegetation was recorded at all sites. There were no noxious species recorded. The mean total cover of exotic species in the riparian zone was low, averaging 5% (range of 4-5%) and, therefore, the sites rated a low level of invasion by exotic species (1-5% cover). The only structural type present was a vine, in the form of *Passiflora foetida*.

♦ *Aquatic Vegetation*

There was no aquatic vegetation recorded at sites assessed within this sub-section.

♦ *Instream and Bank Habitats*

The cover and diversity of instream and bank habitats was rated as either high (50% of sites) or moderate (50%). Subjectively, the overall aquatic habitat condition was rated as poor (100% of sites).

Six instream habitat types were recorded. The major types listed were individual branches, individual logs, leaves/twigs and rocks. The covers provided by these habitat types was generally <10%, although leaves/twigs provided a mean cover of 25%.

Three different types of overhanging bank cover were recorded at all sites. Vegetation canopy cover occurred along 64% of the bank and had a mean width of 3.4m. Vegetation overhang occurred along 18% of the bank and had a mean width of 0.9m. Some root and bank overhang was also recorded.

At water mark, 50% of sites would have partly restricted passage for fish and other aquatic organisms, and 50% would be very restricted.

♦ *Overall Condition*

The overall condition rating for all sites assessed in this sub-section was high.

Moderate bed aggradation (Site 21b/1: King River)

5.15.1.3 Dry River

Sub-section 22 includes the catchment area of Dry River. Three sites, located on Dry River, have been fully assessed within this sub-section.

♦ *Reach Environs and Site Features*

Sites were rated as having reach environs that had some modification (67% of sites) or were essentially natural (33%). Subjective disturbance ratings indicated that sites had either low levels of disturbance along the reach environs (67% of sites) or low to moderate levels (33%).

Land tenure was freehold or leasehold at all sites. Grazing was the major land use and occurred on thinned native pastures (100% of sites) and virgin timbered native pastures (67%).

The major disturbances likely to affect stream reaches were grazing (100% of sites), roads/tracks (67%), causeways/crossings (67%) and watering point for stock/ferals (33%). The major floodplain features recorded were billabongs (67% of sites) and prominent flood channels (33%).

♦ *Channel Habitat Types, Diversity and Dimensions*

The mean reach length studied was 112m (range 79-149m). Pools were present at all sites, and also dominated the reach lengths, averaging 63%. Other habitat types present included riffles (67% of sites) and runs (33% of sites). The channel type diversity rating in this sub-section was high (100% of sites). The creeks were dry at the time of sampling.

Table 5.77 presents the mean dimensions for the pool and riffle habitats. Pools, although relatively shallow at 0.8m deep, were deeper and wider than riffles. Both habitats recorded a moderate width:depth ratio. Upper banks were quite narrow and low, with low-moderate slopes. Banks along the reaches had either moderate or steep slopes and were convex-shaped.

Table 5.77 Channel Dimensions for Habitat Types

Dimension		Pool	Riffle
Reach Covered (%)		63.0 (57-75)	43.0 (-)
Mean Length (m)		56.7 (40-85)	49.0 (34-64)
Mean Depth (m)**		0.8 (0.7-0.9)	0.5 (0.4-0.6)
Mean Width (m)**		9.3 (6.7-12.0)	6.7 (4.8-8.6)
Width:Depth Ratio		11.1 (10-13)	15.0 (8-22)
∗UB:	Width (m)	5.3 (2.5-11.0)	5.0 (2.6-9.5)
	Height (m)	2.6 (1.2-3.6)	2.4 (1.4-3.1)
	Slope (^{o})	29.4 (16.2-40.0)	28.7 (16.4-41.5

∗UB = Upper Bank ** Measured from the water mark.

♦ *Bank Condition and Stability*

The reaches assessed in this sub-section were rated as having stable banks (100% of sites). Subjective ratings indicated that the overall bank instability and susceptibility of banks to further erosion was low (100% of sites) or low to moderate (33%).

Erosion was the dominant bank process recorded at all sites. The erosion was mostly occurring at obstacles (100% of sites), along outside bends (100%) or irregularly (67%). The lower banks were stable, with 6% (range 5-10%) of the bank length recorded as eroding. The upper banks, on the other hand, recorded erosion along an average of 10% (range 8-18%) of the bank length. No aggradation was recorded along the banks.

The major factors identified as affecting bank stability at all sites was high flow. Other more minor factors were roads/bridges/crossings, runoff and stock.

♦ *Bed and Bar Condition and Stability*

The reaches assessed in this sub-section were subjectively rated as having stable beds (100% of sites). There were no sand and gravel bars present at any of the sites. The gravel forming the bed was mostly sphere-shaped or disc-shaped and contained sub-angular or angular material. Bed compaction was either low (100% of sites), moderate (33%) or packed (33%).

At 67% of sites there were no factors identified as affecting bed stability, although agriculture/grazing was recorded as a minor factor at 33% of sites. Fallen trees (67% of sites) and rock outcrops (33%) provided a degree of bed stabilising influence.

♦ *Bed and Bank Sediments*

The bed and bank material at pool and run habitats was predominantly fines/clays and sand. The riffle had a bed that comprised the full range of sediment sizes, from fines through to boulders, while the banks were mostly fines and small sand. Organic matter was present in both bed and banks of habitat types and ranged from 9-22%. Rock outcrops were recorded in the bed and banks at 67% of sites.

♦ *Riparian Vegetation*

The riparian vegetation was rated as having moderate cover and structural diversity at all sites. The vegetation type recorded was vegetation associated with freshwater streams. The mean width of the riparian vegetation was 8m (range 5-13m), with 67% of sites recording riparian widths of between 5-10m and 33% between 11-20m.

The structural types recorded are shown in Table 5.78. There were 7 of the 13 structural types present at all sites. Covers ranged from 0-65%. The highest mean cover was 46% and was recorded for grasses. Medium-sized trees dominated the overstorey vegetation (25% cover).

Table 5.78 Structural Categories Present in the Riparian Zone and Cover for all Vegetation (Native and Exotic)

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (>30m)	0	0
Trees (10-30m)	100	24.8 (22-30)
Trees (2-10m)	100	15.5 (12-18)
Regen. Trees (<2m)	100	5.8 (5-10)
Woody Shrubs (<2m)	100	4.8 (4-5)
Vines	100*	5.5 (4-10)
Rushes and Sedges	0	0
Phragmites	0	0
Forbs (or Herbs)	100*	4.7 (4-5)
Grasses	100	45.8 (25-65)
Ferns	0	0
Mangroves	0	0
Salt Marsh	0	0
Palms	0	0

* Contains exotic species

Understorey vegetation provided a much greater cover than overstorey vegetation. The upper bank recorded an average of 54% bare (range 35-75%) for understorey vegetation cover compared to 73% bare (range 70-75%) for the overstorey vegetation.

Exotic vegetation was present at 33% of sites. There were no noxious species recorded. The site that recorded exotic species was rated as having a low level of invasion (1-5% cover). Overall, the mean total cover of exotic species in the riparian zone was very low, averaging 1% (range 0-6%). The structural types present were vines and forbs. The exotic species recorded were *Passiflora foetida* and *Melochia pyramidata.*

♦ *Aquatic Vegetation*

There was no aquatic vegetation recorded at sites assessed within this sub-section.

♦ *Instream and Bank Habitats*

The cover and diversity of instream and bank habitats was rated as moderate at all sites. Subjectively, the overall aquatic habitat condition was rated as poor (100% of sites).

Seven instream habitat types were recorded. The major types listed were individual branches, individual logs, branch piles, log jams, leaves/twigs and rocks. The covers provided by these habitat types was generally <10%, although leaves/twigs provided a mean cover of 25% (range 15-30%).

Three different types of overhanging bank cover were recorded at all sites. Vegetation canopy cover occurred along 71% of the bank and had a mean width of 3.2m. Vegetation and root overhang occurred along 8% of the bank and had a mean width of 0.9m and 0.2m respectively.

At water mark, all sites would have partly restricted passage for fish and other aquatic organisms.

♦ *Overall Condition*

The overall condition rating for sites assessed in this sub-section was either high (67% of sites) or very high (33%).

Very high overall condition (Site 22/2: Dry River)

5.15.1.4 Durrinyan Creek

Sub-section 23 includes the catchment area of Durrinyan Creek. Of the 2 sites located in this sub-section, 1 site was fully assessed.

♦ *Reach Environs and Site Features*

The site was rated as having some modification to the reach environs. Subjective disturbance ratings indicated that the site assessed had low to moderate levels of disturbance.

Both sites had land tenure that was freehold or leasehold. Grazing was the major land use and occurred predominantly on thinned native pastures or virgin timbered native pastures. Grazing and a watering point for stock/ferals were identified as the major disturbances likely to affect stream reaches.

♦ *Channel Habitat Types, Diversity and Dimensions*

The reach length studied was 205m. Pools and runs were recorded at the site studied. Pools were the dominant habitat type, taking up 63% of the reach length. The habitat type diversity rating for the site studied was high. The bed was dry at the time of sampling.

Table 5.79 presents the dimensions for the pool and run habitats recorded at one site. The pool sampled was the largest in the area, although it did not maintain water throughout the dry season. As a result, the pool was much wider, deeper and longer compared to the run habitat. The banks for both habitats were similar in height and width and were moderate in slope and convex in shape.

Table 5.79 Channel Dimensions for Habitat Types

Dimension	Pool	Run
Reach Covered (%)	63.0	37.0
Mean Length (m)	130.0	75.0
Mean Depth (m)**	1.4	0.4
Mean Width (m)**	20.8	4.5
Width:Depth Ratio	14.9	11.3
∗UB: Width (m)	3.3 (3.0-3.5)	3.0 (1.0-5.0)
Height (m)	1.2 (1.1-1.2)	1.2 (0.8-1.5)
Slope (°)	19.6 (18-22)	27.7 (17-39)

∗UB = Upper Bank ** Measured from the water mark.

♦ *Bank Condition and Stability*

The site assessed in this sub-section was rated as having stable banks. Subjectively, the overall bank instability and the susceptibility of banks to further erosion were rated as low to moderate. The major factors identified as affecting bank stability were high flow, runoff, stock and vermin.

Erosion was the dominant bank process recorded. The erosion was predominantly occurring along outside bends, irregularly, at obstacles or seepage/ runoff points. The lower bank was more stable than the upper banks, with 91% of the lower bank recorded as stable, compared to 82% for the upper bank. No aggradation along the banks was recorded.

♦ *Bed and Bar Condition and Stability*

The site assessed in this sub-section was subjectively rated as having a stable bed. The major factor identified as affecting bed stability was agriculture/grazing. No sand and gravel bars were present at this site. The gravel forming the bed was sphere-shaped and angular. Bed compaction was low.

♦ *Bed and Bank Sediments*

The bed and bank material at the pool habitat was predominantly fines/clays. The bed material at the riffle habitat was predominantly fines/clays, sand and small gravel, whereas the bank material was mostly fines/clays. Organic matter was present in both bed and banks and ranged from 7-8%. No rock outcrops were recorded.

♦ *Riparian Vegetation*

The riparian vegetation at this site was rated as having moderate cover and structural diversity. The riparian vegetation zone was very narrow, averaging 5m. As a result the riparian zone width category recorded for this site was 5-10m.

The structural types recorded included trees 2-30m, regenerating trees, shrubs, herbs and grasses. Covers ranged from 0-40%. The highest cover (38%) was recorded for grasses. Medium-sized trees (10-30m) and small trees (2-10m) dominated the overstorey component and recorded covers of 25% and 15% respectively. The remaining covers where <10%.

Understorey vegetation provided greater cover. The upper bank recorded an average of 63% bare for understorey vegetation cover compared to 72% bare for the overstorey. No exotic species were recorded and as a result the site rated very highly.

♦ *Aquatic Vegetation*

There was no aquatic vegetation recorded at the site assessed within this sub-section.

♦ *Instream and Bank Habitats*

The cover and diversity of instream and bank habitats was rated as moderate. Subjectively, the site was rated as having a poor to good overall aquatic condition. At water mark, the site would have a partly restricted passage for fish and other aquatic organisms.

Four instream habitat types were recorded. They included individual branches, individual logs, leaves/twigs and branch piles. There were no permanent pools deeper than 1m recorded. The cover provided by these habitat types was generally 10% or less, though leaves/twigs provided 25% cover.

Three different types of overhanging bank cover were recorded. Vegetation canopy cover occurred along 75% of the bank, with a mean width of 5.0m. Vegetation and root overhang occurred along 7% of the bank and had a width of 2.5m and 0.3m respectively.

♦ *Overall Condition*

The overall condition rating for the site assessed in this sub-section was high.

Large dry pool on Durrinyan Creek (Site 23/2)

5.15.1.5 Comparison of King and Dry River Sub-sections

The *reach environs* along King River and a section on Dry River were rated as being essentially natural, while other sections on Durrinyan Creek and Dry River were somewhat modified. All sites were located on freehold or leasehold land and grazing was the main landuse. Grazing activity, and to a lesser extent, roads/tracks and causeways/crossings, were identified as the major disturbances likely to affect the majority of reaches.

Channel type diversity was high for all reaches. In most cases only 2 habitat types were recorded along a reach, although the proportion of pools versus riffle-type habitats was more even, with pools occupying around 62% of the reach length. The river beds were dry along the majority of reaches at the time of sampling.

Bank stability – all reaches were rated as having stable banks. Some bank erosion, particularly along the upper banks, was occurring along all reaches though, averaging between 5-18% of the bank length. High flow, stock and roads/bridges/crossings were identified as the major factors affecting bank stability within the sub-sections.

Bed and bar stability – all reaches had stable beds, except for a site located on King River. This site was subjectively assessed as moderately aggrading and instream siltation was identified as affecting bed stability. Severe erosion of a creek crossing and gully erosion along an access track were also causing localised problems at this site. Bars were only recorded along King River and were moderate in size, averaging 17%, downstream of Dry River junction. Grazing activity was identified as affecting bed and bar stability at nearly half the reaches.

The *riparian vegetation* was rated as having moderate cover and structural diversity along all reaches. Grasses dominated the vegetation structural types, averaging between 38-50% cover. The higher proportion of grasses corresponded to a lower tree cover. Trees (2-10m and 10-30m tall) each averaged between 13-25% cover. The remaining structural types each recorded <10% cover. Sections along King River and lower Dry River recorded wider riparian zones (11-30m wide) than did other reaches that recorded widths between 5 and 10m.

Exotic vegetation was located along half the reaches. Where present, the cover recorded for exotic species was low and, therefore, these sites were rated as having a low level of invasion (1-5% cover), although a reach on King River rated a moderate level (6-10% cover). *Passiflora foetida* was the predominant exotic species recorded. No noxious species were recorded.

Only 2 reaches along lower King River recorded the presence of *aquatic vegetation* in the form of emergents. Covers were relatively low, averaging 10%. No submerged or floating aquatic vegetation was recorded.

The cover and diversity of *instream and bank habitats* was rated as either moderate and to a lesser extent high. Instream habitat types were somewhat diverse, although the covers were generally <10%, except for leaves/twigs and, occasionally, rock faces. Canopy cover along the banks was better along upper King River, Dry River and Durrinyan Creek, averaging 64-75% of the bank length, than along lower King River, which averaged 43% of the bank length.

The *overall condition* rating for reaches throughout the sub-catchment was predominantly high, although a reach on Dry River rated very highly.

5.15.2 Discussion

The general condition of most attributes examined was similar for all reaches resulting in a high, or in one instance, a very high overall condition rating. The reach on Dry River that rated very highly overall was one of 17 throughout the Daly River catchment to do so.

All reaches were rated as stable, except for a site on King River which was moderately aggrading and was also experiencing localised problems due to an eroding creek crossing and access track. Poor maintenance of river crossings and tracks can influence the condition of creeks at a local scale, as was shown in this instance.

Reach environs were essentially natural, except for sections on Durrinyan Creek and Dry River, which were somewhat modified. Channel type diversity was high due to a higher proportion of the reach being taken up with riffles or runs versus pool habitats. The condition rating for both instream and bank habitats and riparian vegetation was predominantly moderate and tended to reflect the low covers and in some instances the lack of diversity for many of the instream habitat types and vegetation structural types. Exotic riparian vegetation was not particularly a problem as the cover for *Passiflora foetida*, the most widespread exotic species, was generally low. No noxious species were recorded. Aquatic vegetation was very limited in its distribution, possibly due to the ephemeral nature of the streams.

5.16 Seventeen Mile Creek

5.16.1 Results

Sub-section 24 includes the catchment area of Seventeen Mile Creek. One site was fully assessed within this sub-section.

♦ *Reach Environs and Site Features*

The site was rated as having an essentially natural reach environs. It was located within Nitmiluk National Park and disturbances were generally low. Subjective disturbance ratings indicated that the site assessed had low levels of disturbance.

The site had land tenure and land use that was associated with being a National Park. The major disturbances were roads/tracks, a creek crossing and people (as this site was located on a walking trail).

♦ *Channel Habitat Types, Diversity and Dimensions*

The reach length studied was 138m. Pools and riffles were recorded at the site studied. Pools were the dominant habitat type, taking up 61% of the reach length. The habitat type diversity rating for the site assessed was high. At the time of sampling, the water level was at water mark (or its normal level).

Table 5.80 presents the dimensions for the pool and riffle habitats recorded at one site. Both habitat types were shallow in depth and narrow in width. The banks for both habitats were similar in height and width and were moderate or low in slope and convex or concave in shape.

♦ *Bank Condition and Stability*

The site assessed in this sub-section was rated as having stable banks. Subjectively, the overall bank instability and the susceptibility of banks to further erosion were rated as low.

Erosion was the dominant bank process recorded. The erosion was predominantly occurring at obstacles or floodplain scours/breakout points. Both the lower and upper banks were stable, with over 90% of the bank being recorded as stable. Aggradation (8% cover) was recorded at obstacles along the upper bank.

The major factors identified as affecting bank stability were high flow and tracks/crossings.

Table 5.80 Channel Dimensions for Habitat Types

Dimension	Pool	Riffle
Reach Covered (%)	61.0	39.0
Mean Length (m)	28.0	18.0
Mean Depth (m)**	0.4	0.2
Mean Width (m)**	5.7	5.2
Width:Depth Ratio	15.8	27.4
∗UB: Width (m)	33.8 (26.5-41.0)	34.0 (21.9-46.0)
Height (m)	3.3 (3.0-3.6)	3.4 (2.8-3.9)
Slope (^{o})	5.7 (5-7)	6.8 (4-10)

∗UB = Upper Bank ** Measured from the water mark.

♦ *Bed and Bar Condition and Stability*

The site assessed in this sub-section was subjectively rated as having a moderately aggrading bed. The major factor identified as affecting bed stability was instream siltation.

Sand and gravel bars were present at this site, averaging 12% cover and occurring as high flow deposits. The gravel forming the bed and bars was sphere-shaped or disc-shaped and had sub-angular or angular material. Bed compaction was moderate. There were no controls recorded that were stabilising the bed.

♦ *Bed and Bank Sediments*

The bed and lower bank material at the pool and riffle habitats was predominantly sand and gravel. The upper bank material was predominantly fines/clays. Organic matter was present in both bed and banks and ranged from 22-45%. No rock outcrops were recorded.

♦ *Riparian Vegetation*

The riparian vegetation at this site was rated as having high cover and structural diversity. The vegetation was described as vegetation associated with freshwater streams. The width of the riparian vegetation zone was 34m (range 22-45m), with one bank recording a width of 21-30m and the other >40m.

The structural types recorded included trees 2-30m, regenerating trees, shrubs, vines, herbs, sedges and grasses. Covers ranged from 0-45%. The highest cover (43%) was recorded for medium-sized trees (10-30m). The remaining covers where 10% or less, except for small trees (19% cover).

Overstorey vegetation provided a much greater cover. The upper bank recorded an average of 79% (range 75-82%) bare for understorey

vegetation cover compared to 55% (range 50-60%) bare for the overstorey.

Four types of exotic species were present at this site, including noxious species. The mean total cover of exotic species in the riparian zone was 12% and therefore this site rated a high level of invasion by exotic vegetation (11-15% cover). The structural types present were shrubs, vines and forbs. The noxious species recorded were *Senna occidentalis, Hyptis suaveolens* and *Sida acuta*. The covers for the noxious species averaged 2%. The only other exotic species recorded was *Passiflora foetida* (a naturalised vine) which recorded a cover of 8%.

♦ *Aquatic Vegetation*

Aquatic vegetation was present in the form of emergent vegetation. The only structural type present was rushes/sedges (ie *Fimbristylis sp.*) which recorded a cover of 5%.

♦ *Instream and Bank Habitats*

The cover and diversity of instream and bank habitats was rated as moderate. Subjectively, the site was rated as having a good overall aquatic condition.

Six instream habitat types were recorded. They included individual branches, individual logs, leaves/twigs, log jams, branch piles and algal clumps. There were no permanent pools deeper than 1m recorded. The cover provided by each of these habitat types was <10%.

Three different types of overhanging bank cover were recorded. Vegetation canopy cover occurred along 95% of the bank and had a width of 4.0m. Vegetation overhang occurred along 13% of the bank and had a mean width of 0.4m. Root overhang was recorded along 5% of the bank and had a width of 0.2m.

At water mark, the site would have a moderately restricted passage for fish and other aquatic organisms.

♦ *Overall Condition*

The overall condition rating for the site assessed in this sub-section was high.

5.16.2 Discussion

This site was located within Nitmiluk National Park, which contributed to a reach environs rating that was essentially natural. Disturbances to the reach environs, although low, were still present.

The river banks along the reach were rated as stable although high flows and the presence of a crossing were factors that affected the river banks to some degree. The bed was assessed as moderately aggrading due to the fact that the channel was shallow and uniform in shape, and high flow deposits were present. Instream siltation was identified as affecting bed stability.

Although the cover provided by many of the vegetation structural types was 10% or less, the cover provided by trees was very good, and contributed to a high cover and diversity rating. The riparian zone was moderately wide, averaging 34m. The presence of 4 types of exotic species, including 3 noxious species, within the riparian zone led to a low rating for this site. Even though *Passiflora foetida* was the dominant species present, the main problematic species recorded were *Senna occidentalis*, *Hyptis suaveolens* and *Sida acuta*. The cover for each type of noxious species was generally low though, but their control should be considered because they are not only located within a National Park, but they are also located on a walking trail, which may aid in their spread throughout the park.

There was a fair variety of instream habitat types present, although the covers were <10%, and the canopy cover along the banks was excellent. These factors contributed to a moderate cover and diversity rating for the instream and bank habitats. Even though there was only two habitat types present along the reach (ie pools and riffles), the proportion of these habitats was more even, thus resulting in a high rating for channel type diversity.

Moderate bed aggradation; high riparian vegetation rating (Site 17/1: Seventeen Mile Creek)

6. SUMMARY – DALY RIVER CATCHMENT

♦ *Reach Environs and Site Features*

Nearly two-thirds of the reach environs assessed were rated as being essentially natural, while one-third had some modification. Generally, these sites had relatively lower impact land uses that had not greatly modified the reach environs (eg grazing on native or thinned pastures), undisturbed vegetation and few local disturbances. The few sites that recorded moderate modification to the reach environs were predominantly associated with the population centre of Katherine where land uses and disturbances to the reach environs were more intensive and varied ranging from rural or urban residential to tree cropping. Subjective reach environs disturbance ratings indicated that nearly half the sites recorded either a low level of disturbance or were low to moderately disturbed.

Land tenure along the reaches studied was predominantly freehold or leasehold. Grazing was the major land use adjacent to streams in the catchment. The major disturbances to stream reaches were grazing activity and, to a lesser extent, roads/tracks or causeways/river crossings. Only 3% of sites throughout the catchment recorded no local disturbance to the reach environs.

♦ *Channel Habitat Types, Diversity and Dimensions*

Reaches studied averaged 824m in length. Pools were the dominant habitat type located throughout the catchment. Pools also dominated the reach lengths, averaging 74%. Riffles were also quite prevalent and occurred at over half the sites. Cascades and waterfalls were associated with areas of steeper topography (eg gorge systems, tufa formations). Rapids were predominantly located along mid to upper sections of Daly River and along Katherine River where river gradients were steeper. Runs were mostly located along Daly, Katherine and Douglas Rivers.

When the sites were assessed for their variability or diversity of channel habitat types, nearly three-quarters of the sites recorded a high diversity. The majority of reaches were comprised of only 2 habitat types. Few sites (13%) recorded more than 2 habitat types present. 77% of sites recorded either 10-30% or >30% of the reach being occupied by habitat types other than pools. One to two sections of Douglas River, Daly River, Flora River, Fergusson River and Hayes Creek recorded a very high diversity of channel types. Low channel type diversity was recorded for: a section of the Daly River estuary where pool habitats were very uniform; along one other Daly River section where very long pools dominated the reach extensively; or where only one habitat type was recorded along the reach (i.e. a section of Katherine and Edith Rivers). Reaches with very low diversity ratings were located on Birdie Creek and a tributary of Stray Creek where only one habitat type was noted and there was little or no variation in depths.

The dimensions for most habitat types varied considerably throughout the catchment. Pools located along the tidal section of Daly River were the deepest and longest in the catchment, except for those assessed in Katherine Gorge, which were somewhat deeper (i.e. ranging up to 10.2m in depth).

♦ *Bank Condition and Stability*

The majority of river banks throughout the catchment were stable and, to a much lesser extent, had limited instability. No river banks were suffering from extensive or extreme instability. Those very few reaches with moderate bank instability (ie Depot and Aroona Creeks) were suffering from localised erosion problems. A subjective assessment of the stability of the banks indicated that most sites recorded low overall bank instability. The high level of bank stability recorded throughout the catchment is reflected in the fact that the riparian vegetation is relatively in tact and has not been impacted on by extensive clearing or development.

Bank erosion, even though minor in places, was the dominant process recorded throughout the catchment, with some aggradation also being noted. Lower banks were more stable than upper banks with an average of 91% and 87% of the bank length respectively being recorded as stable. The erosion was occurring mostly at obstacles, like tree roots, and outside bends. Aggradation occurred mostly along inside bends and at obstacles.

The major factors affecting bank stability were high flow and stock, although infrastructure (ie roads, tracks, river crossings, *etc*) and floodplain scours or breakout points along the river were also prevalent at over one-third of the sites. Bank protection measures, including fencing, were rarely observed.

♦ *Bed and Bar Condition and Stability*

An assessment of the stream bed stability indicated that two-thirds of sites had stable beds, while nearly one-third of sites were assessed as moderately aggrading. Few sites recorded moderate bed erosion and no sites had beds that were severely eroding or aggrading.

Moderate bed aggradation was generally confined to: a section of the Daly River between Oolloo Crossing and Fergusson River junction; lower Daly River estuary; Stray Creek; Upper Chilling and Muldiva Creeks; upper Katherine River (downstream of Centipede Dreaming Gorge); lower Birdie Creek; sections of Fergusson, Edith and Cullen Rivers; sections of Eight Mile and Copperfield Creeks. In many cases, these channels were described as being shallow, uniform in cross-sectional shape and carrying a large amount of sediment. Large instream bars and high flow deposits were often very common along these reaches which may indicate increased sediment supply to these stream systems.

Moderate bed erosion was infrequent and generally was linked to local disturbances caused by river crossings (eg upper Hayward, Depot and Bamboo Creeks), stock activity (eg Bamboo Creek) or recent high flow events (eg a section of Edith River).

The major factor that was considered to affect bed stability throughout the catchment was agriculture/ grazing activities, which was occurring at less than half the sites, while instream siltation was affecting one-fifth of the sites. At one-third of the sites, no factors were affecting bed stability.

Bars were recorded along the majority of reaches, averaging 16% of the bed and ranging to as high as 70%. Point bars were the most prevalent type of bar and were present at over one-third of sites. Rock outcrops, which provide a degree of bed stabilising influence, were quite prevalent throughout the catchment, being present at over half the sites.

♦ *Bed and Bank Sediments*

A range of size classes, from clays to boulders, was recorded for river beds. Pool, run and glide habitats had a higher proportion of smaller bed sediments; riffles had a range of bed sediments sizes; rapids had a higher proportion of larger bed sediments; and cascades and waterfalls had boulder beds. Lower and upper banks consisted mainly of clays and small sand. Organic material was present in both bed and bank material.

♦ *Riparian Vegetation*

Nearly two-thirds of the riparian vegetation along the reaches assessed had moderate cover and structural diversity, with a further one-third having high cover and diversity. A mangrove-dominated community on the lower part of the estuary rated poorly due to a lack of structural diversity. The majority of sites along the Daly River upstream of the estuary (mid section) to Fergusson River junction were assessed as having a high cover and structural diversity. Other sections that rated highly include Douglas River (lower and mid), Flora River (lower and upper), upper Katherine River, mid Edith River as well as sections along other smaller creeks.

The results provide an indication of how structurally diverse and dense the riparian vegetation is throughout the catchment. Generally the riparian vegetation is relatively in tact and has not been impacted on by extensive clearing or development, although stock activity was recorded as a factor affecting river banks to varying degrees at over two-thirds of sites.

The average width of the riparian zone was 22m, which can be considered to be the natural width because little clearing of the riparian vegetation has occurred. This width is similar to the mean width of the upper bank (ie 18m) and emphasises the importance of the upper bank as a 'refuge area' for riparian vegetation. Most sub-catchments recorded a site (or sites) with a riparian zone width of <10m. Those sites that recorded a riparian zone width of >31m were mostly located on the Daly River and, to a lesser extent, the Katherine and lower sections of the Douglas, Flora and Fergusson Rivers.

Throughout the catchment, grasses were present at all sites. Forbs, woody shrubs, regenerating trees, trees (2-30m) and vines were also very prevalent and were present at >90% of sites. Rushes and sedges, phragmites and ferns were not as prevalent. Trees (taller than 30m), mangroves and palms recorded a more scattered distribution. Trees (2-30m tall) and grasses dominated the riparian vegetation providing the highest covers. The other structural categories each averaged <10% cover. At the majority of sites, overstorey vegetation provided a greater cover than understorey vegetation.

Exotic vegetation was widely distributed with over three-quarters of sites recording the presence of exotic species. Vegetation species that are declared noxious within the Northern Territory were located at over half the sites.

Nearly half the sites recorded a low level of invasion by exotic species (1-5% cover), whereas over one-third of the sites recorded a greater level of invasion (>5% cover and up to 32%). Overall, exotic species within the riparian zone averaged 6% cover and were predominantly vines and forbs. *Passiflora foetida*, a naturalised vine, was the most prevalent exotic species throughout the catchment being present at over half the sites. *Hyptis suaveolens* (Hyptis) and *Xanthium occidentale* (Noogoora Burr), both noxious weeds, were also quite prevalent being present at 37% and 23% of sites, respectively.

Passiflora foetida was widely distributed throughout the Daly River catchment and covers between 1-20% were recorded. *Hyptis suaveolens* also had a wide distribution and was recorded throughout the majority of sub-sections, although not at every site (excluding upper Daly and Fergusson Rivers, Chilling Creek, Dead Horse Creek, King and Dry Rivers and the low/mid sections along Katherine River). Covers for *Hyptis* were generally low (<5%), although a lower Flora River site recorded much higher covers (11-15%). *Xanthium occidentale* was more confined in its distribution and was located at all non-tidal sites along the Daly River and one-third of sites in the tidal area. Other sub-sections where *Xanthium occidentale* was recorded, at one or more sites, included Chilling, Hayward, Limestone and Dead Horse Creeks and lower Fergusson and Katherine Rivers. Where present, the average cover of *Xanthium occidentale* was relatively high, averaging 11%, although along the Daly River covers between 5-28% were recorded.

♦ *Aquatic Vegetation*

Over half the sites recorded the presence of aquatic vegetation, mostly in the form of emergent vegetation. One-fifth of sites recorded the presence of submerged aquatic vegetation and only one upper catchment reach recorded the presence of floating vegetation. There was no aquatic vegetation species recorded that were exotic.

Sites along Daly, Flora, Katherine and Fergusson Rivers, and to a lesser extent the lower Douglas River, recorded the presence of both submerged and emergent aquatic vegetation. Factors influencing the distribution and abundance of aquatic plants throughout the Daly River catchment may include suitability of flow regimes, appropriate water quality and channel form, including the width, depth and sediment composition of the channel.

Pandanus, Melaleucas, rushes or sedges and Phragmites dominated the emergent vegetation types. Chara or Nitella and filamentous algae dominated the submerged aquatic vegetation. Covers for all structural types were low with only Melaleucas and Pandanus averaging over 5% cover.

♦ *Instream and Bank Habitats*

Just over half the sites were rated as having high cover and diversity of instream and bank habitats, while just under half the sites rated moderately. Sections on Dead Horse and Limestone Creeks rated the worst in the Daly River catchment. The few sites recording very high cover and diversity were located on Flora and Douglas Rivers and Green Ant Creek. Nearly half the sites were subjectively assessed as having a good to very high overall rating for all aquatic life. While another one-fifth of sites had poor aquatic habitat and nearly one-third of sites poor to good.

The most commonly occurring instream habitat types were logs, leaves and twigs, branches, rock faces/boulders, and permanent pool habitats deeper than 1m. Stream bed cover provided from the banks was dominated by vegetation canopy cover, which occurred along an average of 63% of the bank length. Vegetation overhang, which was less than 1m from the water, was also very prevalent although it occurred over only one-fifth of the bank length.

The fact that instream habitat is provided predominantly by vegetative debris, such as logs and leaves, and the bank habitat from canopy cover, which involves the presence of trees and shrubs, emphasises the importance of riparian zones to aquatic organisms.

Passage for aquatic organisms at half the sites was generally partly to very restricted at the time of the survey, although one-third of sites had no passage. Assessments of passage at the water mark indicated that some form of restriction remained at 72% of sites.

♦ *Overall Condition*

The overall condition of the majority of sites throughout the Daly River catchment was high. Reaches that rated very highly overall were located on Douglas River (5 sites), Daly River (3), Green Ant Creek (3), Flora River (2), Katherine River (2), Edith River (1) and Dry River (1). The only site to record a moderate overall condition, the poorest rating in the Daly River catchment, was located on Eight Mile Creek. No sites were rated as being degraded overall.

7. CONCLUSIONS, BROAD MANAGEMENT ISSUES AND RECOMMENDATIONS

The major conclusions that can be drawn from the survey of the Daly River and its tributaries, including broad management issues and recommendations, are:

1. The overall condition of the majority of rivers and creeks studied throughout the Daly River catchment was high.

When the six components that make up the overall condition rating were taken into account, the majority of rivers and creeks studied throughout the Daly River catchment rated highly, with areas along Douglas, Daly, Flora, Katherine, Edith and Dry Rivers and Green Ant Creek rating very high overall. The only site to record a below average overall condition was located on Eight Mile Creek. No sites were rated as being degraded when all six components were taken into account. As the overall condition of the reaches surveyed was high, there is an opportunity to monitor for any deterioration in this high status over time.

Even though the overall condition ratings were relatively consistent, the six components that make up the overall condition rating varied. Generally, the rivers and creeks studied were physically stable, although sections were experiencing bed aggradation problems, in particular, or localised bank erosion. The degree of modification to the reach environs reflected the land uses and disturbances and most were essentially natural. The riparian vegetation was relatively intact and the cover and structural diversity rated moderately for most reaches, except for sections along Daly, Douglas, Flora, Katherine, Edith Rivers which rated highly. Instream and bank cover varied with most reaches rating highly. The degree of invasion of the riparian zone by exotic species also varied greatly.

2. Even though two-thirds of reach environs were classified as essentially natural, very few sites recorded reach environs that were unimpacted or recorded no local disturbance.

The degree of modification to the reach environs depended on the level of intensity of the land use and the types and extent of local disturbances. Grazing, the major land use and disturbance factor recorded throughout the Daly River catchment, was generally classed as being less disturbing to the reach environs than was extensive clearing and development for rural/urban residential or cropping (including broadacre cropping and horticulture), as was seen in the results for sites close to the population centre of Katherine.

In areas where:

(i) land uses and disturbances to the reach environs becomes more intensive and diversified through increased agricultural activity (eg cropping and horticulture);
(ii) clearing of floodplains occurs; and
(iii) the sub-division of lands bordering rivers and creeks into smaller units or rural residential blocks occurs,

the modification to the reach environs will change (rate lower) over time from being essentially natural to having some or a greater level of modification, as has been shown in areas close to Katherine. It will, therefore, be important to particularly monitor the state of the reach environs in areas where (i), (ii) and (iii) (mentioned above) are occurring.

Steps to ensure that the river corridor and reach environs are kept intact need to be implemented. Any regional strategy should ensure that the riparian vegetation is protected, ad hoc access points and river crossings are restricted, fencing and off-river watering points for stock are encouraged and that weed invasion of the riverine environment is managed. In the Katherine region, consideration should be given to extending the current "Katherine River Plan of Management for the Central Katherine Zone" to cover the 'Shady Lane', 'The Rural River' and 'Manbulloo' zones identified in that plan.

3. The majority of river banks throughout the catchment were stable.

The majority of river banks throughout the catchment were stable or had limited instability, however, some form of erosion was recorded. The few sites that recorded a below average bank stability were suffering from localised erosion problems. High flow was contributing to the erosion of river banks as was stock accessing the streams to water, shelter or graze. Infrastructure, such as roads, tracks and crossings, was identified as the third major factor affecting bank stability and, in several instances, was the cause of localised bank instability problems.

Monitoring the proportion of bank lengths that are stable, eroding or aggrading assists with monitoring the extent of change in bank stability over time throughout the catchment. It will also be possible to make the link between bank stability and whether any increase in the rate or extent of erosion or sedimentation can be attributed to human activities within the catchment.

The high level of bank stability recorded throughout the catchment is reflected in the fact that the riparian vegetation is relatively in tact and has not been impacted on by extensive clearing or development.

Bank protection measures, such as controlled stock access points to rivers and fencing along rivers, were rarely observed. If, over time, there is a deterioration in the stability of the river banks, or areas of important riparian habitat or unique riparian vegetation communities are identified, practices like those mentioned above will need to be encouraged. If fencing along rivers does occur, the responsibility for management of the riverine corridor needs to be addressed so that activities, such as, weed and feral animal control and maintenance of fencing does occur.

4. The river beds throughout the catchment were not as stable as the river banks

Two-thirds of the sites surveyed had stable river beds. This bed stability is quite probably linked to low interference to flow and sediment regimes as well as a relatively low level of clearing throughout the catchment.

Nearly one-third of the sites were experiencing moderate bed aggradation problems. Generally many of these reaches were located within, or downstream of, sandstone and/or granite country; were relatively remote; and, aside from feral animals and fires, had low impact land uses. Several of these reaches were located within the Fergusson River sub-catchment (granite and sandstone country) and upper Katherine River (sandstone country). As well, the Daly River, below the junction with the Fergusson River, and Stray Creek, recorded instream siltation problems. Both these streams were very shallow in places and were observed to be carrying a large amount of sediment, including sands.

Sandstone and granite rock formations could be a source of sand to these river systems following high flow and runoff events. High flow events would be required to transport this sediment through the river system. Large instream bars and high flow deposits were often very common along the reaches experiencing moderate levels of aggradation. Further investigation into the level of bed aggradation within these sub-catchments is required in order to identify the causes and to make appropriate management recommendations.

Moderate bed erosion was infrequent and was generally linked to local disturbances caused by river crossings, stock activity or high flow events.

5. The riparian vegetation was relatively intact and had predominantly a moderate cover and structural diversity.

Riparian zones are a vital link between land and water environments. Riparian vegetation perform many essential functions, including: the protection of river banks from erosion processes; acting as a buffer or filter for sediments and their attached nutrients and pollutants; maintaining good water quality; providing organic material, shade and shelter for instream communities; increasing the physical habitat diversity in aquatic ecosystems; and acting as a wildlife corridor. The effectiveness of the riparian zone in carrying out these functions is significantly influenced by its structural diversity, width and integrity (species diversity, overall cover, and the degree of invasion and impact caused by exotic species).

It was found from this study that the riparian vegetation was relatively intact and had generally not been impacted on by extensive clearing or development. Several factors, of varying degrees, were found to be impacting on the reach environs and river banks at many sites, including high flows, grazing/stock and infrastructure like roads, crossings and bridges.

When the cover and structural diversity were assessed, the riparian vegetation rated moderately and, to a lesser extent, highly. The results showed that the diversity of the different vegetation structural types present (eg small trees, large trees, woody shrubs, forbs, grasses, vines, *etc*) rated higher than did the cover provided by these structural types. Although most sites recorded the presence of many structural types, aside from trees (2-30m tall) and grasses, most structural categories recorded very low covers. Overstorey and understorey vegetation (trees and shrubs >1.3m) generally provided a greater cover than did ground cover vegetation, although sites within Fish, Cullen, Dry and King Rivers and Dead Horse, Eight Mile, Mathison, Limestone and Durrinyan Creek sub-sections had grass-dominated riparian vegetation communities.

It is possible that the density of shrubs and ground covers (particularly forbs, vines, rushes and sedges) is naturally low due to seasonal aspects. Continual high flows over the wet season, particularly along the lower parts of the banks, and deposition of sediment during this period, or water availability during the dry season, may influence the occurrence of ground covers and, therefore, the structural diversity and covers recorded.

The cover and structural diversity of the riparian vegetation varied somewhat, even in instances when the stability of the river banks did not vary. River bank stability does influence the condition of the riparian zone but, as has been shown in these results, other factors were also contributing to the cover and diversity of the riparian vegetation. These factors may include aspects like water availability, climate and location within the catchment.

The average width of the riparian zone throughout the catchment was 22m. The width of riparian vegetation is the 'natural' width at most sites and, therefore, this width can be used as a guideline for planning or recommending appropriate buffer widths throughout the catchment. From this study the following average riparian vegetation widths and ranges were recorded for the three stream sizes (as categorised on Map 8 ' Stream Orders'):

- Minor streams (stream orders 1 and 2) – 7m (range 3-19m)
- Medium-sized streams (orders 3, 4 and 5) – 16m (range 2-88m)
- Major streams (stream orders 6 and 7) – 35m (range 8-50m)

Larger bands of vegetation are required along larger streams. A minimum width of riparian vegetation is necessary for the sustainability of aquatic ecosystems and processes as well as the sustainability of the riparian buffer itself. According to Riding and Carter (1992), the most commonly recommended width for stream buffers is 20-30m, though these recommendations ranged from 10-100m. However, Riding and Carter (1992) suggest that this width may not be adequate, depending on site characteristics and for the maintenance of habitat value. Riding and Carter (1992) also suggest that due to the limited knowledge of effective buffer widths for different land uses, recommending a wider zone rather than a more narrow zone may be necessary until long-term studies have concluded.

Priority should be given to ensuring that the riparian vegetation is maintained at its natural width and that this is recognised in tree clearing guidelines or recommendations on appropriate riparian buffer widths.

Further interpretation of the vegetation species found throughout the catchment is also required in order to identify important or unique riparian vegetation communities. Once identified, steps should be taken to ensure that these riparian vegetation communities are preserved.

6. The distribution of exotic riparian vegetation was widespread.

Exotic species, particularly vines and forbs, were generally widely distributed. Over three-quarters of sites throughout the Daly River catchment recorded the presence of exotic vegetation and over half the sites recorded species that are declared noxious within the Northern Territory. The degree of invasion of the riparian zone by exotic species varied greatly, with most sites recording a low level of invasion. At times, the reaches rated poorly for exotic species compared to the other attributes assessed.

The three major exotic species recorded included *Passiflora foetida* (a naturalised vine), *Hyptis suaveolens* (a noxious forb) and *Xanthium occidentale* (a noxious forb).

Passiflora foetida and *Hyptis suaveolens* (Hyptis) were both widely distributed throughout the catchment. *Xanthium occidentale* (Noogoora Burr), on the other hand, was more confined in its distribution and was particularly prevalent along the Daly River and several tributaries that were close to the junction with the Daly River, including: Chilling, Hayward, Limestone and Dead Horse Creeks and lower Fergusson and Katherine Rivers.

Invasion of the riparian zone by exotic/noxious species is of concern, particularly if it is displacing other native ground covers. Control of weed species should be considered so as to maintain or to improve the condition of the riparian vegetation. There is a need to understand whether exotic species are out-competing native species and generally how the level of weed invasion has affected the riparian vegetation. For example, the issue of whether the exotic species have resulted in a significant change to the integrity and structure of the native riparian vegetation communities, should be addressed.

Noxious weeds should be controlled in protected and high use areas, such as National Parks and Nature Parks. Other high use areas and recreational areas along rivers and creeks, including Claravale and Oolloo Crossings and Black Bull Yard on the Daly River, should be targeted for the control of noxious weeds in order to prevent their spread by people to other areas. This is particularly the case for Noogoora Burr that readily attaches itself to clothing, and Hyptis, which can be transported via vehicles.

Controlling weeds along streams should be approached on a catchment basis. There is limited use in controlling weeds and preventing their spread in one particular area if a continual supply of weed seed is brought into that area from upstream. In order to manage weed control on a catchment basis, it is imperative that weed control strategies and distribution maps are formulated. Such strategies and maps are also required in order to monitor the distribution and abundance of weeds, to target specific weeds and to make best use of available resources.

The active involvement of land owners and managers along rivers in controlling weeds is required. Public awareness of what weed species should be controlled and information on how to undertake this is important. The current research and trials being conducted into the biological control of certain weeds (eg *Xanthium occidentale* and *Parkinsonia aculeata*) is important due to the large property and lease sizes that exist within the Northern Territory.

7. Larger rivers recorded the presence of both submerged and emergent aquatic vegetation.

Nearly two-thirds of the sites surveyed recorded the presence of aquatic vegetation. Emergent vegetation was the most common type of aquatic vegetation and was found at over half the sites. Submerged aquatic vegetation was much more confined in its distribution, being recorded at one-fifth of sites; and only one site recorded floating aquatic vegetation. The larger rivers (ie Daly, Flora, Katherine and Fergusson Rivers and, to a lesser extent, lower Douglas River), recorded the presence of both submerged and emergent aquatic vegetation. Covers for all types of aquatic vegetation were generally low.

Factors influencing the distribution and abundance of aquatic plants throughout the Daly River catchment may include suitability of flow regimes (dry season baseflows being maintained, high wet season flows), appropriate water quality and channel form, including the width, depth and sediment composition of the channel. Further studies would be required to determine the factors influencing the distribution and abundance of aquatic vegetation within the Daly River catchment.

No exotic aquatic vegetation species were recorded along the reaches surveyed throughout the Daly River catchment.

8. Instream and bank habitats were quite diverse and provided a fair degree of cover.

Most sites had a high to moderate cover and diversity of instream and bank habitats. Sections along Dead Horse and Limestone Creeks rated below average, whilst sections along Flora and Douglas Rivers and Green Ant Creek rated highly for this attribute.

The ratings reflect the level of cover and diversity provided by instream organic debris, aquatic vegetation and other habitat types on the river bed, as well as the cover and diversity provided by the canopy and other habitats along the river banks. The most commonly occurring instream habitat types were organic debris, such as logs, leaves, twigs and branches; rocks; and permanent pool habitats deeper than 1m. Stream bed cover provided from the banks was dominated by vegetation canopy cover. The vegetation canopy along the banks did not provide a continuous cover, averaging 63% of the bank length.

The results suggest that the instream and bank habitats were fairly diverse and provided a fair degree of cover or habitat areas to support a diversity of instream fauna, including macro-invertebrates, and fauna associated with the riparian zone. A comparison with other fauna diversity studies, such as the 'Ausrivas Program' and recent studies of bird populations in riparian zones, would be required to determine if this is the case.

9. The diversity of channel habitat types was predominantly high.

The variability or diversity of channel habitat types throughout the catchment varied yet was predominantly high. Although the site reaches were generally dominated by two channel habitat types, the proportion of the reach occupied by pools versus other habitat types rated more highly. The reaches recording low channel type diversity ratings coincided with very long, uniform pools, as found along the Daly River estuary, and where only one uniform habitat type was recorded along a section of stream (eg Birdie Creek).

Channel diversity is related to natural features such as topography and geology. The results, therefore, reflect not only the diversity of channel habitats along rivers, but also the natural variations throughout the catchment. Cascades, waterfalls and rapids were associated with areas of steeper topography (gorge systems, tufa formations) or where river gradients were steeper. Very long pools were associated with the lower sections of the Daly River.

A comparison with other studies of fauna diversity, such as the 'Ausrivas Program', would be required to determine whether the high channel habitat diversity has influenced the diversity of fauna throughout the Daly River catchment.

10. Some protected areas were being impacted on by disturbances, such as feral animals and noxious weeds.

Some protected areas, including National Parks and Nature Parks, were being impacted on by feral animals and noxious weeds.

In order to benefit the stability of the rivers and creeks, there is a need to control the large number of feral animals (including buffaloes, donkeys, wild horses and pigs) along sections of the upper Katherine River that lie within Nitmiluk and Kakadu National Park and Arnhem Land Aboriginal Land. Noxious weeds (mainly *Hyptis suaveolens*) were also recorded along some of these upper catchment streams, and considering the areas are relatively remote, could indicate that their spread is assisted by motor vehicles.

The site along lower Seventeen Mile Creek, which lies within Nitmiluk National Park, recorded the presence of three types of noxious weeds - *Senna occidentalis*, *Hyptis suaveolens* and *Sida acuta*. Even though the covers for these noxious weeds were generally low, their control should be considered as they are not only located within a National Park, but they are also located on a walking trail, which may aid in their spread throughout the park.

A site located within Flora River Nature Park also recorded disturbances to the riparian zone by the presence of *Hyptis suaveolens* and *Sida acuta*. Upstream of the Nature Park though there was a moderate infestation along Mathison and Aroona Creeks by several noxious species including *Hyptis suaveolens*, *Parkinsonia aculeata*, *Jatropha gossypiifolia*, *Pennisetum polystachion* and, a weed identified by DPI&F, *Martynia annua* (Devil's Claw). Control of these noxious species should be considered to prevent their spread downstream to Flora River Nature Park where visitation levels are higher.

Other protected areas to record the presence of noxious weeds included Butterfly Gorge and Umbrawarra Gorge Nature Parks.

11. Grazing and stock activity were identified as the most common detrimental influence impacting upon stream and riparian attributes.

Grazing and stock activity were identified as one of the main disturbances to stream reaches and river bank and bed stability at many sites and, therefore, the impacts of this activity should be monitored.

Consideration should be given to fencing off any areas along rivers and creeks that are showing signs of localised erosion problems or are suffering from stock activity. Stock watering points away from rivers can be used where fencing along rivers has occurred.

12. Measures required to maintain or, in some cases, to improve the stability and condition of rivers.

As the majority of rivers and creeks within the Daly River catchment are physically quite stable, the Northern Territory is well placed to be proactive in order to ensure that the streams are not degraded over time and that they remain in a stable condition.

Measures that are required to maintain or, in some cases, to improve the stability and condition of rivers include:

- Maintaining and protecting the riparian vegetation and, in so doing, the aquatic habitat;
- Ensuring that tracks and river crossings are properly designed, constructed and maintained; and
- Monitoring and controlling the impacts of grazing/stock activity along rivers (discussed in 11).

Ensuring that riparian vegetation is kept in tact will help to maintain a good level of bank stability. As well, the riparian vegetation can perform its many other essential roles (mentioned in 5 above). In so doing, the condition of the aquatic habitat is maintained because instream cover is largely provided by organic material derived from riparian vegetation, and bank cover mostly involves the presence of trees and shrubs.

Extensive clearing or development within the riparian zone should be avoided. This allows the banks to have a greater chance of withstanding the annual high flows during the wet season that was identified, along with stock activity, as the major factor affecting bank stability.

Infrastructure, such as roads, tracks and crossings, was identified as the third major factor affecting bank stability. Several reaches, including those along King River, upper Hayward Creek and Douglas River, lower Depot and Stray Creeks, were experiencing localised problems due to eroding river crossings and/or access tracks. The results show that poor track and river crossing design and maintenance can influence the condition of streams at a local scale.

It is important to properly locate crossings, avoiding outside bends or steep banks, and targeting areas where the creeks are shallower and have larger sediments along the bed, like gravels, cobbles or boulders. As little riparian vegetation should be disturbed as possible when constructing the crossings. Tracks should be maintained on a regular basis and should be designed so as not to concentrate flows along their length, otherwise erosion will occur.

13. There is a need to actively involve the community in river management.

Land tenure along the rivers and creeks is predominantly freehold or leasehold. Therefore, any on-ground river management activities or promotion of river management issues (eg through river management plans, regional or catchment planning), needs to actively involve the landowners, property managers and community groups.

There is a 'window of opportunity' within the Northern Territory to be proactive with regard to river management issues because the rivers and creeks within the Daly River catchment are not degraded. Maintaining or, in some cases, improving the condition of rivers and creeks and, in so doing, preventing river degradation, should be a priority.

14. Ensure linkages are made with other projects and initiatives.

The results of this study can contribute to:

- Katherine-Daly Natural Resources Management Strategy;
- Environmental Flows Initiative Program;
- NT Weeds Management Strategy;
- Vegetation clearing guidelines;
- Recommendations on riparian vegetation buffer widths; and
- Construction guidelines for tracks and river crossings.

Linkages to other projects and initiatives that address other issues relating to rivers is important to aid overall river management decision-making processes. These include:

- 'Ausrivas' project;
- Riparian vegetation assessments;
- Long term water flow and quality databases (eg Hydsys);
- Developing environmental flows guidelines;
- Vegetation databases; and
- 'Wild Rivers' assessment.

15. There is a need to design and implement a suitable strategy and schedule for ongoing surveys.

There will need to be follow-up surveys over time in order to monitor the rate of change in river condition and stability, as has been benchmarked by this project. The project can, therefore, be used as a monitoring tool to look at management induced improvements or to monitor areas where management practices and land uses have changed or intensified within the catchment.

Department of Lands, Planning and Environment are the custodians of the project and the data and therefore will need to be responsible for designing and implementing a suitable strategy and schedule for ongoing surveys within the Daly River catchment. There will also be a need to identify what raw data should be re-collected. It is envisaged that selected priority sub-sections (or preferably sub-catchments) be targeted if the whole of the Daly River catchment cannot be re-surveyed. Long time periods (5 years or more) are generally required before changes in indicators like river channel physical form (eg river bank and bed stability) and the streamside zone (eg assessment of riparian vegetation and reach environs) can be measured.

A waterfall off Arnhem Land Escarpment

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GLOSSARY

Aggradation	The long term build-up of sediment on a length of stream bed, or filling in of the stream channel, so as to raise its overall surface level and form bars.
Alluvial	Anything that is deposited by stream flow.
Aquatic Vegetation	Plants that live or grow in, on, or near water. Structural categories include submerged, floating or emergent aquatic vegetation.
Aquifer	A layer of sand, gravel or porous rock which holds groundwater and allows it to percolate through to wells or springs.
Armour	A surface layer of large gravel particles which overlays and protects finer sediments beneath it from erosion except during high flows.
Avulsion	A sudden change in the course of a stream by which a portion of land is cutoff, as where a stream cuts across and forms an oxbow.
Bank Protection	Materials placed on the face and toe of a bank to protect it from high flow velocities.
Bankfull	The discharge that results in water levels at the tops of the banks in most places along a stream. This is the flow that usually causes channel change.
Bar	A temporary deposit of sediment (ie sand, gravel or other unconsolidated sediment) within a stream channel that protrudes out of the water at water mark.
Bar Types	The 8 bar types include: point, bars with encroaching vegetation, high flow deposits, mid-channel islands, alternate/side irregular, channel bar plain, bars around obstructions and low flow meander infilled channel.
Baseflow	The low flow within a river or creek during the dry season which may be maintained by the discharge of groundwater.
Baseline Monitoring/ Data	To establish a reference point or benchmark of the condition of rivers and creeks against which changes in condition can be monitored over time through follow-up replicate surveys. Collecting baseline data is particularly important where there is little existing information.
Basin	See 'Catchment'
Bed	The bottom of a channel for the passage of water.
Bedload	The larger, heavier material such as coarse sand, gravel and boulders carried by the natural flow of a stream on or immediately above its bed.
Bedrock	Rock in a stream bed or banks that is resistant to erosion over long periods of time.
Bed Stability	The general stability of the stream bed. Aggradation or erosion (degradation) are forms of bed instability.
Billabong	A section of cut off stream channel on a floodplain which is typically saturated with water.
Braided Stream	A stream flowing in several channels that divide and reunite.
Breakout	The place where flood flow has broken through a bank.
Cascade Habitat	A series of small steps, slides or falls characterised by a step height <1m; gradient 5-60^{o}; and strong currents.

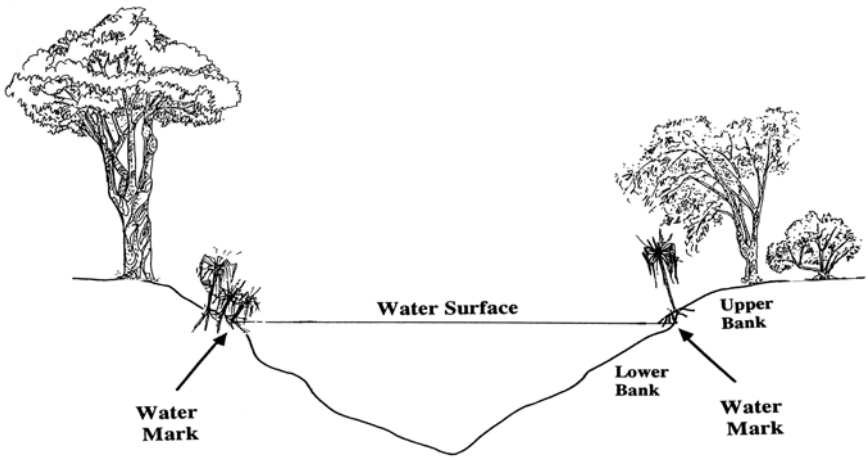
Catchment (river)	An area in which surface runoff collects and from which it is carried by a drainage system, as a river and its tributaries. Also known as drainage basin or watershed.
Causeway or Crossing	A road constructed across the bed of a stream. All stream flow goes over the road.
Channel	The whole area between the two high banks.
Channel Habitat Types	Waterfall, cascade, rapid, riffle, glide, run, pool or backwater
Colluvial	Loose deposits at the foot of a slope or cliff, brought there principally in response to gravity.
Control (bed)	An erosion-resistant section of stream bed that prevents short term bed degradation (ie lowering of a stream bed by erosional processes) and bed slope changes.
Cross-section	A diagram showing the land surface profile across a stream channel, plotted looking downstream.
Cross-section Survey	Depth measurements across the stream at right angles to the bank.
Cut Off Meander	A stream diversion or cut off through the neck of a meander or horseshoe bend where a new, relatively short channel is formed. This can occur artificially or naturally.
Deposition	An accumulation of sediment.
Degradation	The long term vertical erosion of sediment from a length of river bed so as to lower its overall surface level.
Discharge (Q)	The volume of flow per unit of time. Usually expressed as cubic metres per second (m^3/sec) or megalitres per day (ML/day).
Diurnal Tides	A tide in which there is only one high water and one low water each lunar day.
Drainage Density	Ratio of the total length of all channels in a drainage basin to the basin area.
Drainage Pattern	The configuration of a natural or artificial drainage system; stream patterns reflect the topography and rock patterns of the area.
Electrical Conductivity	A measure of salinity. The higher the electrical conductivity of a stream, the greater the salinity.
Ephemeral Stream	A stream which carries water a considerable portion of the time, but which ceases to flow occasionally or seasonally.
Erosion	A loss of material.
Estuary	That part of a river which has a free connection with the open sea, where freshwater comes into contact with sea water and which is affected by tides.
Exotic Species	Introduced species from other regions or countries (ie not indigenous or endemic to an area).
Flood Channel	A channel across a floodplain that only carries water during floods.
Floodplain	Depositional surface adjacent to a river that is flooded periodically forming broad alluvial or coastal floodplains.
Flow Regime	The long term (annual or greater) character of the timing and amount of flow in a stream.

Fluvial	Related to the flow in a river or stream.
Geomorphology	The study of the processes which shape the landscape.
Glide Habitat	A shallow, slow flowing section of water characterised by a depth <0.1m; gradient 1-3^{o}; small currents; and an unbroken and smooth water surface.
Groundwater	All subsurface water, especially that part that is in the zone of saturation.
Homogeneous Stream Sections	Stream sections which share similar natural features and are in similar condition.
Hydrology	The study of rainfall and runoff processes.
Incise	Erode the bed of a stream, deepen, degrade severely.
Inside Bend	The convex bank on a stream bend as observed from mid-stream.
Instream Habitat	The river itself, the banks and the channel.
Intermittent Stream	See 'Ephemeral Stream'
Left Bank	The left hand bank of a stream when looking downstream.
Levee	An artificial or natural linear ridge on a floodplain, sometimes deposited by a stream on its sides, that holds back flood water.
Longitudinal Profile	A diagram showing the land surface profile along a stream channel, usually along the thalweg (elevation plotted against river distance from the mouth).
Longitudinal Profile Survey	Depth measurements along the streams' thalweg.
Lower Bank	Is that part of the bank between the water mark (or normal dry season inundation level) and the water surface.
Low Flow	The normal discharge in a stream during the dry season, when the tops of most bars are exposed.
Meandering	A channel pattern that looks like a series of tight bends or loops with the river confined to a single channel.
Native Species	Species that are native to a specific region or country (ie are indigenous or endemic to a region).
Noxious Species	A plant declared under the *NT Noxious Weeds Act* to be a "noxious weed".
Outside Bend	The concave bank on a stream bend as observed from mid-stream.
Overstorey Vegetation	Woody plants >1.3m tall, usually with a single stem (eg Eucalypts, Melaleucas, *etc*). Shrubs >1.3m tall have also been included with overstorey vegetation.
Oxbow Lake	A horseshoe-shaped channel or lake on a floodplain created by a cut off and the abandonment of a meander loop.
Perennial Stream	A stream which contains water at all times except during extreme drought.
pH	A measure of the concentration of the acidity or alkalinity of the water (hydrogen ions in water).

Point Bar	A bar located on the inside of a bend of a stream.
Point of Inflexion	The point on the upper bank where the bank changes direction and curves over, away from the river channel.
Pool	A deep body of still or slow moving water, generally occurring in the main channel in an alternating sequence with riffles or runs. Pools are characterised by a depth >0.5m, where the stream widens or deepens and the current declines.
Rapid Habitat	A section of fast flowing water characterised by a depth >0.3m; gradient 3-5^{o}; strong currents and rocks emerge to break the water's surface.
Reach	A length of stream channel chosen as the boundary for a survey site and generally representative of the channel habitats and the instream condition. Each reach usually consists of at least two complete pools and riffle/run habitats.
Reach Environs	Lands immediately adjacent to the river and the riparian zone along the reach and includes the floodplain and valley flat.
Recharge	The processes involved in the replenishment of water to the zone of saturation.
Riffle Habitat	A shallow area of a stream, often separating pools, characterised by a depth 0.1-0.3m; gradient 1-3^{o}; moderate currents and an unbroken/unsmooth water surface.
Right Bank	The right hand bank of a stream when looking downstream.
Riparian Zone	Distinct corridor, including the vegetation, along the edge of a stream. This zone is inextricably linked with the stream both in providing litter (eg leaves, branches, *etc*) to the stream and being affected by the extra moisture that is available.
Riparian Vegetation	A distinct corridor of vegetation located along the edge of a stream or river.
River	A large, natural freshwater surface stream having a permanent or seasonal flow and moving toward a sea, lake, or another river in a definite channel.
Riverine Corridor	The river channel and its riparian land, including part of the adjacent floodplain.
River Morphology	The study of the channel pattern and the channel geometry at several points along a river channel, including the network of tributaries within the drainage basin.
River System	The aggregate of stream channels draining a river basin.
Run Habitat	An area of stream that is too deep to be a riffle and with too large a flow to be a pool. Runs are characterised by a depth >0.3m; gradient 1-3^{o}; small but distinct and uniform current; and an unbroken water surface.
Runoff	That part of rainfall which finds its way into streams after some of it has evaporated, been taken up by plants or seeped into the ground.
Sample Point	Is the point along a reach, at a site, where survey information is collected such as cross-sections. Usually two sample points are selected at each site, one at a pool habitat and one at a shallow habitat-type like a riffle or run.
Scour	Stream bed, bank or floodplain erosion caused by water turbulence shearing or plucking particles away from the surface.
Sediment	Material carried by flowing or mixing water that falls out to the bottom and deposits when the flow or mixing stops. This can include boulders, gravel, sand, silt, clay and organic matter.

Sedimentation	The long term deposition or permanent filling of a stream channel or estuary with sediment.
Semi-diurnal Tides	A tide having two high waters and two low waters during a tidal day.
Siltation	See 'Sedimentation'.
Site	Is a location on a river or creek where information is collected on the condition of the steams. That is, surveys are completed at sample point/s or photographs only are taken.
Spring	a general name for any discharge of deep-seated, hot or cold, pure or mineralised water.
Stable River	The existence in a stream of a balance between erosion and deposition (ie dynamic equilibrium). The channel changes in location but not in pattern, form or slope.
Stratified Sampling	The sample area (ie catchment) is sub-divided into areas which are different (ie sub-sections). Doing this maximises the difference between the areas and minimises the difference within the area. Usually each sub-divided area is sampled randomly.
Stream Order	The designation by a dimensionless integer series (1,2,3,…….) of a relative position of stream segments in the network of a drainage basin.
Stream Profile	The longitudinal profile of a stream.
Sub-catchment	Part of a river catchment that has been sub-divided to show the major tributaries within the catchment.
Sub-section	Part of a sub-catchment that has been further sub-divided according to attributes including geology, stream gradient, altitude, natural and artificial barriers, bed and bank substrates, stream order, landuse and the tidal limit.
Surface Water	All bodies of water on the surface of the earth.
Thalweg	A line down a stream linking the deepest parts and sites of greatest flow.
Tidal	Water level affected by the tide.
Tidal Bore	A high, breaking wave of water, advancing rapidly up an estuary.
Total Alkalinity	A measure of a waters acid-neutralising capacity. The sum of all the titratable bases. It is usually a measure of the bicarbonate / carbonate / hydroxide content of water but can also include contributions from phosphates, borates, silicates or other bases if present.
Total Phosphorus	The sum of the concentrations of soluble and in-soluble phosphorus.
Tributary	A stream that feeds or flows into or joins a larger stream or lake.
Tufa	A spongy, porous limestone formed by precipitation from evaporating springs and river waters, often onto leaves and stems of neighbouring plants. Also known as calcareous tufa.
Turbidity	Visible pollution (dirtiness) due to suspended material in the water causing a reduction in the transmission of light.
Understorey Vegetation	Woody plants <1.3m tall, frequently with many stems arising at or near the base). Ground covers (plants without woody stems, eg grasses, sedges *etc*) have also been included with understorey vegetation.

Upper Bank	Is that part of the bank between the water mark (see below) and the high bank where it stops rising and flattens off. Also called 'high bank'.
Vegetation Cover	Used to assess the foliage density of each of the vegetation structural categories (eg trees, shrubs, grasses, submerged aquatic vegetation, *etc*). The cover is estimated in terms of the total imaginary shadow cast by each type of vegetation and is recorded as a percentage. The cover estimates for each type of vegetation are all made independently, and so the total covers do not necessarily add up to 100%.
Vegetation Profile	A survey of riparian vegetation (involving species identification and measurements such as diameter at 1.3m, bole and tree height, and crown width) within a 10m-wide belt transect. This transect is located at right angles to the water's edge and extends to the upper bank or edge of riverine vegetation. The vegetation profiles have also been represented diagrammatically.
Vegetation Width	Width of vegetation from edge of the low flow channel to where the vegetation changes from riparian vegetation to eg woodland vegetation.
Vegetation Zonation	The pattern or zoning of plant communities from the water's edge to the high bank.
Vegetation Structural Categories	The riparian vegetation is broken into structure and size classes including: tall trees >30m, medium trees 10-30m, small trees 2-10m, regenerating trees <2m, woody shrubs <2m, vines, rushes and sedges, phragmites, herbs, grasses, ferns, mangroves, salt marsh and palms. Submerged, floating and emergent aquatic vegetation are also broken into groups.
Velocity	The rate of movement of water in a stream. Usually expressed as metres per second (m/sec).
Water's Edge	The edge of the water at the time of the survey.
Waterfall Habitat	A perpendicular or nearly perpendicular descent of water in a stream. Waterfalls are characterised by a height >1m and gradient >60^{o}.
Water Surface	The surface of the water at the time of the survey.
Water Mark	A mark left on the bank at the 'normal' inundation level for the stream in the dry season (see below), before water levels subside as the dry season progresses. It's location is shown by (i) the edge of terrestrial grasses, ferns (eg *Ampelopteris prolifera*) and other vegetation (eg *Pandanus aquaticus*) which cannot tolerate more frequent and prolonged inundation; (ii) by an area of erosion; or (iii) the boundary between different sediment types.



Wetland	An area characterised by a high content of soil moisture, such as a swamp or bog.

APPENDICES

The following Appendices appear in this section:

Appendix A: Evolution of the Daly River Estuarine Plains
Appendix B: Summary of Data Sheet Information
Appendix C: Summary of Condition and Stability Ratings

Appendix A: Evolution of the Daly River Estuarine Plains

Below is a map (refer Figure A.1) of the lower Daly River, showing the track of active channel migration, ancient shorelines, and the 6,000-year mangrove swamp region (discussed in Section 2.7.1). Much of the Daly River plains are underlain by 6,000 year old mangrove muds (Chappell, 1987). The Daly River meanders are very actively migrating through continued deposition of new sediment. According to Woodroffe and Chappell (1990), rates of meander migration, and scroll plains, palaeochannels and the proportion of the big swamp reworked are all likely to be greater on the rivers with larger catchments. This model is substantiated by studies on large rivers such as the Daly and South Alligator River (Woodroffe and Chappell, 1990).

As discussed by Chappell (1987), all river channels began to evolve when their plains formed soon after sea level stabilised, 6000 years ago. Change is most rapid in the Daly River (compared to the Adelaide and South Alligator Rivers), where meanders have formed, broken down, and reformed many times in the last 6000 years. The Daly River has a highly active meander plain where meander cutoffs, and both cuspate and sinuous forms have formed within historical times (Woodroffe *et al.*, 1986). According to Woodroffe *et al.*, the Daly River catchment has experienced a history of Holocene sea-level changes and has a floodplain contained within a prior valley that is much longer than it is wide.

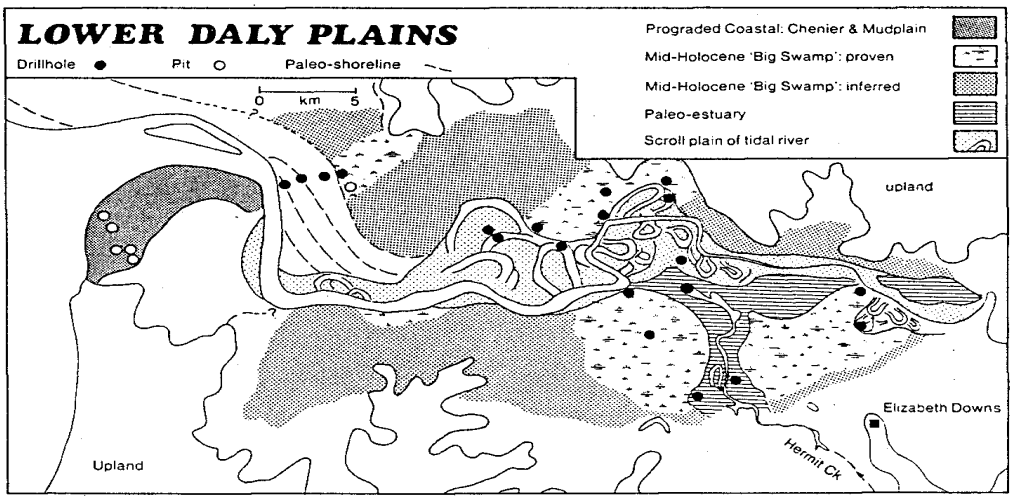


Figure A.1

Lower Daly River, showing the track of active channel migration, ancient shorelines and the 6000-year mangrove swamp region

Source: Chappell (1987)

According to Woodroffe and Chappell (1990) 'chenier plains', as shown in Figure A.1, are broad progradational muddy plains, upon which there are isolated coarse sandy or shelly ridges, representing former shorelines. These plains are common flanking open low-energy embayments; they have developed during the last 6,000 years since sea level has stabilised. While the plains have prograded under low-energy conditions, this gradual build-out has been punctuated by intermittent high-energy periods during which the ridges have formed.

Chappell and Woodroffe (1985) and Woodroffe *et al.* (1986) identify four channel segments within a tidal river system. A hypothetical tidal river composed of these four channel segments and characteristics of these are shown in Figure A.2 (taken from Chappell and Woodroffe, 1985).

These four segments have the following features:

Estuarine funnel
The first channel segment is termed the 'estuarine funnel' (refer to 1a). The funnel is broad at the mouth and tapers exponentially in width. It is typically flanked by a prograding coastal plain, which has a zoned mangrove fringe along with chenier ridges. Estuarine funnels in the northern rivers typically have a few large dog-leg bends and may have shoals or mangrove islands near the mouth.

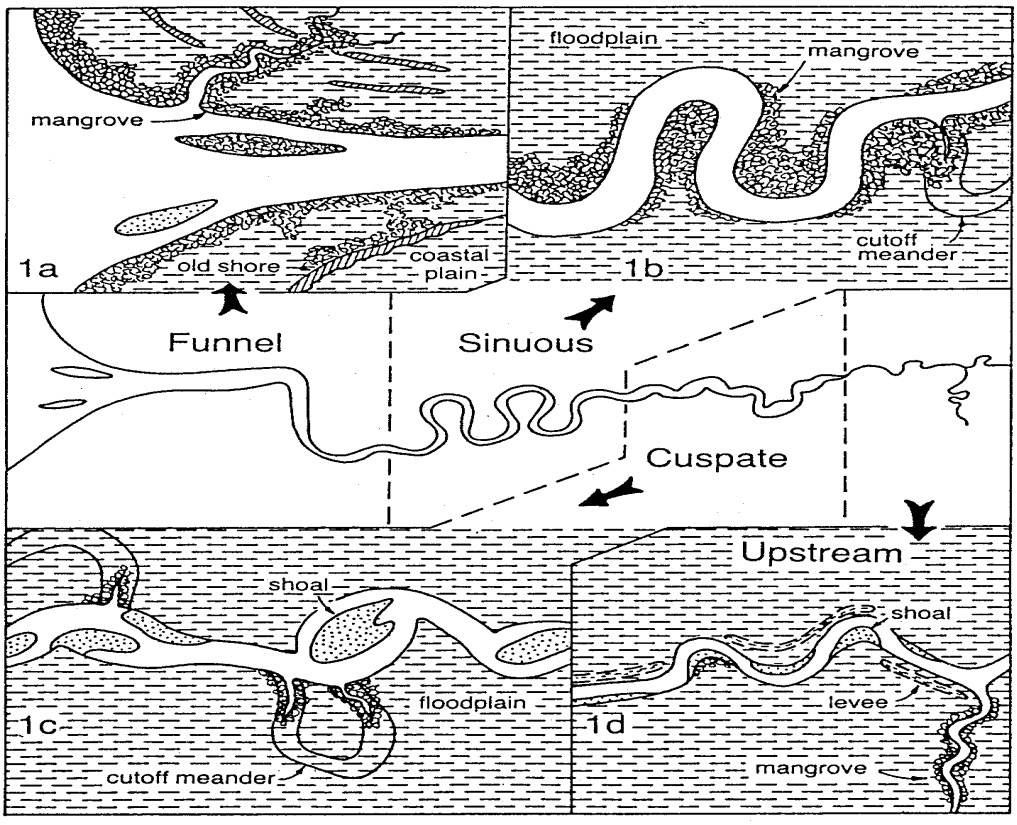


Figure A.2

Schematic tidal river of the Northern Territory, showing characteristics of different river segments

Source: Chappell and Woodroffe (1985)

Sinuous segment
The next segment is made up of a series of regular meanders, geometrically similar to a meandering fluvial river with points of inflection asymmetrical relative to the mid-line (refer to 1b). Substantial mangrove forests are typical on the inside of each bend and the channel is relatively deep.

Cuspate segment
Beyond the sinuous segment is a series of bends typified by sharp points on the inside of each one, sometimes with shoals near these points, otherwise with broad mid-channel shoals. Mangroves are sparse throughout the cuspate reach, banks are steep on both sides, and the channel is wider and generally shallower than sinuous bends immediately downstream (refer to 1c).

Upstream segment
The last segment, reaching to the tidal limit, typically has a series of irregularly spaced bends interspersed with straight reaches, significantly narrower than cuspate bends immediately downstream. Shoals, if present, occur on the insides of bends, and the channel is generally deeper than the cuspate segment. Discontinuous levees may occur (refer to 1d).

The four channel segments of Adelaide, South Alligator and Daly Rivers are shown in Figure A.3. All of these rivers show the estuarine funnel and the upstream segments, but the cuspate segment occurs only on some. The figure shows that proportionate lengths of the different segment types vary between the Adelaide, South Alligator and Daly Rivers. Compared with the Adelaide and Alligator Rivers, the Daly has a relatively long upstream channel segment and a short sinuous/cuspate reach. This may reflect the fact that in the Daly River, with its much larger flood discharge, the point at which the mean annual flood peak discharge equals the peak spring tide flow occurs closer to the river mouth than in the other two cases (Chappell and Woodroffe, 1985).

According to Chappell and Woodroffe (1985), cuspate bends develop either by direct meander cutoff, or when a widening channel, with a new radius of curvature, cuts back into the prior sinuous bend of different dimensions. The presence of sinuous paleochannels (prior channels preserved on the floodplain) illustrates this process.

Chappell and Woodroffe (1985) also suggest that the cuspate segment forms at the expense of previous sinuous bends. Also, that the widespread bank failure stems from the reduction of the riparian mangrove forests typical of sinuous bends, to a narrow fringe of low trees, through continued bank-top sedimentation. The thin band of trees provides little insulation against scour and bank failure.

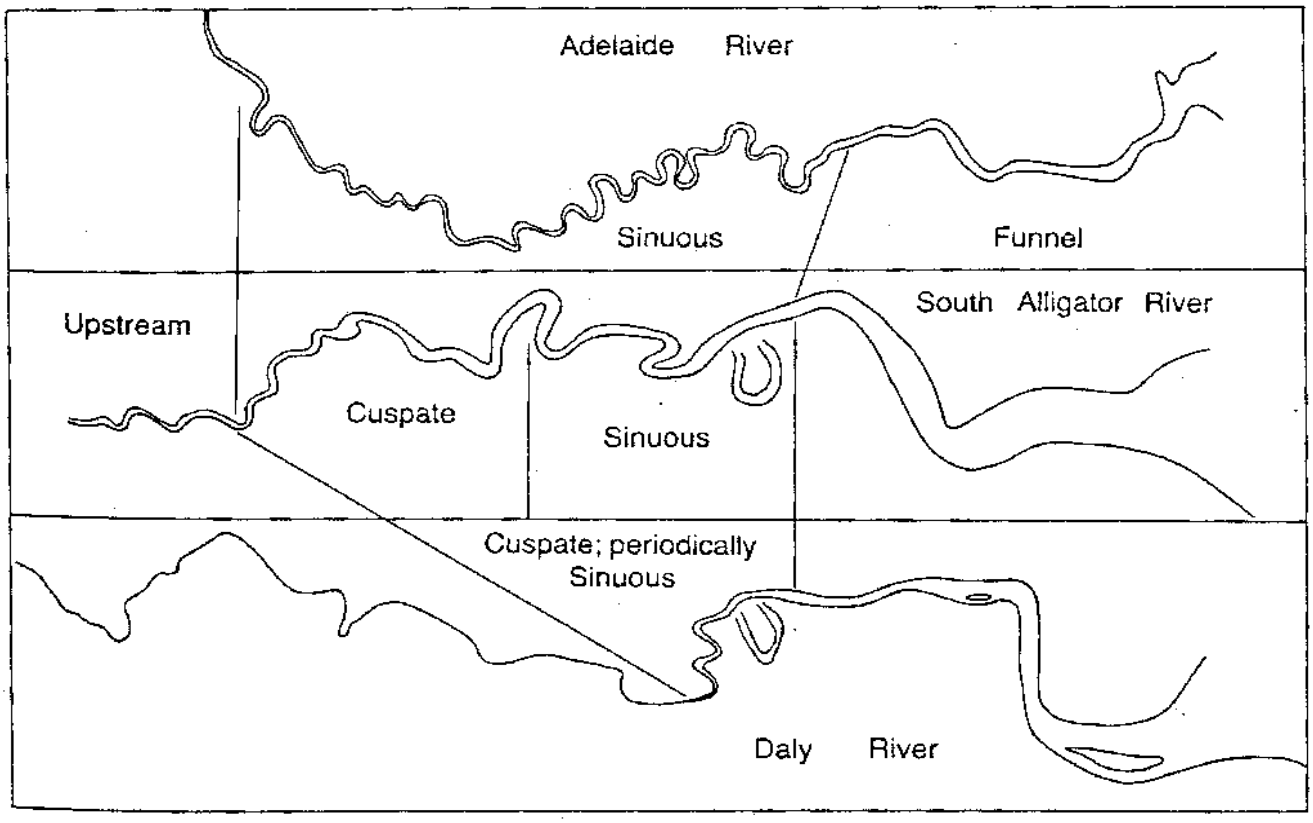


Figure A.3 Channel segments of Adelaide, South Alligator and Daly Rivers
Source: Chappell and Woodroffe (1985)

As noted by Chappell and Woodroffe (1985) and Woodroffe *et al.* (1986) the Daly River channel also appears to be considerably more mobile. In the Daly River, historical migration of meander loops which are seen from successive aerial photos have shown them to move by up to 30 metres per year. Whilst aerial photos of the South Alligator show channel migration of only about one metre per year (Woodroffe *et al.,* 1986). Cutoff meander loops are more abundant on the Daly floodplain, adjacent to the sinuous and/or cuspate segments, than in the other two cases. The Daly has nests of up to five successive paleochannels adjacent to its sinuous segment, the South Alligator has well preserved paleochannels but rarely more than one cutoff in any area, and the Adelaide River has very few paleochannels adjacent to its sinuous segment (Woodroofe *et al.,* 1986). Channel migration in the Daly River is also shown by active lightly-ridged point bar plains, with youthful vegetation, adjacent to the present channel. These do not occur on the other two rivers. The length of the sinuous segment of the Daly has contracted through time, shown by nests of abandoned meander loops well upstream of the present cuspate/sinuous limit.

The sinuous/cuspate transformation is less pronounced on the Daly River compared to South Alligator River. It is suggested by Chappell and Woodroffe (1985), that on the Daly River the formation of the South Alligator type of cuspate channel is prevented by continued deposition and reworking of the river's considerably larger and more sandy sediment load, in its middle and lower reaches.

Appendix B: Summary of Data Sheet Information

Below is a summary of the raw data collected on each data sheet. Also refer to Anderson (1993b,c).

- *Site Description*

- Basin No.
- Sub-section No.
- Site No.
- Tributary Name → Flows into → Flows into
- Date
- Recorder and Assistant
- Site Description (locality name)
- Location Description
- Type of Site: Photograph only, full survey site, stream gauge, water quality, veg. profile, veg. samples, cross-section/s only.
- Grid reference: Zone (52 or 53), Easting, Northing – using GPS or Other (noting position error)
- Map name, scale and number
- Distance upstream from river mouth
- Stream order number
- Is the site tidal or non-tidal?
- Catchment area (in km^2)
- Altitude
- Photographs taken – film no., shot no. and description. (The standard set consists of one shot looking upstream, downstream, at left and right banks, reach environs and other features).
- Access sketch (to relocate site for follow-up surveys)

- *Reach Environs*

- Overall disturbance rating: very low, low, moderate, high, very high or extreme.
- Water level at sampling time: completely dry, isolated pools with no flow, low flow/low level, moderate < water mark, high > water mark, flood > bankfull, within 1 hr of high tide or low tide, incoming/between tide, outgoing/between tide.
- Channel pattern at a local scale: straight, mildly sinuous, irregular, regular meanders, irregular meanders, tortuous, braided, swampy, channelised.

- Local land use:

Horticulture small crops/vines	horticulture tree crops / fruit
irrigated broadacre row crops	rainfed broadacre row crops
grazing – sown pasture	grazing – native – cleared
grazing – native – thinned	grazing – native – virgin timber
intensive livestock	urban residential
urban manufacturing/processing	national/environment park or reserve
urban park or reserve	rural residential / hobby farm, other

- Local disturbance:

road/track	bridge/culvert
causeway/river crossing/ford	boat ramp
weir	channelisation
river works	discharge pipe
irrigation runoff/pipe outlet	water extraction/pump
sewage effluent	grazing
water point for stock/ferals	forestry activities
dredging	sand/gravel mine
other mine	people
none	

- Floodplain features: oxbows/billabongs, remnant channels, floodplain erosion/scours, floodplain deposits/silt, prominent flood channels.

- Local land tenure: freehold/leasehold, national park, state park, reserve/environmental park, state forest, urban reserve, urban, other/unknown.

- Local vegetation habitat / type:

eucalypt wet sclerophyl	eucalypt open-forest
eucalypt woodland	eucalypt open-woodland
sandstone monsoon vine-forest	monsoon vine-forest on rock
lowland monsoon vine-forest	coastal monsoon vine-forest
freshwater streams	melaleuca woodland
melaleuca swamp	phragmites swamp
floodplain glassland/sedgeland	mangrove
salt marsh/saline tidal flats	grassland
shrubland	heathland
palms	plantation
other	

- *Channel Habitat*

- Channel habitat type/s present:

Waterfall	Height >1m; gradient > 60^{o}.
Cascade	Step height <1m; gradient 5-60^{o}; strong currents.
Rapid	Depth >0.3m (guide only); gradient 3-5^{o}; strong currents; and rocks break surface.
Riffle	Depth 0.1-0.3m (guide only); gradient 1-3^{o}; moderate currents and surface unbroken but unsmooth.
Glide	Depth <0.1m; gradient 1-3^{o}; small currents; surface unbroken and smooth.
Run	Depth >0.3m; gradient 1-3^{o}; small but distinct and uniform current; and surface unbroken.
Pool	Depth >0.5m; where stream widens or deepens and currents declines.
Backwater	Cut-off section away from the channel.

- Average dimensions for each type: % of section length
  height for waterfall and cascade
  depth at water level and water mark for all types except waterfalls and cascades,
  width at water mark.
- Total length of reach.
- Sketch of reach and location of sample points (where cross-section surveys done).
- If boat access is available, a longitudinal profile survey (depth measurements along the river using a GPS and depth sounder) is undertaken in order to select the reach, measure lengths for each habitat type and to locate the deepest section along the reach.

- *Cross-Sections located at Sample Points (usually two are measured for each site)*

- Sample point letter
- Grid reference for each sample point: Zone (52 or 53), Easting and Northing
- Type of habitat: Pool, riffle, run, glide, cascade, rapid, waterfall, backwater
- Dimensions of habitat: length, average width, average depth at water level and water mark
- Cross-section at water surface, bed dry (depths @ water mark) or water mark covered (no lower bank).
- Transect width at the water surface or where transect taken, width at water mark, total channel width.
- Distance and depth measurements across the transect line. These cross-sections have been shown diagrammatically using Excel.
- Width, height and slope of each bank, lower and upper (refer Figure A.4).
- Sketch and measurements for each bank – marking on the 'point of inflexion', upper bank and edge of riverine vegetation / riparian zone (refer Figure A.4).

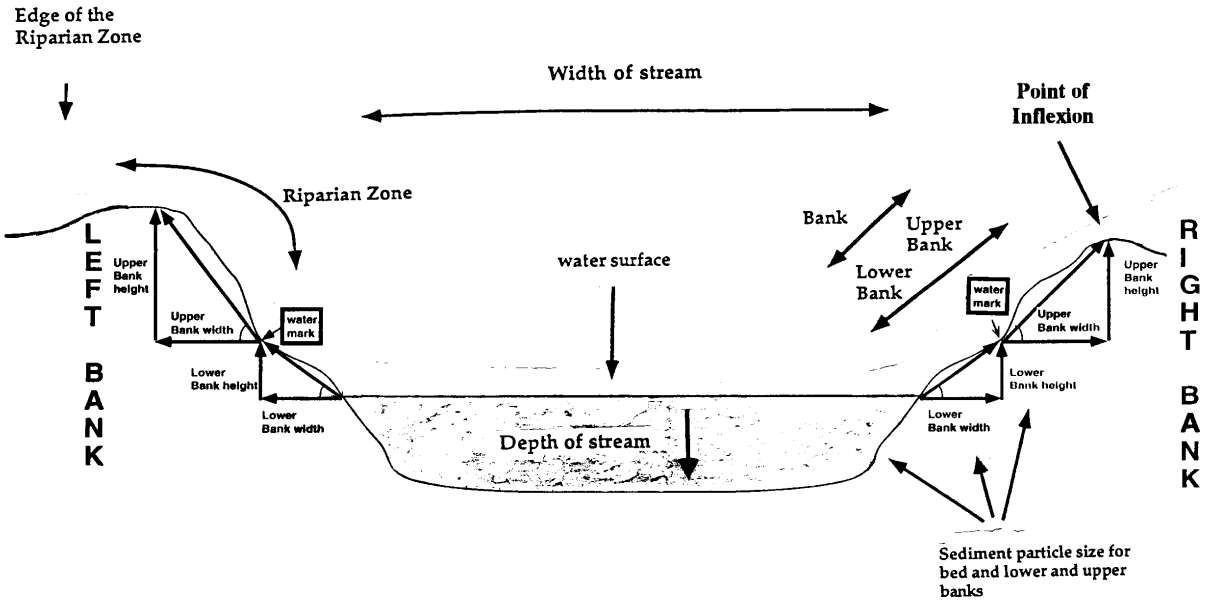


Figure A.4: Diagrammatic Representation of a River Channel Showing the Type of Information Collected During Cross-section Surveys

- Bank sediments for each bank, lower and upper, totalling 100%. Percentage of organic matter within sediment sample. Sediment size classes include:
  - fines (<0.06mm)
  - small sand (0.06-0.5mm)
  - large sand (0.5-2mm)
  - small gravel (2-5mm)
  - medium gravel (5-20mm)
  - large gravel (20-60mm)
  - cobble (60-300mm)
  - boulders (>300mm)
- Bed sediments totalling 100%. Percentage of organic matter within sediment sample. Usually three bed sediment samples are taken at each cross-section.
- Presence and location of rock outcrops – left lower/upper bank, right lower/upper bank, bed, none.

- *Stream Gauging – Flow/Discharge Measurement*

- Method: float or current meter
- Quality of gauging: excellent, good, fair, poor
- Current meter details: body type, body number, fan number.
- Up to three flow measurements are made (using either float method or a current meter) at each cross-section at 60% of the depth in order to calculate a mean velocity and overall discharge.

- *Bank Condition*

- Percentage of each bank, lower and upper, recorded as being stable, eroding or aggrading.
- Location of instability: outside bends, inside bends, at floodplain scours, at obstacles, at seepage and runoff points, irregularly or all along.
- Slope of each banks (ranked): vertical, steep, moderate, low, flat.
- Shape of each bank (ranked): concave, convex, stepped, wide lower bench, undercut, cliff.
- Factors affecting bank stability (ranked):

high flow	wash from boats
tidal influence	seepage
runoff	floodplain scours/breakouts
stock	cultivation near rivers
people tracks	vermin
clearing of vegetation	extraction of sand/gravel
mining	road/river crossings/culvert *etc*
none	other

- Artificial bank protection measures: revegetation works, rock revetment, mesh/gabions, log wall, groynes, concrete wall, fenced watering points/along river, fenced human access.
- Presence of levee banks – height and width.
- Subjective rating of the overall condition of each bank.
  Overall instability and susceptibility rated as either: minimal
  low
  moderate or
  high

- *Bed and Bar Condition*

- Overall bed stability rating: bed stable
  moderate erosion
  severe erosion
  moderate aggradation
  severe aggradation.

- Bar type, if present: point
  alternate/side irregular
  mid-channel island
  encroaching vegetation
  around obstructions
  channel bar plain
  low flow meander infilled channel
  high flow deposits

- Percentage of the bed surface along the reach protruding out of the water at water mark and forming a bar.
- Gravel features (bed and bar) – angularity (very angular, angular, sub angular, rounded, well rounded); shape (sphere, disc, blade or rod-shaped).
- Whether gravel surface covered by algae/silt or whether clean.
- Bed compaction – tightly packed/armoured, packed but not armoured, moderate compaction, low compaction/poor grading, low compaction/loose array.
- Factors affecting bed stability (ranked): bed deepening / lowering
  bank erosion
  in-stream siltation
  channelisation / concentration of flows
  sediment starvation
  extraction (sand, gravel, dredging)
  agriculture or grazing
  none
  other

- Controls stabilising the bed: bridge/river crossing/culvert, rock outcrops, fallen trees, bed stabilising structures, none.
- Passage for fish and other organisms at the time of the survey and @ water mark:
  no passage
  very restricted (<0.1m deep and narrow)
  moderately restricted (<0.3m deep and narrow)
  partly restricted (<0.5m deep and narrow)
  good passage (0.5-1m deep, wide, no torrent)
  unrestricted (>1m deep and almost channel wide)

- *Vegetation (Riparian and Aquatic)*

- Width of the riparian zone for left and right banks.
- Percentage of each bank, lower and upper, that is bare of overstorey (vegetation >1.3m) and understorey (groundcover) vegetation.
- Riparian vegetation – An assessment of the percentage foliage cover or density for native and exotic species is made for each of the following 14 vegetation types or growth forms using the percentage cover diagram (Figure A.5) as a guide:

trees >30m	phragmites
trees 10-30m	herbs
trees 2-10m	grasses
regenerating trees <2m	ferns
woody shrubs <2m	mangroves
vines	salt marsh
rushes/sedges	palms

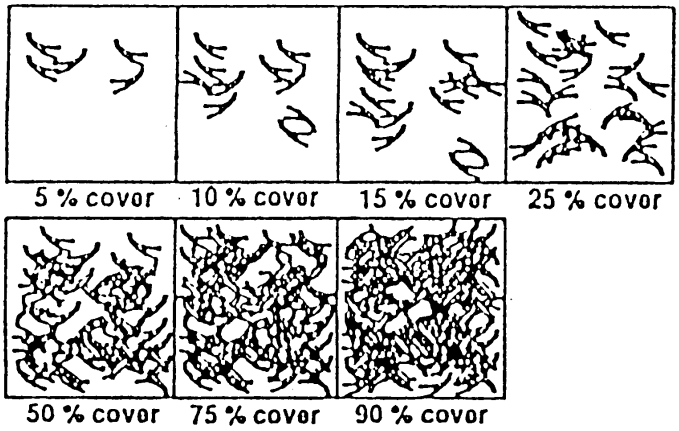


Figure A.5:

Diagrams used in the Field to Estimate Percentage Cover for Riparian Vegetation, Aquatic Vegetation and Instream Habitat

Source:
Anderson (1993 b,c)

- Total percentage of weeds and exotic species in the riparian zone.
- Local species checklist recording whether more common species absent, scattered or abundant. The more common species include: Eucalypts, Melaleuca, Barringtonia, Pandanus, Casuarina, Leichardt Pine, Acacias, Bamboo, Ficus, Leptospermum, Lophostemon, Syzygium, Grevillea, Palms, Phragmites, Fern, Passiflora, Flagellaria vine, Noogoora Burr, Hyptis.

- Aquatic vegetation – percentage cover (refer Figure A.5) for:

submerged vegetation	(algae, Chara/Nitella, Vallisneria, Myriophyllum, *etc*)
floating vegetation	(water hyacinth, Azolla, water lilies)
emergent vegetation	(Phragmites, Typha, Para Grass, rushes/sedges, Pandanus, Melaleuca, other shrubs/trees, other groundcovers)
exotic aquatic vegetation	

- Vegetation survey / Belt transect: Location of transect including a Grid Reference, transect width (usually 10m wide). The location of the overstorey vegetation (including everything >1.3m tall) is recorded within this transect, along with a trunk diameter, bole and tree height, crown width and species name. The belt transects were located at right angles to the water's edge and extended to the upper bank or edge of riverine vegetation. Other species not located within the belt transect but are present at a site are also recorded. Groundcovers (eg grasses, herbs, ferns, *etc*) were recorded within this vegetation profile through the use of a $1m^2$ quadrat, usually located at 5m intervals along the profile length, starting at the water's edge. Percentage covers for each species type located within each quadrat is recorded. The vegetation profiles have been represented diagrammatically using Microstation in order to show the zonation of, and a typical cross-section through, the riverine vegetation.

- Vegetation lists (of the major species) are recorded for sites where a vegetation survey is not undertaken. The lists give no indication of abundance of the species at the site but rather whether they were present.

- *Aquatic Habitat*

- An overall aquatic rating for all aquatic life is subjectively rated for each site as:
  very high/pristine
  good
  poor
  very poor

  The rating takes into account the diversity of depths and substrates, level of disturbance, diversity and extent of cover, extent of canopy and other vegetation cover, and whether the stream dries up completely.

- Percentage bed cover (refer Figure A.5) is recorded for the following instream debris types:

  individual log
  log jam, 50% or >50% dense
  individual branch
  branch pile, <50% or >50% dense
  terrestrial leaves and twigs
  macrophyte fragments
  algal clumps and debris
  large/deep submerged vegetation - freshwater and marine
  mangroves
  large patches of floating vegetation
  emergent vegetation in permanent water >0.5m deep
  tree roots
  rock faces, boulders and cobbles
  permanent pool >1m deep
  man-made structures and debris

- Cover provided by each bank (ie canopy cover, vegetation overhang <1m from the water surface, root overhang, bank overhang and man-made overhang) is recorded as a percentage of the bank length. An average width for each type of cover is also recorded.

Appendix C: Summary of the Condition and Stability Ratings

Below is a summary of the condition and stability ratings and associated formulae used for this project.
** indicates those formulae that have been modified from the 'State of the Rivers' methodology (Anderson, 1993c).*

- *State of the Reach Environs ** *(Map 11)*

The state of the reach environs is based on an assessment of the land corridor along the survey reach and on the adjacent floodplain. The rating takes into account land use and local disturbances. A higher rating is achieved for sites which have undisturbed vegetation and no local disturbances likely to impact directly on streams. Sites in areas where floodplain and valley flat areas have been cleared for grazing, intensive agriculture or for rural residential occupancy are rated more poorly.

The calculated ratings are derived by re-ordering the categories used for recording the various types of local disturbance and land use. The revised categories for each type (land use, disturbance) is determined and then scaled to 100% (see below), before being multiplied by the weightings and added to give the final derived ratings. If more than one category is recorded, the average is used.

Land use categories: (scaled between 0% and 100%)	1	Urban manufacturing	(7%)
	2	Urban residential	(14%)
	3	Intensive livestock	(21%)
	4	Rural residential	(29%)
	5	Urban park	(36%)
	6	Horticulture – small crops	(43%)
	7	Horticulture – tree crops	(50%)
	8	Irrigated broadacre crops	(57%)
	9	Rainfed broadacre crops	(64%)
	10	Grazing – sown pasture	(71%)
	11	Grazing – native – cleared	(79%)
	12	Grazing – native – thinned	(86%)
	13	Grazing – native – virgin	(93%)
	14	Park or Reserve	(100%)
Local disturbance categories: (scaled between 0% and 100%)	1	Sand/gravel mine	(7%)
	2	Other mine	(13%)
	3	Dredging	(20%)
	4	Sewage effluent	(27%)
	5	Water point for stock/ferals	(33%)
	6	Forestry	(40%)
	7	Irrigation runoff / pipe outlet	(47%)
	8	Channelisation	(53%)
	9	River works	(60%)
	10	Water extraction / pump	(67%)
	11	Grazing	(73%)
	12	Discharge pipe	(80%)
	13	Causeway / crossing / ford	(87%)
		Boat ramp	(87%)
		Weir	(87%)
	14	Bridge / culvert	(93%)
		Road / track	(93%)
		People	(93%)
	15	None	(100%)

These revised and scaled categories are then applied using the formula:

State of the Reach Environs = local disturbance x (50%) + land use x (50%)

- *Channel Type Diversity (This component is not used to derive the overall condition rating) * (Map 12)*

The channel type diversity categories take into account:

1. The number of different channel habitat types present (cascades, glides, pools, rapids, riffles, runs and waterfalls); and
2. The proportion of the reach occupied by pools versus other habitat types.

1. Number of Channel Habitat Types

Each site is rated out of 5 according to Table A.1:

Table A.1: Channel Type Diversity Rating based on Number of Channel Habitat Types

Number of Channel Habitat Types	Rating (out of 5)
Uniform habitat or depths (1 type) – (100% riffle or pool in smaller streams with no variation in depth or intermittent pools in larger streams)	1
Slight variety of habitat or depths (1 type) – (100% riffle or pools in smaller streams with some variation in depth or 100% pools in larger streams)	2
Some variety of habitats (2 types)	3
Good variety of habitats (3 types)	4
Wide variety of habitats (4 types)	5

2. Proportion of Reach Occupied by Pools Versus Other Habitat Types

Each site is rated out of 5 according to Table A.2:

Table A.2: Channel Type Diversity Rating based on Proportion of Reach Occupied by Pools Versus Other Habitat Types (Adapted from Mitchell, 1990)

Proportion of Reach Occupied by Pools Versus Other Habitat Types*	Rating (out of 5)
100% riffle or pool in smaller streams with no variation in depth or intermittent pools in larger streams	1
100% riffle or pools in smaller streams with some variation in depth or 100% pools in larger streams	2
<10% riffles	3
10-30% riffles	4
>30% riffles	5

* The term 'riffle' refers to habitat types other than pools that may be present. These habitat types include: riffles, rapids, cascades, waterfalls, glides and runs.

Rating results from 1 and 2 above are added to give a final rating out of 10 for each site. A channel type diversity category is assigned to each site according to the following:

1-2	**Very Low Diversity**
3-4	**Low Diversity**
5-6	**Moderate Diversity**
7-8	**High Diversity**
9-10	**Very High Diversity**

- *Bank Stability* *(Map 13)*

Bank stability ratings are determined from the recorded percentages of the banks on each side of the reach which are rated as stable. Upper banks are assigned a greater proportion of the score (80%) than lower banks (20%). The final condition ratings represent the average percentage of the bank that is unstable at the site. A score of 100% is achieved for sites where the entire banks are completely stable. Low scores occur when a high proportion of the bank is unstable (eroding or aggrading). The dominant process at each site (erosion or aggradation) is also recorded.

Bank Stability Rating	**=**	**(80%) % upper bank stable* + (20%) % lower bank stable* (*averaged for each bank)**

- *Bed Stability ** *(Map 14)*

Bed stability ratings are determined from a subjective assessment made in the field of whether the river bed is stable; moderately eroding or aggrading; or severely eroding or aggrading. The symptoms for assigning a bed stability category to a site include:

- Stable bed: The river bed is consolidated; bed and bar material is the same size, alluvium balanced; and banks stable.
- Moderate erosion: There is little alluvium; signs of deepening; eroded banks; bed deep, narrow and steep; unconsolidated.
- Moderate aggradation: There is moderate build-up at obstructions and bars; bed is flat, uniform, wide and shallow; some over-bank siltation.
- Severe erosion: The bed is scoured of sand; signs of deepening; bare eroded banks; erosion heads; erosion causes; and a steep bed.
- Severe aggradation: The bed is flat, wide but shallow and channel blocked; bars large, covering most of bed and bank; bed is loose and unconsolidated.

A bed stability rating (out of 10) is assigned to each site according to the following:

2	**Severe Erosion or Aggradation**
6	**Moderate Erosion or Aggradation**
10	**Stable**

- *Cover and Structural Diversity of Riparian Vegetation ** *(Map 15)*

The cover and structural diversity rating for riparian vegetation takes into account:

(1) The foliage cover or density provided by the overstorey, understorey and ground cover vegetation types or 'growth forms'; and
(2) The structural diversity or number of different growth forms present.

A higher rating is only achieved for sites that have recorded a high foliage cover and a diversity of structural types present within the riparian zone. The width of riparian vegetation (refer Map 16) and the cover of exotic riparian vegetation (refer Map 17) are dealt with separately.

There are 14 riparian vegetation types or growth forms and these are divided into three vegetation layers: overstorey, understorey and ground covers. The distinction between these three vegetation layers is:

Overstorey vegetation:	trees >30m tall	(1)
	trees 10-30m tall	(2)
	palms	(3)
Understorey vegetation:	trees 2-10m tall	(4)
	mangroves	(5)
	woody shrubs <2m tall	(6)
	regenerating trees <2m tall	(7)
Ground covers:	vines	(8)
	rushes/sedges	(9)
	Phragmites	(10)
	forbs	(11)
	grasses	(12)
	ferns	(13)
	salt marsh	(14)

(1) Foliage Cover or Density

In the field, an assessment of the percentage foliage cover or density (refer Figure A.5) is made for each of the 14 vegetation types or growth forms.

The percentage foliage cover recorded for the growth forms within each stratum are added together. That is, covers for growth forms 1 to 3, 4 to 7 and 8 to 14 (shown above) are added together. If these covers are >100%, they are classed as 100%. **These covers include both native and exotic species**. A negative factor (-15%) is applied to each stratum for the percentage of **bare ground** recorded along the upper bank within the riparian zone. For example:

*sum of % covers for overstorey – (sum of % covers for overstorey * % of bare ground *15%)*

The percentage of bare ground is estimated for the (i) overstorey/understorey and (ii) ground covers in the field for both the upper banks (UB) and lower banks (LB). For the above formula use the following as the "% of bare ground":

*0.1 * % cover for overstorey/understorey UB + 0.66 * % cover for ground cover UB*

Each stratum (ie overstorey, understorey and ground covers) is rated out to 10 according to Table A.3:

Table A.3: Foliage Cover or Density Categories Used to Rate Each Vegetation Stratum in the Riparian Zone

Vegetation Cover	Foliage Cover or Density* (%)	Rating (out of 10)
Very sparse	<10%	2
Sparse	10-30%	4
Mid-dense (a)	31-50%	6
Mid-dense (b)	51-70%	8
Dense	71-100%	10

* These Foliage Projective Cover categories were defined by Specht (1981)

The ratings for the overstorey, understorey and ground covers are added together to give a rating out of 30 and are then re-scaled to give a rating out of 5 **(A).**

2. Structural Diversity

The structural diversity is derived by counting the number of vegetation types or growth forms (out of 14) present at a site, and assigning a rating (out of 5) according to Table A.4 **(B)**:

Table A.4 Structural Diversity Rating based on Number of Vegetation Types or Growth Forms

Number of Growth Forms (out of 14)	Rating (out of 5)
0	1
1-4	2
5-7	3
8-10	4
>10	5

The final rating is out of 10 once applied to the following formula:

Cover and Structural Diversity of Riparian Vegetation Rating = Foliage cover (A) + Structural diversity (B)

- *Cover of Exotic Riparian Vegetation ** *(Map 17)*

The ratings take into account the percentage cover recorded in the field for exotic species within the riparian zone (refer Figure A.5). The average of the percentage exotic species cover recorded for each bank is used. The number of different types of exotic species recorded at a site, if present, is shown on Map 17 but does not contribute to the rating.

A rating (out of 10) is assigned to a site depending on the degree of invasion by exotic species, summarised below:

High Invasion By Exotic Species	% Cover Category	Rating (out of 10)
↑	16 - max. % cover recorded	2
	11 – 15	4
	6 – 10	6
	1 – 5	8
No Invasion By Exotic Species	0	10

- *Aquatic Vegetation ** *(Maps 21 and 22)*

A condition rating for aquatic vegetation **has not been derived**, but rather the cover and distribution of submerged aquatic vegetation and emergent aquatic vegetation (the two dominant structural types) are shown in Maps 21 and 22 respectively.

- *Cover and Diversity of Instream and Bank Habitats ** *(Map 23)*

The instream and bank habitat ratings are based on a combination of:

1. The cover (refer Figure A.5) and diversity provided by instream organic debris (logs, branches, leaves/twigs, *etc*), aquatic vegetation and other habitat types (such as rock, permanent pools) on the bed; and
2. The cover and diversity provided by the canopy and other habitats (low vegetation, roots, bank overhang) along the river banks.

1. Instream Habitat Cover and Diversity

Instream habitat categories include:

1. individual log
2. log jam, <50% and >50% dense (Add these % together)
3. individual branch
4. branch pile, <50% and >50% dense (Add these % together)
5. terrestrial leaves and twigs
6. macrophyte fragments
7. algal clumps and debris
8. large/deep submerged vegetation – freshwater and marine (Add these % together)
9. mangroves
10. large patches floating vegetation
11. emergents permanent water >0.5m deep
12. tree roots
13. rock faces, cobbles, boulders
14. permanent pools >1m deep
15. man-made structures/debris

(a) Instream Cover

Ratings are derived for (i) organic debris, (ii) aquatic vegetation, and (iii) other habitat types. The results for (i), (ii) and (iii) outlined below are added together to give a final instream cover rating out of 15. Re-scale to 10.

(i) Organic Debris – Includes instream habitat categories 1-6 listed above.
The covers are added together for these 6 categories and can be >100%. The sites are rated (out of 5) according to Table A.5:

Table A.5 Instream Cover Rating for Organic Debris (Adapted from Mitchell, 1990)

% Cover	Rating (out of 5)
0	1
1-10	2
11-20	3
21-40	4
>40 (but if log jam >80%, then rate as 2)	5

(ii) Aquatic Vegetation – Includes instream habitat categories 7-11 listed above.
The covers are added together for these 5 categories and can be >100%. The sites are rated (out of 5) according to Table A.6:

Table A.6 Instream Cover Rating for Aquatic Vegetation (Adapted from Mitchell, 1990)

% Cover	Rating (out of 5)
0 or >80	1
1-5 or 61-80	2
6-20	3
21-30	4
31-60	5

(iii) Other Habitat Types – Includes instream habitat categories 12-15 listed above.
Pools strongly influence this rating so are treated separately to the other habitat types.
(a) Add categories 12, 13 and 15 together (can be >100%)
(b) Keep category 14 separate

Rate both (a) and (b) out of 5 according to Table A.7 and use the average.

Table A.7 Instream Cover Rating for Other Habitat Types

% Cover	Rating (out of 5)
0	1
1-10	2
11-20	3
21-50	4
>50	5

(b) Instream Habitat Diversity
Is derived by counting the number of habitat types (out of 15) present at a site and assigning a rating (out of 10) according to Table A.8:

Table A.8 Instream Habitat Diversity Rating based on Number of Habitat Types

Number of Instream Habitat Types (out of 15)	Rating (out of 10)
0	2
1-4	4
5-7	6
8-10	8
>10	10

Add (a) Instream Cover (out of 10) and (b) Instream Habitat Diversity (out of 10) to give a figure out of 20. Re-scale to 50% for inclusion in final formula **(A)**.

2. Bank Habitat Cover and Diversity

Bank habitat categories include:

1. canopy cover
2. vegetation overhang <1m from water surface
3. root overhang
4. bank overhang
5. man-made overhang

(a) Bank Cover
Ratings are derived for (i) canopy cover along bank (% bank length), (ii) vegetation overhang <1m from water surface, and (iii) root, bank and man-made overhang. The results for (i), (ii) and (iii) outlined below are added together to give a final bank cover rating out of 25. Re-scale to 10.

(i) Canopy Cover along Bank (% Bank Length) – Is bank habitat category 1 listed above. The sites are rated (out of 5) according to Table A.9:

Table A.9 Rating for Canopy Cover along Bank

% Bank Length Cover	Rating (out of 5)
0	1
1-30	2
31-60	3
61-80	4
>80	5

(ii) Vegetation Overhang <1m from Water Surface (% Bank Length) – Includes bank habitat category 2 listed above. The sites are rated (out of 5) according to Table A.10:

Table A.10 Rating for Vegetation Overhang along Bank

% Bank Length Cover	Rating (out of 5)
0	1
1-15	2
16-30	3
31-60	4
>60	5

(iii) Root, Bank and Man-made Overhang (% Bank Length) – Includes bank habitat categories 3-5 listed above. Each of these bank habitat types are rated (out of 5) according to Table A.11:

Table A.11 Rating for Root, Bank and Man-made Overhang along Bank

% Bank Length Cover	Rating (out of 5)
0	1
1-5	2
6-20	3
21-40	4
>40	5

(b) Bank Habitat Diversity

Is derived by counting the number of habitat types (out of 5) present at a site and assigning a rating (out of 10) according to Table A.12:

Table A.12 Bank Habitat Diversity Rating based on Number of Habitat Types

Number of Bank Habitat Types (out of 5)	Rating (out of 10)
0	2
1	4
2	6
3	8
4-5	10

Add (a) Bank Cover (out of 10) and (b) Instream Habitat Diversity (out of 10) to give a figure out of 20. Re-scale to 50% for inclusion in final formula **(B)**.

The rating formula gave higher ratings to sites with a diversity of types present as well as the proportion of the bed or banks with each individual cover types present. In deriving the final rating, 50% contribution was given for the instream habitat cover and diversity and 50% for the bank habitat cover and diversity.

Cover and Diversity of Instream and Bank Habitat Rating	**=**	**Instream cover and diversity (A) (50%)**	**+**	**Bank cover and diversity (B) (50%)**

- *Overall Condition ** *(Map 24)*

Provides an indication of the overall condition of the sites based on the following six components that were assessed:

- State of the Reach Environs
- Bank Stability
- Bed Stability
- Cover and Structural Diversity of Riparian Vegetation
- Cover of Exotic Riparian Vegetation
- Cover and Diversity of Instream and Bank Habitats

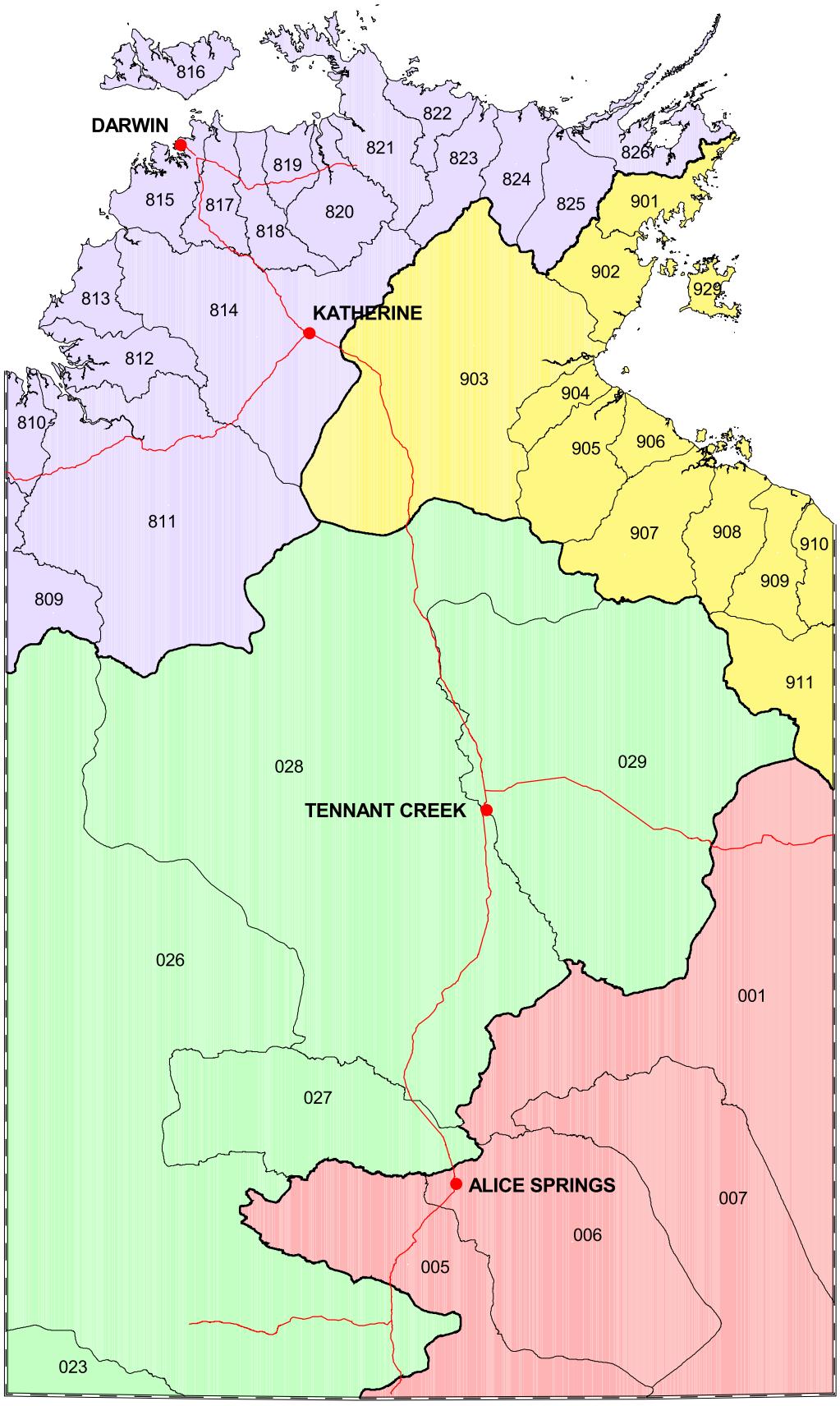
The ratings for each of these six components are re-scaled to a number out of 10 (if not already) and then are added together before re-scaling to a rating out of 100%. These six components are combined equally to produce the Overall Condition rating for each site.

Overall Condition Rating	**=**	**State of the Reach Environs + Bank Stability + Bed Stability + Cover and Structural Diversity of Riparian Vegetation + Cover of Exotic Riparian Vegetation + Cover and Diversity of Instream and Bank Habitats**

MAPS

The following Maps appear in this section:

The maps published in this report were compiled using ArcView (Geographic Information System) by DLP&E, Katherine. The catchment and sub-section boundaries were delineated by J. Faulks (DLP&E, Katherine) onto 1:50,000 topographic map sheets and this linework was then digitised by Geoimage Pty Ltd (Darwin).



DRAINAGE DIVISIONS

LAKE EYRE

001 Georgina River
005 Finke River
006 Todd River
007 Hay River

WESTERN PLATEAU

023 Warburton
026 Mackay
027 Burt
028 Wiso
029 Barkly

TIMOR SEA

809 Ord River
810 Keep River
* 811 Victoria River
812 Fitzmaurice River
813 Moyle River
* 814 Daly River
815 Finniss River
816 Bathurst & Melville Islands
817 Adelaide River
818 Mary River
819 Wildman River
820 South Alligator River
821 East Alligator River
822 Goomadeer River
823 Liverpool River
824 Blyth River
825 Goyder River
826 Buckingham River

GULF OF CARPENTARIA

901 Koolatong River
902 Walker River
903 Roper River
904 Towns River
905 Limmen Bight River
906 Rosie River
907 McArthur River
908 Robinson River
909 Calvert River
910 Settlement River
911 Nicholson River
929 Grooyte Eylandt

Division Boundary
Basin Boundary

N

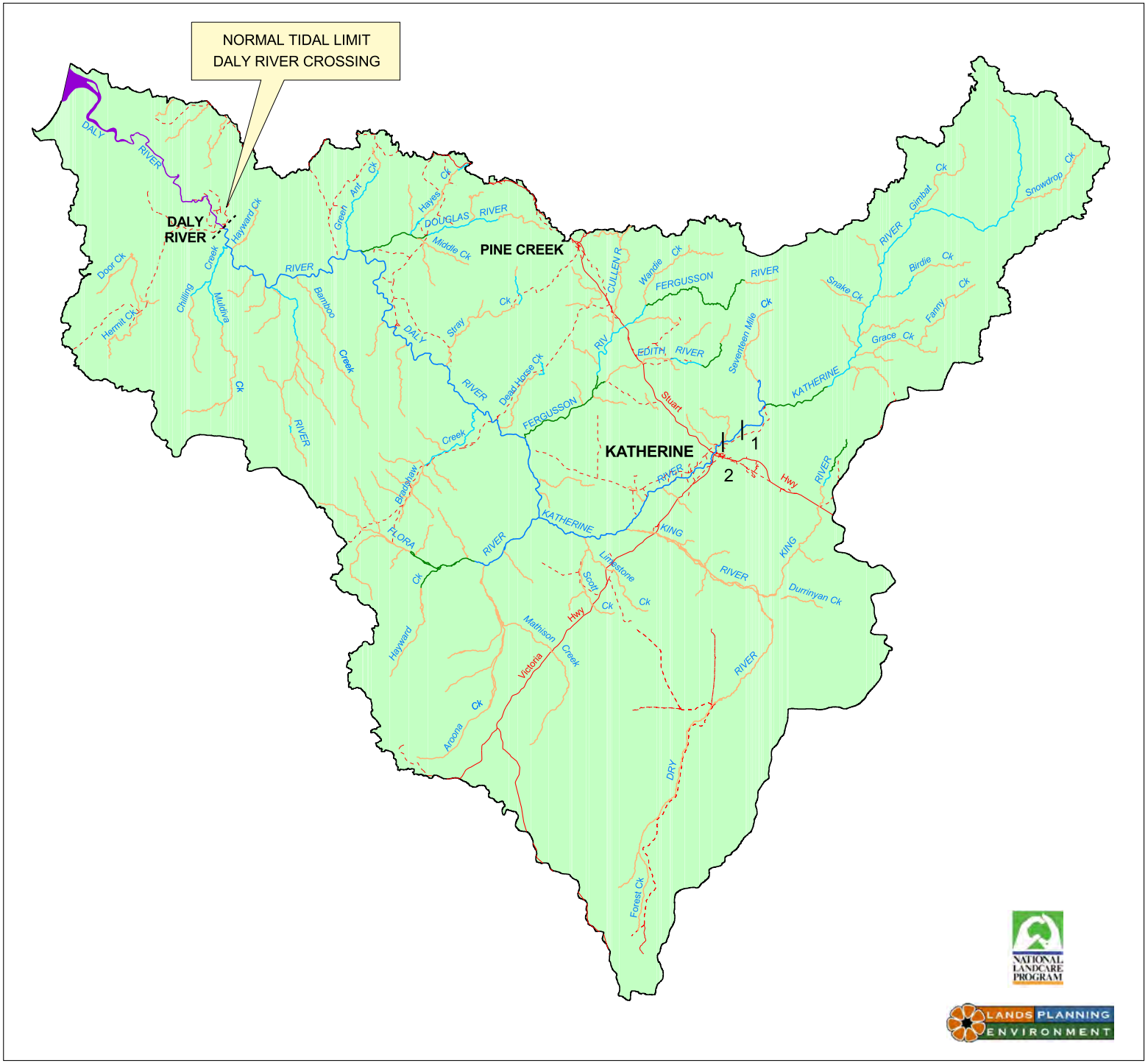
0 50 100 150 200
Kilometres

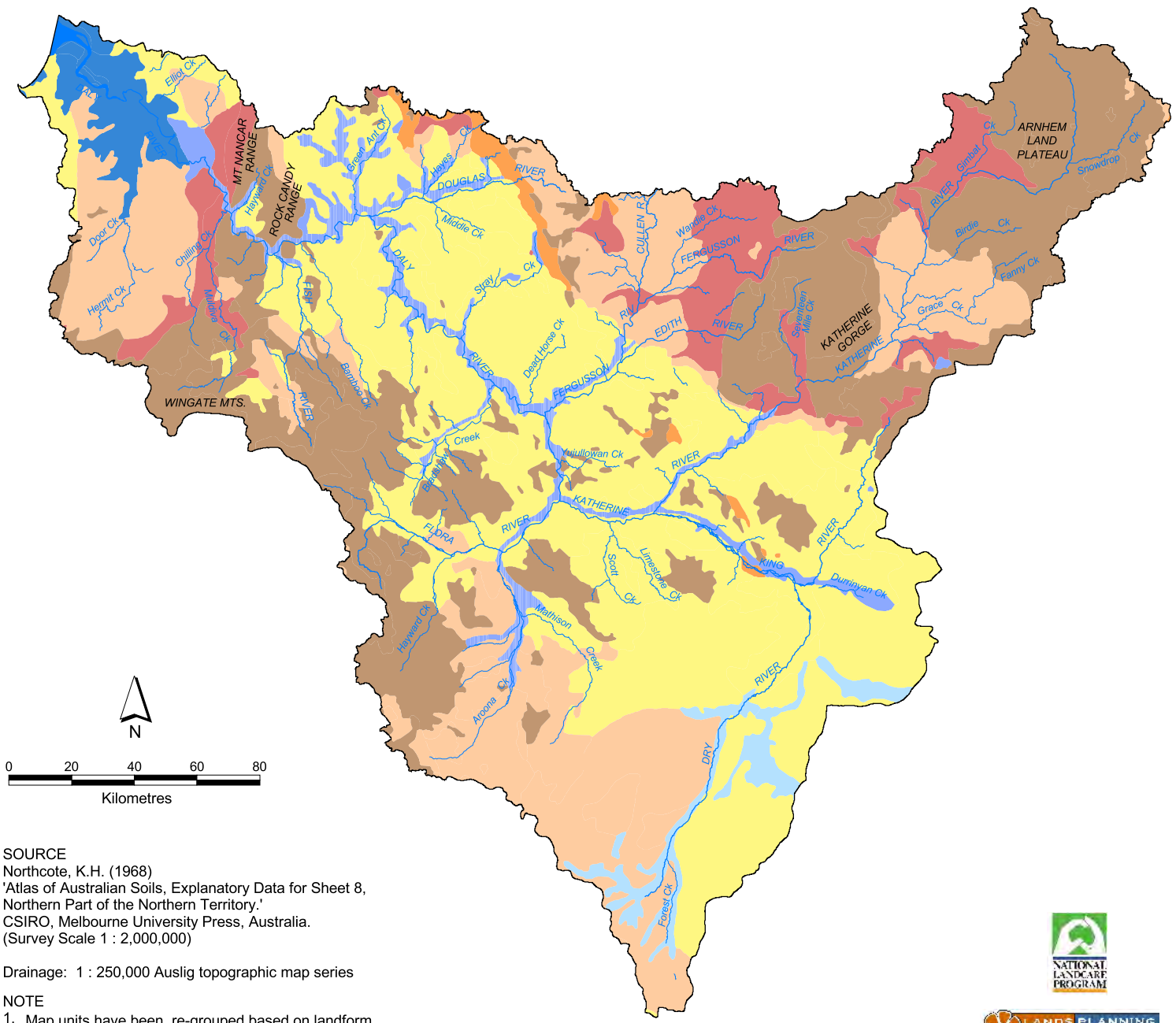
* Baseline data collected for Top End Waterways Project (1995 - 1997)

NT DRAINAGE DIVISIONS AND BASINS

as defined by the Australian Water Resources Council

Map 1


NORMAL TIDAL LIMIT
DALY RIVER CROSSING
DALY RIVER
PINE CREEK
KATHERINE
1
2
DALY RIVER
Hayward Ck
Green Ant Ck
Hawes Ck
DOUGLAS RIVER
Middle Ck
Door Ck
Hermit Ck
Chilling Creek
Mulchiva Ck
RIVER
Bamboo Creek
DALY Stray Ck
Dead Horse Ck
RIVER
FERGUSSON Creek
RIVER
CULLEN R
Wandie Ck
FERGUSSON RIVER
RIV
EDITH RIVER
Seventeen Mile Ck
Stuart
KATHERINE
RIVER
Hwy
RIVER
Bradshaw
KATHERINE
FLORA
RIVER
KING
Limestone
Scott Ck
Ck
Mathison Creek
Victoria Hwy
Hayward Ck
Aroona Ck
RIVER
KING
RIVER
Durrinyan Ck
DRY
Forest Ck
Snake Ck
Gimbat Ck
RIVER
Birdie Ck
Fanny Ck
Grace Ck
Snowdrop Ck
DRY SEASON FLOW REGIME
Permanent Flow >100 L/s (high)
Permanent Flow 10 - 100 L/s (medium)
Permanent Pools and Flow <10 L/s (low)
Dry (ephemeral)
Tidal
LEGEND
Catchment Boundary
Major Road
Minor Road
Weir
1. Donkey Camp Weir
2. Knotts Crossing Weir
DARWIN
Katherine
Tennant Creek
Alice Springs
CATCHMENT LOCATION
N
0 20 40 60 80
Kilometres
NATIONAL LANDCARE PROGRAM
LANDS PLANNING ENVIRONMENT
TOP END WATERWAYS PROJECT
DALY RIVER CATCHMENT
LOCALITY PLAN AND DRY SEASON FLOWS
Map 2



SOURCE
Northcote, K.H. (1968)
'Atlas of Australian Soils, Explanatory Data for Sheet 8, Northern Part of the Northern Territory.'
CSIRO, Melbourne University Press, Australia.
(Survey Scale 1 : 2,000,000)

Drainage: 1 : 250,000 Auslig topographic map series

NOTE
1. Map units have been re-grouped based on landform
2. The soil survey does not fully align with the drainage due to the difference in original mapping scales

LANDFORM DESCRIPTION

- Undulating plains to hilly country with isolated mesas and buttes (Map units AC13, CC56, If4, Mo23, Mo24, My68, SQ1, Wd12, Wd13)
- Plateaus, mesas, buttes, plateau escarpments and adjacent rough rocky hills (Map units AB33, BA6, BA7, JV1, JV2, My83)
- Hilly to steep hilly ranges and strike ridges (Map units LK22, LK23, Mw33, Tb134)
- Flat to undulating terrain (Map units JV3, MJ1, Mt4, Mt5, My67, My70, My71, My72, My73, My74, My79, Wd11)
- Low to steep hills, ridges and cuestas with areas of bouldery outcrop (Map units JJ28, OO4)
- Floodplains and back plains, adjacent sideslopes and stony rises, levees, billabongs and channels (Map units Mb15, OO1, OO2, OO3, OO8)
- Flat to gently undulating plains with either narrow drainage or broad shallow valleys (Map units II5, II8)
- Seasonally flooded coastal plains and adjacent sand dunes (Map units Jw1, NN3, NN5)

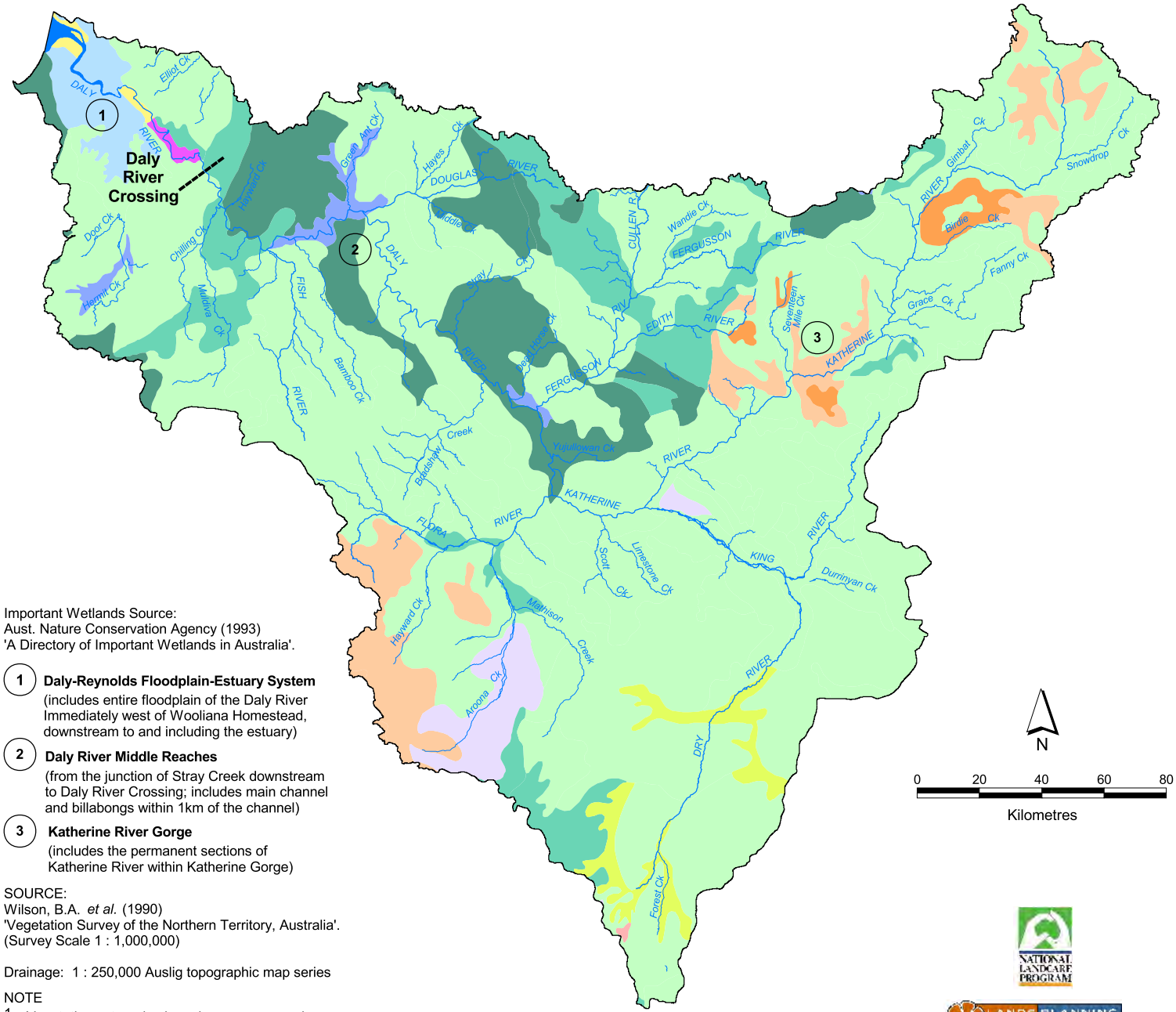
LEGEND

- Catchment Boundary
- River
- Creek

TOP END WATERWAYS PROJECT
DALY RIVER CATCHMENT

LANDFORM
(Broad scale mapping)

Map 3



Important Wetlands Source:
Aust. Nature Conservation Agency (1993)
'A Directory of Important Wetlands in Australia'.

1. **Daly-Reynolds Floodplain-Estuary System**
   (includes entire floodplain of the Daly River Immediately west of Wooliana Homestead, downstream to and including the estuary)
2. **Daly River Middle Reaches**
   (from the junction of Stray Creek downstream to Daly River Crossing; includes main channel and billabongs within 1km of the channel)
3. **Katherine River Gorge**
   (includes the permanent sections of Katherine River within Katherine Gorge)

SOURCE:
Wilson, B.A. *et al.* (1990)
'Vegetation Survey of the Northern Territory, Australia'.
(Survey Scale 1 : 1,000,000)

Drainage: 1 : 250,000 Auslig topographic map series

NOTE
1. Vegetation categories have been re-grouped
2. The vegetation survey does not fully align with the drainage due to the difference in original mapping scales

VEGETATION DESCRIPTION

CLOSED - FOREST
Mixed species closed-forest
(Monsoon vine forest thicket)

EUCALYPT WITH GRASS UNDERSTOREY
Open - Forest
E. miniata, E. tetradonta with *Sorghum* grassland understorey
Woodland
E. bleeseri, E. dichromophloia, E. ferruginea, E. latifolia, E. miniata, E. papuana, E. patellaris, E. polycarpa, E. tectifica, E. tetradonta, E. terminalis
Grassland understorey
Chrysopogon fallax, Sehima nervosum, Plectrachne pungens, Sorghum
Low Woodland
E. chlorophylla, E. dichromophloia, E. microtheca, E. terminalis, E. tintinnans, Excoecaria parvifolia, E. pruinosa
Grassland understorey
Eulalia aurea, Dichanthium, Chrysopogon fallax, Sehima nervosum, Plectrachne pungens, Sorghum
Low Open - Woodland
E. microtheca with *Eulalia aurea, Dichanthium* grassland understorey

EUCALYPT WITH HUMMOCK GRASS UNDERSTOREY
Low Woodland
E. phoenicia with *Plectrachne pungens* hummock grassland understorey
Low - Open Woodland
E. brevifolia, E. dichromophloia, E. miniata with *Plectrachne pungens* hummock grassland understorey

MIXED SPECIES LOW OPEN-WOODLAND WITH GRASS UNDERSTOREY
E. pruinosa, Lysiphyllum cunninghamii, Terminalia arostrata, with *Eulalia aurea, Dichanthium, Chrysopogon fallax, Sehima nervosum*
grassland understorey

MELALEUCA
M. viridiflora, Eucalyptus low open - woodland with *Chrysopogon fallax* grassland understorey

FLOODPLAINS
Mixed closed - grassland / sedgeland (Seasonal Floodplain)

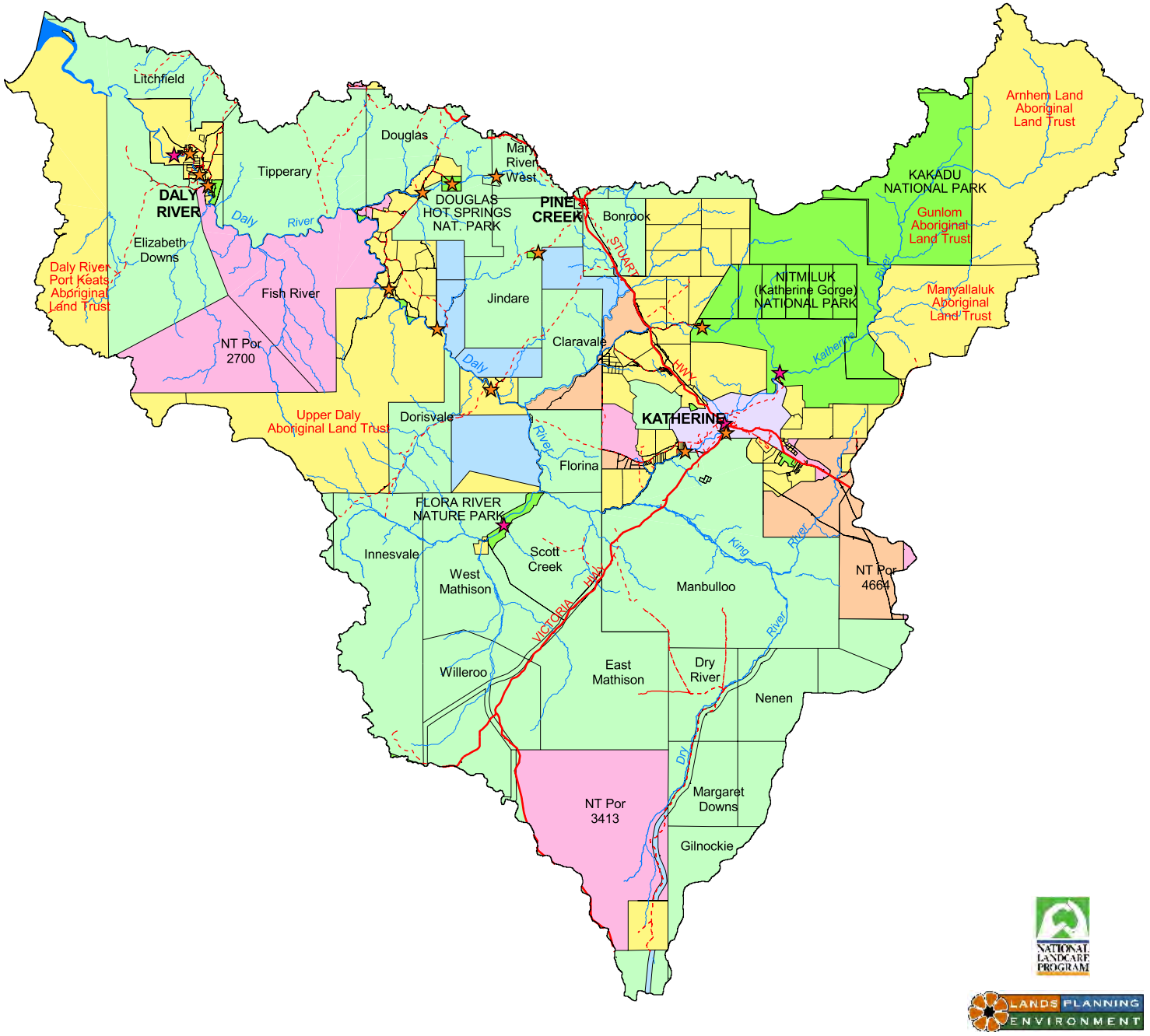
ACACIA WITH GRASS UNDERSTOREY
A. shirleyi open - forest with open - grassland *understorey*

LITTORAL
Mangal low - closed forest (Mangroves); saline tidal flats with scattered chenopod low shrubland

TOP END WATERWAYS PROJECT
DALY RIVER CATCHMENT

VEGETATION AND IMPORTANT WETLANDS

(Broad scale mapping) **Map 4**



LAND CLASSIFICATION

- Katherine Municipal Boundary
- National Park or Reserve
- Pastoral Lease
- Vacant Crown Land
- Private Freehold
- Crown Lease Term
- Crown Lease Perpetual

LEGEND

- Public Recreation Area and Boat Ramp
- Public Recreation Area
- Catchment Boundary
- Cadastral Boundary
- Major Road
- Minor Road
- River
- Creek

NOTE

In general, where waterways form property boundaries the bed and banks of the waterway separating such properties is classified as Crown land. Where a waterway lies within a property the bed and banks of the waterway belong to the property owners but the water rights over such waterways belong to the Crown.

N

0 20 40 60 80

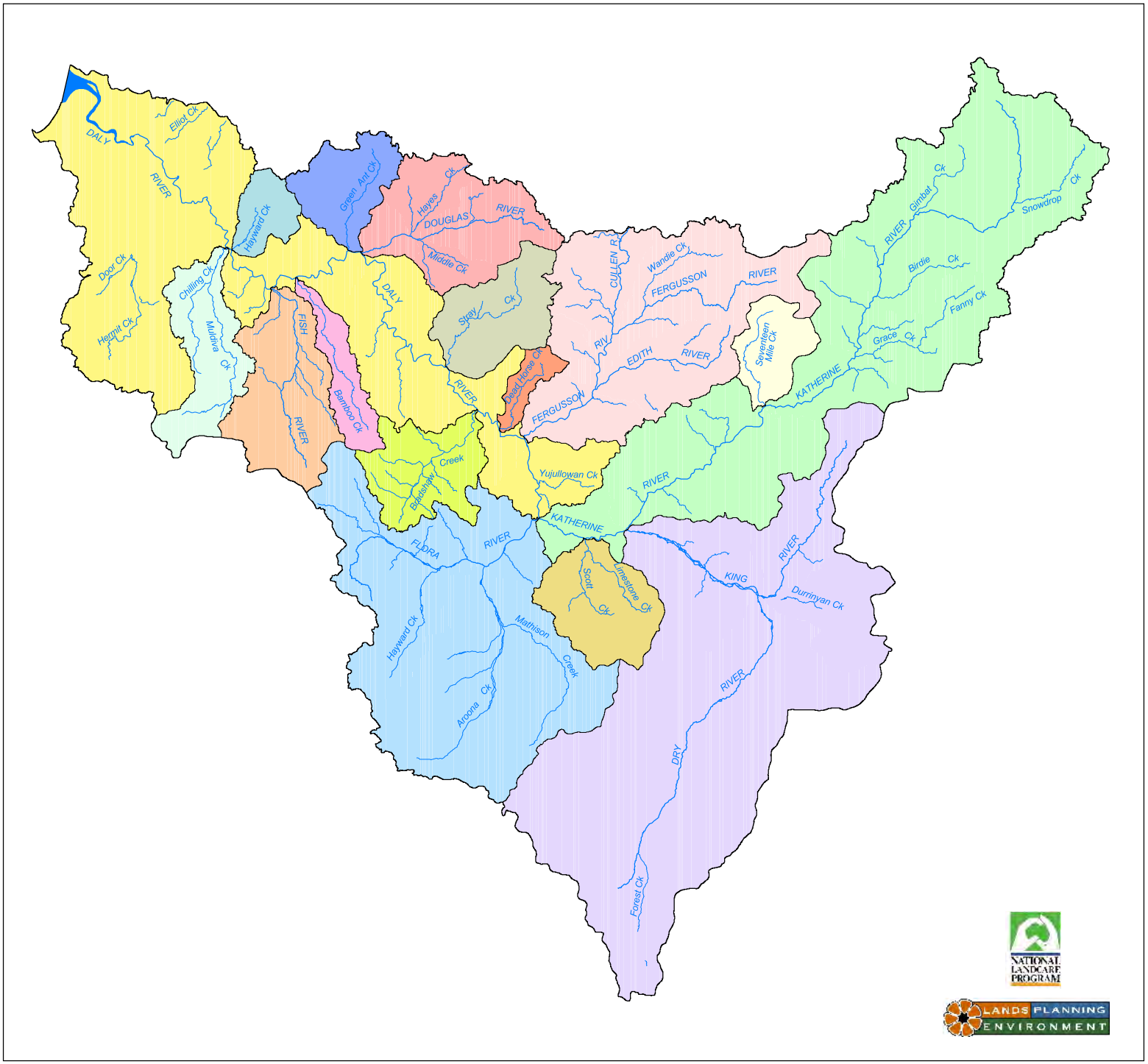
Kilometres

TOP END WATERWAYS PROJECT

DALY RIVER CATCHMENT

LAND TENURE AND LAND USE

Map 5



MAJOR SUB-CATCHMENTS

- Daly River
- Chilling Creek
- Hayward Creek
- Fish River
- Bamboo (Moon Boon) Creek
- Green Ant Creek
- Douglas River
- Stray Creek
- Bradshaw Creek
- Dead Horse Creek
- Fergusson River
- Flora River
- Katherine River
- Limestone Creek
- King and Dry Rivers
- Seventeen Mile Creek

LEGEND

- Catchment Boundary
- Sub-catchment Boundary
- River
- Creek

N

0 20 40 60 80

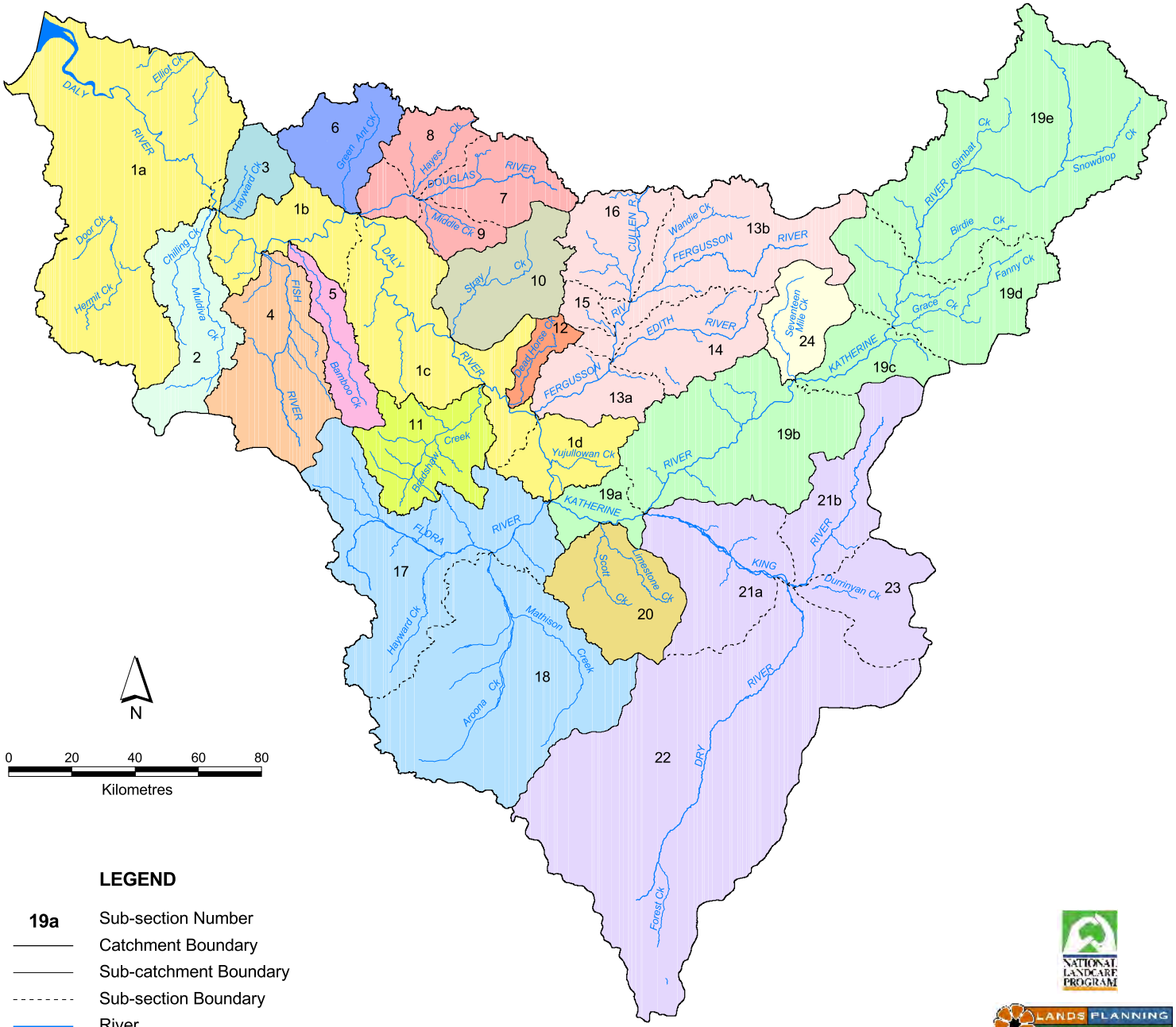
Kilometres

TOP END WATERWAYS PROJECT

DALY RIVER CATCHMENT

MAJOR SUB-CATCHMENTS

Map 6



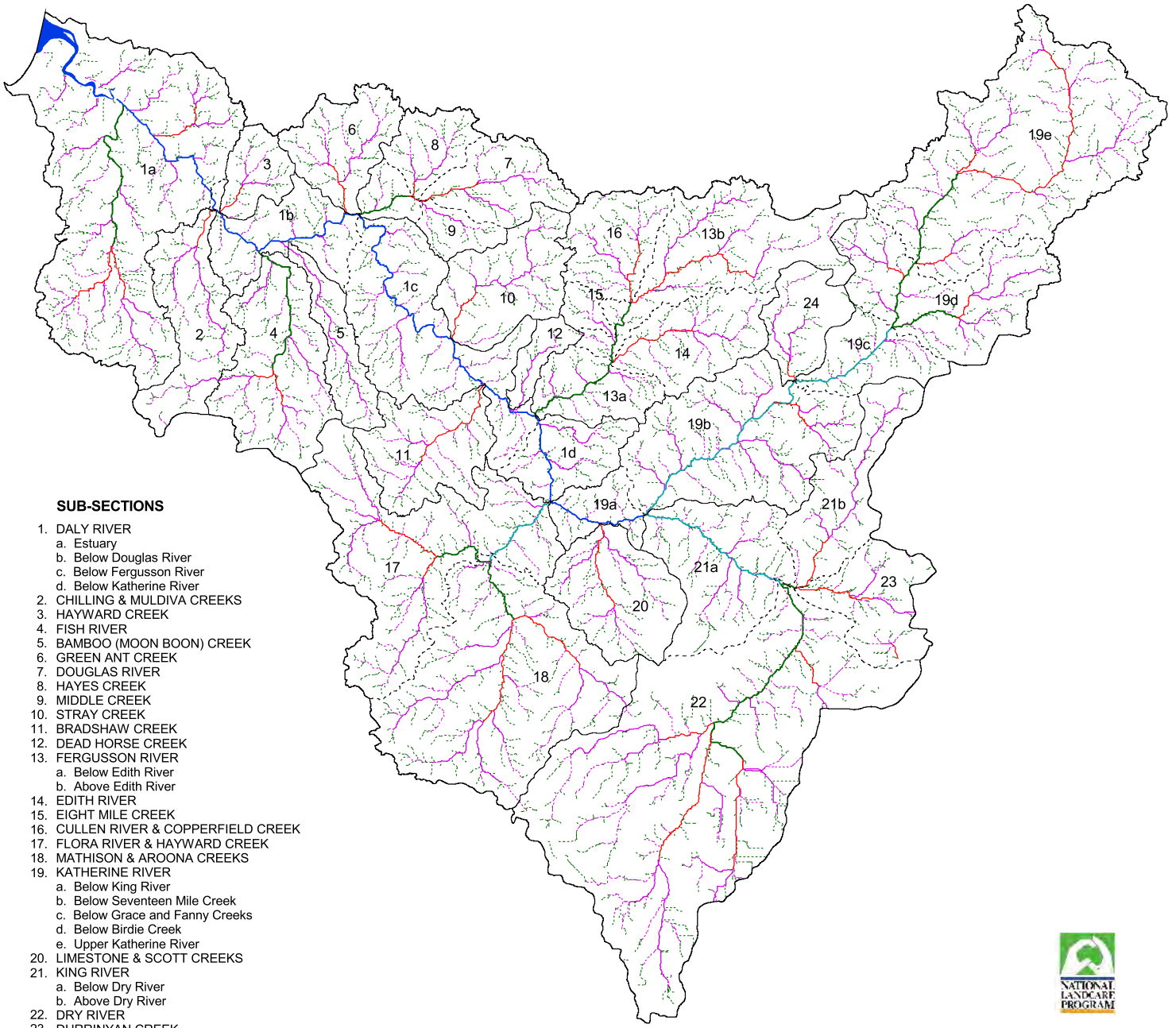
SUB SECTION NUMBER	AREA (km^2)	SUB SECTION NAME
1.	8,884	DALY RIVER
		a. Estuary
		b. Below Douglas River
		c. Below Fergusson River
		d. Below Katherine River
2.	1,241	CHILLING & MULDIVA CREEKS
3.	472	HAYWARD CREEK
4.	1,748	FISH RIVER
5.	602	BAMBOO (MOON BOON) CREEK
6.	914	GREEN ANT CREEK
7.	1,116	DOUGLAS RIVER
8.	535	HAYES CREEK
9.	313	MIDDLE CREEK
10.	1,216	STRAY CREEK
11.	1,181	BRADSHAW CREEK
12.	278	DEAD HORSE CREEK
13.	2,672	FERGUSSON RIVER
		a. Below Edith River
		b. Above Edith River
14.	1,057	EDITH RIVER
15.	180	EIGHT MILE CREEK
16.	879	CULLEN RIVER & COPPERFIELD CK
17.	2,946	FLORA RIVER & HAYWARD CK
18.	3,790	MATHISON & AROONA CKS
19.	9,569	KATHERINE RIVER
		a. Below King River
		b. Below Seventeen Mile Creek
		c. Below Grace and Fanny Creeks
		d. Below Birdie Creek
		e. Upper Katherine River
20.	1,275	LIMESTONE & SCOTT CREEKS
21.	2,815	KING RIVER
		a. Below Dry River
		b. Above Dry River
22.	7,208	DRY RIVER
23.	989	DURRINYAN CREEK
24.	696	SEVENTEEN MILE CREEK
TOTAL	52,577	DALY RIVER CATCHMENT

TOP END WATERWAYS PROJECT

DALY RIVER CATCHMENT

SUB-SECTIONS

Map 7



SUB-SECTIONS

1. DALY RIVER
   a. Estuary
   b. Below Douglas River
   c. Below Fergusson River
   d. Below Katherine River
2. CHILLING & MULDIVA CREEKS
3. HAYWARD CREEK
4. FISH RIVER
5. BAMBOO (MOON BOON) CREEK
6. GREEN ANT CREEK
7. DOUGLAS RIVER
8. HAYES CREEK
9. MIDDLE CREEK
10. STRAY CREEK
11. BRADSHAW CREEK
12. DEAD HORSE CREEK
13. FERGUSSON RIVER
    a. Below Edith River
    b. Above Edith River
14. EDITH RIVER
15. EIGHT MILE CREEK
16. CULLEN RIVER & COPPERFIELD CREEK
17. FLORA RIVER & HAYWARD CREEK
18. MATHISON & AROONA CREEKS
19. KATHERINE RIVER
    a. Below King River
    b. Below Seventeen Mile Creek
    c. Below Grace and Fanny Creeks
    d. Below Birdie Creek
    e. Upper Katherine River
20. LIMESTONE & SCOTT CREEKS
21. KING RIVER
    a. Below Dry River
    b. Above Dry River
22. DRY RIVER
23. DURRINYAN CREEK
24. SEVENTEEN MILE CREEK

Stream Order	Stream Length (kms - approx)	No of sites
1	8,114	5
2	3,955	8
3	2,072	25
4	841	32
5	426	17
6	213	13
7	362	31

LEGEND

- Catchment Boundary
- Sub-catchment Boundary
- Sub-section Boundary

NOTE

Stream orders were compiled using ArcGrid. The stream network was generated using a Digital Elevation Model (DEM) and was based on a 1:250,000 map scale.
Stream orders have been assigned to rivers and creeks using the Strahler system. Seven stream orders were recorded for Daly River Catchment.

- Minor streams = stream orders 1 and 2.
- Medium - sized streams = stream orders 3, 4 and 5.
- Major streams = stream orders 6 and 7.

N

0 20 40 60 80

Kilometres

NATIONAL LANDCARE PROGRAM

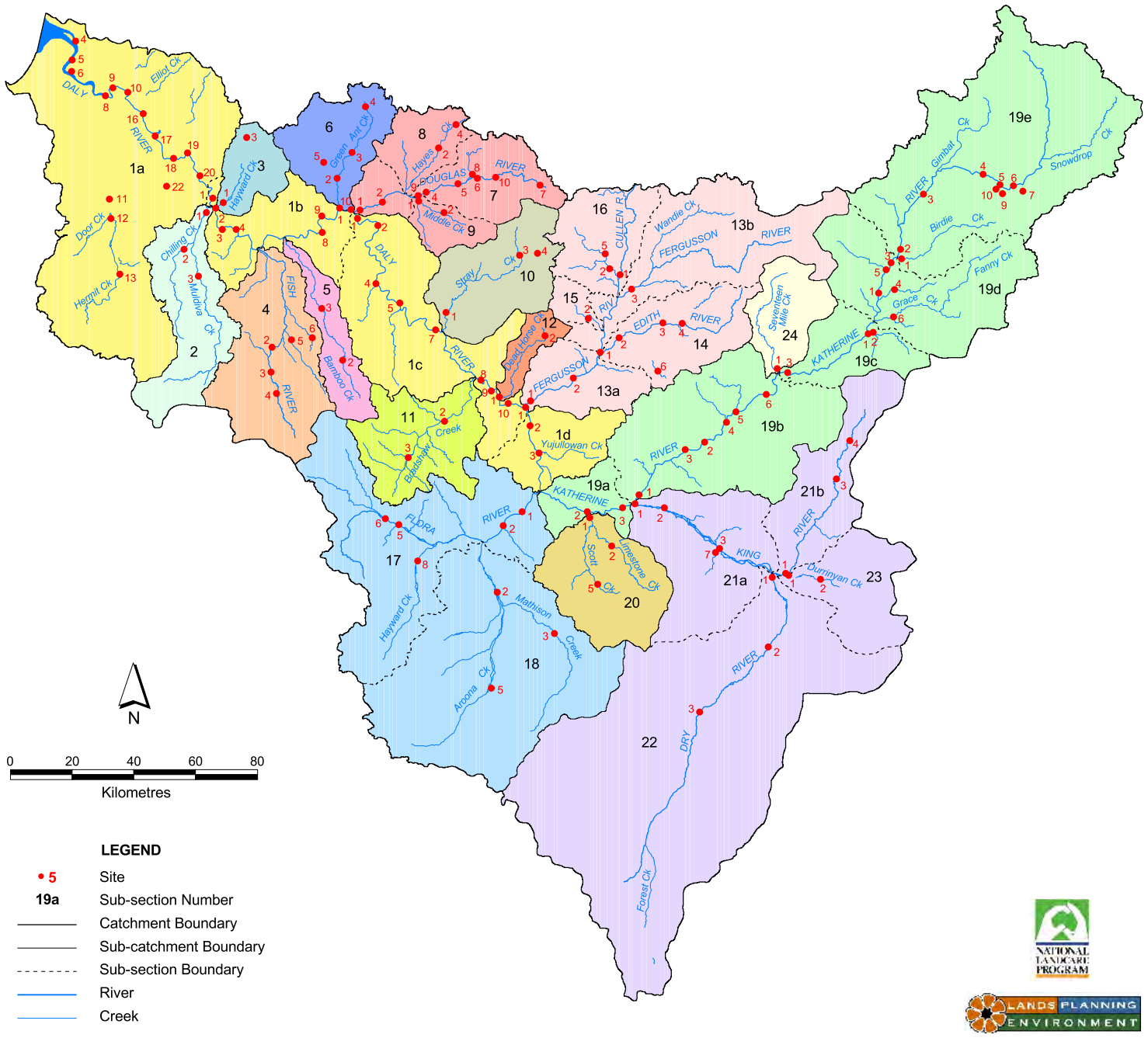
LANDS PLANNING ENVIRONMENT

TOP END WATERWAYS PROJECT

DALY RIVER CATCHMENT

STREAM ORDERS

Map 8



SUB SECTION NUMBER	SUB SECTION NAME
1.	DALY RIVER
	a. Estuary
	b. Below Douglas River
	c. Below Fergusson River
	d. Below Katherine River
2.	CHILLING & MULDIVA CREEKS
3.	HAYWARD CREEK
4.	FISH RIVER
5.	BAMBOO (MOON BOON) CREEK
6.	GREEN ANT CREEK
7.	DOUGLAS RIVER
8.	HAYES CREEK
9.	MIDDLE CREEK
10.	STRAY CREEK
11.	BRADSHAW CREEK
12.	DEAD HORSE CREEK
13.	FERGUSSON RIVER
	a. Below Edith River
	b. Above Edith River
14.	EDITH RIVER
15.	EIGHT MILE CREEK
16.	CULLEN RIVER & COPPERFIELD CK
17.	FLORA RIVER & HAYWARD CK
18.	MATHISON & AROONA CKS
19.	KATHERINE RIVER
	a. Below King River
	b. Below Seventeen Mile Creek
	c. Below Grace and Fanny Creeks
	d. Below Birdie Creek
	e. Upper Katherine River
20.	LIMESTONE & SCOTT CREEKS
21.	KING RIVER
	a. Below Dry River
	b. Above Dry River
22.	DRY RIVER
23.	DURRINYAN CREEK
24.	SEVENTEEN MILE CREEK

NATIONAL LANDCARE PROGRAM

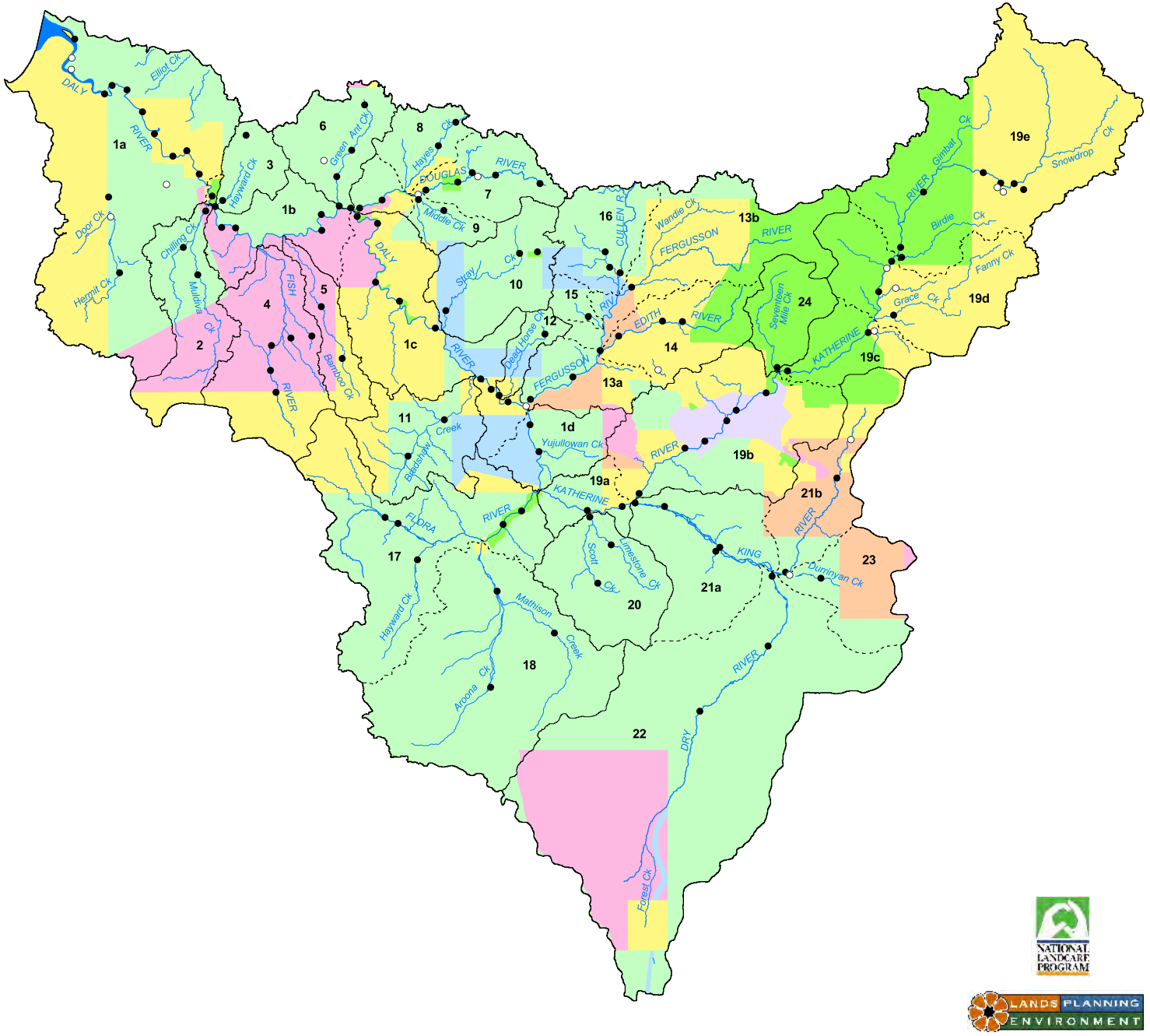
LANDS PLANNING ENVIRONMENT

TOP END WATERWAYS PROJECT

DALY RIVER CATCHMENT

LOCATION OF SITES

Map 9



LAND CLASSIFICATION

- Katherine Municipal Boundary
- National Park or Reserve
- Pastoral Lease
- Vacant Crown Land
- Private Freehold
- Crown Lease Term
- Crown Lease Perpetual

LEGEND

- Surveyed Site
- Site Not Assessed
- 19a — Sub-section Number
- Catchment Boundary
- Sub-catchment Boundary
- Sub-section Boundary
- River
- Creek

NOTE

A summary of the land tenure along the reach environs is shown below:

Land Tenure Category	Percent of Sites (%)
Freehold/Leasehold	90
Urban Reserve	1
State Forest	0
Reserve/ Environmental Park	6
State Park	0
National Park	8

N

0 20 40 60 80

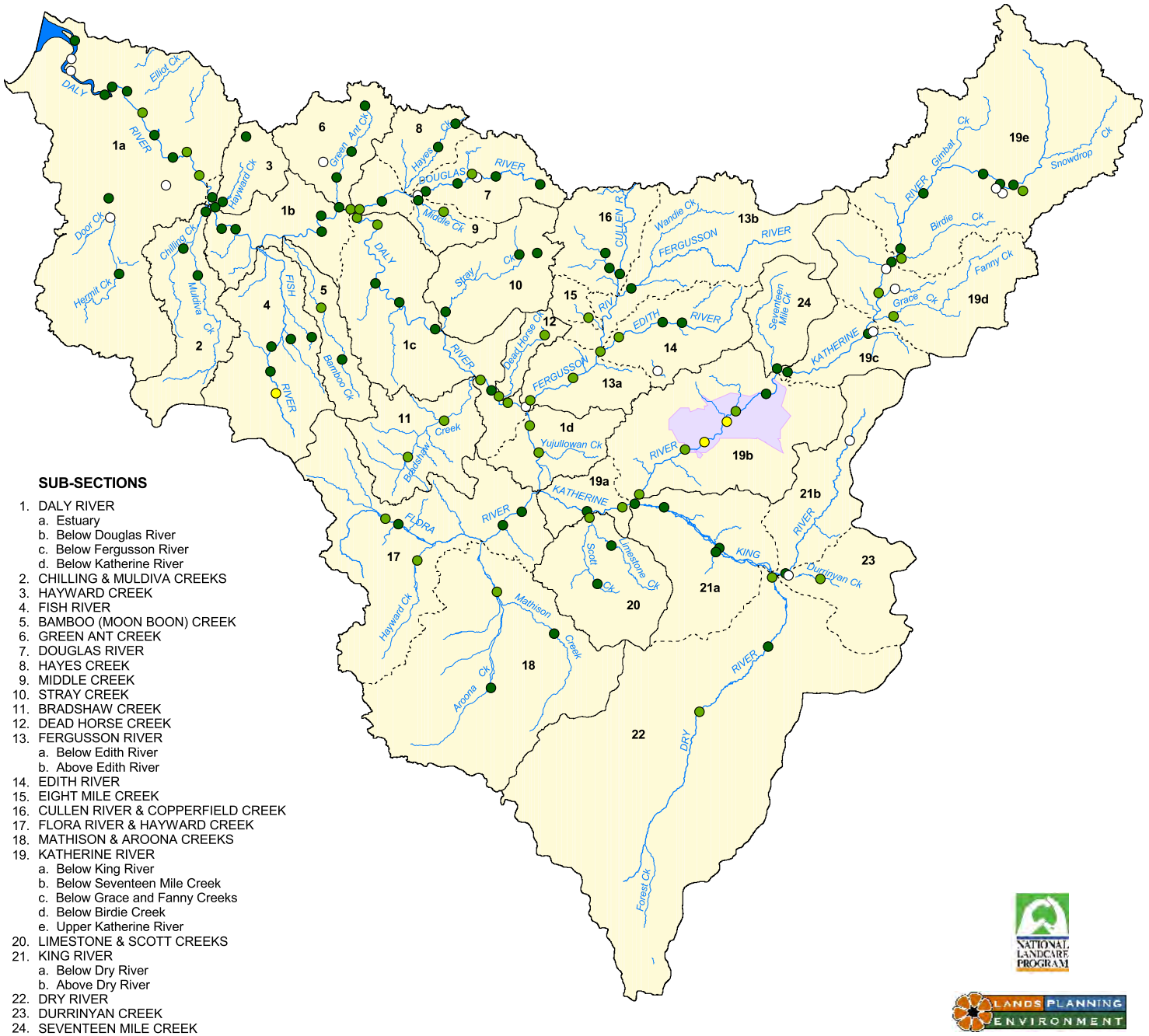
Kilometres

TOP END WATERWAYS PROJECT

DALY RIVER CATCHMENT

LOCAL LAND TENURE

Map 10



SUB-SECTIONS

1. DALY RIVER
   a. Estuary
   b. Below Douglas River
   c. Below Fergusson River
   d. Below Katherine River
2. CHILLING & MULDIVA CREEKS
3. HAYWARD CREEK
4. FISH RIVER
5. BAMBOO (MOON BOON) CREEK
6. GREEN ANT CREEK
7. DOUGLAS RIVER
8. HAYES CREEK
9. MIDDLE CREEK
10. STRAY CREEK
11. BRADSHAW CREEK
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    e. Upper Katherine River
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21. KING RIVER
    a. Below Dry River
    b. Above Dry River
22. DRY RIVER
23. DURRINYAN CREEK
24. SEVENTEEN MILE CREEK

NATIONAL LANDCARE PROGRAM

LANDS PLANNING ENVIRONMENT

LEGEND

SITE LOCATION	REACH ENVIRONS CATEGORY	RATING (%)
	Extreme Modification	0 - 20
	Major Modification	21- 40
	Moderate Modification	41- 60
	Some Modification	61- 80
	Essentially Natural	81-100
	Site Not Assessed	

19a Sub-section Number

Catchment Boundary

Sub-catchment Boundary

Sub-section Boundary

River

Creek

Katherine Municipal Boundary

NOTE

State of the Reach Environs -
The rating is based on an assessment of the land corridor along the survey reach and on the floodplain adjacent to the reach. The rating takes into account local land use and local disturbances along the reach environs.

N

0 20 40 60 80

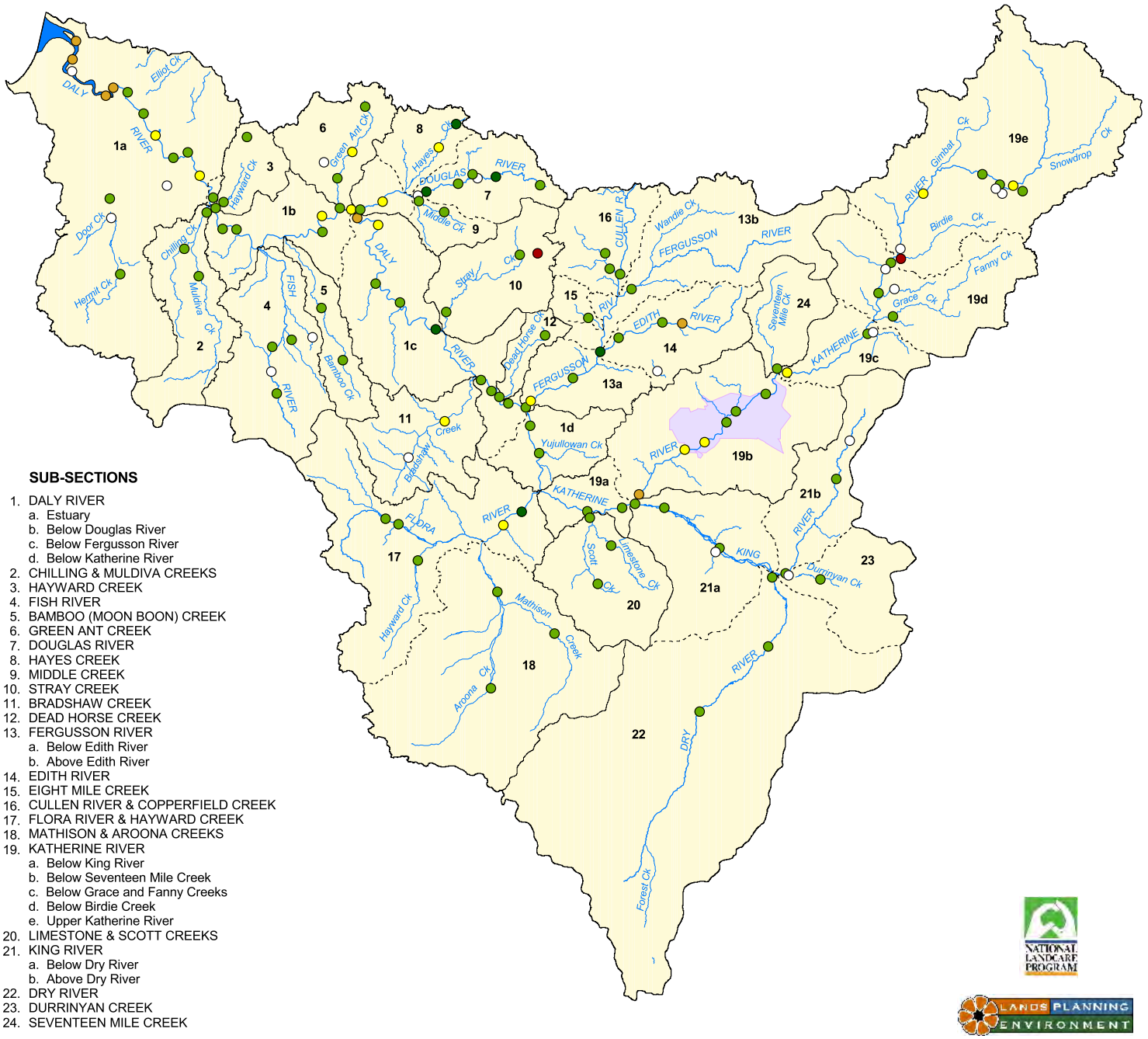
Kilometres

TOP END WATERWAYS PROJECT

DALY RIVER CATCHMENT

STATE OF THE REACH ENVIRONS

Map 11



SUB-SECTIONS

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   c. Below Fergusson River
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    e. Upper Katherine River
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21. KING RIVER
    a. Below Dry River
    b. Above Dry River
22. DRY RIVER
23. DURRINYAN CREEK
24. SEVENTEEN MILE CREEK

LEGEND

SITE LOCATION	DIVERSITY CATEGORY	RATING (out of 10)
	Very Low Diversity	1 - 2
	Low Diversity	3 - 4
	Moderate Diversity	5 - 6
	High Diversity	7 - 8
	Very High Diversity	9 - 10
	Site Not Assessed	

19a Sub-section Number

Catchment Boundary

Sub-catchment Boundary

Sub-section Boundary

River

Creek

Katherine Municipal Boundary

NOTE

Channel Type Diversity -
The diversity categories take into account the number of different channel habitat types present (cascades, glides, pools, rapids, riffles, runs, waterfalls) and the proportion of the reach occupied by pools versus other habitat types.

The derived ratings for this component are NOT used to produce the Overall Condition Rating for each site.

N

0 20 40 60 80

Kilometres

NATIONAL LANDCARE PROGRAM

LANDS PLANNING ENVIRONMENT

TOP END WATERWAYS PROJECT

DALY RIVER CATCHMENT

CHANNEL TYPE DIVERSITY

Map 12

SUB-SECTIONS

1. DALY RIVER
   a. Estuary
   b. Below Douglas River
   c. Below Fergusson River
   d. Below Katherine River
2. CHILLING & MULDIVA CREEKS
3. HAYWARD CREEK
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21. KING RIVER
    a. Below Dry River
    b. Above Dry River
22. DRY RIVER
23. DURRINYAN CREEK
24. SEVENTEEN MILE CREEK

LEGEND

SITE LOCATION	STABILITY CATEGORY	RATING (%)
	Extreme Instability	0 - 20
	Extensive Instability	21- 40
	Moderate Instability	41- 60
	Limited Instability	61- 80
	Stable	81-100
	Site Not Assessed	

DOMINANT PROCESS AT EACH SITE

A — Aggradation

Erosion
(the dominant process at all sites assessed, other than those with an 'A', is erosion)

19a — Sub-section Number

Catchment Boundary

Sub-catchment Boundary

Sub-section Boundary

River

Creek

Katherine Municipal Boundary

NOTE

Bank Stability -
The ratings are determined from the recorded percentages of the banks on each side of the reach which are rated as stable. Upper banks are assigned a greater proportion of the score than lower banks. The dominant process at each site (erosion or aggradation) is recorded.

N

0 20 40 60 80

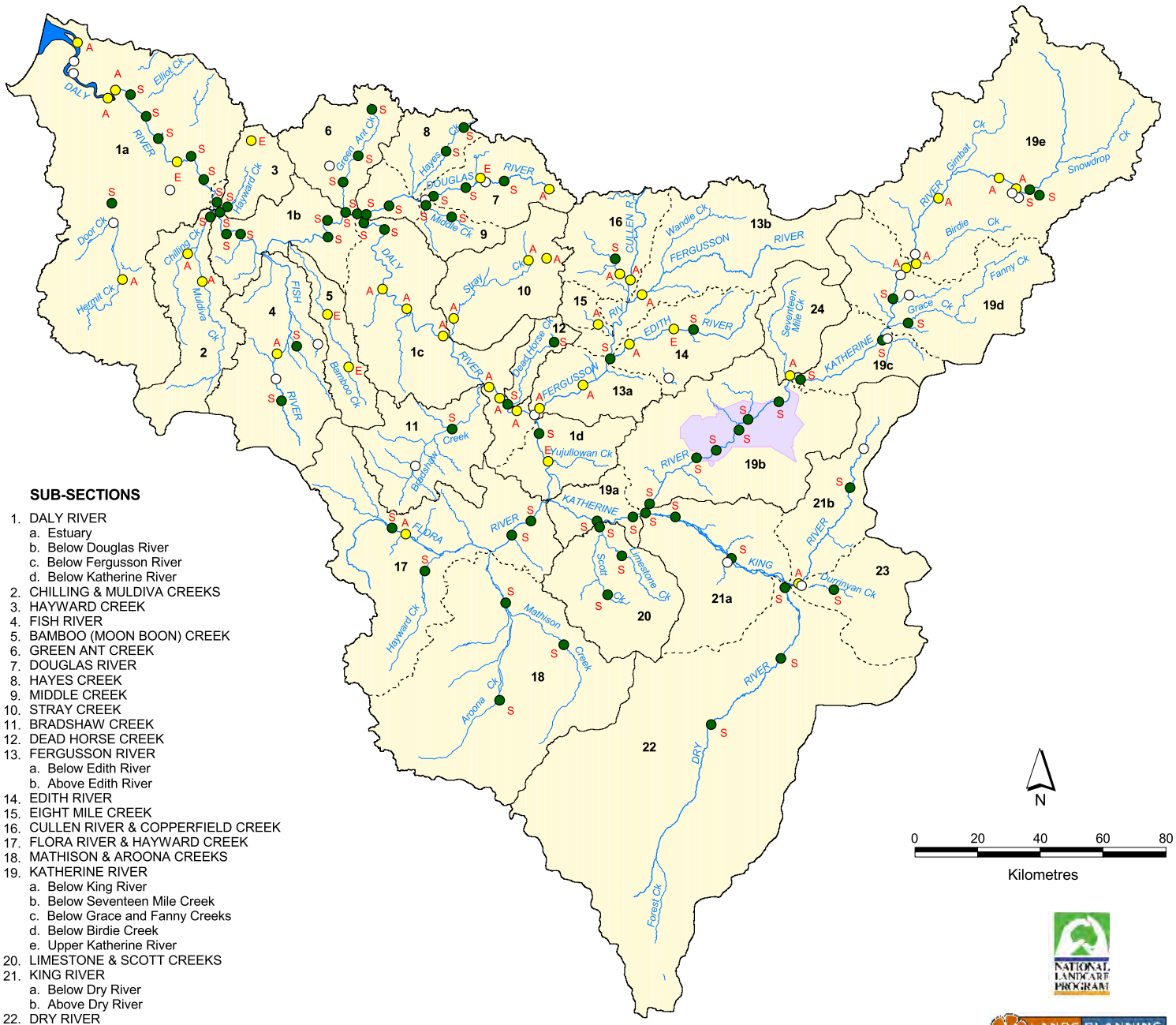
Kilometres

TOP END WATERWAYS PROJECT

DALY RIVER CATCHMENT

BANK STABILITY

Map 13



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    a. Below Dry River
    b. Above Dry River
22. DRY RIVER
23. DURRINYAN CREEK
24. SEVENTEEN MILE CREEK

LEGEND

SITE LOCATION	STABILITY CATEGORY	RATING (out of 10)
●	Severe Erosion or Aggradation	2
●	Moderate Erosion or Aggradation	6
●	Stable	10
○	Site Not Assessed	

DOMINANT PROCESS AT EACH SITE

- A — Aggradation
- E — Erosion
- S — Stable (No Process)

- 19a — Sub-section Number
- Catchment Boundary
- Sub-catchment Boundary
- Sub-section Boundary
- River
- Creek
- Katherine Municipal Boundary

NOTE

Bed Stability -
The ratings are determined from a subjective assessment made in the field of whether the river bed is stable; moderately eroding or aggrading; or severely eroding or aggrading. That is,

- Stable bed: The river bed is consolidated; bed and bar material is the same size; alluvium balanced; and banks stable.
- Moderate erosion: There is little alluvium; signs of deepening; eroded banks; bed deep, narrow and steep; unconsolidated.
- Moderate aggradation: There is moderate build-up at obstructions and bars; bed is flat, uniform, wide and shallow; some over-bank siltation.
- Severe erosion: The bed is scoured of sand; signs of deepening; bare eroded banks; erosion heads; erosion causes; and a steep bed.
- Severe aggradation: The bed is flat, wide but shallow and channel blocked; bars large, covering most of bed and bank; bed is loose and unconsolidated.

NATIONAL LANDCARE PROGRAM

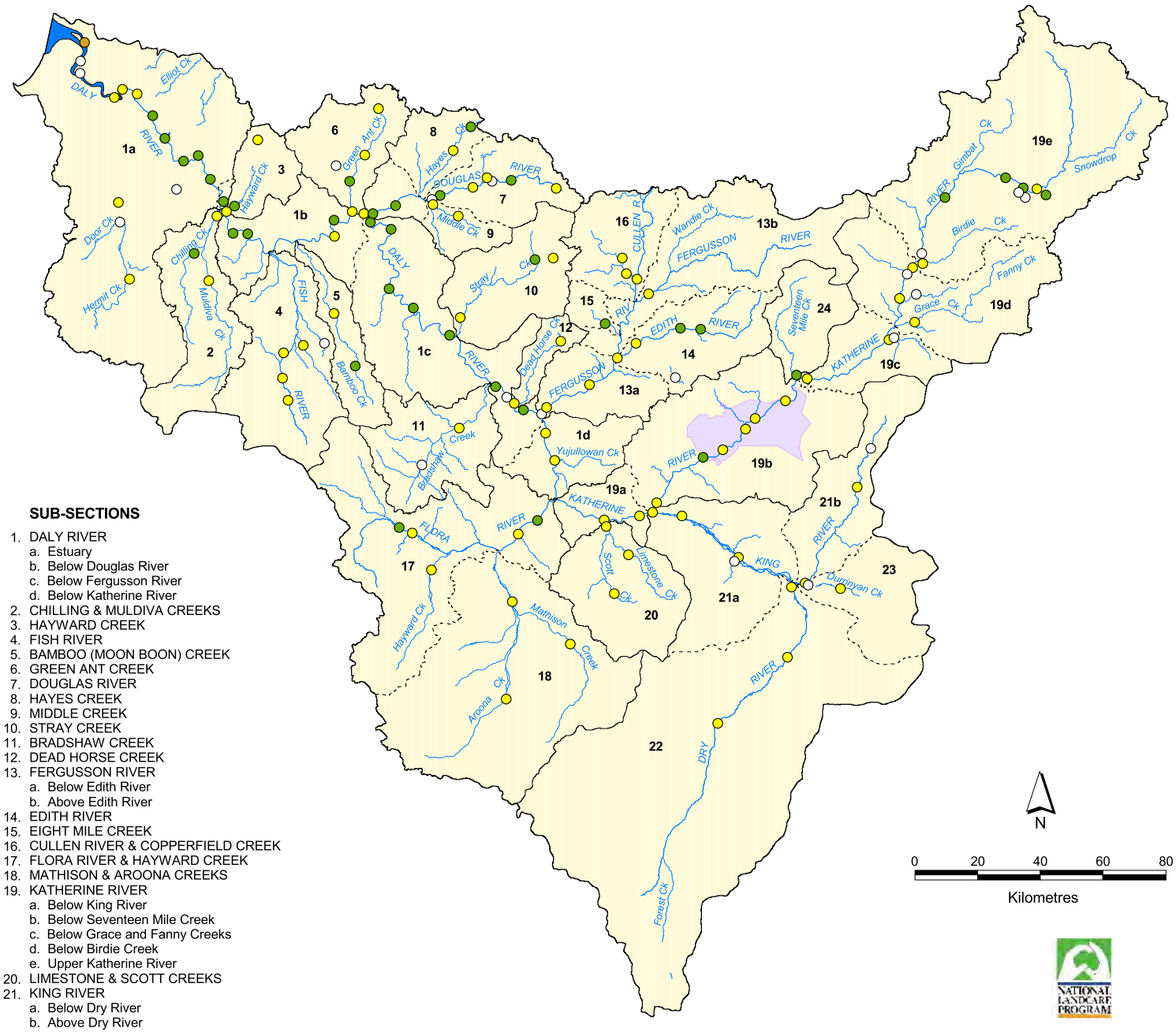
LANDS PLANNING ENVIRONMENT

TOP END WATERWAYS PROJECT

DALY RIVER CATCHMENT

BED STABILITY

Map 14



SUB-SECTIONS

1. DALY RIVER
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    d. Below Birdie Creek
    e. Upper Katherine River
20. LIMESTONE & SCOTT CREEKS
21. KING RIVER
    a. Below Dry River
    b. Above Dry River
22. DRY RIVER
23. DURRINYAN CREEK
24. SEVENTEEN MILE CREEK

LEGEND

SITE LOCATION	RIPARIAN VEGETATION CATEGORY	RATING (out ot 10)
	Very Low Cover/Diversity	1 - 2
	Low Cover/Diversity	3 - 4
	Moderate Cover/Diversity	5 - 6
	High Cover/Diversity	7 - 8
	Very High Cover/Diversity	9 - 10
	Site Not Assessed	

19a Sub-section Number
Catchment Boundary
Sub-catchment Boundary
Sub-section Boundary
River
Creek
Katherine Municipal Boundary

NOTE

Cover and Structural Diversity of the Riparian Vegetation - The ratings take into account:

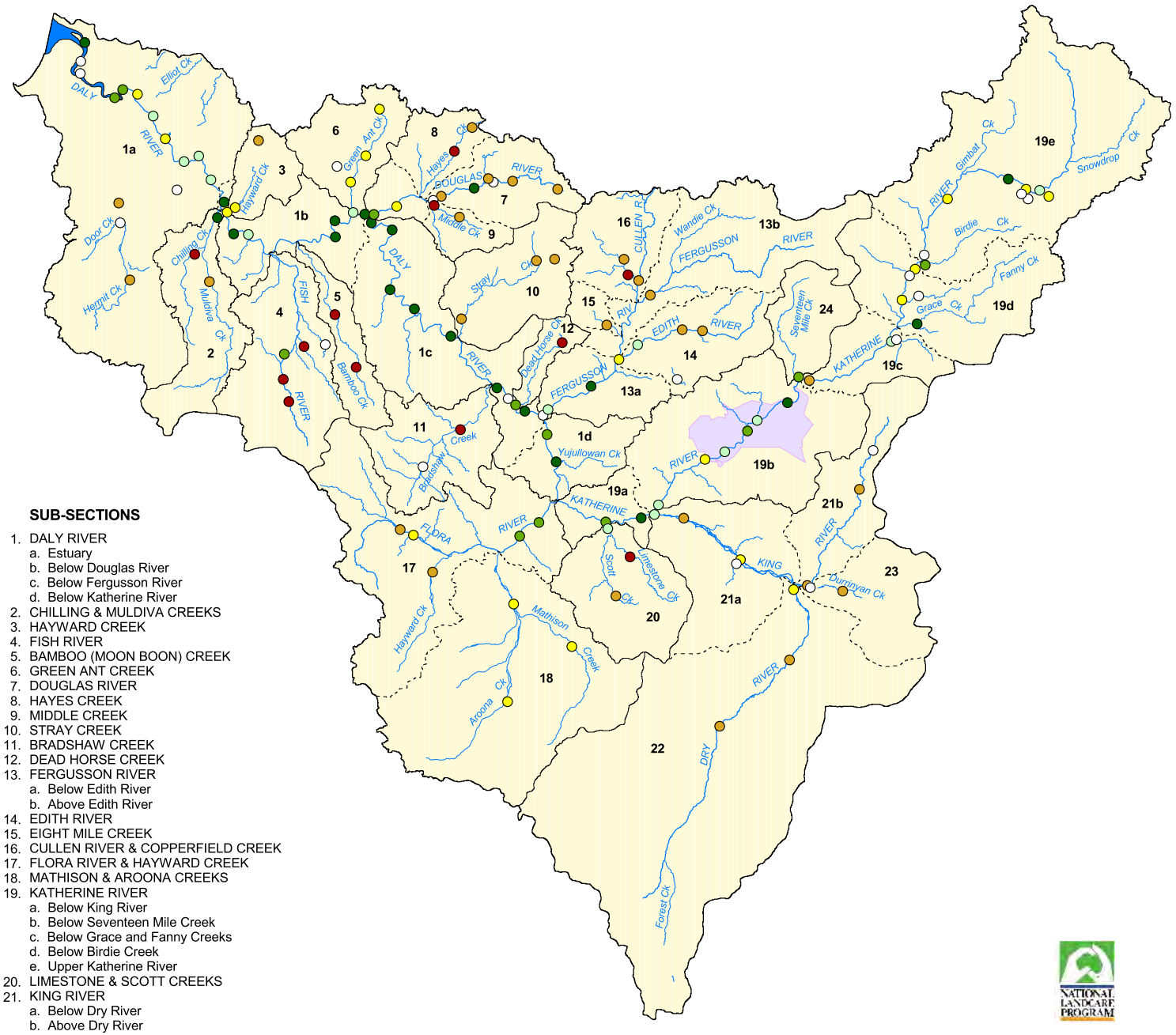
a. The foliage cover or density provided by the overstorey, understorey and ground cover vegetation types or growth forms . The distinction between these three vegetation layers is -
   - overstorey vegetation includes large trees (>30m tall), medium-sized trees (10-30m tall) and palms;
   - understorey vegetation includes small trees (2-10m tall), regenerating trees (<2m tall), mangroves and woody shrubs (<2m tall);
   - ground cover vegetation includes vines, rushes/sedges, forbs, salt marsh, ferns, grasses and Phragmites.

   Both native and exotic vegetation species are included when calculating the covers. The extent of bare ground along the river banks within the riparian zone reduce the ratings.
b. The structural diversity or number of different growth forms present (eg trees of different height classes, palms, shrubs, vines, forbs, grasses, ferns, *etc*).

TOP END WATERWAYS PROJECT
DALY RIVER CATCHMENT

COVER AND STRUCTURAL DIVERSITY OF RIPARIAN VEGETATION

Map 15



SUB-SECTIONS

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   a. Estuary
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22. DRY RIVER
23. DURRINYAN CREEK
24. SEVENTEEN MILE CREEK

NATIONAL LANDCARE PROGRAM

LANDS PLANNING ENVIRONMENT

LEGEND

SITE LOCATION	RIPARIAN VEGETATION WIDTH CATEGORY (m)
	< 5
	5 - 10
	11 - 20
	21 - 30
	31 - 40
	> 40
	Site Not Assessed

19a Sub-section Number

Catchment Boundary

Sub-catchment Boundary

Sub-section Boundary

River

Creek

Katherine Municipal Boundary

NOTE

The width of the riparian vegetation is averaged for both river banks at a site before being assigned a width category.

N

0 20 40 60 80

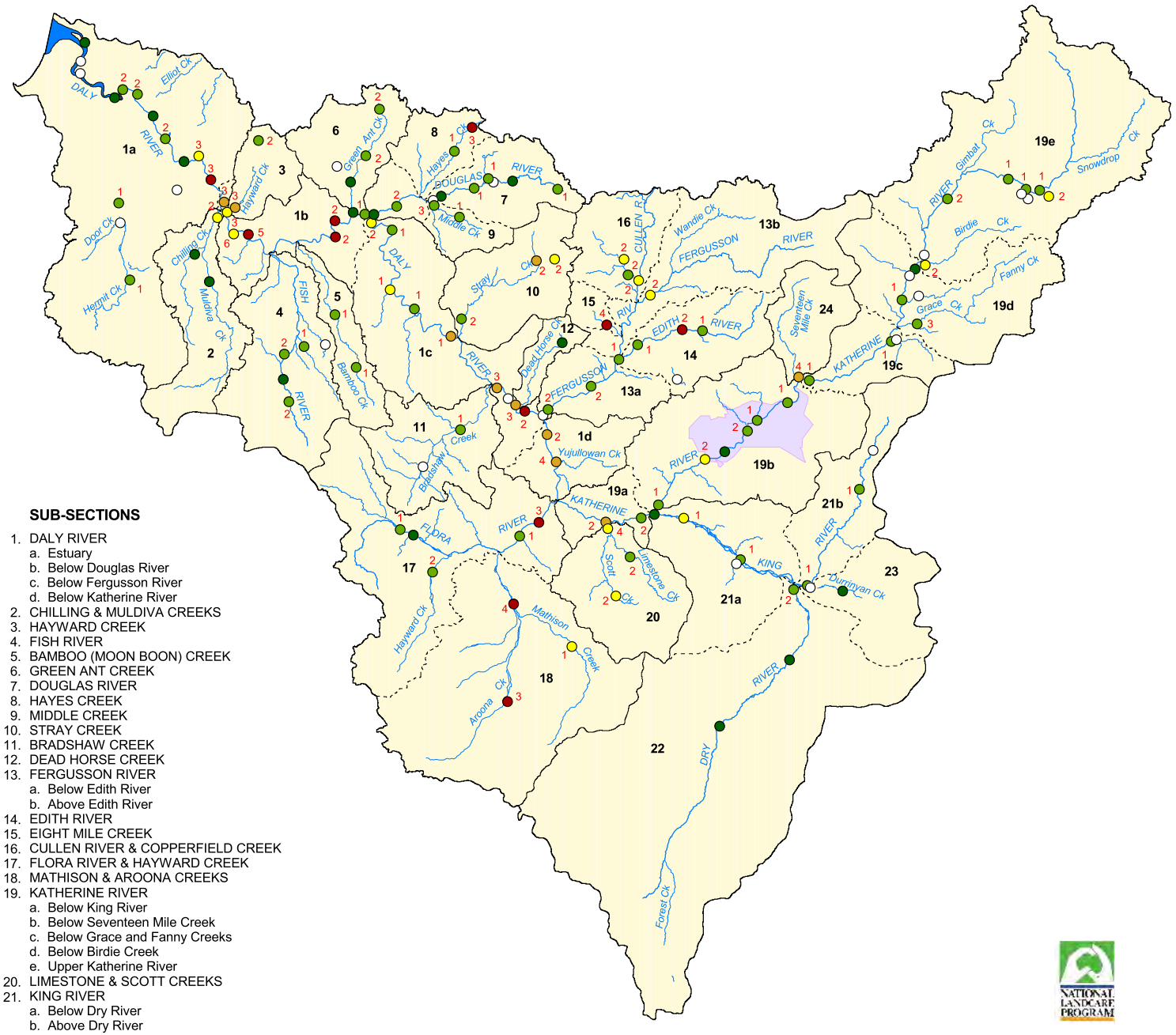
Kilometres

TOP END WATERWAYS PROJECT

DALY RIVER CATCHMENT

WIDTH OF RIPARIAN VEGETATION

Map 16



SUB-SECTIONS

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22. DRY RIVER
23. DURRINYAN CREEK
24. SEVENTEEN MILE CREEK

LEGEND

SITE LOCATION	% COVER CATEGORY	RATING (out of 10)
●	16-32*	2
●	11-15	4
●	6-10	6
●	1-5	8
●	0	10
○	Site Not Assessed	

NUMBER OF TYPES OF EXOTIC SPECIES

1 - 6 The number of different types of exotic species recorded at a site, if present.

19a Sub-section Number

Catchment Boundary

Sub-catchment Boundary

Sub-section Boundary

River

Creek

Katherine Municipal Boundary

NOTE

Cover of Exotic Riparian Vegetation -
The ratings take into account the percentage cover recorded for exotic species within the riparian zone, averaged for both river banks at a site. The higher the percentage cover recorded for exotic species, or the higher the degree of invasion, the lower the rating. The number of different types of exotic species recorded at a site, if present, is shown.

* The maximum percentage cover recorded for exotic riparian vegetation was 32%.

N

0 20 40 60 80

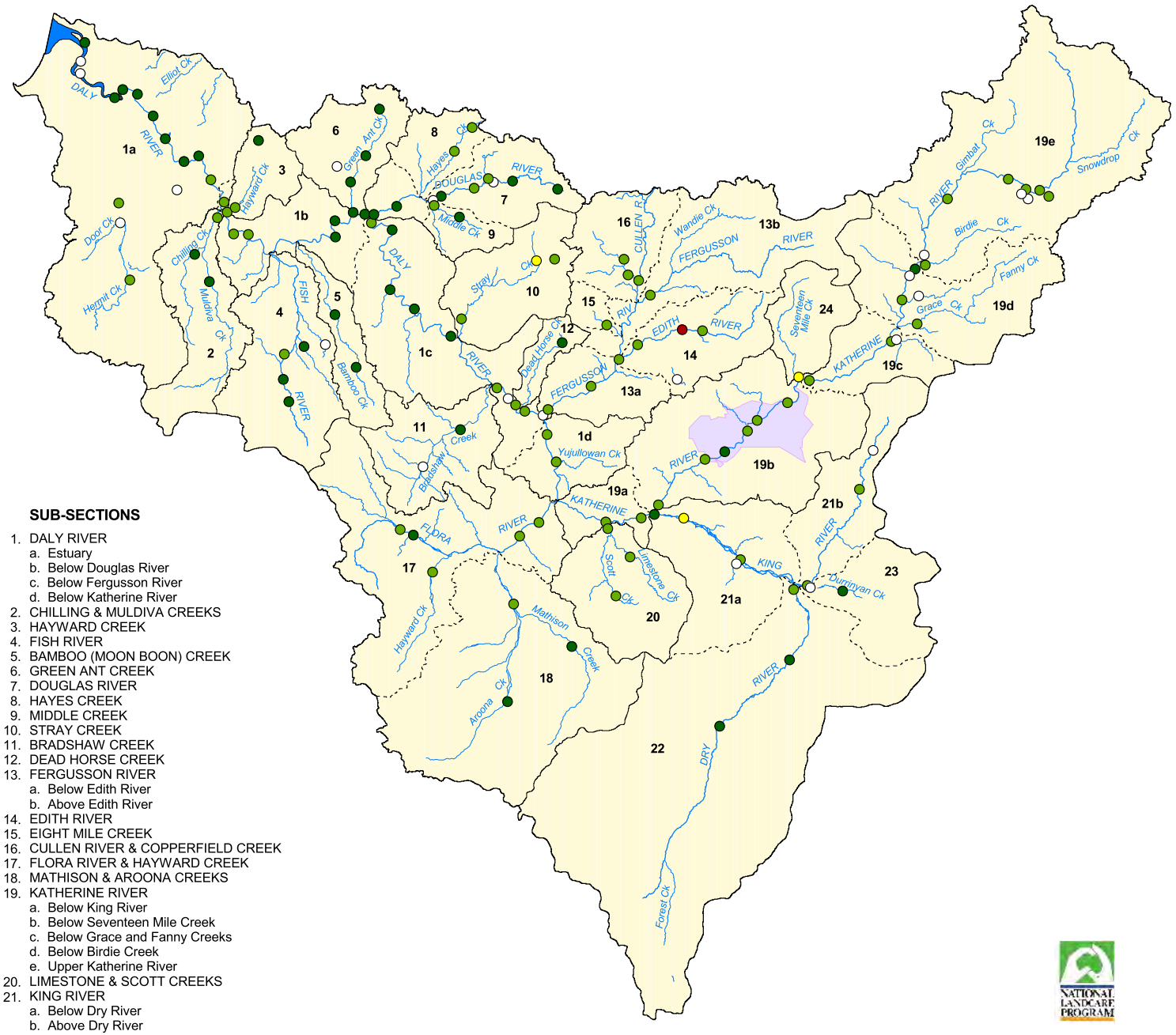
Kilometres

TOP END WATERWAYS PROJECT

DALY RIVER CATCHMENT

COVER OF EXOTIC RIPARIAN VEGETATION

Map 17



SUB-SECTIONS

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24. SEVENTEEN MILE CREEK

LEGEND

SITE LOCATION	% COVER CATEGORY
●	16-20*
●	11-15
●	6-10
●	1-5
●	0
○	Site Not Assessed

19a Sub-section Number
Catchment Boundary
Sub-catchment Boundary
Sub-section Boundary
River
Creek
Katherine Municipal Boundary

NOTE

Passiflora foetida, a naturalised vine, was the major exotic species recorded throughout the catchment. Its distribution and the percentage cover recorded are shown. Percentage covers are averaged if the species is recorded for both river banks at a site.

* The maximum percentage cover recorded for *Passiflora foetida* was 20%.

N

0 20 40 60 80

Kilometres

NATIONAL LANDCARE PROGRAM

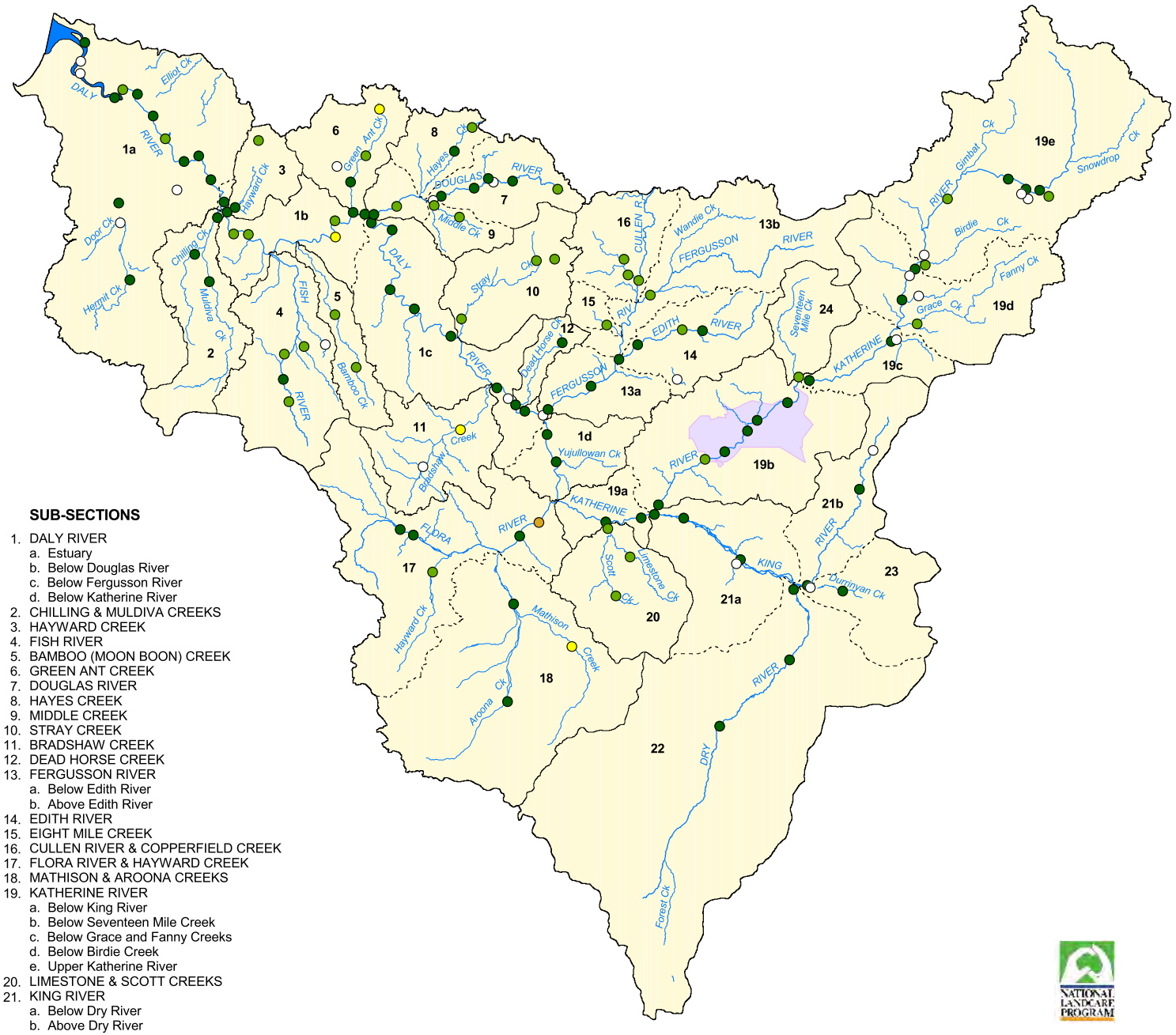
LANDS PLANNING ENVIRONMENT

TOP END WATERWAYS PROJECT

DALY RIVER CATCHMENT

COVER AND DISTRIBUTION OF *Passiflora foetida*

Map 18



SUB-SECTIONS

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24. SEVENTEEN MILE CREEK

LEGEND

SITE LOCATION	% COVER CATEGORY *
●	> 15
●	11-15
●	6-10
●	1-5
●	0
○	Site Not Assessed

19a Sub-section Number
Catchment Boundary
Sub-catchment Boundary
Sub-section Boundary
River
Creek
Katherine Municipal Boundary

NOTE

Hyptis suaveolens, a forb, was the second major exotic species recorded throughout the catchment. Its distribution and the percentage cover recorded are shown. Percentage covers are averaged if the species is recorded for both river banks at a site.

* The maximum percentage cover recorded for *Hyptis suaveolens* was 11%.

N

0 20 40 60 80

Kilometres

NATIONAL LANDCARE PROGRAM

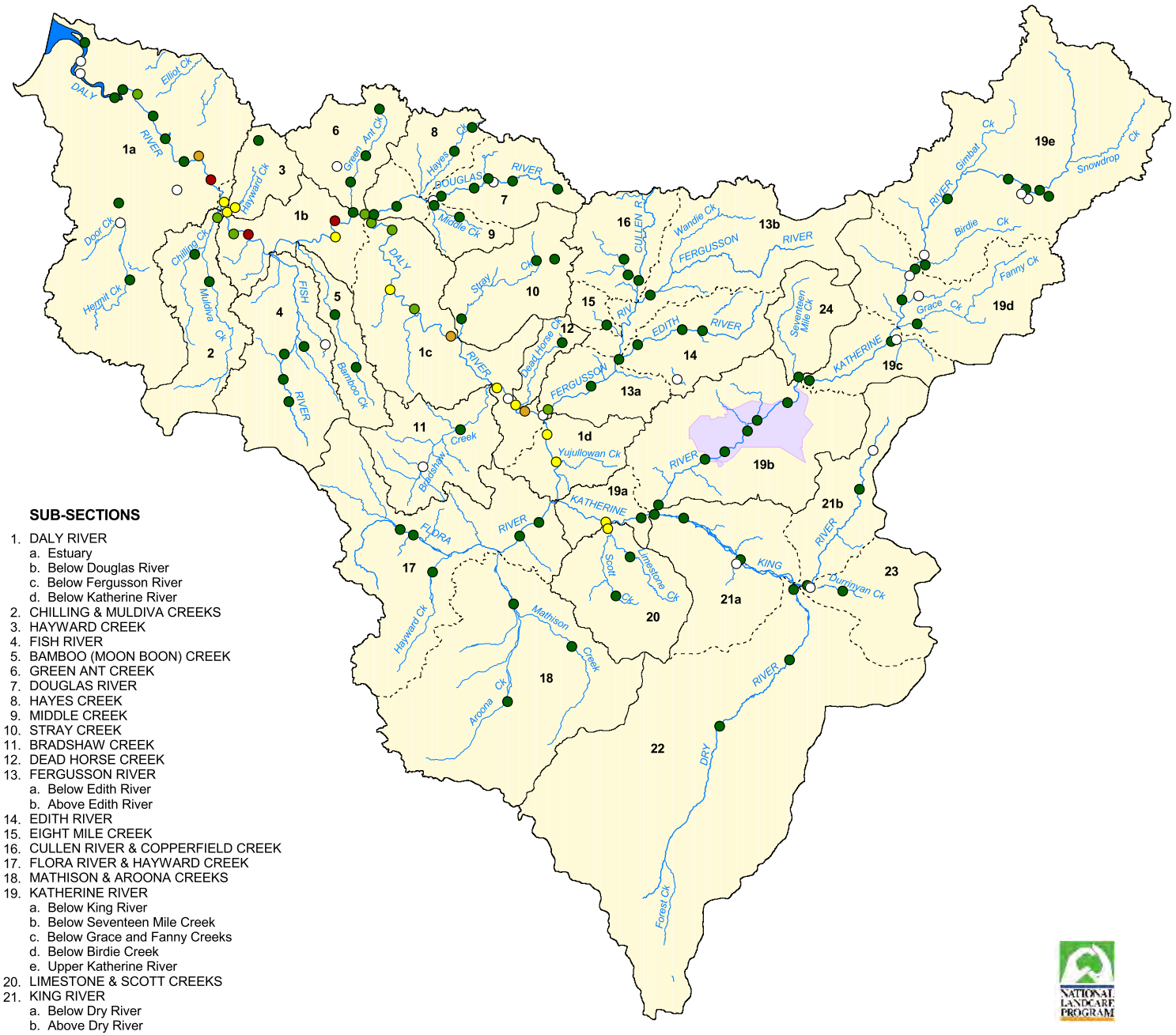
LANDS PLANNING ENVIRONMENT

TOP END WATERWAYS PROJECT

DALY RIVER CATCHMENT

COVER AND DISTRIBUTION OF *Hyptis suaveolens*

Map 19



SUB-SECTIONS

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6. GREEN ANT CREEK
7. DOUGLAS RIVER
8. HAYES CREEK
9. MIDDLE CREEK
10. STRAY CREEK
11. BRADSHAW CREEK
12. DEAD HORSE CREEK
13. FERGUSSON RIVER
    a. Below Edith River
    b. Above Edith River
14. EDITH RIVER
15. EIGHT MILE CREEK
16. CULLEN RIVER & COPPERFIELD CREEK
17. FLORA RIVER & HAYWARD CREEK
18. MATHISON & AROONA CREEKS
19. KATHERINE RIVER
    a. Below King River
    b. Below Seventeen Mile Creek
    c. Below Grace and Fanny Creeks
    d. Below Birdie Creek
    e. Upper Katherine River
20. LIMESTONE & SCOTT CREEKS
21. KING RIVER
    a. Below Dry River
    b. Above Dry River
22. DRY RIVER
23. DURRINYAN CREEK
24. SEVENTEEN MILE CREEK

LEGEND

SITE LOCATION	% COVER CATEGORY
●	16-28*
●	11-15
●	6-10
●	1-5
●	0
○	Site Not Assessed

19a Sub-section Number

Catchment Boundary

Sub-catchment Boundary

Sub-section Boundary

River

Creek

Katherine Municipal Boundary

NOTE

Xanthium occidentale (Noogoora Burr), a forb or sub-shrub, was the third major exotic species recorded throughout the catchment. Its distribution and the percentage cover recorded are shown. Percentage covers are averaged if the species is recorded for both river banks at a site.

* The maximum percentage cover for *Xanthium occidentale* was 28%.

N

0 20 40 60 80

Kilometres

NATIONAL LANDCARE PROGRAM

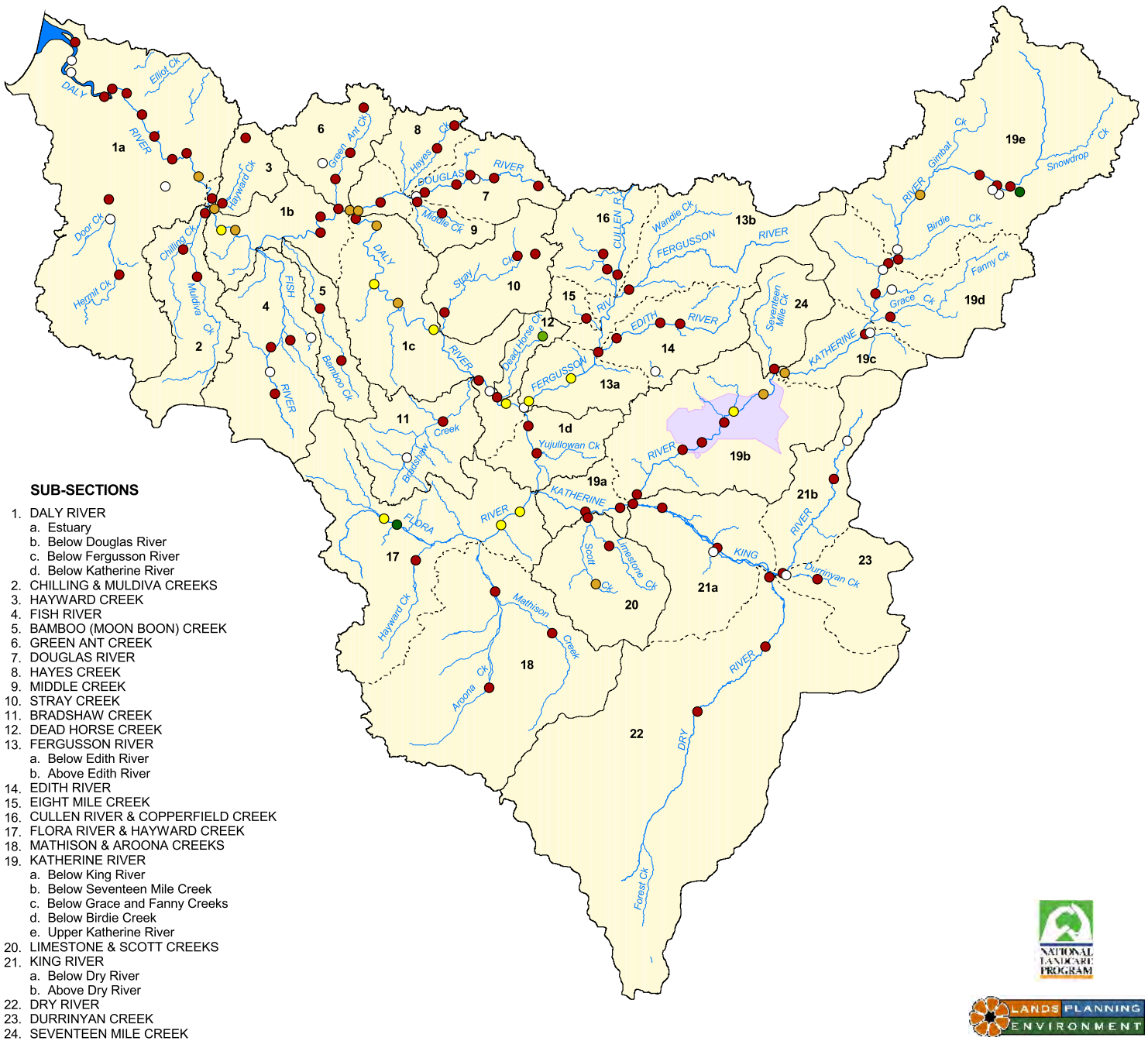
LANDS PLANNING ENVIRONMENT

TOP END WATERWAYS PROJECT

DALY RIVER CATCHMENT

COVER AND DISTRIBUTION OF *Xanthium occidentale*

(Noogoora Burr) **Map 20**



SUB-SECTIONS

1. DALY RIVER
   a. Estuary
   b. Below Douglas River
   c. Below Fergusson River
   d. Below Katherine River
2. CHILLING & MULDIVA CREEKS
3. HAYWARD CREEK
4. FISH RIVER
5. BAMBOO (MOON BOON) CREEK
6. GREEN ANT CREEK
7. DOUGLAS RIVER
8. HAYES CREEK
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    b. Above Dry River
22. DRY RIVER
23. DURRINYAN CREEK
24. SEVENTEEN MILE CREEK

LEGEND

SITE LOCATION	% COVER CATEGORY
●	0
●	1-5
●	6-10
●	11-15
●	16-25*
○	Site Not Assessed

19a Sub-section Number
Catchment Boundary
Sub-catchment Boundary
Sub-section Boundary
River
Creek
Katherine Municipal Boundary

NOTE

Cover and Distribution of Submerged Aquatic Vegetation - The categories where covers were recorded include filamentous algae, Chara/Nitella, Vallisneria and Myriophyllum. No exotic species were recorded.

* The maximum percentage cover recorded for submerged aquatic vegetation was 25%.

N

0 20 40 60 80

Kilometres

NATIONAL LANDCARE PROGRAM

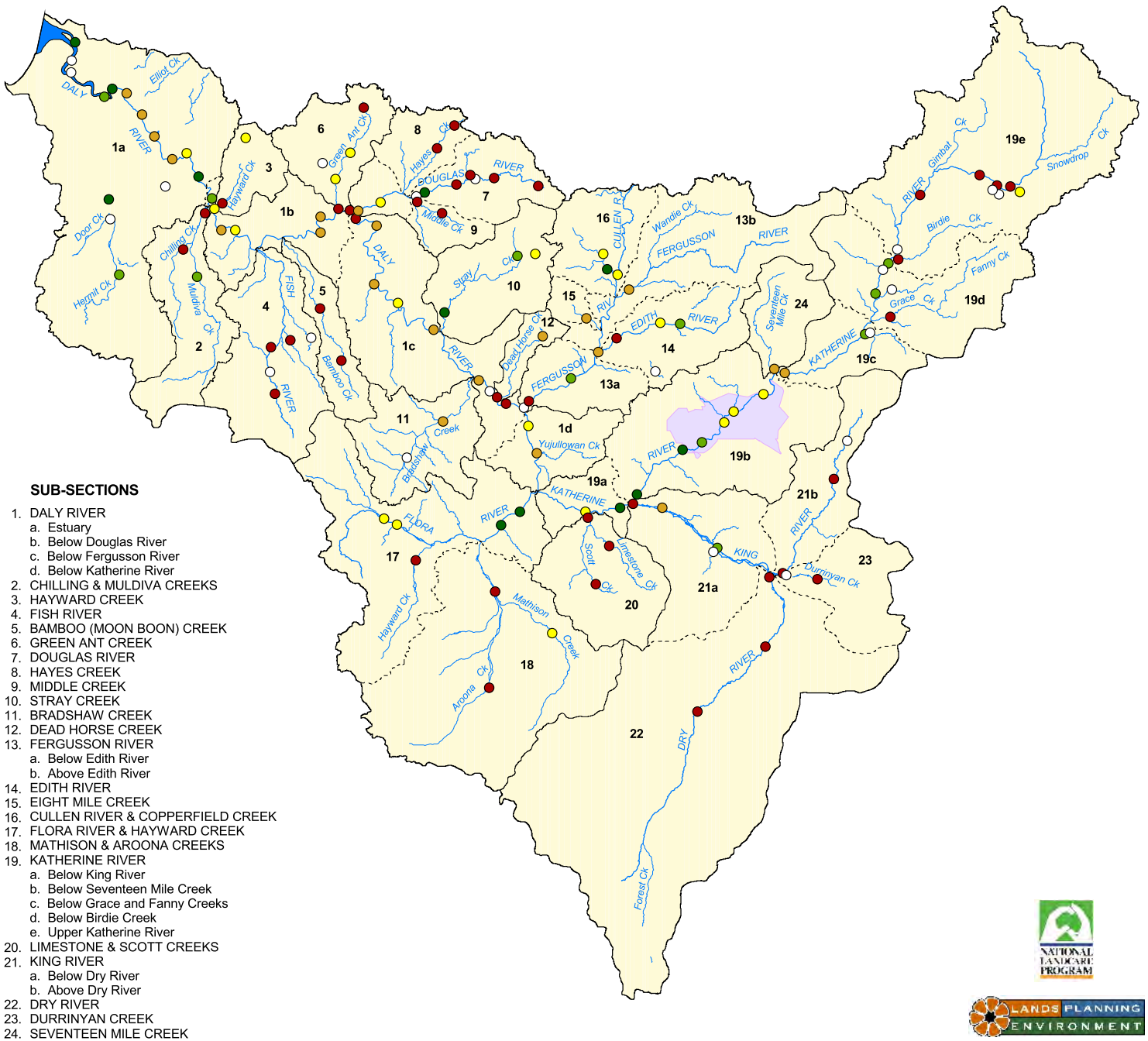
LANDS PLANNING ENVIRONMENT

TOP END WATERWAYS PROJECT

DALY RIVER CATCHMENT

COVER AND DISTRIBUTION OF SUBMERGED AQUATIC VEGETATION

Map 21



SUB-SECTIONS

1. DALY RIVER
   a. Estuary
   b. Below Douglas River
   c. Below Fergusson River
   d. Below Katherine River
2. CHILLING & MULDIVA CREEKS
3. HAYWARD CREEK
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23. DURRINYAN CREEK
24. SEVENTEEN MILE CREEK

LEGEND

SITE LOCATION	% COVER CATEGORY
●	0
●	1-5
●	6-10
●	11-15
●	16-45*
○	Site Not Assessed

19a Sub-section Number
Catchment Boundary
Sub-catchment Boundary
Sub-section Boundary
River
Creek
Katherine Municipal Boundary

NOTE

Cover and Distribution of Emergent Aquatic Vegetation - The categories where covers were recorded include Phragmites, rushes/ sedges, Pandanus, Melaleuca, other shrubs/ trees and ground covers. No exotic species were recorded.

* The maximum percentage cover recorded for emergent aquatic vegetation was 45%.

N

0 20 40 60 80

Kilometres

NATIONAL LANDCARE PROGRAM

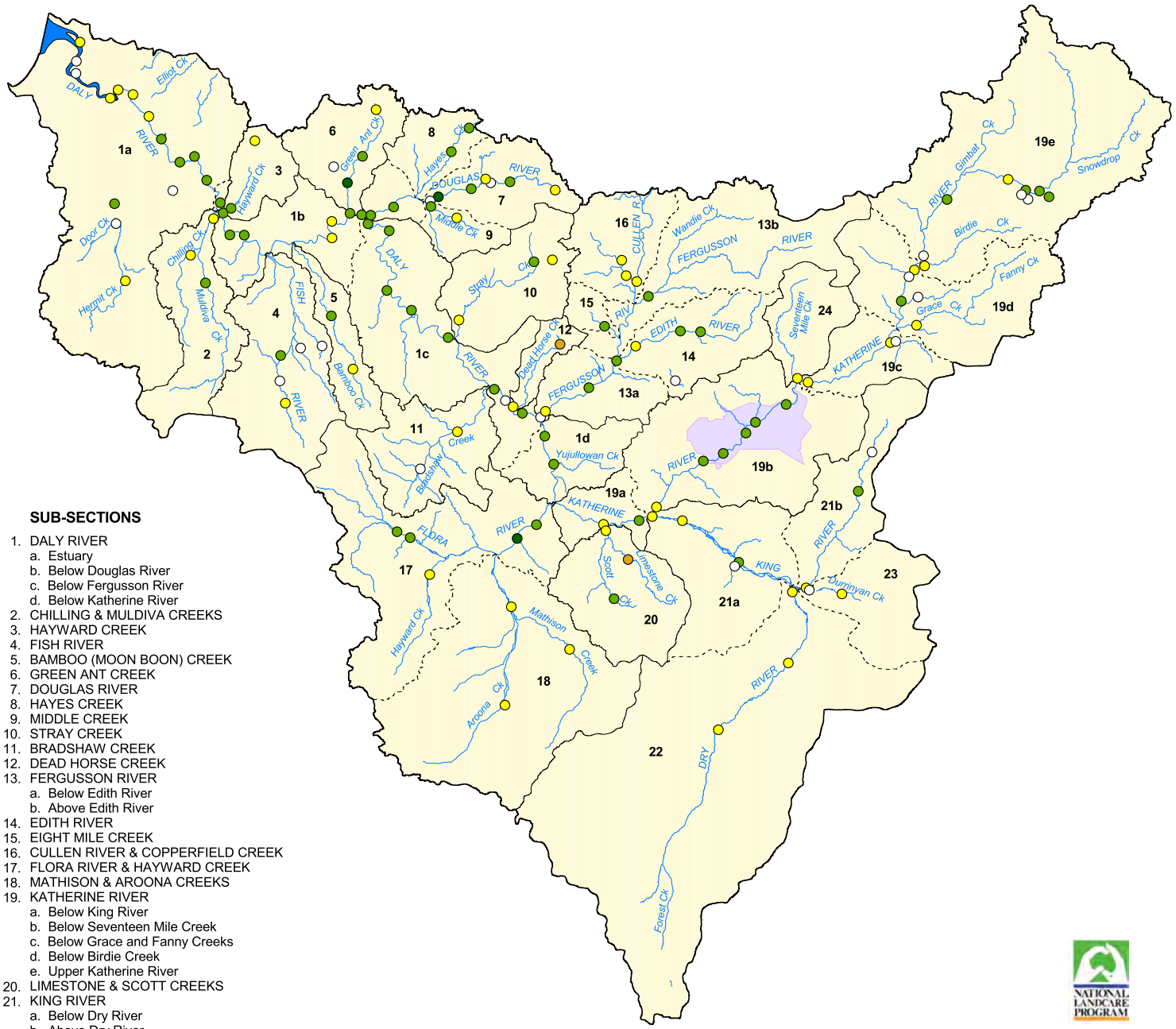
LANDS PLANNING ENVIRONMENT

TOP END WATERWAYS PROJECT

DALY RIVER CATCHMENT

COVER AND DISTRIBUTION OF EMERGENT AQUATIC VEGETATION

Map 22



SUB-SECTIONS

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24. SEVENTEEN MILE CREEK

LEGEND

SITE LOCATION	INSTREAM / BANK HABITAT CATEGORY	RATING (%)
	Very Low Cover/Diversity	0 - 20
	Low Cover/Diversity	21- 40
	Moderate Cover/Diversity	41- 60
	High Cover/Diversity	61- 80
	Very High Cover/Diversity	81-100
	Site Not Assessed	

19a Sub-section Number

Catchment Boundary

Sub-catchment Boundary

Sub-section Boundary

River

Creek

Katherine Municipal Boundary

NOTE

Cover and Diversity of Instream and Bank Habitats - The ratings are based on a combination of the cover and diversity provided by instream organic debris (logs, branches, leaves/twigs, *etc*), aquatic vegetation and other habitat types (such as rock, permanent pools) on the bed, as well as the cover and diversity provided by the canopy and other habitats (low vegetation, roots, bank overhang) along the river banks.

N

0 20 40 60 80

Kilometres

NATIONAL LANDCARE PROGRAM

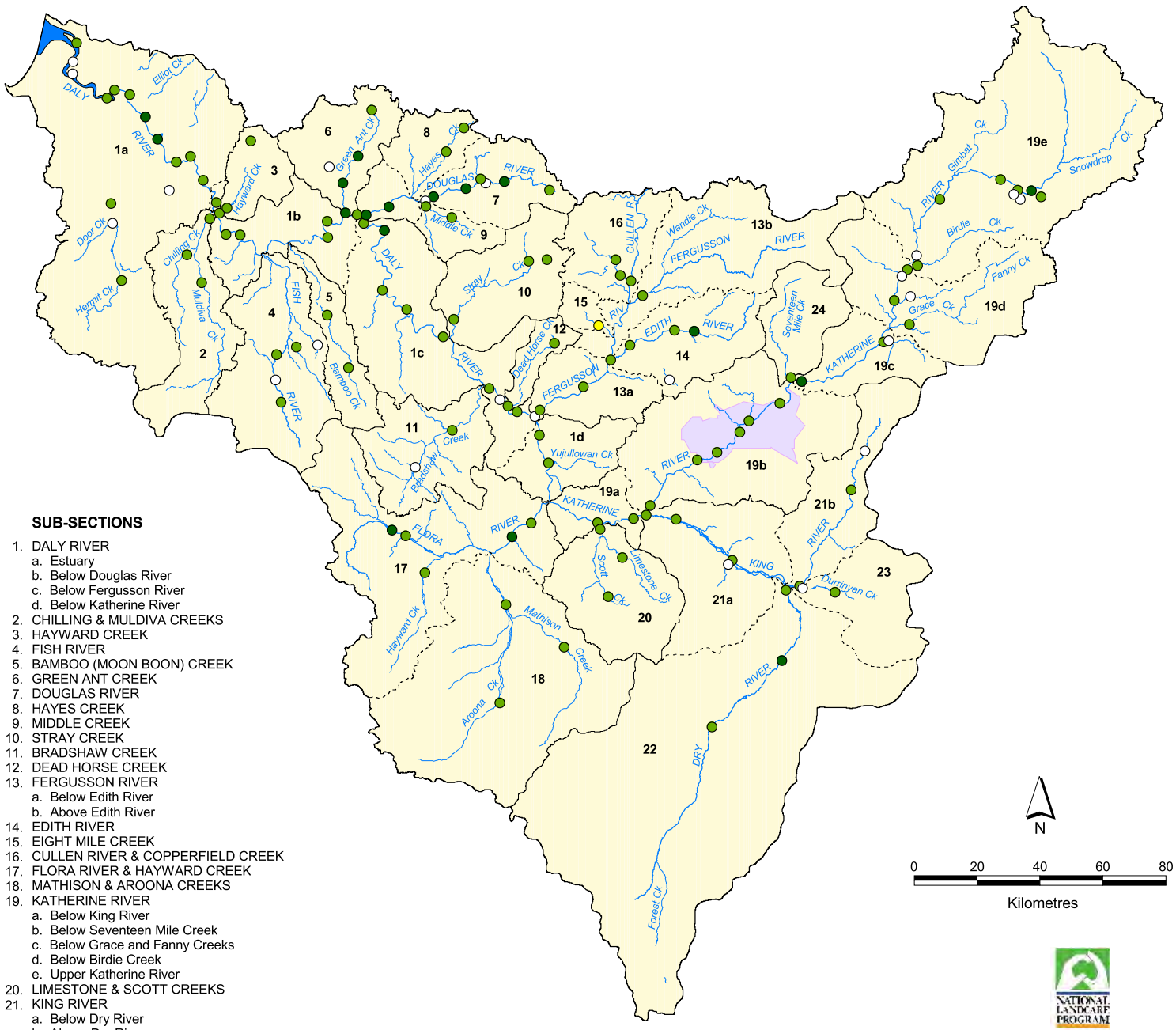
LANDS PLANNING ENVIRONMENT

TOP END WATERWAYS PROJECT

DALY RIVER CATCHMENT

COVER AND DIVERSITY OF INSTREAM AND BANK HABITATS

Map 23



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24. SEVENTEEN MILE CREEK

LEGEND

SITE LOCATION	OVERALL CONDITION CATEGORY	RATING (%)
●	Extreme Modification/ Instability, Very Low Cover/ Diversity or Very High Cover for Exotics	0 - 20
●		21-40
●		41 - 60
●		61 - 80
●	Essentially Natural/ Stable, Very High Cover/ Diversity or Exotics Absent/Negligible	81 - 100
○	Site Not Assessed	
19a	Sub-section Number	
———	Catchment Boundary	
———	Sub-catchment Boundary	
- - - -	Sub-section Boundary	
———	River	
———	Creek	
▭	Katherine Municipal Boundary	

NOTE

Overall Condition -
Provides an indication of the overall condition of the sites based on the following six components that were assessed:

- state of the reach environs
- bank stability
- bed stability
- cover and structural diversity of riparian vegetation
- cover of exotic riparian vegetation
- cover and diversity of instream and bank habitats

The rating for each component is combined equally to produce an Overall Condition Rating for each site.

TOP END WATERWAYS PROJECT
DALY RIVER CATCHMENT

OVERALL CONDITION

Map 24

LEGEND

- Flow Gauge Station - open
- Flow Gauge Station - closed
- G814003 — Gauge Station Number
- (H) — High Flow Station
- (T) — Tide Station
- Spring
- Monitoring Bore
- 19a — Sub-section Number
- Catchment Boundary
- River
- Creek
- Road
- Katherine Municipal Boundary

OPEN FLOW GAUGE STATIONS

Station	Tributary	Location	Years Recording
G8140003	Daly River	At Police Station	1952-present
G8140040	Daly River	At Mt Nancar	1969-present
G8140042	Daly River	2km d/s Beeboom Crossing	1981-present
G8140067	Daly River	U/s Dorisvale Crossing	1960-present
G8140063	Douglas Riv	D/s old Douglas Homestead	1957-present
G8140011	Dry River	At Manbulloo bdy	1967-present
G8140152	Edith River	At dam site	1962-present
G8140008	Fergusson Riv	At old railway bridge	1957-present
G8140044	Flora River	U/s Kathleen Falls	1966-present
G8140161	Green Ant Ck	At Tipperary	1966-present
G8140001	Katherine Riv	At railway bridge	1960-present
G8140023	Katherine Riv	At Gorge Caravan Park	1972-present
G8140218	Katherine Riv	At Mt Epsworth	1966-present
G8140219	Katherine Riv	D/s Birdie Ck	1997-present
G8140158	McAdden Ck	At dam site	1962-present
G8140159	Seventeen Mile Ck	At waterfall view	1962-present

CLOSED FLOW GAUGE STATIONS

Station	Tributary	Location	Years Recording
G8140234	Bradshaw Ck	At Wambungi Rd Crossing	1965-1981
G8140062	Copperfield Ck	Chinamans Camp	1972-1987
G8140041	Daly River	At Gourley	1959-1981
G8140266	Daly River	U/s of Moon Billabong	1967-1986
G8140166	Fish River	At Gorge	1963-1987
G8140005	Flora River	Upper and Picker Pocket	1967-1986
G8140019	Katherine Riv	At Katherine Gorge	1954-1987
G8140068	King River	D/s Victoria Hwy	1958-1986
G8140086	King River	D/s Stuart Hwy	1964-1987
G8140151	Mathison Ck	At Victoria Hwy	1961-1987
G8140214	Scott Creek	At Victoria Hwy	1963-1987

NOTE

Refer Table 4.36 in report for a summary of stream flow information.

N

0 20 40 60 80

Kilometres

TOP END WATERWAYS PROJECT

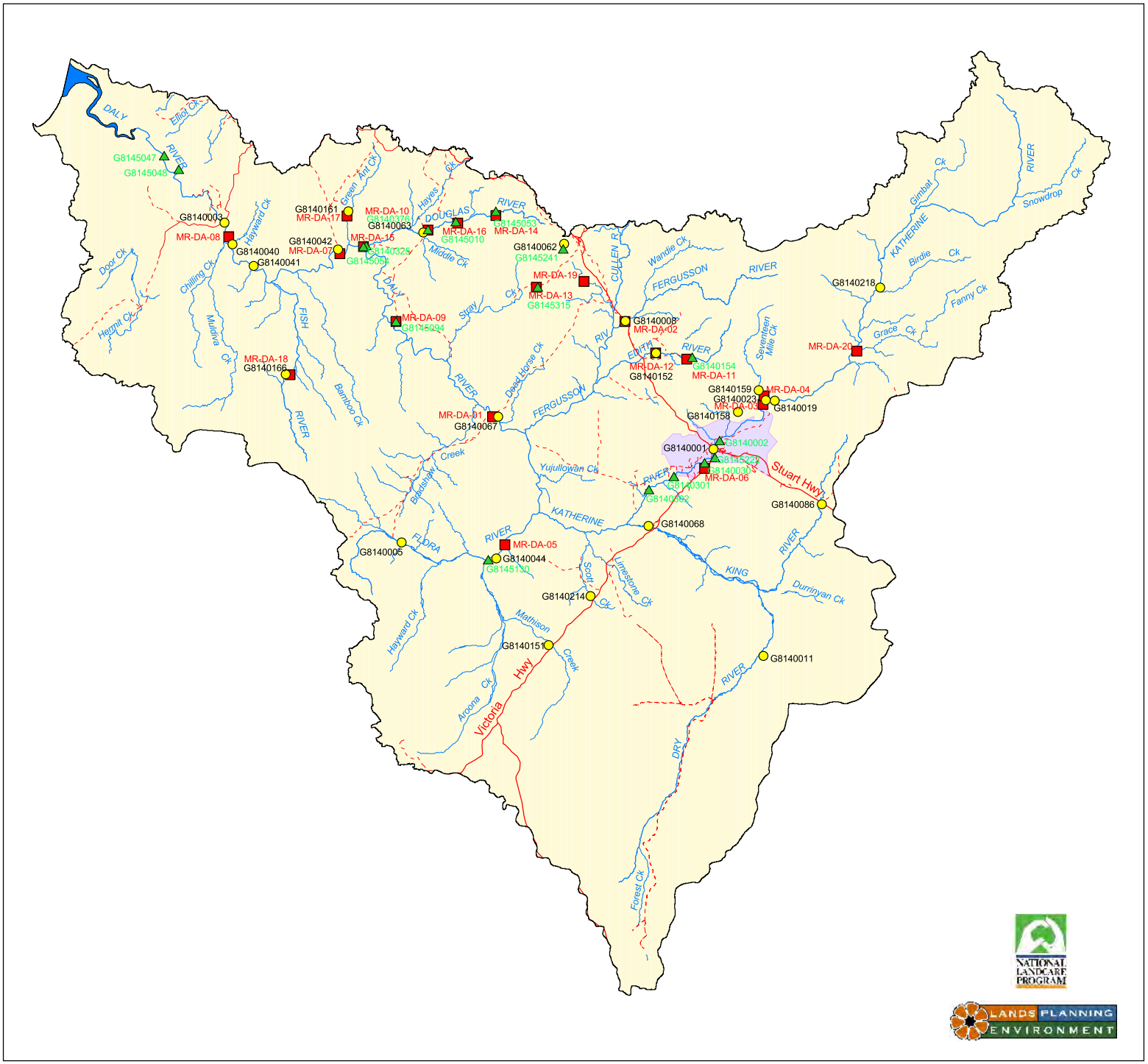
DALY RIVER CATCHMENT

FLOW GAUGE STATIONS, MONITORING BORES AND SPRINGS

Map 25

NATIONAL LANDCARE PROGRAM

LANDS PLANNING ENVIRONMENT



LEGEND

- 19a — Sub-section Number
- Catchment Boundary
- River
- Creek
- Road
- Katherine Municipal Boundary

- G8140040 — Water Quality Sampling Point located at a Flow Gauge Station. Parameters tested include 1, 2, 4 - 7 * (Refer Table 4.37 in report for a summary of the results).
- G8145010 — Water Quality Sampling Point NOT located at a Flow Gauge Station and where >10 results for a parameter and/or results >1985. Parameters tested include 1, 2, 4 - 7 * (Refer Table 4.38 in report for a summary of the results).
- MR-DA-20 — Water Quality Sampling Point located at an 'Ausrivas' Project Site (previously known as a 'Monitoring River Health 'Site) Parameters tested include 1, 3 - 7 * (Refer Table 4.39 in report for a summary of the results).

*** WATER QUALITY PARAMETERS**

1. Electrical Conductivity (Lab)
2. Turbidity (Lab)
3. Turbidity (Field)
4. Water Temperature (Field)
5. pH (Lab)
6. Total Alkalinity (Lab)
7. Total Phosphorus (Lab)

N

0 20 40 60 80

Kilometres

TOP END WATERWAYS PROJECT

DALY RIVER CATCHMENT

WATER QUALITY SAMPLING POINTS

Map 26