

VICTORIA RIVER CATCHMENT

An Assessment of the Physical and Ecological Condition of the Victoria River and its Major Tributaries



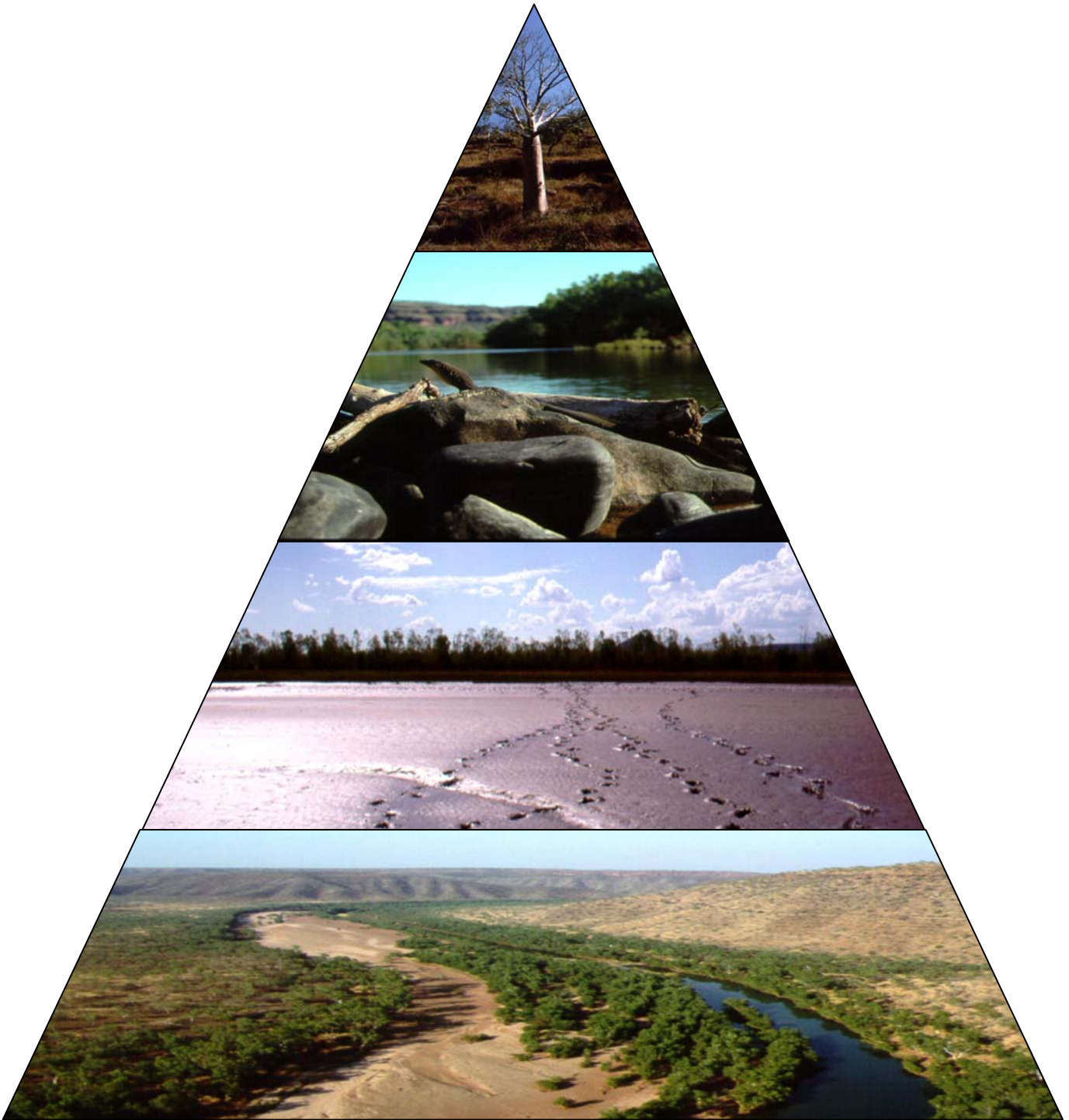
Technical Report No. 40/2004K

S.L. Kirby & J.J. Faulks

Conservation and Natural Resources Group
Department of Infrastructure, Planning and Environment
Katherine, NT

December 2004





Photograph on front cover:

Wickham River, Helimuster dreaming

Photographs on this page (top to bottom):

Baobab tree
Water Monitor in Gregory National Park
Victoria River, leave only footprints ...
Victoria River

Photograph on next page:

Jasper Gorge, Gregory National Park



Top End Waterways Project

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by

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ISBN 0 7245 4872 6

The report is available from the following locations:

- DIPE Information Resource Centre, Darwin, Northern Territory Library, Darwin, and the National Library, Canberra, through interlibrary loan;
- DIPE website <http://www.ipe.nt.gov.au/whatwedo/water-resources/surface/topendwaterways/index.html>; and
- Katherine Regional Office of the Department of Infrastructure, Planning and Environment (DIPE) as a hard copy or CD.

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Acknowledgements

The Top End Waterways Project commenced in 1995 to assess the ecological condition of the Daly, Roper and Victoria Rivers and their major tributaries with joint funding from the Natural Heritage Trust and Department of Infrastructure, Planning and Environment (DIPE). Field work for the three rivers was undertaken between 1995 and 1999 and the Daly River and Roper River Reports were completed in 1998 and 2001 respectively. Further funding for writing up this report has been provided by the Natural Heritage Trust and DIPE, and the Victoria River District Conservation Association (VRDCA) has contributed to the report printing costs.

I have handled the co-ordination and management of all aspects of the project since 1995 and have thoroughly enjoyed it. Dealing with the usual staffing issues, time constraints and budgetary concerns was a constant challenge. Developing a suitable assessment method for Northern Territory Rivers was an extremely worthwhile experience, as was the production of a database and report template. Organising and undertaking the field assessment was a challenge in this Top End environment. I was assisted with field surveys and data collection throughout the Victoria River catchment by Mathew Connelly, Brent Whitworth and Jim Cryer. The memorable estuary trip was undertaken with the assistance of Nigel Scullion and Angus Cameron. The helpfulness of everyone throughout the field surveys was extremely appreciated. The great sites and experiences will never be forgotten. Particular thanks to Jane Lloyd (nee Suggit) for letting me tag along on one of her Ausrivas data collection trips with Steve Sly; allowing me to experience my first ride in a Jet Ranger helicopter and taking the time to establish the important link between our two projects.

I am extremely grateful to Sally Kirby who took all the collected information and did such a wonderful job in compiling it into this finished report.

Judy Faulks

I was employed in March 2003 to complete the Victoria River Report and associated maps detailing findings and management issues. It was a challenge checking data and knowing I had to write a report without visiting any of the sites, however having a report template and Judy's assistance every step of the way has made the whole experience very rewarding and enjoyable. I would also like to thank Caroline Green for her patience and all her help compiling the GIS information and producing the maps for the report. I will also take this opportunity to thank all of the DIPE staff in Katherine for allowing me to work part time from home whilst on maternity leave, and for putting up with Ella on her frequent visits to the office. I have enjoyed working on the project, and hope you are satisfied with the results.

Sally Kirby

Both authors would like to acknowledge the contributions made by the following people throughout the project: Redgum Technology designed and implemented the database and associated queries. This input has been invaluable, as the database can now be built on, and the queries have been set up so that new data can be interrogated to give meaningful results, with little effort. The GIS support, mapping and vegetation sketches were provided by Caroline Green, DIPE (Katherine). Caroline's attention to detail is tireless, and we are extremely grateful for her expertise and patience. Data entry and general assistance was provided by Jenny Orton, Megan Morris and Gwen Anderson. Flow and water quality data was supplied by Steve Tickell, Rodney Metcalfe, Gary Willis and Peter Dostine, DIPE (Darwin). Stream ordering was thankfully undertaken by Dave Williams, DIPE (Darwin). Landform information was reworked and kindly provided by Brian Lynch, Co-operative Research Centre for Tropical Savannah Management. Most of the photographs in the report were taken during field surveys; however Annemarie vanDoorne, Patrick Carmody and Royce Sample provided some additional photos which are appreciated. Background information was supplied by various people within DIPE (Darwin), the VRDCA Co-ordinator(s), Parks and Wildlife Services NT (PWS), Timber Creek Local Council and DBIRD. Special thanks to Maria Wauchope for answering endless questions about Gregory and Keep River National Parks. Identification of the large quantity of vegetation samples was carried out by the NT Herbarium (PWS). Support, information and comments were also supplied by a number of other DIPE staff members within the Katherine and Darwin offices. Thanks also to the property owners/managers and Aboriginal communities who allowed access to the survey sites located on their lands and provided background information on the rivers and creeks. This first hand knowledge of the area is an invaluable contribution to the project.



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EXECUTIVE SUMMARY



Overview

The 'Top End Waterways Project' commenced in 1995 and has been jointly funded over the years by the Natural Heritage Trust and the Northern Territory Government. The Victoria River District Conservation Association (VRDCA) made a contribution for the production of this final report, and was instrumental in their support of the project. The Department of Infrastructure, 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. As part of a previous study, the major tributaries within the Daly River and Roper River catchments were assessed. This report provides an assessment of the Victoria River catchment and major tributaries, in terms of the physical and environmental condition of these streams at the time of survey (June to December, 1996). The use and management of the waterways within the Victoria River catchment have been identified, major river management issues have been highlighted and broad river management recommendations have been proposed.

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 used to assess river condition and stability on a catchment by catchment basis. From the Queensland '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 reviewed and modified by a NT Technical Working Group so that the results would reflect Northern Territory conditions. Section 3 discusses in more detail the methods used including the sampling strategy, survey components and the condition and stability ratings.

Although the data for this project was collected in 1996 and the report was not written until 2005, the project provides an important reference point or "snapshot" of what the rivers and creeks were like in 1996. This means there is a baseline with which to compare future studies, so follow up surveys to assess the rivers and tributaries can use the existing framework and database to detect the rate and direction of change in the catchment, making this project a very useful monitoring tool.

By overlapping survey sites with other studies such as the 'Ausrivis' scheme, and creating connections with long term databases such as water flow and quality databases, the project also provides an important link to allow possible correlations to be drawn between studies, as well as providing a longer term record of the catchment. The overview of the Victoria River catchment also provides useful background information and an up to date literature review of the region.

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. Technical information from this study can be used within planning frameworks such as the Natural Resources Plan (Sample, 2004) or the Interim Natural Resources Management Plan (Northern Territory Land Council, 2005).

This report identifies key issues, problems and priorities in the major rivers and tributaries of the Victoria River catchment and outlines the extent and some of the processes and causes of river degradation (eg weed infestation, accelerated erosion, concentrated use, etc). This information can be used to assist decision makers in the development of strategic and effective river management policies and to identify actions to reverse any deterioration.

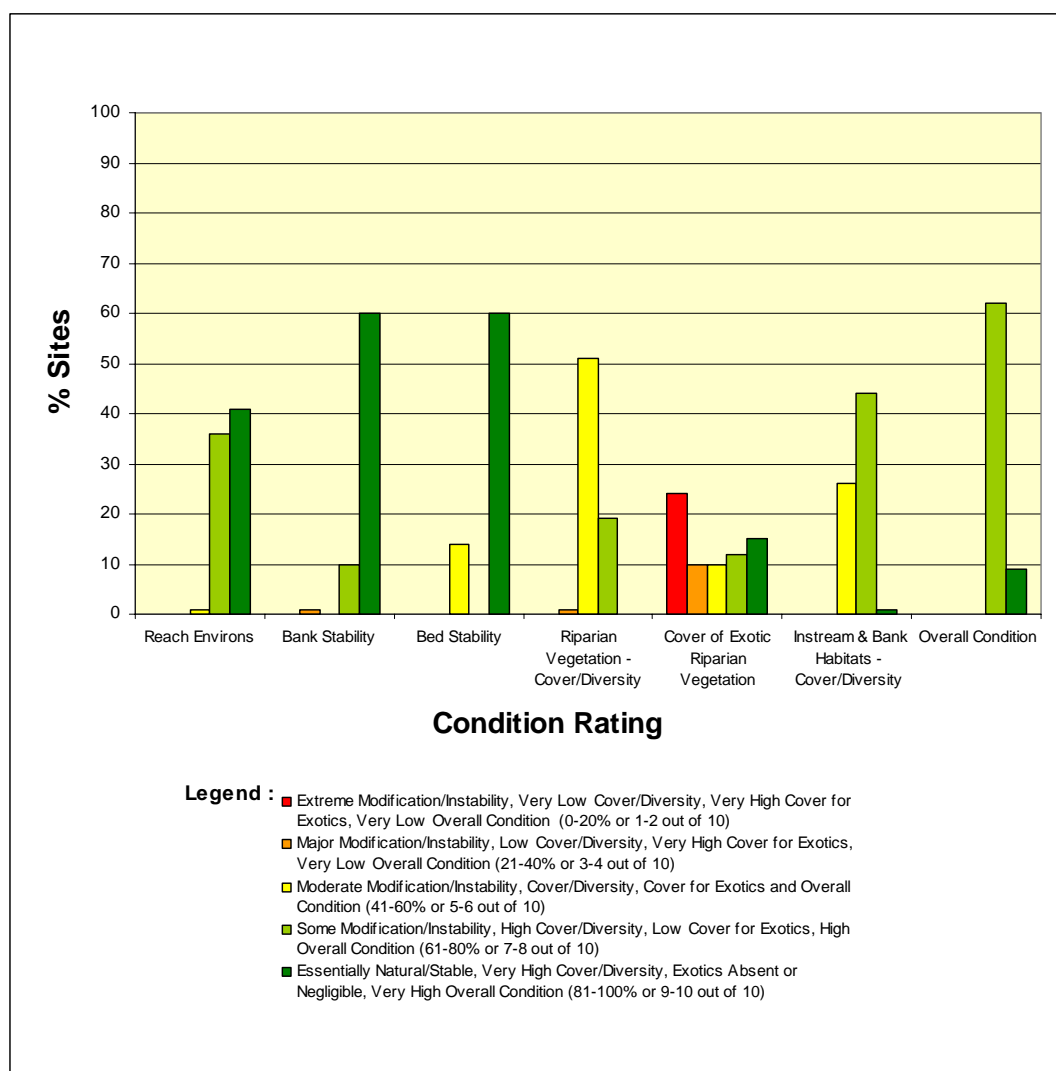
This report provides an overview of the Victoria River catchment and its tributaries in 1996 and outlines a useful monitoring framework for detecting changes to the catchment in the future.



Summary of Victoria River Catchment Condition

Maps 10-25 show the results for the condition and stability ratings and other attributes examined.

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



◆ Reach Environs and Site Features

Just over half the sites assessed were rated as having essentially natural reach environs, and the remainder had some modification. Only one site had moderate modification to the reach environs and no sites were assessed as having major or extreme modification. Generally, the sites with essentially natural reach environs had relatively low impact land uses, undisturbed vegetation and few local disturbances like grazing, infrastructure and concentration of animals at watering points.

Subjective disturbance ratings conducted in the field indicated that the majority of sites had low to very low levels of disturbance, and the remainder had low to moderate and moderate levels of disturbance. One site was reported to have moderate to high level of disturbance due to the presence of an access track and people using the river reach for recreational activities. No sites were highly, very highly or extremely disturbed.

The majority of land adjacent to stream reaches studied was under either freehold or leasehold tenure, including Aboriginal land. The major land use recorded adjacent to the streams was grazing, and to a much lesser extent, National Park. Grazing activity, roads/tracks, river crossings, and watering points for stock and feral animals were the three major disturbances to stream reaches.

◆ *Channel Habitat Types, Diversity and Dimensions*

Reaches studied averaged 2,238m in length and ranged from 50-20,300m. Pools and riffles were the dominant habitat types located throughout the catchment. Pools generally occurred with riffles and runs, and waterfalls were also associated with areas of steeper topography such as Limestone Gorge and Cow Creek. There were only three rapids recorded in the catchment, and one cascade. The majority of survey work was conducted during the dry season so many rivers and creeks were either completely dry or had isolated pools.

Channel type diversity assessed the number of different channel habitat types present and the proportion of the reach occupied by pools versus other habitat types. The majority of sites recorded a high diversity of channel habitat types and these mostly had two habitat types present. Sites with very high diversity usually had three to four habitat types, and were found in the steeper rocky sections of the catchment. Very low and low diversity ratings were predominantly recorded in tidal sections where the pools were very long and uniform. Sites with moderate channel type diversity had two habitat types, of which pools dominated the reaches.

◆ *Bank Condition and Stability*

The majority of river banks throughout the catchment were considered stable, with a few (ie 10 sites) that had limited instability, and one site that was suffering from extensive instability due to stock and the presence of a vehicle crossing and track (Site 9_4 on Poison Creek). A subjective assessment of bank stability conducted in the field indicated that the majority of sites recorded low overall bank instability, however many sites had low to moderate and moderate bank instability, and some sites also had moderate to high and high levels of instability.

Though most river banks were rated as being stable, some form of erosion processes were recorded at the majority of sites, and aggradation was recorded at one site. Only two sites were considered absolutely stable. Lower banks were more stable than upper banks with an average of 94% of the lower bank considered stable, and 85% considered stable for the upper bank.

The major factors affecting bank stability were high flow and stock, and to a lesser extent, infrastructure (eg roads, tracks, crossings, bridges), floodplain scours, runoff and vermin. Smaller contributing factors included tidal influence, people tracks and clearing of vegetation. The only types of artificial bank protection measures recorded were fencing along the river and/or at stock watering points, which occurred at several sites, and gabions at one site.

◆ *Bed and Bar Condition and Stability*

A subjective assessment of the overall bed stability indicated that the majority of sites had stable river beds, while 13 sites recorded moderate bed aggradation and one site recorded bed erosion problems.

Moderate bed aggradation was located on Victoria River (5 sites), Bullo River (3 sites), Camfield River (3 sites), Jasper Creek and Gordon Creek. Most of the Victoria River and Bullo River sites were tidal, and experience aggradation as sediments move through the estuary. Other sites, such as those on Camfield River and Gordon Creek, had relatively flat, uniform and shallow river beds with a large amount of sand and gravel. These sites were all near stock watering points and vehicle crossings, and had bank erosion, floodplain scouring and new channels forming. The site recording erosion problems was located on Poison Creek at the road crossing into Mt Sanford Outstation (Site 9a_4). Stock, and to a lesser extent the vehicle crossing and access track, have caused severe erosion of both the bed and banks at this location.

Bars were widespread and were recorded at nearly three-quarters of sites, averaging 18% of the bed and ranging to as high as 55%. Bars with encroaching vegetation and alternate bars were the two most prevalent bar types.

Nearly half of sites had no factors affecting bed stability, however at the remaining sites, the major factor affecting bed stability was grazing, with bank erosion, concentration of flows, instream siltation and bed deepening contributing to a lesser extent.

◆ *Bed and Bank Sediments*

A range of size classes, from clays to boulders, were recorded in the river bed and banks. Pool habitats had a higher proportion of smaller bed sediments; runs and riffles had a range of bed sediment types; and rapids had a higher proportion of cobbles and boulders. The sediments along the lower and upper banks for all habitat types consisted mainly of smaller sediment sizes (eg small sand and clays), except rapid habitats, which had boulders on the lower banks.

◆ *Riparian Vegetation*

All sites were assessed as having moderate to high cover and structural diversity for riparian vegetation except one estuary site, which rated as low. The average width of the riparian zone was 23m ranging up to 155m. Only one site on Giles or Wattie Creek recorded a narrow riparian width of less than five metres. 15% of sites had riparian widths of greater than 40m, including sites on the larger river systems: Victoria, Bullo, East Baines, Wickham and Armstrong Rivers.

A range of structural categories were present in the riparian vegetation except for tall trees >30m and salt marsh. Trees, shrubs, forbs and grasses were the most prevalent structural types (recorded at over 90% of sites). Grasses provided the highest percentage cover of all structural types, followed by trees and shrubs.

Eucalyptus camaldulensis was the most widespread native overstorey species, followed by *Lophostemon grandiflora*, *Terminalia platyphylla*, *Pandanus aquaticus*, *Ficus coronulata* and *Melaleuca leucadendra*. *Acacia holosericea* was the most common native shrub, and *Eriachne festuacea* the most common native grass species. The most common mangrove species was *Avicennia marina*, which was confined to sites in the Victoria River estuary.

◆ *Instream and Bank Habitats*

All but one site were rated as having moderate or high cover and diversity of instream and bank habitats. One site on the Wickham River had a very high cover and diversity. A subjective assessment of the aquatic environment was also undertaken and the results showed that over two-thirds of sites were rated as being in good to pristine condition, whilst nearly one-third of sites rated as being in poor to very poor condition.

The most commonly occurring instream habitat types included branches, leaves and twigs, logs, tree roots, rock faces and deep permanent pools. Vegetation overhang from riparian vegetation provided canopy cover for instream habitats and had a mean width of 2.6m occurring along 63% of the bank length on average.

At the time of survey fish passage was restricted at nearly half of the sites assessed due to the formation of isolated pools. It was concluded that fish passage would be restored in the wet season.

◆ *Overall Condition*

The overall condition rating is based on equally combining the ratings for the following six components:

- State of the reach environs;
- Bank stability;
- Bed stability;
- Cover and structural diversity of riparian vegetation;
- Cover of exotic riparian vegetation; and
- Cover and diversity of instream and bank habitats.

The majority of sites (87%) recorded a high overall condition rating whilst the remaining sites (13%) rated very high. Therefore, no sites were rated as being degraded overall. The sites that rated very highly overall were located on Angalarrri River, Wickham and Humbert River, Victoria River below Jasper Creek, in the upper catchment of the Victoria River, Baines River, Armstrong River and Jasper Creek.

Sub-section Name	Sub-section/ Site No.	Tributary Name	(1) Reach Environments	(2) Bank Stability	(3) Bed Stability	(4) Riparian Vegetation	(5) Exotic Riparian Vegetation	(6) Instream & Bank Habitats	(7) Overall Condition
Gregory and Delamere Creeks	5_1	Gregory Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	5_2	Gregory Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	5_3	Gregory Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	5_5	Delamere Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	5_6	Delamere Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	6_1	Battle Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
Battle Creek	6_2	Battle Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	6_3	Battle Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	6_4	Waterbag Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	7_1	Jasper Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
Jasper Creek	7_2	Jasper Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	7_3	Slaty or Jasper Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	7_4	Surprise Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	8_1	Wickham River	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
Wickham and Humbert Rivers	8_2	Wickham River	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	8_3	Wickham River	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	8_4	Wickham River	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	8_5	Gibbie Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	8_6	Humbert River	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	9_1	Gordon Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
Gordon Creek	9_2	Gordon Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	9_3	Fever Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	9_4	Poison Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	10_1	Armstrong River	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
Armstrong River	10_2	Armstrong River	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	10_3	Coolibah Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	10_4	Coolibah Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	10_5	Townsend Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	11_1	Camfield River	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	11_2	Camfield River	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
Camfield River	11_3	Camfield River	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	11_4	Camfield Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	12_1	Wattie Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
	12_2	Lily Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
Giles or Wattie Creek	12_3	Stevens Creek	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●

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); Limited Erosion (E) or Aggradation (A) (3); 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 Erosion (E) (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 and Broad Management Issues

In order of overall condition, if all sites within each sub-section are averaged and then ranked from highest to lowest, the sub-sections are listed below:

1. Angalarri River
2. Armstrong River
3. Wickham and Humbert Rivers
4. Giles or Wattie Creek
5. Victoria River – upper catchment
6. Baines River
7. Jasper Creek
8. Victoria River – estuary
9. Gregory and Delamere Creeks
10. Battle Creek
11. Gordon Creek
12. Bullo River
13. Victoria River – below Jasper Creek
14. Camfield River
15. Victoria River – below Camfield River

Even though all the rivers and creeks were assessed to be of high or very high overall condition, all sites had some degree of degradation. That is, no site rated very highly for every attribute assessed. The type of degradation ranged from exotic species invasion, lack of cover and structural diversity of riparian vegetation, lack of diversity of instream and bank habitats, disturbances to the reach environs, and bank and/or bed instability. Disturbance factors included grazing, roads and tracks, concentration of stock and/or feral animals at watering points, high flows, runoff, floodplain scours and breakouts, people, and, to a limited extent, tidal influence.

Of the six factors contributing to the overall condition rating for sites assessed, the major issues within the Victoria River catchment in order of priority are listed below:

1. High level of weed invasion (all 15 sub-sections)
2. Lack of cover and structural diversity of riparian vegetation (all 15 sub-sections)
3. Lack of diversity of instream and bank habitats (all 15 sub-sections)
4. Disturbance to reach environs (14 sub-sections)
5. Bank instability (8 sub-sections)
6. Bed instability (6 sub-sections)

The following section outlines the major issues and conclusions that can be drawn from the survey of the Victoria River and its tributaries.

1. *High level of weed invasion*

Weed invasion in the riparian zone was identified as the major issue affecting the condition of the Victoria River and its tributaries. Exotic vegetation species, particularly vines and forbs, were widely distributed throughout the catchment and were recorded in all sub-sections and over three-quarters of sites assessed. The degree of invasion, or extent, of weeds in the riparian zone varied significantly (ie from 0-42% cover), with nearly half the sites recording a level of greater than 10% cover.

Weeds are generally opportunistic species, and outcompete native species for light, space and nutrient, effectively displacing them in the river corridor. This can alter the structural diversity and biodiversity of riparian areas, and has implications for river health in terms of affecting bank stability, stream flows, water quality, the aesthetic appeal of an area, movement of animals and people, and increasing the fuel load for fires.

Mechanisms for weeds being introduced to the Victoria River catchment include spreading down rivers and creeks; people deliberately introducing species for shade or ornamental plants, or accidentally on the soles of their shoes or attached to clothing; birds and mammals (including stock and feral animals) carrying seed in tails or spreading through dung after eating fruits or transported in hay; or cars and trucks carrying seed on tyres or unwittingly packed into their equipment.

Once introduced, weeds generally colonise areas denuded of other vegetation such as heavily utilised areas around stock bores, cattle yards, river crossings, camping areas, boat ramps and washouts following high flows or flood events (they can also colonise and stabilise sand bars, altering stream morphology).

Impacts of weeds for land managers include loss of productivity on pastoral properties as grass species decline, and reduced recreational activities (eg fishing, camping, walking etc) in areas where access or aesthetic appeal is affected. River reaches with high levels of weed invasion were located on different land tenure including Aboriginal land, pastoral leases, National Parks and Department of Defence land, as well as in close proximity to infrastructure such as the Victoria Highway.

Plants can be 'Declared Weeds' under the NT *Weed Management Act 2001*, and landholders then have a legal responsibility to control them on land that they manage. Declared weeds are categorised into Classes A, B and C, depending on whether they need to be eradicated, their growth and spread is to be controlled, or they are not to be introduced into the NT. All other plants growing in the wrong place are known as an environmental weed.

Passiflora foetida, the most prevalent weed species in the Victoria River catchment at the time this survey was conducted, is an environmental weed. It is a fast growing species which chokes out native vegetation, and is also suspected of poisoning stock. *Parkinsonia aculeata* is a Declared Weed (Class B), and is also a Weed of National Significance (WONS species). This species was introduced into Australia as a shade tree in the 1890s. It forms impenetrable thorny thickets blocking access to creek lines and rivers and excluding native species. It is a very hardy plant that can withstand long dry periods and seeds remain viable for many years. The other most prevalent weed in the catchment was *Xanthium occidentale*, also a Declared Weed (Class B). This species was reportedly imported into Australia with cotton seed and forms dense thickets along river systems. These three species, along with the other weeds identified in the catchment pose a serious environmental problem for the people responsible for managing land.

In general, controlling weeds along streams requires a whole of catchment approach, as 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. Therefore weed control strategies along the Victoria River and its tributaries needs a collaborative approach from all land owners and managers, making the best use of available resources such as equipment and technology. Public awareness is also important to prevent the spread of weeds to new areas.

Individual landholders are responsible for weed management on their land, and most properties undertake some form of weed control (eg spraying, burning, slashing etc). There have been several organised campaigns to combat the weed situation in the catchment in recent years. *Parkinsonia aculeata* was the target of a weed control program conducted by landholders with Natural Heritage Trust (WONS) funding and assistance from DIPE between 2002 and 2004. Ongoing programs include a Lions Tail Control Program funded by Heytsbury Beef Pty Ltd undertaken by the Caring for Country Unit, Timber Creek. There is a Devils Claw Festival, which is an annual event organised through NT Parks and Wildlife Service on Gregory National Park. There have also been committed control programs on a number of pastoral properties to manage devils claw which has significantly reduced the extent of the infestations. It is important that there is continued follow up to keep the devils claw contained. The VRDCA are in the process of applying for funding through the Weeds Menace Program to undertake a Barleria Control Program, and DIPE are currently developing an Integrated Weed Control Program for the control of Bellyache Bush, which is on the boundary of the Victoria River catchment.

The Katherine Regional Weed Management Strategy 2005-2010, prepared by the Katherine Regional Weed Advisory Committee, advocates weed prevention as the key to weed management, as control can often be un-economic and sometimes even impossible to achieve. Land managers are encouraged to prepare property management plans to prevent the introduction of weeds, and to control the spread of weeds that are already present. The DIPE Weed Management Branch are currently facilitating a weeds risk assessment process to identify priority weeds for the Katherine Region and review the Declared Weeds list for the NT *Weeds Management Act*. Specific NT Species Management Plans will be prepared for each of these species. National Strategic Plans have already been prepared for all of the WONS species and these are available at the Katherine and Timber Creek Weeds Management Officers. It is envisaged that land managers and conservation groups such as the VRDCA will eventually provide weed distribution information to the Weeds Management Branch so that sub-catchment maps can be collated and strategic management plans be developed to assist land managers plan and prioritise on ground works. The Weeds Management Branch of DIPE in Timber Creek or Katherine are the best contacts for further information on the status of weeds in the region and best mechanisms for their control.

2. Lack of cover and structural diversity of riparian vegetation

Cover and structural diversity for riparian vegetation was categorised as moderate for nearly three-quarters of the sites throughout all sub-sections within the Victoria River catchment, making this factor the second most significant issue in the catchment.

The only site that recorded a low cover and structural diversity was along the Victoria River estuary. The low rating for this site was due to the fact that there were only two estuarine species recorded (ie *Avicennia marina* and *Sesuvium portulacastrum*) and these provided poor cover. This demonstrates that cover and structural diversity can be poor due to natural conditions, and is not necessarily a reflection of poor river management.

The riparian vegetation was quite structurally diverse throughout the catchment with trees (between 2-30m), shrubs, forbs and grasses being recorded at more than 90% of sites assessed. The rating was reduced due to the variation between 0-75% cover for the different structural types. Grasses provided the highest cover, but this only averaged 29%, although it ranged up to 75% cover along some reaches. Trees (2-30m) provided an average cover of only 16-18%, although this ranged to as high as 40% cover.

In general, the lower banks had a higher percentage of bare ground than the upper banks which is possibly due to naturally occurring seasonal aspects. Continual high flows over the wet season and deposition of sediment during this period, or water availability or fires during the dry season may influence the occurrence of ground covers and, therefore, the structural diversity and covers recorded.

The study revealed that the riparian vegetation was relatively intact throughout the catchment, and had not been impacted upon by extensive clearing or development. Factors affecting the reaches in general, included grazing, roads and tracks, causeways and river crossings, stock and/or feral animal watering points and bridges or culverts. These factors could also be contributing to the lack of cover and structural diversity of the riparian vegetation found throughout the catchment.

River bank stability can also influence the condition of the riparian zone. Natural factors such as water availability, soil type, climate and location within the catchment can all influence the types of vegetation found in the riparian areas, as do external influences such as grazing, vehicular access, people access, water quality and infrastructure. The cover and structural diversity of the riparian vegetation varied between sites, even in instances when the stability of the river banks did not vary. More specific research would be required to determine the relationship between river bank stability and riparian vegetation in the catchment.

The average width of the riparian zone throughout the catchment was 23m, with a range of 0-155m. The width of riparian vegetation is usually a good indication of the 'natural' width, and can often be used as a guideline for planning or recommending appropriate buffer zone widths throughout a catchment. The larger the stream, the larger the band of vegetation required to buffer potential impacts. From this study however, it is apparent that riparian vegetation widths are influenced by other factors, as the larger stream orders do not have the largest riparian vegetation bands as would be expected. 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) – 31m (range 2-95m)
- Medium-sized streams (orders 3 and 4) – 22m (range 5-68m)
- Major streams (stream orders 5 and 6) – 20m (range 5-89m)

The greatest variation in riparian widths at any one site was recorded in the Victoria River estuary, where the left hand bank had 11m wide vegetation and the right hand bank had 155m of vegetation. This site was located on a bend in the river where the outside bend (left hand bank) was eroding, and there was accumulated sand and associated vegetation on the inside bend (right hand bank). Other factors that may be contributing to narrower than expected riparian widths on the larger stream orders include: grazing by stock, feral animals and other native species (eg wallabies) which can suppress regeneration of natural species; weed invasion out competing native species; naturally low rainfall and limited groundwater resources resulting in less moisture for plants to access further away from the stream.

Riparian zones are a vital link between land and water environments. Riparian vegetation performs many essential functions, including: the protection of river banks from erosion processes; acting as a buffer or filter for sediments; 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 is imperative that riparian areas be protected in the Victoria River catchment. Grasses and other low species, including regenerating shrubs and trees, are particularly susceptible to impacts from grazing, infrastructure and uncontrolled access points to the river (eg boat ramps, camp sites, etc).

There have been several attempts to fence off riparian areas in the catchment in the past, however seasonally high flows and large distances make the cost of repairs and maintenance prohibitive for many landholders. Relocating stock watering points off stream is another mechanism to restore and protect riparian areas. Riparian areas will continue to be degraded for as long as stock and feral animals have unlimited access to these fragile environments.

3. Lack of cover and diversity of instream and bank habitats

The ratings indicate that there is a lack of cover and diversity of instream and bank habitats at over one-third of sites located in all sub-sections. This is not considered to be a major issue in the Victoria River catchment though, as it is probably a natural feature of the landscape rather than a result of degradation.

The rating reflects 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. Instream habitat types were relatively diverse with branches, leaves, twigs, and logs being recorded at over 90% of sites. Bank habitat types were also quite diverse with canopy cover and overhanging vegetation being present at all sites. The cover provided by instream and bank habitats ranged substantially though and it is generally this component that reduced the rating.

Instream and bank habitats are important resources for instream fauna, including macro-invertebrates and fauna associated with the riparian vegetation. The results suggest that the instream and bank habitats were generally diverse and possibly provide habitat areas to support a diversity of fauna. More specific research would need to be undertaken to determine the value of instream and bank habitats in the Victoria River catchment for fauna species. It is possible that the results of this study could be used in collaboration with other fauna studies such as the 'Ausriviv Program' or the Purple-crowned Fairy-wren research project to determine the relationship between instream and bank habitats and fauna species, in this unique seasonally dry-wet environment.

The location of the reach within the catchment, and the geology and topography influences the diversity of instream and bank habitats and subsequently the aquatic vegetation, as the flow varies enormously throughout the year, and mechanical damage during high flows is often an annual event. Riparian vegetation varies depending on the location in the catchment, and this has implications on leaves, twigs and branches falling instream, occurrence of large rock faces, permanent water holes etc. The drying up of many sections of the rivers and creeks each year means that instream vegetation has a limited growing season and has to recolonise each year, compromising the integrity and perhaps also the quality of the habitat it provides. Sites situated on lower stream orders (ie smaller rivers and creeks) generally had a lower cover and diversity of instream and bank habitat than sites situated on the higher stream orders and those in the lower sections of the catchment where there is permanent water.

Management suggestions for protection of instream and bank habitats are similar to those listed for the protection of riparian vegetation and include: removal of weeds, relocation of stock watering points off stream, and control of feral animals. In addition to these measures, instream and bank habitats are also affected by water quality and high flows, as well as potential impacts by recreational and commercial fishing operations and other people using the river to its detriment.

4. Disturbance to reach environs

Disturbances to reach environs were identified as an issue affecting the overall condition of the catchment. 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 was the major land use and disturbance factor recorded throughout the Victoria River catchment, followed by roads and tracks, river crossings and watering points for stock and feral animals. Just over half the sites that rated as essentially natural had relatively low impact land uses, undisturbed vegetation and few local disturbances. Nearly half of the sites that rated as having some modification recorded the presence of a local disturbance such as grazing, concentration of animals (including ferals) around a watering point, river infrastructure (eg tracks, crossings), people or floodplain erosion that reduced the rating from essentially natural.

Infrastructure can cause localised problems, with poor design and/or lack of maintenance leading to erosion and other impacts. It is important to properly locate crossings, avoiding outside bends or steep banks, and to target areas where the creeks are shallower, and have larger sediments along the bed such as gravels, cobbles or boulders. Tracks need to be designed to minimise the concentration of flows along their length, and a regular maintenance program needs to be implemented to avoid severe erosion. Another key consideration when locating infrastructure such as roads, bridges and cattle crossing points, is to disturb as little riparian vegetation as possible. For assistance with this issue the following would be useful references:

- *Victoria River District Road and Fenceline Erosion Control* (VRDCA, 2003) as a video and DVD;
- *Guidelines for the Construction and Maintenance of Formed Roads and Access Tracks in the Northern Territory* (Fulton, 2002);
- *Draft Erosion and Sediment Control Guidelines* expected to be released by the NT Government in early 2006; and
- *The Glove Box Guide to Tracks, Firebreaks and Fencelines*, a CD that was developed by the NT Government with NHT funding in 2002.

Landholders, managers and visitors need to be mindful of the individual actions that contribute to river degradation, and to implement steps to avoid further deterioration and actually promote the restoration and maintenance of the river corridor and reach environs. Any regional strategy should ensure that the riparian vegetation is protected, ad hoc access points and river crossings are restricted, necessary infrastructure is maintained, fencing and off-river watering points for stock are encouraged, feral animals are controlled, and that weed invasion of the riverine environment is managed. It is therefore important to undertake follow up assessments to determine the rate and direction of changes occurring in the catchment and manage the outcomes accordingly.

5. *Bank instability*

Although 85% of the sites were assessed as having stable river banks, only two sites were considered absolutely stable. Erosion, rather than aggradation, was the dominant process affecting bank stability throughout the catchment. Overall, bank stability was not identified as a major issue in the catchment. The stability of banks can also affect other features such as riparian vegetation and instream and bank habitats. There was only one site with extensive bank instability and it was located on Poison Creek in the Gordon Creek sub-section. Stock was causing extensive impacts at this site, along with a track and river crossing.

High flows associated with the wet season was the most significant factor contributing to bank instability, followed by erosion of river banks by stock and feral animals accessing the rivers and creeks for water, shelter and food. As many of the rivers and creeks become isolated pools during the dry season, animals tend to concentrate around these areas if no other water points are available. As a result, trampling and grazing of the river banks and reach environs occurs. Infrastructure such as roads, tracks, crossings and bridges were identified as the third greatest threat to bank stability. The only other major cause of erosion identified in the catchment was floodplain scours and breakouts and runoff, both associated with high flows during the wet season.

The high level of bank stability recorded throughout the catchment is reflected in the fact that the riparian vegetation is relatively intact and disturbances are generally localised and infrequent. The only bank protection measures noted at the time of survey included fencing along the river and/or at stock watering points at 7% of sites, and one site which had gabions. If follow up surveys or anecdotal evidence indicated that there was a deterioration in the stability of the river banks in the future, fencing off riparian areas to exclude stock and feral animals would help riparian vegetation regeneration and stabilise banks. When fencing is done along river corridors, responsibility for management needs to be taken into account so that activities such as weed and feral animal control, and maintenance of fencing do occur.

Monitoring the proportion of bank lengths that are stable, eroding or aggrading can assist with detecting the extent of change in bank stability over time throughout a catchment. It is also possible to identify links between bank stability and any increase in the rate or extent of erosion or sedimentation that can be attributed to human activities within the catchment. There is currently a project examining riparian management and the rate of erosion in the catchment which will address some of these issues (McCloskey, in press).

6. *Bed instability*

Overall, bed stability was not identified as a major issue in the catchment as only 19% of sites recorded bed instability in the form of moderate aggradation, except one site where erosion was the dominant process.

In the lower catchment sites on Victoria River and Bullo River, sites experiencing aggradation were mostly located in the tidal sections, where sediments would be expected to accumulate before eventually being flushed out to sea. Bed aggradation was also found to be occurring in upstream areas. At these sites the river channel was relatively flat, uniform and shallow, and there appeared to be a large amount of sand and gravel. These upstream sites were all near stock watering points and vehicle crossings, and had bank erosion, floodplain scouring and new channels forming.

Site 9_4 on Poison Creek was the only site that recorded bed (and bank) erosion problems due to stock, and to a lesser extent a vehicle crossing and access track into Mt Sanford Outstation. The instability at this site is subsequently affecting the riparian vegetation and reach environment.

Where bed stability was identified as an issue, the major factor affecting it was grazing. Other, less significant factors included bank erosion, concentration of flows, instream siltation and bed deepening.

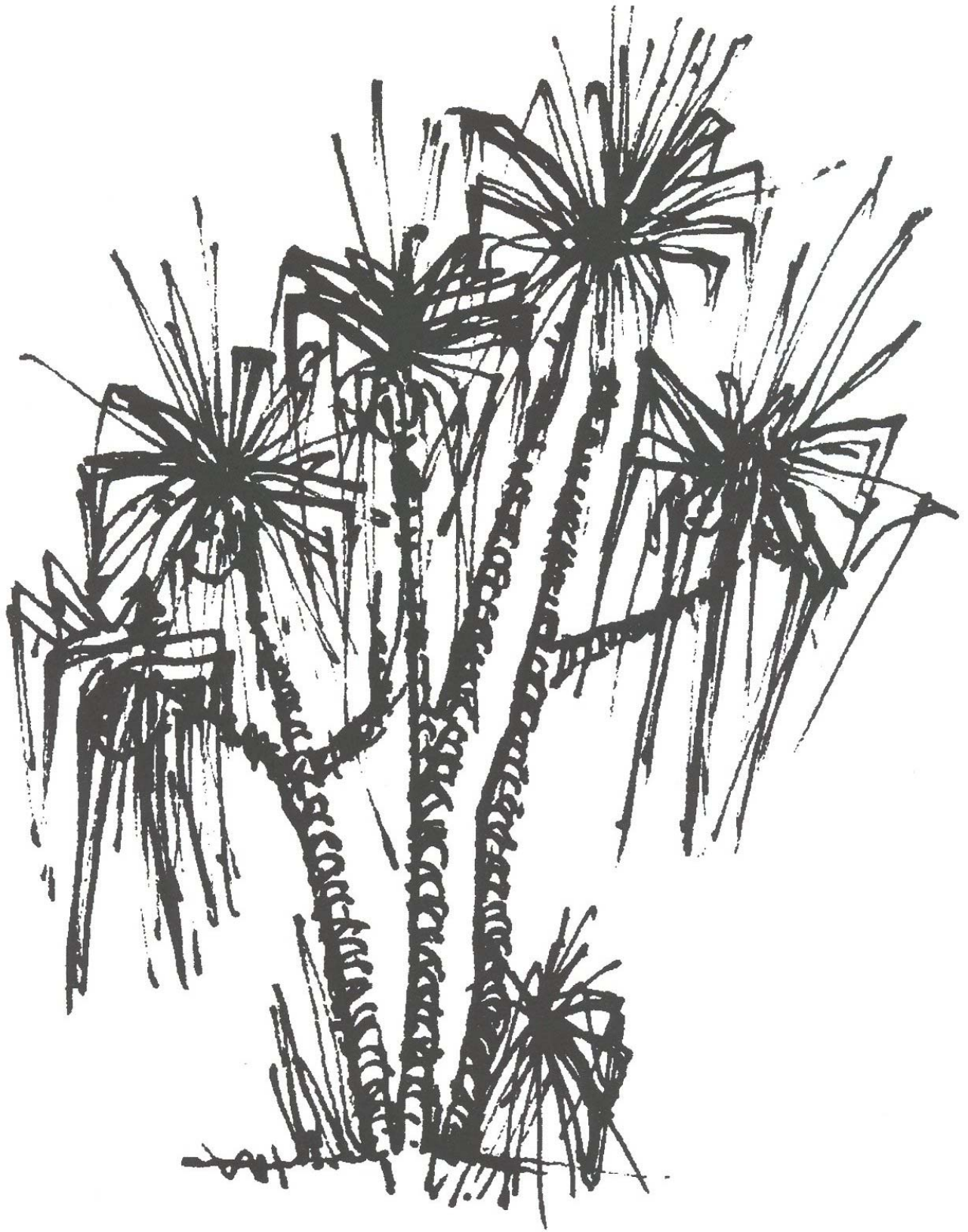


Recommendations

The Victoria River catchment was found to be in reasonably good condition at most sites assessed during the 1996 survey. A follow up survey would be required to enable landholders, managers, the Northern Territory Government and community groups to determine whether the catchment condition has improved or deteriorated over the last decade.

There were several common management issues raised during the discussion on each of the condition rating factors, and these can be taken to be the recommendations from this report:

- Be pro-active in river management as it is cheaper and easier to avoid a problem than to fix one, and target the cause of problems rather than the symptoms;
- Address weeds and feral animals in a strategic and effective way that is sustainable;
- Protect riparian areas through fencing and relocating stock watering points off stream, and ensuring tracks and river crossings are properly designed, constructed and maintained; and
- Approach catchment management issues as a community rather than individual basis, with co-operation and collaboration where possible.



Pandanus spiralis



1. INTRODUCTION

Major waterways of the Northern Territory (NT) 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 to minimise their degradation and to achieve sustainable use.

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

The *Victoria River 'Health' Report* has been funded by the Natural Heritage Trust with support from the NT Government and a contribution from the Victoria River District Conservation Association (VRDCA). The project is a continuation of the Top End Waterways Project which commenced in 1995 under the then National Landcare Program.

The overall aim of the Top End Waterways Project was to assess, describe and report on the land and water resources of the major waterways in the Katherine Region, and to prepare a comprehensive report on each of those waterways.

The Daly River Catchment Report Parts 1 & 2 (Faulks, 1998a, b) and the Roper River Catchment Report (Faulks, 2001) were completed as part of the Top End Waterways Project. The field surveys for the Victoria River Catchment were also undertaken as part of the initial Top End Waterways Project between June and December, 1996.

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 framework for the project (ie sampling strategy, survey methods and data sheets) was adapted from J.R. Anderson's 'State of the Rivers' assessment in Queensland (refer 3. Methods).

Unlike other states, the NT has no Integrated Catchment Management (ICM) framework in place. There is an *Integrated Natural Resource Management Plan* in progress, and the NT Government has a statutory requirement to monitor natural resource condition and has responsibilities for *State of the Environment* reporting and the *National Land and Water Resources Audit*.

It is expected that the main users of the information provided by this project will be the NT Government, research institutions and other groups interested in waterway management, including Landcare and other community groups, property owners and managers. The information provided by this project is intended to assist in developing regional and catchment management strategies.

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 to reverse any deterioration. Rivers and creeks showing signs of degradation such as weed infestation and accelerated erosion will be highlighted.

Through the systematic collection of baseline data, this project provides a reference point or "snapshot" of what the rivers and creeks were like in the 1990s. Follow-up surveys of rivers in priority areas will need to be carried out over time to identify the rate of change in condition and stability. The project can therefore be considered a useful monitoring tool.

The Victoria River Catchment report provides an overview of the Victoria River catchment, the project methodology, and the results on a catchment, as well as a sub-catchment basis.



Aerial view of the tidal section of Victoria River (September 2003)



2. OVERVIEW OF THE VICTORIA RIVER CATCHMENT



2.1 Location

The study area for this report is the Victoria River catchment, which covers approximately 87,900km² and includes the Victoria River and its major tributaries (refer Map 2). The 12 sub-catchments covered in the study area include the Armstrong, Angalarri, Baines, Bullo, Camfield, Victoria, Wickham and Humber River catchments, as well as Battle, Giles or Wattie, Gordon, Gregory and Delamere Creeks, and Jasper Creek catchments.

The Victoria River originates on Riveren Station and travels approximately 720 kilometres through a mixture of grassy plains, rolling savannas, rocky Spinifex country, mesas and plateaux before draining into the Joseph Bonaparte Gulf and ultimately the Timor Sea to the north. Most of the catchment lies less than 450 metres above sea level. The Victoria River is generally shallow with extensive sandbars and rockbars. The major tributaries run into the Victoria River along its course, culminating at the mouth which is more than 10 kilometres wide and characterised by mudflats and extensive mangrove stands. The tidal extent of the Victoria River reaches approximately 500 kilometres, to a series of rapids 20 kilometres upstream of Timber Creek.

There are a number of small settlements in the Victoria River catchment, Timber Creek (300 people) and Top Springs, as well as four major Aboriginal communities, two minor Aboriginal communities, and 13 family outstations. The four major Aboriginal communities are Amanbidji, Daguragu, Kalkarindji and Yarralin, all of which have greater than 100 people, the largest being Yarralin with around 500 people. The nearest major population centres are Katherine to the east and Kununurra to the west (refer Map 2).



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).

Over 90% of the mean annual rainfall in the Victoria River catchment falls during the wet season (November to March). The mean monthly rainfall varies from 0.2 mm during the dry season to 233 mm during the wetter months. Figures 2.1 and 2.2 illustrate the mean monthly rainfall recorded for Timber Creek and Victoria River Downs.

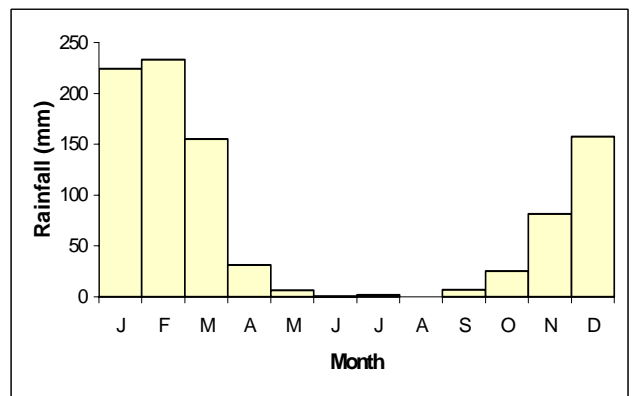


Figure 2.1 Mean Monthly Rainfall for Timber Creek (1981 - 2003)

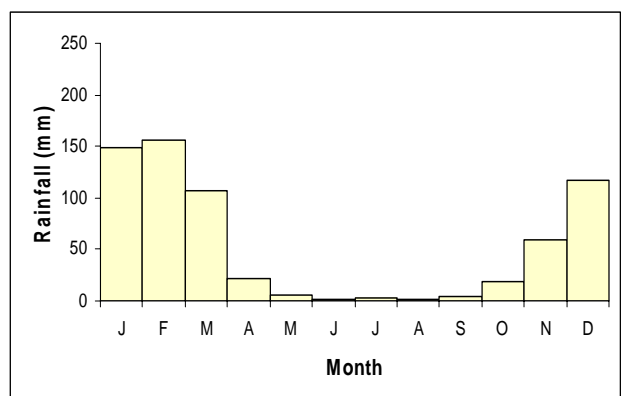


Figure 2.2 Mean Monthly Rainfall for Victoria River Downs (1885 - 2003)

Table 2.1 summarises climate details for two locations in the Victoria River catchment, Timber Creek and Victoria River Station.

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

	Timber Creek (1981 – 2003)	Victoria River Downs (1885 – 2003)
Mean Daily Min-Max Temp. Range (°C)	14.9 – 38.2	11.6 – 38.4
Mean 9am Relative Humidity (%)	61	57
Mean 3pm Relative Humidity (%)	37	35
Mean Annual Rainfall (mm) [No. years]	924 [22]	644.6 [115]
Mean Monthly Rainfall Range (mm)	0.2 – 233 (Aug – Feb)	1.1 – 156 (Aug – Feb)
Highest Recorded Daily Rain (mm)	164 (27 Jan 1998)	222.3 (20 Feb 1927)
Mean Number of Rain Days per Year	75.8	53.1
Mean Total Annual Evaporation (mm)	-	2,466.4

Source: Bureau of Meteorology Website (http://www.bom.gov.au/climate/averages/tables/ca_nt_names.shtml)

Mean daily temperatures recorded at Timber Creek and Victoria River Downs range from 11.6°C to 38.4°C, with the lowest temperature recorded as 1.3°C, and the highest, 45.4°C. Relative humidity varies both daily and seasonally, with typical dry season (May–September) relative humidity averages ranging between 40-53% at 9am and 23-31% at 3pm. Wet season (November to March) relative humidity averages range from 45-83% at 9am to 26-58% at 3pm.

Total annual rainfall is highest in the north of the Victoria River catchment with 926.9mm at Timber Creek, decreasing to 729mm at Kidman Springs, and 635.6mm at Victoria River Downs further to the south. Total annual rainfall is illustrated in Figures 2.3, 2.4 and 2.5. 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.

Average annual evaporation also varies across the catchment, with 2,548mm at Kidman Springs and 2,466.4mm at Victoria River Downs. It is evident from these figures that annual average evaporation greatly exceeds total annual rainfall, which is typical of the north Australian climate (Sivertsen and Day, 1985).

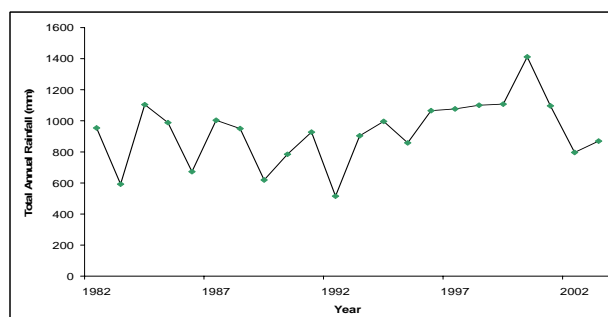


Figure 2.3 Total Annual Rainfall for Timber Creek (1982 – 2003)

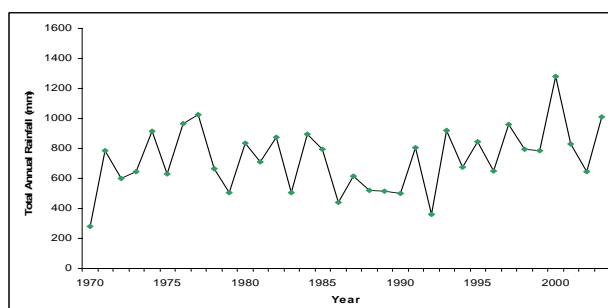


Figure 2.4 Total Annual Rainfall for Kidman Springs (1970 – 2003)

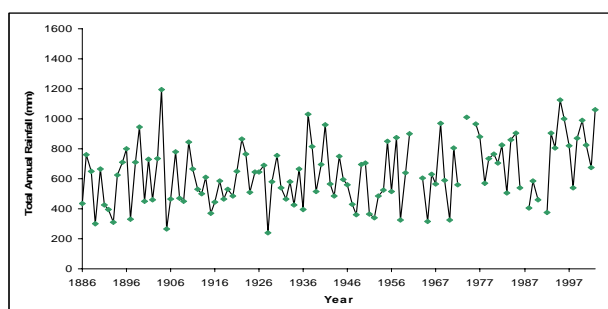


Figure 2.5 Total Annual Rainfall for Victoria River Downs (1886 – 2003)

2.3 Geology, Geomorphology and Landform

The Victoria River region is renowned for its spectacular escarpments, mesas and river environment. Other notable features include the karst formations and cave systems found in Gregory National Park, particularly east of the East Baines River, near its junction with Limestone Creek. Stromatolites, Rillen-karen, tufa, calcite flows and caves can be found around the Limestone Gorge area of the Park (PWCNT, 2002a).



Land system mapping is based on recurring patterns of topography, soils and vegetation (Christian and 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, can also be used to describe the potential or capability of the land (Aldrick and Robinson, 1972).

Many surveys providing detailed land systems, land unit or soils mapping have been carried out for areas throughout the Victoria River catchment.

Figure 2.6 shows the location and reference details of these surveys. Map 3 shows the predominant landforms throughout the Victoria River catchment, based largely on the Land Systems of the Ord-Victoria Area, Western Australia and Northern Territory (Stewart *et al*, 1970). The Atlas of Australian Soils (Northcote, 1968) was used to complete the southern part of the catchment.

Seven major geology types and landforms found in the Victoria River catchment are described below:

1. **Sandstone plateaux and associated valley floors** - includes the rugged sandstone plateaux, steep valleys and scarps of Jasper Gorge at the southern end of Humbert River Station and the northern boundary of Mt Sanford Outstation. The headwaters of the Wickham River and to the west and south of Kalkaringi, as well as the Spencer Ranges north east of Newry Station to Bradshaw and Innesvale Stations also fall into this category.
2. **Sturt plateau remnants and associated valley floors** – is typically flat, and forms the south eastern and south western boundaries of the catchment.
3. **Limestones and calcareous and dolomitic sediments** – This limestone-derived material is generally undulating, and is restricted to the headwaters of Timber Creek, Skull Creek and the headwaters of Jasper Gorge Creek.
4. **Country derived from basalt rock** – is typically undulating to hilly country, comprising major rivers, and are dominated by cracking clay soils.
5. **Sand Dunes** – are found along the southern boundary of the catchment on edges of the Simpson Desert.
6. **Estuarine Plains** – are restricted to the coastal regions at the mouth of the Victoria and Bullo Rivers.

The relationship between geology, geomorphological groups, land systems, soils and pastoral productivity is summarised in Table 2.2.

Other land-related studies undertaken in the region include a Natural Resource Assessment Project to describe the potential 'economic value' of natural resources in the Victoria River Region (Nasca, 1981); A Reconnaissance Erosion Survey of part of the Victoria River District (Condon, 1986); A Land Conservation Strategy for the Victoria River District (Condon, 1988); and A Review of Strategic Options: VRD Land Conservation Proposal (RCS, 1988).

Figure 2.7 shows the elevations throughout the Victoria River catchment in metres and illustrates the predominant landforms.

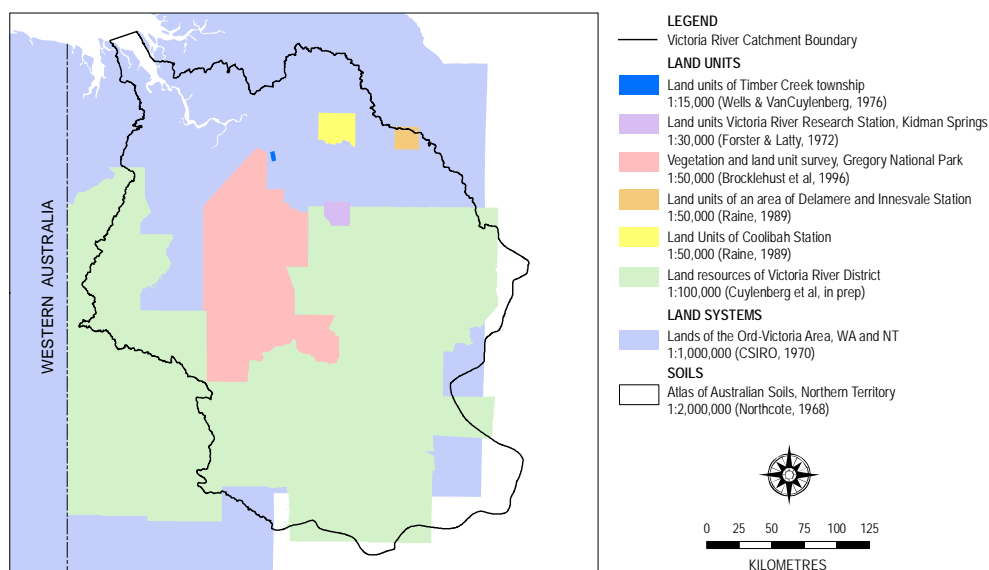
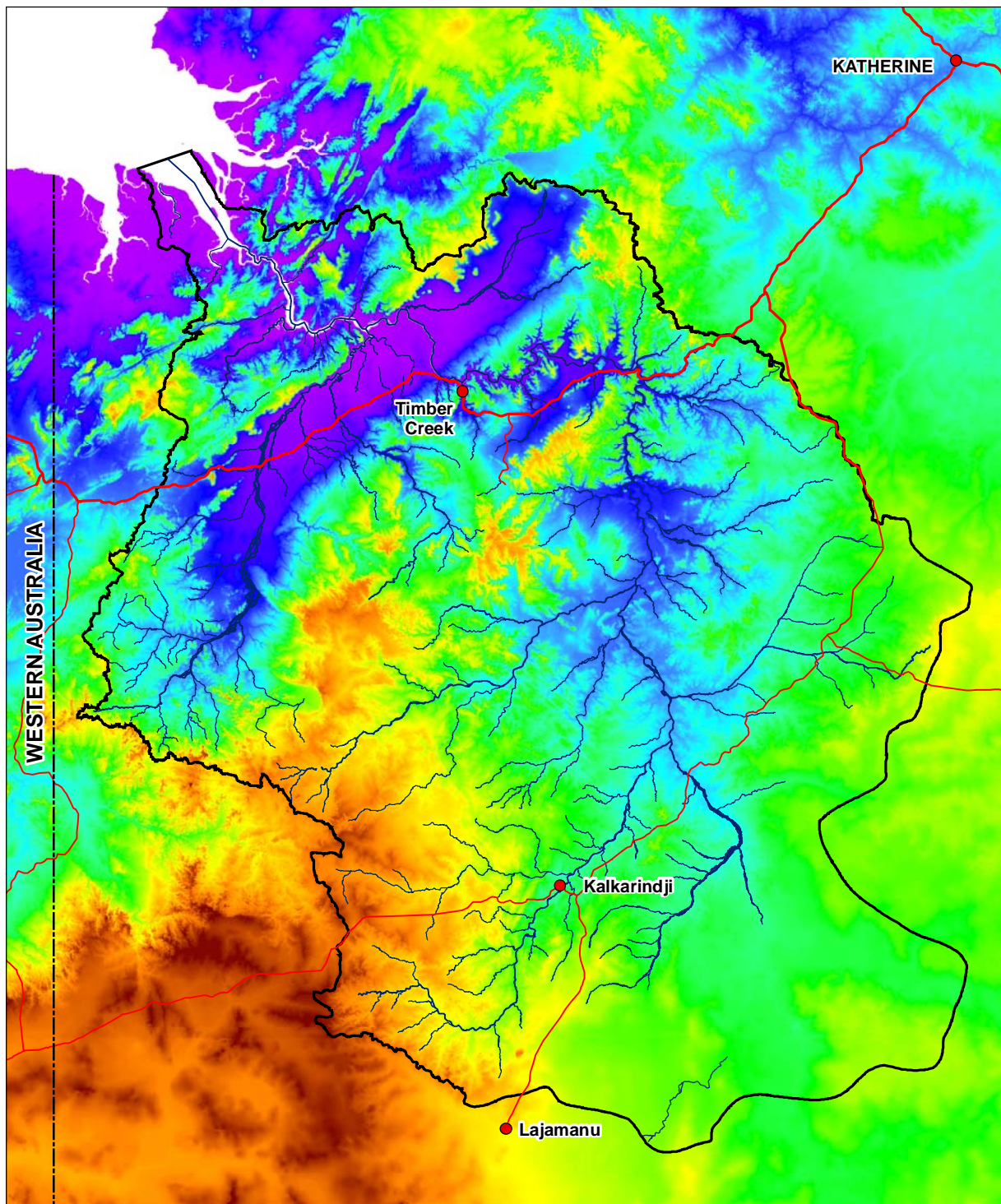


Figure 2.6 Location and Reference Details for Land System, Land Unit and Soil Mapping Surveys in the Victoria River Catchment

Table 2.2 Major Landforms and Land Systems in the Victoria River Catchment

Geological Group	Geomorphological Group	Land Systems	Soils	Pastoral Productivity
Sandstone plateaux and associated valley areas	Rugged stony plateaux and hills	Pinkerton, Wickham	Rock outcrops	Low to very low, much inaccessible
	Plateaux	Franklin, Mullaman, Wingate	Lateritic outcrops with pockets of shallow, sandy reddish soils	Low to very low, much inaccessible
Sturt Plateau remnants and associated valley areas	Lateritic plains	Birrimbah, Barry, Cockatoo, Coolindie, Geebee, Hawk, Redsan	Deep red and yellow sands and earths, sandy loam over laterite; minor grey cracking clays	Low to very low, some inaccessible
Limestones, calcareous and dolomitic sediments	Hilly limestone country	Humbert, Tanmurra	Limestone outcrops; pockets of shallow soils	Mostly moderate, some low with decreasing rainfall. Some inaccessible.
	Undulating shale country	Cockburn	Rock outcrops and shallow, very gravely, skeletal soils	Mostly moderate, some low with decreasing rainfall. Some inaccessible.
	Undulating limestone country	Gordon	Shallow grey to yellow-brown calcareous loamy soils; scattered crops and boulders of limestone	Mostly moderate, some low with decreasing rainfall. Some inaccessible.
	Plains on limestone	Dinnabung, Montejinni	Many limestone boulders and outcrops; red and yellow earths and brown calcareous earths	Mostly moderate, some low with decreasing rainfall. Some inaccessible.
Country derived from basalt rocks	Undulating basalt country	Frayne, Willeroo	Brown loam merging into dark red clay; some brown clay skeletal soils	Moderate to high
	Hilly basalt country	Antrim, Napier	Rock outcrops with basalt boulders and pockets of red clayey soil	Moderate to high
Ancient and recent alluviums and coastal floodplains	Clay plains	Inverway, Argyle	Grey and brown cracking clays	Very high
	Alluvial floodplains	Angallari, Dillinya, Ivanhoe	Grey sandy loam over mottled yellow clay; grey and brown cracking clays	Moderate to high
	Coastal floodplains	Legune	Grey sandy loam over mottled clay, grey cracking clays	Moderate
Sandunes	Dunefields	B32*	Red siliceous sands with stable flanks and mobile crests	Very low
Estuarine plains	Littoral plains	Carpentaria	Highly saline clays	Low to very low

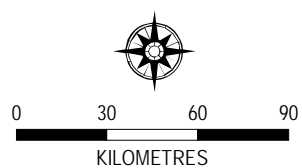
*No Land System Information available. Table adapted from Condon, 1986; Stewart *et al*, 1970; and Northcote, 1986.



DATA SOURCE

Digital Terrain Elevation: Department of Defence
Edition 3, Date 26 Apr 2000, Pixel size is approx 90 m
Rivers: Geoscience Australia (1:250,000 topographic data)
Roads: Geoscience Australia (1:1,000,000 data)

The Victoria River catchment boundary was delineated for the Top End Waterways Project using 1:100,000 and 1:250,000 topographic map sheets taking into account contour lines and spot heights.



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LEGEND

Elevation (metres) within catchment

High : 450

Low : 0

Victoria River
Catchment Boundary

River / Creek

Major road

Figure 2.7 Elevations throughout the Victoria River Catchment

2.4 Vegetation, Important Habitat Areas and Fauna

2.4.1 Vegetation

The Victoria River catchment extends from the higher rainfall forests in the north, to the arid and semi-arid shrublands and grasslands in the south. There is a general decline of species richness from north to south (Kraatz, 2000). However, the flat landscape and lack of barriers has resulted in a broad ecological gradient with a widespread flora, typical of much of northern Australia (PWNCT, 1998).

Prior to 1985, the NT 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). There has also been remarkably little research on riparian systems, their conservation value, condition or ability to withstand increased use (Sattler, 1993; Woinarski, 2000). 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. The information has been further grouped according to the dominant vegetation community (eg Eucalyptus with grass understorey, *etc*) and structural formation (eg open-forest, woodland, *etc*).

Wilson *et al* (1990) describes 112 vegetation communities in the NT, 33 of which occur in the Victoria River catchment (refer Map 4). The dominant vegetation communities include Eucalyptus sp. with grass or hummock grass understorey, comprising woodlands, low woodlands and low open-woodlands. Riparian areas are mostly grasslands, consisting of Mitchell Grass, Golden Beard Grass and Bluegrass mixed with scattered trees and shrubs, and there is a strip of Melaleuca forest/woodland with Sorghum understorey in the vicinity of the West Baines River, and littoral saline tidal flats occur in the estuarine areas. Hummock grasslands dominated by Spinifex sp. with acacia overstorey between sand dunes occur in the more arid regions in the south, as well as lancewood communities in the south east of the region (refer Map 4). This broad scale mapping provides an overview of vegetation in the region, however neglects small or rare communities such as monsoon vineforest which are not specifically described due to the narrowness of the strips along watercourses, or the small size of the patch (Wilson *et al.*, 1990).

Brocklehurst *et al* (1996) has undertaken vegetation mapping in Gregory National Park at a scale of 1:250 000. He describes 69 floristic groups within 15 community structures, recording 230 genera and 584 species, including 15

introduced, and ten rare, or poorly known, species (PWCNT, 2002a). He also describes the more discrete communities such as the monsoon vine-thickets consisting of *Celtis philippensis* and *Xanthostemon psidioides* occurring on sandstone plateaux sideslopes, and *Livistonia sp.* palm forests found near plateau rims in seepage zones (Brocklehurst *et al*, 1990).

The Interim Biogeographic Regionalisation of Australia (IBRA) describes two bioregions in the Victoria River catchment. The Victoria Bonaparte Bioregion comprising *Sporobolus* grasslands and open savannah tall grasses in the Bonaparte Basin, low tree savannas and hummock grasslands on the Victoria Plateau, and low Snappy Gum with hummock grasslands and *Melaleuca minutifolia* and annual sorghums on the floodplain country (Environment Australia, 2000). The Ord Victoria Plains Bioregion comprises grasslands with scattered Bloodwood and Snappy Gum with Spinifex and annual grasses. Both Bioregions are considered to be dry, hot and tropical, with semi-arid summer rainfall (Environment Australia, 2000).

There are two national parks in the Victoria River catchment, Gregory National Park, and part of Keep River National Park (refer Map 5). Ranger Training Camps are conducted in National Parks throughout the NT each year, where biological surveys are undertaken. Three reports have been written for Gregory National Park: the Mueller Commemorative Expedition (PWCNT, 1996a); Upper Wickham River Survey (PWCNT, 1998); and Victoria River Sector (PWCNT, 2001). One Ranger Training Camp has been held at Spirit Hills (near Keep River National Park) (PWCNT, 1996b), and an aquatic fauna survey was conducted in Keep River National Park in 1999 (Larson, 1999). There is a draft Plan of Management for Gregory National Park (PWCNT, 2002a), a draft Plan of Management for Keep River National Park (PWCNT, 2002b), and a concept plan for Spirit Hills Wilderness Conservation Area (PWCNT, 1997). Additional biodiversity inventories in the Victoria River region include studies by Fisher & Woinarski (2002) and Harvey *et al* (2002) in the Bradshaw (Juliki) field training area.



Woodland and grassland communities along Victoria River

PWCNT (1998) described 23 vegetation communities in the Wickham River area of Gregory National Park during a Ranger Training Camp in 1998. The vegetation communities were further categorised according to structure as open forest communities, woodland communities, open woodlands, grasslands and shrublands. During the survey, it was noted that there were very few introduced weed species along the Wickham River, even though *Calotropis procera*, *Parkinsonia aculeata* and *Martynia annua* are serious weed species known to occur along rivers in the same climatic zone. It was suggested that the overall lack of access to the Wickham River may be the reason for the absence of weeds in this location (PWCNT, 1998).

Species of conservation significance found in the Victoria River region listed on the NT *Territory Parks and Wildlife Conservation Act* include: six vulnerable, 42 near threatened, and 146 data-deficient plant species; 13 vulnerable, 29 near threatened, and 35 data-deficient vertebrate fauna species; and four vulnerable invertebrate fauna species. 41 migratory species known to occur in the Victoria River region are listed under international agreements (Sample, 2004).

The mangrove plant communities along the Victoria River, as well as all other river systems in Joseph Bonaparte Gulf and those in the Gulf of Carpentaria show the lowest level of floristic diversity (ie 4-14 species) of all tidal waterways surveyed across the Northern Territory and Kimberley region of Western Australia (Wells, 1985). Wells (1985) suggested that low species diversity might be due to these systems lying in seasonally arid regions, and the fact that northern Australia experiences unfavourable currents for colonisation during the wet season monsoon season, which coincides with most species fruiting (Wells, 1985). The mangrove species recorded along the Victoria River estuary area are shown in Table 2.3.



Mangrove communities along a tributary flowing into Victoria River estuary

Table 2.3 Mangrove Species Recorded along Victoria River Estuary

Mangrove Species Name – Genus species	Frequency Category*
<i>Aegialitis annulata</i>	C
<i>Aegiceras corniculatum</i>	C
<i>Avicennia marina</i>	C
<i>Campostemon schultzei</i>	B
<i>Ceriops tagal</i> var. <i>australis</i>	C
<i>Excoecaria agallocha</i>	C
<i>Lumnitzera racemosa</i>	C
<i>Osbornia octodonta</i>	C
<i>Rhizophora stylosa</i>	C
<i>Xylocarpus australasicus</i>	C

(Source: Wells, 1985)

* The frequency category is based on Wells (1985):

- A. Species that were recorded infrequently
- B. Species that occur, in most instances, in systems throughout the less seasonally arid areas
- C. Species that are often encountered at least in some portion of most tidal systems

Weeds in the Victoria River catchment are concentrated in the riverine habitats, spread by wet season floodwaters or associated with water-holding black soil areas (PWCNT, 2002a; Sample, 2004). Weeds are a major threat to the integrity of ecosystems, and are directly affecting productivity on Pastoral Leases. Eradication of weed species over large areas is generally not feasible, and landholders, including Parks and Wildlife Service, are concentrating on eradication and control in selected areas, and prevention of spreading further downstream where possible.

There are currently 34 weed species listed in Gregory National Park, including Devils Claw (*Martynia annua*), Rubber Bush (*Calotropis procera*), Parkinsonia (*Parkinsonia aculeata*), Noogoora Burr (*Xanthium occidentale*), Khaki Burr (*Alternanthera pungens*), Hyptis (*Hyptis suaveolens*), Sida (*Sida acuta*) and Senna (*Senna occidentalis*) (PWCNT, 2002a). The Northern Land Council have recorded 37 weed species on Aboriginal Land Trust properties in the Victoria River area, and a total of 19 species were recorded during the surveys conducted for this Report (refer Section 4, Catchment Results).

There is a draft Victoria River District Weed Management Plan (DPIF, 1997). This Plan outlines species specific control measures for prevalent weeds in the region. Control measures include chemical, biological and mechanical means, as well as grazing management techniques and suggestions for further research. Major weed species of the Victoria River District are shown in Table 2.4.

Table 2.4 Major Weed Species of the Victoria River District

Priority Rating	Species Name	Common Name
Very High	<i>Xanthium occidentale</i>	Noogoora Burr
	<i>Parkinsonia aculeata</i>	Parkinsonia
	<i>Leonotis nepetifolia</i>	Lions Tail
	<i>Martynia annua</i>	Devil's Claw
	<i>Acacia nilotica</i>	Prickly Acacia
High	<i>Datura spp.</i>	Thornapple
	<i>Senna obtusifolia</i>	Sickle Pod
Moderate	<i>Prosopis limensis</i>	Mesquite
	<i>Tribulus cistoides</i>	Caltrop
	<i>Hyptis suaveolens</i>	Hyptis
	<i>Calotropis procera</i>	Rubber Bush

(Source: DPIF, 1997)

Other weed species listed on the Weed Management Branch database (DIPE, Katherine) include Bellyache Bush, Khaki Weed, Goats Head Burr, Sida, Snake Weed, Grader Grass, Mission Grass and Mossman River Grass.

2.4.2 Important Habitat Areas and Fauna

The Victoria River and most of its tributaries only flow for about six months of the year, breaking up into chains of waterholes which last for varying periods depending on their depth and whether or not they are spring fed (Tickell & Rajaratnam, 1998). The only permanent flowing streams in the Victoria River catchment are the Wickham River, upstream of Humbert River junction, and a short section of the Angalarri River (Midgley, 1981). The seasonality of the rivers makes waterholes, lakes, springs, dams and tanks extremely important habitat areas for flora and fauna in the region.

There are many semi-permanent waterholes and lakes in the Victoria River catchment, including several wetlands of national significance identified in the Australian Wetlands Database (2005). Birrindudu Waterhole and Floodplain (NT015) and Nongra Lake (NT016) are believed to be part of an internal drainage basin, disconnected from the Victoria River by dune movement, resulting in elevated salinity readings (Tickell & Rajaratnam, 1998).

Birrindudu wetlands support the largest coolibah-cooba woodland in the NT, as well as diverse shrub swamps and marshes which provide an important waterbird breeding area for over 50 waterbird species, seven of which are migratory shorebirds utilising the site as a stopover (Australian Wetlands Database, 2005).

Birrindudu wetlands have a particularly soft substrate which is thought to prevent stock access, allowing plants such as lignum and bluebush to grow and provide shelter and nest sites for birds.

Nongra Lake supports the largest examples of Acacia-wooded swamp in the NT. This wetland provides habitat for around 29 species of waterbird, and becomes particularly important when Birrindudu wetlands are dry.

Legune Wetlands (NT030), comprising both the Legune Homestead Swamps and Osmans Lake System, support significant numbers of waterbirds during the dry season, and provide breeding habitat for Magpie Geese, *Anseranas semipalmata*, in the wet season (Australian Wetlands Database, 2005). Legune Homestead Swamps are dominated by *Eleocharis* sedges in deeper areas, and also support *Melaleuca argentea* and *Barringtonia acutangula*, as well as other sedges, grasses and lilies. Some areas are fenced to exclude stock. The Osmans Lake System consists of a lake and more than 15 associated claypans. The lake is the largest such waterbody in the NT, and is dominated by Beetle Grass, *Sesbania cannabina*, *Chenopodium auricomum*, *Xerochloa imberbis*, and *Sporobolus virginicus*. The Legune Wetlands support over 47 bird species, including migratory shorebirds.

Bradshaw Field Training Area (NT033) supports approximately 70% of the rare and endangered species of the Victoria-Bonaparte Bioregion, as well as being surrounded by protected areas on all sides, making these wetlands an important component of the conservation network in the Bioregion (Australian Wetlands Database, 2005). There is a *Xerochloa* grassland habitat in the wetland, and nine of the rare and endangered vertebrate species recorded for the Bioregion. The area also contains many sacred Aboriginal sites, 129 archaeological sites and 55 historic sites. The land is managed by the Department of Defence, and is subject to their stringent Environmental Management Systems. The area is also subject to a Native Title Claim (Australian Wetlands Database, 2005).

Fisher and Woinarski (2002) have identified areas of conservation significance in the Victoria River region due to their physical isolation, and subsequent value as refuge areas from frequent fire. Small "islands" in the tidal mudflats of the Victoria River estuary, and rugged sandstone areas such as the Victoria River Gorge and mesas are examples of areas that provide important habitat for fire sensitive flora and fauna species.

Riparian vegetation provides another important habitat area for fauna. Although these lands occupy only a small proportion of the landscape, they frequently have a much higher species richness and abundance of animal life than adjacent habitats (Lynch and Catterall, 1999). Riparian vegetation along the Victoria River includes *Pandanus aquaticus*, *Eucalyptus camaldulensis*, *Terminalia platyphylla*, *Melaleuca* spp., *Lophostemon lactifluus*, *Ficus* Spp., *Nauclea orientalis* and others (refer Sections 4.6 and 4.7).

A broad-scale survey of bird distribution in riparian vegetation in the Top End of the NT found that despite their relatively small total extent, riparian areas were extremely important for birds (Woinarski *et al.*, 2000). The study concluded that the bird fauna of riparian areas is distinct from that of the surrounding savannas, and this was especially so in lower rainfall areas. Species richness and the 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 *Melaleuca* sp. (Woinarski *et al.*, 2000).

One species of conservation significance in the Victoria River catchment that relies on the riparian habitat is the Purple-crowned Fairy-wren, *Malurus coronatus*. This bird is listed as a vulnerable species under the Commonwealth's *Environment Protection and Biodiversity Conservation Act*. It is strictly a riparian species, inhabiting the Canegrass, *Chionachne cyathopoda*, which grows along the banks of the Victoria River and its tributaries (vanDoorn, in press). *Chionachne cyathopoda* is susceptible to grazing and trampling by stock and feral animals, and has been reduced and fragmented in the region. This, combined with other threats to the riparian habitat, such as weed invasion, erosion and fire, are further threatening the fragile habitat of this species. A comprehensive Management Plan is currently being prepared to ensure the long-term survival of this Fairy-wren through protection of its important riparian habitat (vanDoorn, in press).



Male Purple-crowned Fairy-wren (*Malurus coronatus*).

(Photo provided by Annemarie vanDoorne)

Gregory National Park is in a transition zone between the semi-arid and wet-dry climatic zones, and its geographic location and size are reflected in the diversity of its flora and fauna (PWCNT, 2002a). Over 1200 plant species have been recorded in the National Park, 13 of which are of conservation significance, including *Boronia jucunda*, *Gleichenia microphylla*, *Stenostegia congesta* and *Fimbristylis blakei*. Small patches of monsoon vineforest occur throughout the park, and the lancewood population, *Acacia shirleyi*, is the most westerly recorded population. Both the monsoon vine-forest and the lancewood population are intolerant of fire, and therefore restricted to small remnant stands. Around 444 species of fauna have been recorded in the National Park, including 39 mammals, 76 reptiles, 169 birds, 21 frogs, 34 fish, 52 families of aquatic invertebrate and 58 species of cave invertebrate fauna (PWCNT, 2002a). Species of conservation significance include the Purple-crowned Fairy-wren (*Malurus coronatus*) and the Gouldian Finch (*Erythrura gouldiae*) (PWCNT, 2002a).

Estuarine crocodiles (*Crocodylus porosus*) and freshwater crocodiles (*Crocodylus johnstoni*) inhabit the waters of the Victoria River. Fish species recorded in the Victoria River and its tributaries include Silver Barramundi (*Lates calcarifer*), Blue Catfish (*Arius graeffei*), Black Bream (*Hephaestus jenkinsi*), Drysdale Grunter (*Syncomistes rastellus*), Angalari Grunter (*Scortum* sp.), Long Tom (*Strongylura krefti*), Ox-eye Herring (*Megalops cyprinoides*), Giant Chanda Perch (*Parambassis gulliver*), Sleepy cod (*Oxyeleotris lineolata*) and Purple Spotted Gudgeon (*Mogurnda mogurnda*) (Midgley, 1981; PWCNT, 2002a). Angalari Grunter is listed as vulnerable under NT legislation, and is restricted to the Victoria River catchment.

Larson (1999) recorded a total of 35 fish species in the Keep River and Sandy Creek region. Of note were the Dwarf Sawfish (*Pristis clavata*), and the Freshwater Sawfish (*Pristis microdon*), as they are of national and international significance, respectively. The Freshwater Sawfish is listed on the IUCN's Red List as "potentially threatened". Larson notes that only ten of the 35 fish species recorded in the Keep River system are estuarine compared to 181 estuarine species in Kakadu National Park, and 107 from the Roper River estuary. It is thought that perhaps more species occur in the Keep River estuary than were recorded during this survey (Larson, 1999).

Aquatic macroinvertebrates recorded in the Victoria River catchment as part of the 'Ausrivas' (Australian Rivers Assessment) Scheme included a total of 53 macroinvertebrate groups, with an average of 26 family groups per site (PWCNT, 2002a). This is comparable to other catchments in

the Top End. Organisms included shrimps, prawns, worms, mites, nematodes, aquatic bugs, adult beetles and a large variety of insect larvae such as mayflies, dragonflies, damselflies, caddisflies, midges and beetles (PWCNT, 2002a).

Cave fauna in the Victoria River region have been investigated by the Top End Speleological Society (TESS). The majority of species described by this group have been found in the surface environments and may be widespread throughout the region, however some species are adapted to cave dwelling, and others are totally restricted to the karst region (PWCNT, 2002a). Aside from invertebrate fauna, the most common cave dwellers recorded were bats such as the Common Sheath-tail Bat (*Taphozous georgianus*), Orange Horseshoe Bat (*Rhinonycteris aurantius*), Ghost Bat (*Macroderma gigas*), Dusky Horseshoe Bat (*Hipposideros ater*) and Common Bent-wing Bat (*Miniopterus shreibersii*) (PWCNT, 2002a).

A number of feral animal species occur throughout the Victoria River catchment including buffalo (*Bubalus bubalis*), feral horses (*Equus caballus*), donkeys (*Equus asinus*), feral cattle (*Bos taurus*), feral pigs (*Sus scrofa*), feral dogs (*Canis familiaris*), camels (*Camelus dromedarius*). Domestic mice (*Mus domesticus*) and the Black Rat (*Rattus rattus*) have also been found around human settlements (PWCNT, 2002a). Buffalo and pigs are not widespread in the Victoria River catchment, however donkeys and horses in particular are considered to be in plague proportions in some areas. Camel numbers have also increased dramatically since they were introduced, and feral cats pose a threat to native wildlife (PWCNT, 2002a).

Parks and Wildlife Service staff undertook an aerial survey in 1996 to assess the feral animal population in the Victoria River District. In 1999, a "Pest Control Area" was declared, and between 1999 and 2004 a total of 134,277 donkeys and feral horses were culled in the area. Collaring programs, using radio transmitters, and subsequent aerial culls have been used to control donkey numbers.

The damage caused by feral animals includes: overgrazing; trampling and foraging causing soil disturbance, accelerated erosion, invasion and spread of weed species; destruction of habitats by rooting, burrowing and wallowing, reducing the aesthetic and productive value of land and reducing the lands ability to resist erosion (CCNT, 1994a; Telfer, 1998). The feeding behaviour of these introduced animals has the potential to modify the natural floristic composition of certain areas and/or result in competition for food with native herbivores (CCNT, 1994a).

Landholders are responsible for feral animal control on their property under the *Pastoral Land Act* and the *Territory Parks and Wildlife Conservation Act*. Difficulties arise with the enforcement of the legislation, the resilience of these species to drought conditions, lack of fences in the region, and the limitations of the pet meat industry (DIPE, 2004).

The Cane Toad (*Bufo marinus*), an introduced animal, first entered the NT in the 1983/84 wet season (Dept of Lands and Housing, 1991) and reached the Victoria River catchment in 2004. This species competes with native fauna such as frogs, and is known to poison animals that prey on it, such as birds, reptiles and mammals. No practical control method is presently known which can effectively halt the toad invasion of northern Australia (CCNT, 1994a).



(Photo provided by Patrick Carmody, PWS)



2.5 Land Tenure, Use and Management

Current land classification within the Victoria River catchment is shown on Map 5. The majority of land is under Perpetual Pastoral Lease, however other land tenure types include Right to Freehold Title held by Aboriginal Land Trusts, Perpetual Crown Leases held by Parks and Wildlife, and Term Crown Lease land held by the Department of Defence. Most leases contain covenants to control the usage or development of the land. Term leases are usually issued to allow development to proceed, with land often being converted to freehold title or perpetual leasehold once the development is completed satisfactorily.

It is believed Aboriginal people may have occupied the Victoria River region when they first arrived in Australia in dug-out canoes as far back as 40,000 years ago (Makin, 1992). More recent archaeological remains are common in the area including surface scatters of stone tools and ochre quarries, burial sites, rock shelter occupation deposits and numerous rock art sites (Lewis and

Rose, 1987). Many sites of Aboriginal archaeological significance are listed and protected by the Aboriginal Areas Protection Authority under the *Northern Territory Aboriginal Sacred Sites Act, 1989*.

The Victoria River Aboriginal people believe that the rock art in the district is of Dreaming origin and depicts Dreaming Beings and their activities. Many different language groups claim traditional links to the Victoria River district including Ngaliwurru, Ngarinyman, Nungali, Bilinara, Jaminjung, Karrangpurru and Wardaman (PWCNT, 1998). The history of the people and the district is maintained and transmitted in non written form, and the culture relies heavily on ceremony, art and the older generations to pass on beliefs and practises to the young.

The first European to visit Victoria River was Phillip Parker King in 1819. He sailed into Joseph Bonaparte Gulf and the mouth of the Victoria River, however returned due to bad weather. Later in 1893, Captain John Clements Wickham and Lieutenant John Lort Stokes re-discovered and named the Victoria River. They named the River after her Majesty Queen Victoria, and continued by boat to where Timber Creek is today and proceeded further upstream on foot, a total distance of 230 kilometres from the sea (PWCNT, 2002a). The next expedition up the Victoria River was led by Augustus C. Gregory in 1855. Gregory established a base camp (Gregory's Tree) on the bank of the Victoria River below Timber Creek for eight months, and is believed to have made the first friendly contact with the Aboriginal people in the Victoria River district (Lewis, 1997). Gregory led expeditions to the junction of the Wickham and the Victoria Rivers, and down the Wickham River along Sturt Creek into the Sandy Desert to Lake Gregory. Whilst these expeditions were taking place, the base camp team explored the East Baines River upstream from Bullita Homestead (Birman, 1979). The last European exploration prior to the first settlers arriving was led by Alexander Forrest in 1879, who followed the Overland Telegraph Line from the Kimberley (Lewis, 1997).

European settlers arrived in 1883. Nat Buchanan claimed the upper Victoria River, stocking Wave Hill Station with 4,500 head of cattle from Queensland. Buchanan was then contracted to overland a further 20,000 head of cattle to Victoria River Downs for Victorian investors, Fisher and Lyons. Pastoral companies such as Bovril and Vestey's from London moved into the region and took over many stations from about 1910 (PWCNT, 2002a). By the early 1900s most of the district consisted of large, mostly unfenced cattle and sheep stations (Lewis, 2002).

Aboriginal people initially resisted and impeded pastoral development due to mutual fear and competition for land resources. After a period of violence and confrontation however, Aboriginal people were enticed into the workforce by the promise of food and shelter, and eventually the industry came to rely heavily on their contribution to both stock work and domestic duties. Aboriginal people worked on the stations during the dry season and went 'bush' during the wet, when they used their time to maintain their religious life and to educate younger people in the knowledge, skills and values pertaining to their own country and culture (Rose, 1991). By the 1920s Station economies were almost reliant upon the Aboriginal workforce, and during the Second World War Aboriginal people took on even more responsibility with management. The Aboriginal people were also responsible for teaching survival skills to many army personnel in return for shelter and access to clothing, food and medical assistance (Lewis, 1997).

There was general dissatisfaction amongst the Aboriginal people with housing and work conditions remaining unresolved following the war (Lewis, 1997; PWCNT, 2002a). This dissatisfaction eventually led to the "Wave Hill walk out" in 1966, when the Guringji people left the station to camp in the Victoria River bed, demanding full wages and improved conditions. Ultimately the Aboriginal people demanded formal title of their land, and the strike action continued from 1966 to 1972, causing turmoil to the regional economies (Lewis, 1997). Some stations were able to negotiate labour agreements, and work conditions were ultimately improved, however the extent of the industrial action also led to an increase in expenditure on fencing and other infrastructure, as well as the shift away from large numbers of low paid stockmen in favour of trucks and later, helicopters (Lewis, 1997). The strikes led to the establishment of the *Aboriginal Land Rights Act (NT), 1976*. Kildurk, Fitzroy, Mistake Creek, a large section of Wave Hill and the Hooker Creek Aboriginal Reserve came under Aboriginal control, and areas of Crown Land such as stock routes, reserves and small town commons were also excised from stations as 'living areas'.

Aboriginal people run several cattle stations in the region today, including Amanbidji, Malngin 1 (formerly Mistake Creek), and Malngin 2 (formerly Brumby Plains). Fitzroy and Innesvale Stations are owned by the Daguragu Land Trust and are also used for pastoral purposes (Kraatz, 2000).

The Australian Defence Force purchased Bradshaw Station in 1996. The Station had been used for pastoralism since the late 1800s, and was purchased as a major training resource for Australian and possibly combined foreign forces.

An Environmental Impact Statement (EIS) was prepared in 1998 to assess the potential impact of wastes and unexploded ordnances in the area. The EIS was approved and an Environmental Management Plan was developed for ongoing management of the property. Weeds, fire and feral animal control programs are in use, destocking is complete, and fencing of important wetland areas has been undertaken on Bradshaw Field Training Area (Kraatz, 2000). Department of Defence also undertake military activities on other nearby stations with landholder agreement (Sample, 2004). Aerial bombing practise is conducted on Delamere Range creating local disturbances, however this activity is also subject to strict regulation (Sample, 2004).

Keep River National Park was declared on 1 May 1981. Spirit Hills is also managed by Parks and Wildlife Service, and it is hoped that this area will eventually be declared as an extension of Keep River National Park. Gregory National Park was declared in 1990. The original park boundary has been altered due to successful Aboriginal land claims, including the excision of the Stokes Range section which created the gap between the two sectors. A portion of Mt Sanford Station in 1996 significantly extended the park boundary to encompass most of the Wickham River catchment, however this portion has not yet been formally declared. Gregory National Park also includes Gregory Tree Historical Reserve, Victoria River Depot Historical Reserve (located outside the park), and the proposed Drover's Rest Boab Precinct.

Tourism in the Victoria River region is highly seasonal, occurring mostly during the dry season between May and September. The primary attractions include Gregory and Keep River National Parks, and activities include remote camping, bushwalking, four-wheel driving, boating and fishing. The harsh climate and the remoteness from population centres keeps visitor numbers relatively low in the two National Parks, adding to the appeal for those that do visit (PWCNT, 2002a).

Fishing in the Victoria River and its tributaries includes commercial operators, fishing tour operators and recreational fishermen. There are two public boat ramps in the vicinity of Gregory National Park, at Big Horse Creek and the Victoria River Gorge Picnic Area. However, landholders with access to the river presumably have their own boat ramps, which are used with the owners' permission. There are no public boat ramps in the Keep River National Park, however again, it is assumed that landholders with river access would have boat ramps.

In 2003, in the area extending from Moyle River to Keep River (including the Fitzmaurice River), there were six commercial licensees from three fisheries (Barramundi, Shark and coastal line fisheries) (Sample, 2004). There was only one Barramundi fishing operator in the Victoria River itself, restricted to waters downstream of Bullo River. The catch from the commercial fishing operators equated to less than 2% of the total 2003 NT harvest value for the combined fisheries in 2003 (cited in Sample, 2004). Midgley (1981) commented that the Victoria River has never had a reputation for large fisheries production. Sample (2004) suggested that this is not due to the lack of fish, but rather to the large tidal flows making netting difficult, limited land access, and the NT Government policy of "buyback" of commercial fishing licenses. There is no aquaculture in the Victoria River, however there is a commercial crocodile breeding operation specialising in skin production (Sample, 2004). There were eight fishing tour operators licensed for the Victoria River in 2003, representing 7% of those in the NT. Barramundi fishing dominates the fishing tour operator business, others include game fishing, bottom fishing and crabbing (Sample, 2004). Recreational fishing is pursued in the Victoria River by boat and from the shore, and is relatively infrequent, compared to other rivers closer to population centres.

Currently, the responsibility for river management in the NT lies predominantly with the NT Government. The *Northern Territory Water Act, 1992* is the major legislative framework for managing rivers. 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). The *NT Water Act* restricts and controls the way in which water quality can be affected.

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);
- *Weeds Management Act* (2001);
- *Pastoral Land Act* (1992);
- *Planning Act* (1999);
- *Soil Conservation and Land Utilisation Act* (1992); and
- *Waste Management and Pollution Control Act* (1998)

National legislation of relevance to river management includes the *Environmental Protection and Biodiversity Conservation Act, 2000*. This Act protects significant wetlands and threatened and vulnerable flora, fauna and ecological communities.

Management plans and guidelines currently in place include:

- Gregory National Park Plan of Management - Draft (PWCNT, 2002a);
- Keep River National Park Plan of Management – Draft (PWCNT, 2002b);
- Katherine Regional Weed Management Strategy (Katherine Regional Weed Advisory Committee, 2004);
- Victoria River District Weed Management Plan - Draft (DPIF, 1997);
- Clearing Guidelines for Pastoral Land (Pastoral Land Board, 2004); and
- Resource Management Guidelines for the Northern Territory, Land Clearing Guidelines (DIPE, 2002).
- The Victoria River District Natural Resource Plan (Sample, 2004)

Katherine Regional Weeds Strategy provides direction for strategic weed management in the region, including the Victoria River catchment. The Strategy does not provide species specific information. Advice on control of individual species is provided in the Victoria River District Draft Weed Management Plan (DPIF, 1997). The Resource Management Guidelines for land clearing do not apply where there are existing clearing guidelines (eg on Pastoral Leases and where town planning policies apply). The Resource Management Guidelines recommend buffer widths suitable for riparian protection, which vary depending on the stream order (eg 20m for drainage lines, 200m for wetlands) (DIPE, 2002).

The Victoria River District Conservation Association (VRDCA) was founded by land managers in 1987. The impetus behind forming the group was largely rangeland management and erosion control, and has expanded to include natural resource management in general (Sample, 2004). The current membership of the VRDCA includes pastoral land managers, Aboriginal Land Trusts, Defence Force, Local Government, Crocodile farmers, Parks and Wildlife Service, and some Non Government Organisations. The VRDCA has been granted funding for many natural resource management projects, increasing the knowledge base of its membership, as well as considerable on ground improvements.



2.6 Water Resources

2.6.1 Water Resource Studies

Water resources of the Victoria River District (VRD) were mapped, described and evaluated between 1993 and 1998. The project was requested by the VRDCA to assist landholders in property planning and management. The project was jointly funded by VRDCA, Northern Territory Government and Landcare. The following maps and reports were produced:

- Water Resources of the Victoria River District (Tickell & Rajaratnam, 1998). This report covers the Victoria River drainage basin and includes:
 - 1) water resource maps for supply options of both groundwater and surface water;
 - 2) a description of groundwater systems including aquifer type and water quality;
 - 3) a description of surface water including waterholes, lakes, springs, tanks and dams;
 - 4) a discussion of the sustainability of water supplies in terms of effects of drought on water sources, present water usage and reducing the effects of drought; and
 - 5) information about water resource data, location and availability.
- Water Resources Development Maps and Commentary Notes (Tickell & Rajaratnam, 1996a, b, c, d, e, 1997) at pastoral property scale. This is a series of maps, at 1:250,000 and 1:100,000 scale, based on the following areas of the Western Victoria River District:
 - 1) Hooker Creek Station and Lajamanu Community;
 - 2) Mistake Creek Station;
 - 3) Mt Sanford Station (part of Victoria River Downs Station);
 - 4) Limbunya and part of Riveren Station;
 - 5) Daguragu; and
 - 6) Fitzroy Station and NT Portion 3122.
 There are also separate reports for each pastoral property in this area.
- Assessment of Surface Water Resources for Stock Watering in the Victoria River District (Rajaratnam, 1998). This report assesses the potential of storing surface water for stock watering, and identifies suitable areas for excavated tanks. The report provides guidance on design and dimensions of excavated tanks and provides a map of surface water storage potential.
- Isotope sampling in the VRD (Tickell, 1998).

The main source of stock water in the VRD is groundwater, extracted from bores and pumped to a storage tank such as a turkeys nest or steel tank before being gravity fed to one or more troughs (Tickell & Rajaratnam, 1998). Five aquifer types occur in the area, and water availability varies greatly depending on the characteristics of the underlying aquifer, and the depth of the bore. The majority of the region is underlain by a fractured rock aquifer with low yields, typically in the order of 1 litre per second. A limestone aquifer lying along the eastern side of the region supports higher yielding bores of around 2 litres per second. It is suggested that if these bores were drilled deeper, they could yield between 5-15 litres per second (Tickell & Rajaratnam, 1998). Groundwater resources are recharged by annual rainfall, when weekly rainfall exceeds 100mm (Tickell, unpublished). Groundwater has a short residence time in the VRD, most water is less than 50 years old, the oldest being 3,000 years old. The majority of groundwater in the VRD is fresh and suitable for stock (Tickell & Rajaratnam, 1998).

As discussed in Section 2.4.2, the Victoria River and most of its tributaries only flow for four to six months of the year, before drying into intermittent waterholes. Spring flows and seepages mostly occur low in the landscape, mainly in the headwaters of the Victoria River between Mount Sanford and Top Springs, where the watertable is generally shallow (Tickell & Rajaratnam, 1998). Springs also occur due to geological formations, such as where an aquifer is faulted against an impermeable rock like siltstone, and the groundwater flow is forced to the surface (eg Campbell Springs on Limbunya Station), or where the contact between two aquifers is dissected by a creek (eg Buchanan Springs on Riveren Station). The majority of springs in the Victoria River region are ephemeral. Unidait Spring on Limbunya and Depot Spring on Mount Sanford are the only permanent springs, all the others dry up during the dry season, depending on the amount of rain that fell during the previous wet season (Tickell & Rajaratnam, 1998). Surface water sources accessible by stock are generally less efficient than those that are fenced and regulated through a turkeys nest or steel tank, as unrestricted stock access tends to cause erosion and siltation, making waterholes shallow and more prone to water quality problems (Tickell & Rajaratnam, 1998).

Tanks and dams used to harvest and store surface water flows are not widely used in the VRD, except for where groundwater supplies are difficult to locate (eg the then Bradshaw Station and Auvergne Station). The only areas suitable for excavated tanks to store surface water flows are

flat to gently undulating black soil country, where there is adequate soil to excavate to a depth of at least 3.5 metres. There are very few locations in the VRD that fit this criterion (Tickell & Rajaratnam, 1998).

2.6.2 Stream Flow

Stream flow gauging commenced in the NT in 1952, and the first on the Victoria River was set up at Coolibah Station homestead in September, 1952 (Department of Mines and Energy, 1986). Figure 2.8 shows the location of the flow gauge stations within the Victoria River catchment. A total of 18 stations have been established in the Victoria River catchment, eight of which are still operating today.

Rainfall data for the region are supplemented by information from pluviometer stations. In addition to daily rainfall recordings carried out by the Bureau of Meteorology, there are eight pluviographs (automatic rainfall recorders) operating in the Victoria River catchment for flood hydrology work. These are located at gauge stations including Victoria River at the Crossing, Coolibah Station, Dashwood Crossing, Wave Hill Police Station, Williams Crossing and upstream of Timber Creek, as well as on the East Baines and West Baines Rivers at the Victoria Highway. Many pastoralists also report rainfall to the Bureau of Meteorology.



Flow gauge station on East Baines River (G8110004).

Table 2.5 summaries the stream flow information for the flow gauge stations in Victoria River catchment. G8110007 at Coolibah Homestead is the furthest downstream gauge station in the network, and records a mean annual flow volume of 3,185 million m³, or a mean annual discharge of 162m³/sec. This can be compared to G8110016 at Wave Hill Police Station, the most upstream gauge station on Victoria River, which records a mean annual flow volume of 432.7 million m³, or a mean annual discharge of 19.9m³/sec.

● OPEN FLOW GAUGE STATIONS

Station	Tributary	Location	Years Recording
G8110004	East Baines River	Victoria Hwy	1964-present
G8110006	West Baines River	Victoria Hwy	1960-present
G8110007	Victoria River	Coolbah Homestead	1952-present
G8110012	Timber Creek	2 miles u/s Vic Hwy	1968-present
G8110016	Upper Victoria River	Wave Hill Police Stn	1954-present
G8110110	Surprise Creek	VRD Rd crossing	1959-present
G8110113	Victoria River	Dashwood Crossing	1963-present
G8110232	Wickham River	Williams Crossing	1965-present

● CLOSED FLOW GAUGE STATIONS

Station	Tributary	Location	Years Recording
G8110018	Victoria River	Victoria Hwy	1972-1993
G8110073	Armstrong River	Top Springs	1959-1986
G8110074	Montejinnie Creek	Montejinni Homestead	1973-1986
G8110101	Dick Creek	Victoria Hwy	1962-1978
G8110107	Saddle Creek	Victoria Hwy	1962-1986
G8110184	Middle Creek	VRD Rd crossing	1963-1981
G8110222	Walsh Creek	Sugarloaf Hill	1965-1977
G8110238	Delamere Cerek	Delamere Hstlead	1966-1987
G8110251	West Baines River	Brumby Hill	1965-1965
G8110263	Bullock Creek	1.5 miles d/stream bore	1966-1992

▲ WATER QUALITY SAMPLING SITES

Code	Station	Tributary	Location
1	G8110001	Blackgin Creek	Blackgin Whole
2	G8110004	East Baines River	Victoria Hwy
3	G8110005	Timber Creek	Police Station
4	G8110006	West Baines River	Victoria Hwy
5	G8110007	Victoria River	Coolbah Homestead
6	G8110009	Kidman Springs	Kidman Springs
7	G8110014	Sullivans Creek	U/stream Fig Tree yard
8	G8110015	Wickham River	VRD Homestead
9	G8110016	Upper Victoria Ri	Wave Hill Police Stn
10	G8110017	Victoria River	Pigeon Hole Hstlead
11	G8110018	Victoria River	Victoria Hwy
12	G8110019	Wickham River	Spring Flow
13	G8110073	Armstrong River	Top Springs
14	G8110074	Montejinnie Creek	Montejinni Homestead
15	G8110106	Camfield Creek	Old Road crossing
16	G8110110	Surprise Creek	VRD Rd crossing
17	G8110113	Victoria River	Dashwood Crossing
18	G8110169	Jasper Creek	Jasper Gorge
19	G8110184	Middle Creek	VRD Rd crossing
20	G8110187	Big Horse Creek	Victoria Hwy
21	G8110222	Walsh Creek	Sugarloaf Hill
22	G8110232	Wickham River	Williams Crossing
23	G8110251	West Baines River	Brumby Hill
24	G8110253	Gibbie Creek	Wagon Wheel Whole
25	G8110255	Ikymbon River	Inukalen Cateract
26	G8115000	Victoria River	Fitzroy Station
27	G8115005	Kidman Springs	Kidman Springs
28	G8115009	East Baines River	Auvergne Station
29	G8115023	Gordy Springs	Wave Hill Station
30	G8115089	Camallin Spring	Bradshaw Station
31	G8115113	McDonald Creek	McDonald W/whole
32	G8115114	Victoria River	Kalkarindji d/s road br
33	G8115115	Wickham River	Johnston Billabong
34	G8115116	Limestone Creek	Limestone Gorge
35	G8110253	Gibbie Creek	Wagon Wheel Waterhole
36	G8115110	Victoria River	Pigeon Hole
37	G8115117	Cow Creek	Cow Ck Falls
38	G8115118	West Baines River	Hurricane Hills Yd
39	G8115119	Boxer Springs Ck	Boxer Springs Ck

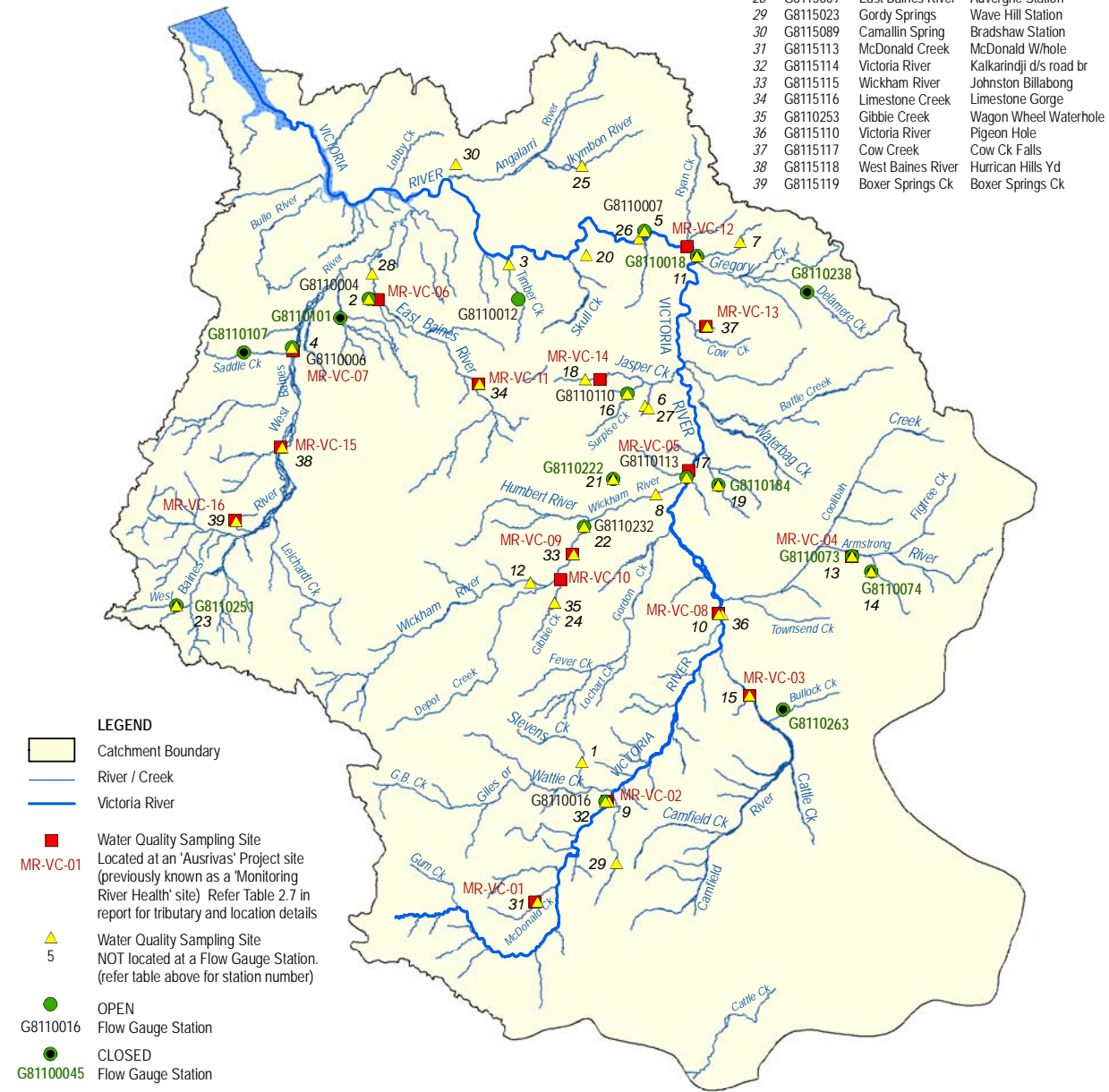
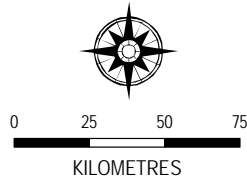


Figure 2.8 Location of Flow Gauge Stations and Water Quality Sampling Sites throughout the Victoria River Catchment

Table 2.5 Summary of Stream Flow Information for the Victoria 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)	Mean Monthly Discharge (min-max) (m ³ /sec)
G8110004	East Baines River	2,432	238,600,000	12.4	11.3	12.1 (0-2,808)
G8110006	West Baines River	10,204	706,900,000	40	21.7	42.5 (0-3,355)
G8110007	Victoria River	44,900	3,185,000,000	162	118	164.9 (0.1-13,404)
G8110012	Timber Creek	164	25,370,000	1.4	0.9	1.2 (0-704.5)
G8110016	Upper Victoria River	4,916	432,700,000	19.9	17.4	20.3 (0-6,644)
G8110110	Surprise Creek	361	31,960,000	3	2.7	3.2 (0-310.7)
G8110113	Victoria River	33,400	2,206,000,000	125	102	140.2 (0-6,708)
G8110232	Wickham River	5,018	53,060,000	11.9	10.5	12.2 (0.2-127.2)
G8110018*	Victoria River	43,600	4,176,000,000	909	172	844.6 (0-13,411)
G8110073*	Armstrong River	810	84,750,000	3.6	3.3	3.8 (0-1,198)
G8110074*	Montejinnie River	139	2,498,000	0.1	0.1	0.1 (0-13.8)
G8110101*	Dick Creek	888	92,400,000	8.6	6.9	7.0 (0-152.4)
G8110107*	Saddle Creek	234	18,870,000	1.5	1.4	1.2 (0-77.3)
G8110184*	Middle Creek	120	17,850,000	1.9	1.5	1.7 (0-235.8)
G8110222*	Walsh Creek	45	7,343,000	1.5	1.2	1.2 (0-146.7)
G8110238*	Delamere Creek	653	8,221,000	0.8	0.7	0.9 (0-11.4)
G8110251*	West Baines River	168	22,690,000	0.9	0.8	0.8 (0-617.8)
G8110263*	Bullock Creek	474	18,400,000	1.2	0.7	1.0 (0-1,088)

* Closed Gauge Station

Source: Figures obtained from 'Hydsys' and were up-to-date at the time of extraction (2004). Stream flow information is based on data from some stations that are no longer in operation or have a limited number of gaugings and, consequently, the ratings that generate the stage-to-discharge relationship cannot be guaranteed.

The stream flow contributions to the Victoria River from the various tributaries vary considerably. Aside from East and West Baines Rivers, the greatest contribution to the Victoria River (on which flow gauge stations exist or have existed), is from Dick Creek, Armstrong and Wickham Rivers. G8110018, a closed gauge station on the Victoria River at the Victoria Highway Crossing, has the largest catchment area and reports the greatest mean annual flow volume of all the measured locations in the Victoria River catchment.

The mean monthly discharges for the Victoria River and several tributaries are shown in Figures 2.9 to 2.11. The concentration of monsoonal rains during the wet season (November to March) is reflected in marked seasonal changes in stream flows. In the wet season, river flows increase due to rainfall runoff. Generally, river discharge tends to increase as the wet season advances even though, in a normal wet season, the rainfall may be more or less uniformly distributed from December through March. Rainfall can be variable and high intensity falls can occur (eg 211mm of rain was recorded at Victoria River Downs Station on 15th April 1985, and the monthly average for April, based on 118 years of records, is 22.1mm).

The mean monthly discharge recorded for the Victoria River (Figure 2.9) is in the order of ten times those of the East Baines, West Baines and Wickham Rivers (Figure 2.10), and one hundred times the mean monthly discharge recorded for smaller tributaries such as Timber Creek, Surprise Creek, Armstrong River and Delamere Creek (Figure 2.11).

Figures 2.9 to 2.11 illustrate the highly seasonal nature of the rivers in the Victoria River catchment, as flows mostly cease between May and November each year. Some small contributions from groundwater discharge from springs or seepage points may be present, however the majority of the streams are ephemeral, and dry into a series of pools by the end of the dry season. Figure 2.9 shows that the highest mean monthly discharge along the Victoria River occurs in March and ranges from 45m³/sec at Wave Hill Police Station (G8110016) to 1,393m³/sec at the Victoria Highway (G8110018). The lowest mean monthly discharge along Victoria River occurs in August and ranges from 0.062m³/sec at Wave Hill Police Station (G8110016) to 0.619m³/sec at the Victoria Highway (G8110018).

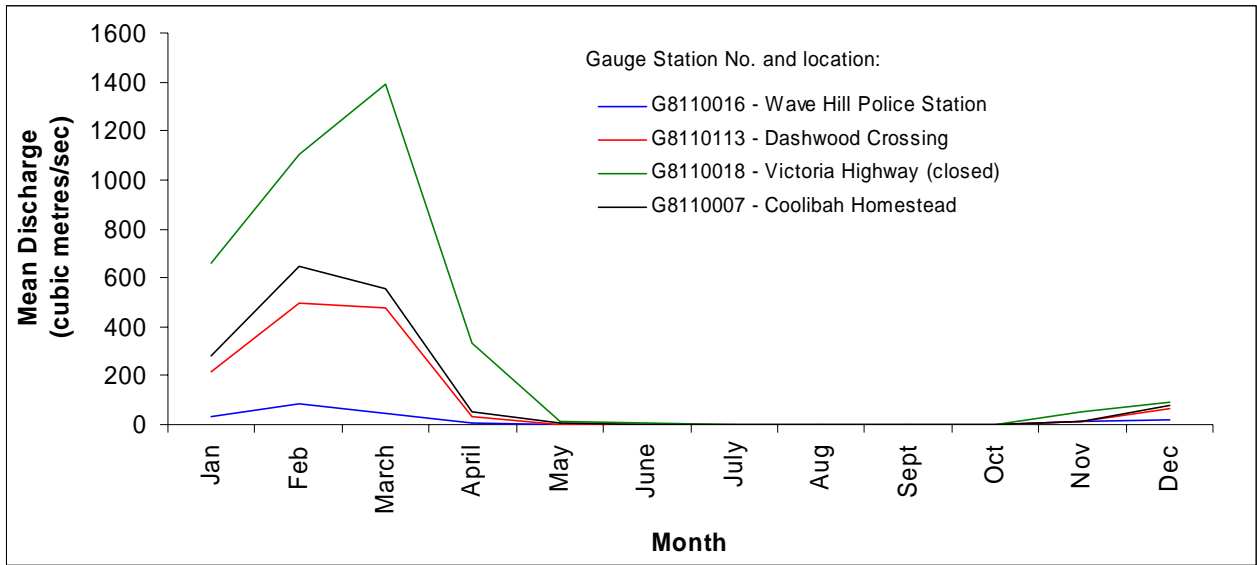


Figure 2.9 Mean Monthly Discharge Recorded for Victoria River

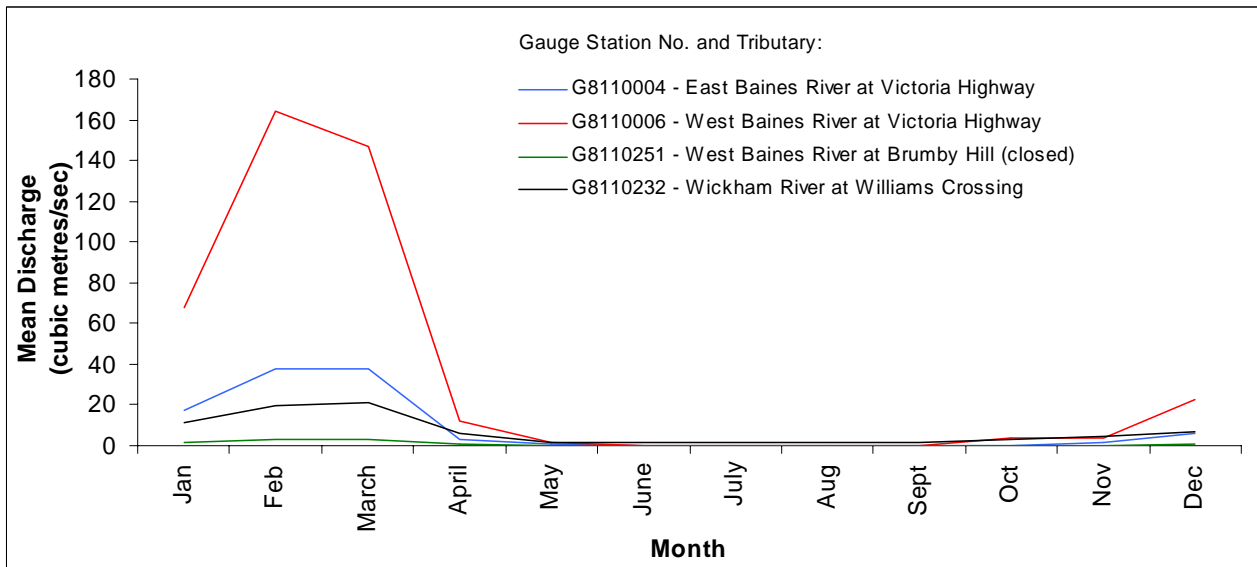


Figure 2.10 Mean Monthly Discharge Recorded for East Baines, West Baines and Wickham Rivers

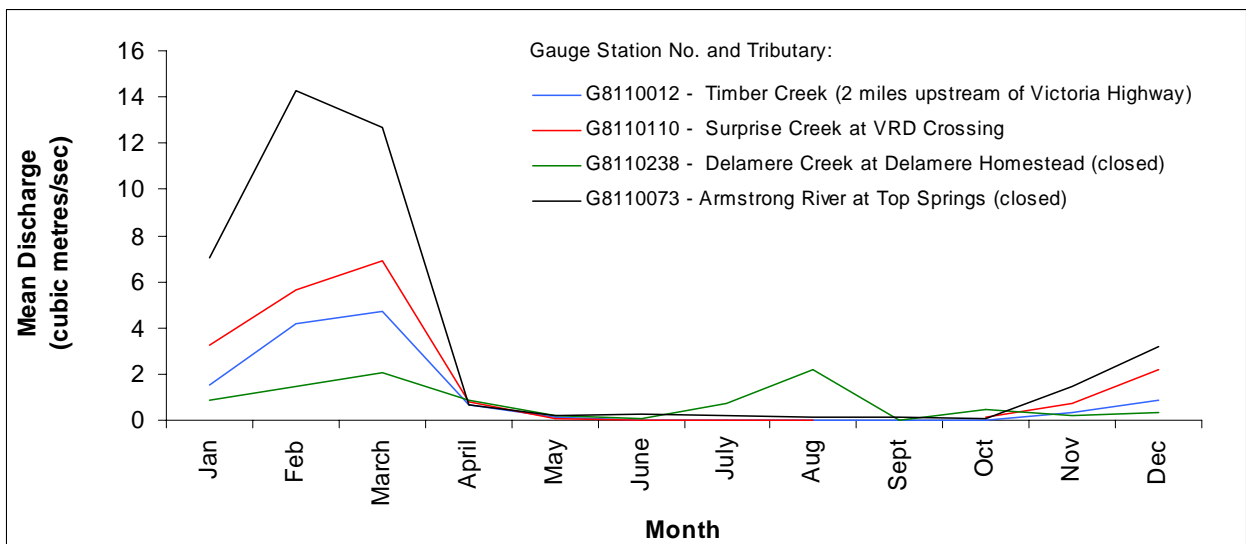


Figure 2.11 Mean Monthly Discharge Recorded for Timber Creek, Surprise Creek, Armstrong River and Delamere Creek.

The highest mean monthly discharge recorded for the Baines and Wickham Rivers occurs in February, and ranges from 164m³/sec recorded on West Baines River at Victoria Highway (G8110006), to 3m³/sec recorded on West Baines River at Brumby Hill (G8110251) (refer Figure 2.10). The lowest mean monthly discharge recorded for these two stations occurs in August and September, with 0.1m³/sec recorded at Victoria Highway and 0.02m³/sec recorded at Brumby Hill. Likewise with the smaller tributaries, the highest mean monthly discharges are recorded in the downstream sites during the wet season, and the lowest discharges are recorded in the upstream sites during the dry season.

Extraction of water from rivers and creeks (ie surface waters) occurs for stock and domestic purposes within the Victoria 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 Infrastructure, Planning and Environment under the *NT Water Act*. There is currently only one Water Extraction Licence valid in the Victoria River catchment, held by Power and Water Corporation for Bulla Camp Community for 10ML/year. Roadworks licences were issued in 2004, but none were valid at the time of writing this report.

2.6.3 Water Quality

A surface water quality network was established in 1984 in the NT with a program of spot measurements for basic key quality parameters (ie pH, temperature, electrical conductivity and turbidity) at flow gauge stations (Dept of Mines and Energy, 1986). Total phosphorus and total alkalinity are also measured at some gauge stations on an irregular basis.

There are also dedicated water quality sampling locations (located away from gauge stations), where monitoring is carried out on a project basis by the Department of Infrastructure, Planning and Environment (DIPE). This sampling has generally been ad hoc, and often provides a snap shot of that particular waterway as a result of a one-off water quality survey. There is no long term series data collection in the Victoria River catchment.

Apart from water quality monitoring undertaken by DIPE, specific water quality studies conducted within the Victoria River catchment include the following reports:

- 'A Biological Resource Study of freshwaters of the Victoria River and its tributaries conducted during August to September, 1981 (Midgley, 1981). Water quality parameters included Turbidity, pH,

Total Dissolved Solids, Temperature, Dissolved Oxygen, Alkalinity and Hardness.

- 'Ausrivas' (Australia-wide Assessment of River Health) (Dostine, 2002). The aim of this project was to develop predictive models for the assessment of ecological condition of running water sites using aquatic macroinvertebrates as biological indicators of health. Water quality was also assessed for verification.

The locations of 226 water quality sampling sites in the Victoria River catchment are shown in Figure 2.8 (Section 2.6.2). Tables 2.6, 2.7 and 2.8 summarise the results for six water quality parameters: electrical conductivity (EC), turbidity, water temperature, pH, total alkalinity and total phosphorus. The water quality results have not been analysed to detect seasonal trends due to the general scarcity of results and ad hoc nature of the data collection.

From Tables 2.6, 2.7 and 2.8, mean EC results range from 23µS/cm to 19,300µS/cm. Generally, EC levels in excess of 600µS/cm can cause deterioration in taste (ANZECC, 1992). EC levels exceeded this level at six of the 51 sites recorded. The highest recorded EC result is from Big Horse Creek, with 19,300µS/cm. This is a result from a one off survey, and no further testing has been undertaken at this location to establish the cause. pH was mostly between 7 and 8, with the exception of a low mean pH of 4 recorded at G8110019 on the Victoria River, 6 at Cow Creek Falls, 6.5 on Ikymbon River, and a high mean of 9 recorded at G8110004 on East Baines River. Most natural freshwaters have a pH close to 7 (ANZECC, 1992). pH and salinity (EC) are largely determined by the geology and soils of the catchment, however other factors can affect pH such as the quality of water runoff entering rivers and tributaries.

Turbidity (ie NTUs) indicates water clarity. Stream bank erosion and suspended matter affect turbidity levels, and the ANZECC (1992) recommendation for protection of aquatic ecosystems is that the seasonal mean NTUs should not change by more than 10%, although this does not necessarily apply to the Victoria River and its tributaries, as this can occur naturally due to high flows during the wet season. Median turbidity readings ranged from 1NTU to 5,000NTUs, however some sites recorded consistently high or low levels, whilst others varied greatly. Without long term, strategic monitoring, it is not possible to conclude whether fluctuating turbidity readings in the catchment are related to erosion or disturbances such as river crossings, stock or vermin, or due to natural factors such as high flows or tidal influence.

Table 2.6 Summary of Water Quality Information for Sampling Sites Located at a Flow Gauge Station

Gauge Station Number**	Tributary	Mean Electrical Conductivity - Lab (uS/cm) (No. of results)	Median Turbidity - Lab (NTUs) (No. of results)	Mean pH - Lab (No. of results)	Mean Total Alkalinity - Lab (mg/L) (No. of results)	Mean Total Phosphorous - Lab (mg/L) (No. of results)
G8110001*	Blackgin Waterhole	410 (1)		7.5 (1)	181 (1)	
G8110004	East Baines River	453 (16)		9 (11)	234 (16)	0.013 (3)
G8110005*	Timber Creek	452 (3)		8 (3)	185 (3)	
G8110006	West Baines River	272 (10)	130 (1)	8 (3)	133 (10)	0.033 (2)
G8110007	Victoria River	454 (18)	8 (12)	8 (18)	206 (11)	
G8110009*	Kidman Springs	523 (1)		7.3 (1)	54 (1)	
G8110014*	Sullivans Creek	373 (8)		8 (8)	185 (8)	
G8110015*	Wickham River	588 (4)		8 (4)	349 (4)	
G8110016	Upper Victoria River	413 (7)	73 (7)	7 (7)	173 (7)	
G8110017*	Victoria River	309 (3)			146 (3)	0.026 (3)
G8110018*	Victoria River	449 (8)	4 (1)	4 (8)	211 (8)	0.019 (3)
G8110019*	Wickham River	610 (1)		7.8 (1)	287 (1)	
G8110073*	Armstrong River	212 (17)	1,170 (10)	7 (13)	83 (17)	0.035 (3)
G8110074*	Montejinnie Creek	527 (17)	1 (3)	8 (17)	290 (15)	
G8110106*	Camfield Creek	1,323 (4)		8 (2)	147 (4)	0.027 (2)
G8110110	Surprise Creek	204 (4)		8 (3)	102 (4)	
G8110113	Victoria River	399 (24)	131 (2)	8 (20)	189 (16)	0.012 (3)
G8110169*	Jasper Creek	129 (3)		7 (1)	58 (3)	0.014 (2)
G8110184*	Middle Creek	350 (1)		7.4 (1)	115 (1)	
G8110187*	Big Horse Creek	19,300 (1)		8 (1)	188 (1)	
G8110222*	Walsh Creek	145 (15)	5,000 (59)	7 (15)	73 (15)	
G8110232	Wickham River	522 (19)	14 (6)	8 (16)	281 (15)	
G8110251*	West Baines River	584 (7)		8 (7)	291 (7)	
G8110253*	Gibble Creek	407 (5)	1 (1)	7 (2)	213 (4)	0.015 (3)
G8110255*	Ikymbon River	95 (1)		6.5 (1)	33 (1)	
G8110263*	Bullock Creek	343 (2)	180 (1)	8 (2)	157 (2)	

* Closed Gauge Stations ** Refer to Figure 2.8 for location details

Source: Figures obtained from 'Hydsys' and were up-to-date at the time of extraction (2004)

Table 2.7 Summary of Water Quality Information for Sampling Sites Not Located at a Flow Gauge Station

Gauge Station Number*	Tributary	Mean Electrical Conductivity - Lab (uS/cm) (No. of results)	Median Turbidity - Lab (NTUs) (No. of results)	Mean pH - Lab (No. of results)	Mean Total Alkalinity - Lab (mg/L) (No. of results)	Mean Total Phosphorous - Lab (mg/L) (No. of results)
G8115000	Fitzroy Station (Vic Hwy)	419 (3)		8 (3)	208 (3)	
G8115005	Kidman Springs	523 (3)		8 (3)	282 (3)	
G8115009	East Baines River	367 (5)	1 (1)	8 (5)	178 (5)	
G8115023	Gordy Springs	894 (4)		7 (4)	414 (4)	
G8115089	Camballin Spring	46 (3)	5 (1)		12 (3)	
G8115113	McDonald Waterhole	588 (3)			181 (3)	0.017 (3)
G8115114	Victoria River	438 (3)			209 (3)	0.019 (3)
G8115115	Johnston Billabong	510 (3)			269 (3)	0.011 (3)
G8115116	Limestone Gorge	342 (3)			281 (3)	0.01 (3)

* Refer to Figure 2.8 for location details

Source: Figures obtained from 'Hydsys' and were up-to-date at the time of extraction (2004).

Table 2.8 Summary of Water Quality Information collected at 'Ausrivias' Project Sites

Ausrivas Site Number* (Hydsys Site Number)**	Tributary and Location Description	Mean Electrical Conductivity - Field (mS/cm)	Median Turbidity - Field (NTUs)	Mean Water Temp - Field (oC)	Mean pH - Field	Mean Total Alkalinity - Lab (mg/L)	Mean Total Phosphorus - Lab (mg/L)
MR-VC-01 (G8115113)	McDonald Creek at McDonalds Waterhole	575	16	27.1	8.59	181	0.017
MR-VC-02 (G8110016)	Victoria River at Kalkarindji downstream of road bridge	514	17	27.8	8.34	209	0.019
MR-VC-03 (G8110106)	Camfield River at Camfield Homestead	988	26	28.9	8.12	164	0.025
MR-VC-04 (G8110073)	Armstrong River at Old Top Springs Roadhouse	396	25	26.7	7.60	264	0.029
MR-VC-05 (G8110113)	Victoria River at Dashwood Crossing	430	29	29.5	8.25	245	0.010
MR-VC-06 (G8110004)	East Baines River at Victoria Highway Crossing	414	8	29.4	8.44	239	0.011
MR-VC-07 (G8110006)	West Baines River upstream of Victoria Highway Crossing	261	35	30.0	8.16	138	0.025
MR-VC-08 (G8115110)	Victoria River at Pigeon Hole	393	14	28.0	8.22	146	0.026
MR-VC-09 (G8115115)	Wickham River at Billabong on road to Mt Sanford	504	5	28.8	8.30	281	0.010
MR-VC-10 (G8110253)	Gibbie Creek on road to Mt Sanford	521	8	29.1	8.18	277	0.013
MR-VC-11 (G8115116)	Limestone Creek at Limestone Gorge	513	2	28.4	7.67	287	0.009
MR-VC-12 (G8110018)	Victoria River at Victoria River Roadhouse	420	9	28.6	8.21	221	0.016
MR-VC-13 (G8115117)	Cow Creek Falls on Cow Creek	23	1	26.9	5.94	2	0.010
MR-VC-14 (G8110169)	Jasper Gorge on Jasper Creek	89	8	26.9	7.49	49	0.013
MR-VC-15 (G8115118)	West Baines River north west of Hurricane Hill Yards, Amanbidji	539	19	27.9	8.35	237	0.023
MR-VC-16 (G8115119)	Boxer Springs Creek	902	2	26.6	8.03	522	0.010

Source: Figures obtained from the 'Ausrivias' Project. Four to five water quality tests were carried out during the dry season between 1994 and 1996.

*MR-VC site numbers are from the Monitoring River Health (Ausrivias Project) sites in the Victoria River Catchment.

**G811 site numbers are unique numbers attributed to monitoring sites in the NT Government's Water Resources Database (Hydsys).

Mean total alkalinity ranged from 2-522mg/L. Higher total alkalinity levels are often related to groundwater discharge. The mean total alkalinity results in Tables 2.6-2.8 are not comprehensive enough to draw conclusions about groundwater discharge areas. Total phosphorus levels were generally low, ranging from 0.009 to 0.03mg/L. Water temperature ranged from 26°C to 30°C, which is typical of waterways in northern Australia.

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. The 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).



Elevated turbidity due to vehicles crossing



Elevated turbidity due to tidal influence



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. 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 Queensland Government 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 trialled, 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 a previous catchment that was studied (ie Daly River catchment – Faulks, 1998a,b), 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 previous 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 and it should be only one source of information on which to base decision making processes.

The 'State of the Rivers' survey focuses 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, as this would involve measuring changes in volume due to naturally occurring seasonality. To overcome this, the 'Top End Waterways Project' has summarised the stream flow information that exists for gauge stations within the Victoria River catchment, which includes measurements from different seasons (refer Section 2.6). The influence of artificial barriers on the hydrology of streams is 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 Victoria River catchment (refer Section 2.6). Temporal variability in water quality (eg seasonal changes, influence of groundwater particularly during the dry season) was therefore not assessed.

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

Linkages to long term databases (eg Hydsys) and other projects and initiatives relating to rivers are important to aid the 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 to facilitate future studies, and to allow possible correlations to be drawn between these studies.

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.

The 'Top End Waterways Project' has been established to monitor the rate of change in river condition, to look at management induced improvements or areas where management practices/land uses have changed or intensified. To achieve this, it will be necessary to conduct follow-up surveys. Selected priority sub-sections (or preferably sub-catchments) could be targeted in any follow-up surveys if whole catchments could not 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. As the field surveys for this project were conducted in 1996, changes would now be detectable.

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 catchment boundary that was delineated for the Victoria River is shown on Map 2 and differs somewhat to the one defined by the National Land and Water Resources Audit.

The delineation of the “homogeneous stream sections” involved a progressive division of the catchment into smaller and smaller units. Initially, the Victoria River catchment was divided into 12 major sub-catchments (shown in Map 6). These represent the major tributaries within the Victoria River catchment.

The major tributaries were further sub-divided into 15 sub-sections (shown in Map 7). Planning of these sub-sections was done using 1:100,000 (where available) and 1:250,000 topographic map sheets, aerial photography and landsat imagery. Generally, sub-section boundaries were established at major tributary junctions. Attributes including geology, stream gradient, altitude, landuse and the tidal limit assisted with sub-dividing the Victoria River further.

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 Victoria River catchment as compared to the river catchments being studied in Queensland (ie most of the Victoria River catchment is less than 450m); there are very few artificial barriers, like weirs, on rivers; the rivers are not impounded by dams; the catchments are less developed; access is often difficult and time consuming; the resources available (ie time, staff) to sample a large number of sub-sections is not available.

The project methodology was developed to assess a number of sites within each sub-section that represented the range and extent of stream types and conditions, including a range of stream orders. To account for the scale of the area covered in this survey, 6 stream orders were defined for the Victoria River catchment, based on the Strahler system at a 1:250,000 map scale (refer Map 8). Victoria River recorded the largest stream order of 6, on which 16 sites were sampled along an approximate stream length of 490km.

Map 8 also shows the number of sites assessed for each stream order, as well as the percentage of total stream length represented in each stream order. The minor stream orders (1 and 2) make up a large proportion of the total stream length, however it was felt that a greater focus should be placed on the medium and larger sized rivers and creeks given the constraints on the number of sites that could be sampled.

Landsat imagery, 1:250,000 topographic map sheets, aerial photography along Victoria River estuary and the Ausrivas project were used to select sites within each sub-section. Access for both vehicles and boats were 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 80 sites were sampled throughout the Victoria River catchment between June and December 1996 (refer Map 9). Appendix A lists all sites and provides a location description. In addition, sketches of each reach were made at the time of survey, and these are available to assist in finding the sampling point in the future. Of these sites, 71 were full survey sites. The remaining nine ‘photo sites’ were visited in order to gain a greater understanding of the range and extent of stream types throughout the catchment. On average, one to two sites were sampled per day by a team of two people (ie 80 sites sampled over 64 days). Some sites were accessed using a helicopter.

The Qld ‘State of the Rivers’ methodology was designed as a rapid survey where 8-10 sites could be surveyed per day. The reduced number of sites sampled per day 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, etc); and the limited resources available (staff, time etc).

To counter for the reduced number of sub-sections delineated for the Victoria 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 were made on data sheets set up to describe the stream, the river banks and environs. The components of the field surveys are summarised below. Appendix B summarises the data sheet information. Those survey components that have been modified from the ‘State of the Rivers’ method are identified 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) were recorded. A location description for each site, including an access sketch, was 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 Global Positioning System (GPS) was also used to provide geographic location information for each site and sample point. Data was collected in Eastings and Northings, using datum WGS84. A standard set of colour slides was taken at each site including upstream and downstream views, at each bank, along the reach environs and at other key features. These slides were numbered sequentially and accompanied by an associated description.

• Reach Environs and Site Features

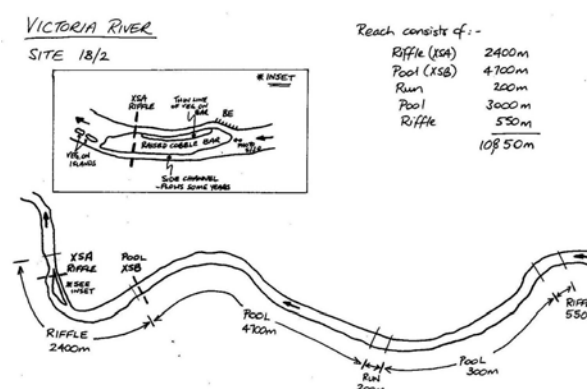
Reach environs are those lands immediately adjacent to the riparian zone along the reach and include the floodplain and valley flat. Local information was recorded about these lands including land use, local disturbance, land tenure, local vegetation/habitat type and floodplain features. This information 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, was also recorded.

The water level at the time of sampling was 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 2,238m; range 50m to 20,300m). 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.



Example of a reach sketch

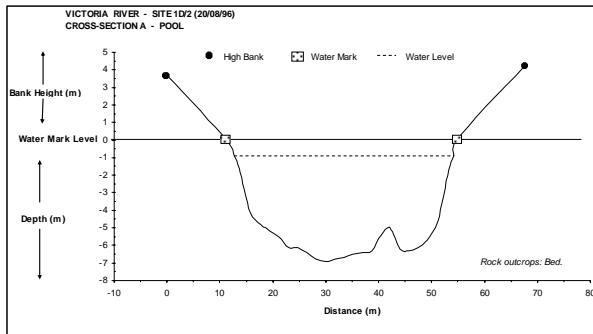
A cross-section survey was done across each sample point/habitat type at right angles to the bank. The survey was aimed to pass over the point of maximum depth and minimum flow in a pool section and maximum flow and minimum depth in a riffle/run habitat. The extremes were chosen in order to establish 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 were dependent on the prevailing discharge at the time of the survey and were 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. Cross-section graphs have been created and have been stored in the projects' database.



Example of a cross-section graph



- *Bank Condition and Stability*

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

Local factors affecting stability were identified. Features relating to the gravel angularity and shape, bed compaction and the type of controls (eg rock outcrops, culverts, etc) stabilising the bed was 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, were 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.



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, were recorded separately. The total percentage cover of exotic species within the riparian zone for each bank was also assessed. The width of the riparian zone for each bank was recorded and 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 and compiled vegetation lists of the major species for each site. Vegetation profiles were completed at 36 sites. The ten meter 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 one meter square quadrat, usually located at five meter intervals along the profile length starting at the water's edge. Percentage covers for each species type located within the quadrat was recorded.



Collecting vegetation samples for identification

- *Aquatic Vegetation*

Aquatic vegetation was divided into either submerged (eg filamentous algae, Chara/Nitella, Myriophyllum and other herb-like forms), floating (eg water lilies, etc) or emergent (eg Phragmites, rushes/sedges, Pandanus, Melaleuca, etc) groups, and were 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.

- *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 as a 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 Victoria River catchment, and extracted from a database system called ‘Hydsys’, have been used to summarise flow volumes and monthly discharges (refer Section 2.6.2).

Water quality information collected throughout the catchment at 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 (EC), 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 (refer Section 2.6.3).

Background information on the catchment has been gained through a literature review, as well as liaising with landowners/managers, Aboriginal groups, councils, other government departments and the Victoria District Conservation Association.



3.6 Data Analyses and Presentation of Information

An Access Relational Database, designed for the 'Top End Waterways Project', has been used to enter, verify, store and analyse the raw data. This database can be used as an ongoing management tool to store and analyse the information collected over time. This database can also be directly interfaced with the GIS package 'ArcGIS'.

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 can be 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 completely 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 10-25 shows the results for the condition and stability ratings and other attributes for each site (refer '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)
Essentially Natural ⁽¹⁾ Stable ^{(2) & (3)} Very High Cover/Diversity ^{(4) & (6)} Exotics Absent ⁽⁵⁾ Very High Overall Condition ⁽⁷⁾	81 - 100	9 - 10
Some Modification ⁽¹⁾ Limited Instability ⁽²⁾ High Cover/Diversity ^{(4) & (6)} Low Cover for Exotics ⁽⁵⁾ High Overall Condition ⁽⁷⁾	61 - 80	7 - 8
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
Major Modification ⁽¹⁾ Extensive Instability ⁽²⁾ Low Cover/Diversity ^{(4) & (6)} High Cover for Exotics ⁽⁵⁾ Low Overall Condition ⁽⁷⁾	21 - 40	3 - 4
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

(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. Although the results are not 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. Charts summarising the overall condition rating score (out of 60) for sites within each sub-section are provided in 'Sub-catchment Results'. The overall condition rating score takes into account categories 1-6 shown in Table 3.1.

A presentation of the map series has been produced using ArcGIS software. Catchment and sub-section boundaries were delineated using 1:100,000 or 1:250,000 topographic map sheets, taking into account contours and spot heights. Cross-sections have been produced using Excel and have been stored within the projects' database. A CD containing the report, the map series, a selection of site photographs and an interactive GIS (using 'Arc Explorer') is being used to distribute the results of the project.

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

State of the reach environs:



Bank stability:



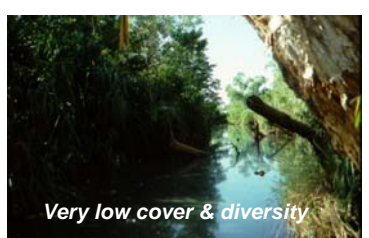
Bed stability:



Cover and structural diversity of riparian vegetation:



Cover and diversity of instream and bank habitats:



Overall condition:





4. CATCHMENT RESULTS

Maps 10-25 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 land adjacent to stream reaches studied was under freehold or leasehold tenure, including Aboriginal land (90% of sites). The only other land tenure type recorded was National Parks (10%).

The major land use recorded adjacent to the streams in the catchment was grazing on thinned native pasture (78% 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	78
Grazing - native - virgin	12
Park or Reserve	10
Grazing - native - cleared	3
Rural Residential	3
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, roads or tracks, causeways or river crossings and watering points for stock and feral animals were the major disturbances to streams. No local disturbance was recorded at 5% of sites.

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

Disturbance Type	Percent of Sites (%)
Grazing	87
Road / track	72
Causeway / river crossing	42
Watering point for stock / ferals	37
Bridge / culvert	14
People	5
Boat ramp	3
Water extraction	3
River Works	1
Weir	1

Subjective disturbance ratings indicated that only 5% of sites recorded a very low disturbance level (refer Table 4.3). The majority of sites (94%) recorded low, low to moderate and moderate disturbance levels.

Table 4.3 Disturbance Levels along Reach Environs based on Subjective Ratings

Disturbance Category	Percent of Sites (%)
Very Low	5
Very Low to Low	0
Low	54
Low to Moderate	22
Moderate	17
Moderate to High	1
High	1
Very High	0
Extreme	0

Sites recording a very low subjective 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. Disturbances observed along the reach included some impact from animals and recreational activities, although these were minor.

A low or low to moderate disturbance rating meant that the riparian vegetation was generally intact but was being impacted on by things like stock/feral animals (eg trampling, grazing, watering), people, clearing for cattle watering points, infrastructure (eg tracks, crossing, pumps, buildings), exotic vegetation, severe flooding and bank erosion.



Stock crossing and utilising rivers for grazing or watering points are major factors contributing to the disturbance of the reach environs at some sites.

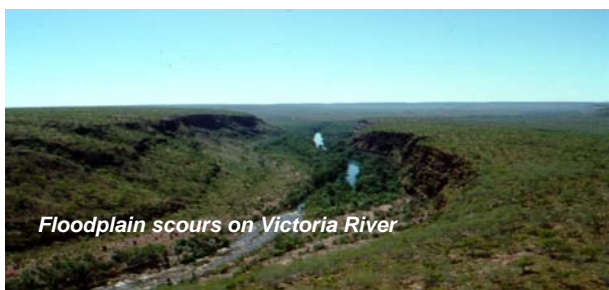
A summary of the state of the land corridor along the survey reach and on the floodplain adjacent to the reach (from derived ratings which take into account the land use and local disturbances) is shown in Table 4.4 and Map 11.

The results indicate that the sites throughout the catchment were classified as having either essentially natural reach environs (53% of sites) or some modification to the reach environs (46%). Generally, the sites with essentially natural reach environs had relatively low impact land uses, undisturbed vegetation and few local disturbances. Those sites that had some modification to the reach environs recorded local disturbances (ie concentration of animals at watering points, grazing, tracks or roads, river works and causeways) that reduced the ratings from essentially natural. Victoria River near Kalkarindji recorded moderate modification to the reach environs (Site 1d_3).

Table 4.4 State of the Reach Environs

Reach Environs Category (Rating)	Number of Sites (%)
Essentially Natural (81-100%)	41 (53)
Some Modification (61-80%)	36 (46)
Moderate Modification (41-60%)	1 (1)
Major Modification (21-40%)	0 (0)
Extreme Modification (0-20%)	0 (0)

The floodplain features were recorded at each site. The major features included scours (60% of sites), prominent flood channels (46%), billabongs/oxbows (5%) and floodplain deposits (5%). The dominant channel patterns included regular meanders (78% of sites), braided channels (12%), mild sinuous channels (6%), and irregular meanders (4%).



4.2 Channel Habitat Types, Diversity and Dimensions

The mean reach length studied was 2,238m (range 50-20,300m). The channel habitat types recorded are listed in Table 4.5. The dominant habitat types that occurred were pools (96% of sites) and riffles (81%). Pools generally occurred in conjunction with a riffle or a run. Waterfalls were associated with areas of steeper topography such as Limestone Gorge on Limestone Creek and a waterfall on an arm of Cow Creek in the upper catchment of the Victoria River. Three rapids were located on the Victoria River, and the only cascade was recorded at Limestone Gorge.

Table 4.5 Channel Habitat Types

Channel Habitat Type	Number of Sites (%)
Pool	74 (96)
Riffle	62 (81)
Run	7 (9)
Rapid	3 (4)
Waterfall	2 (3)
Cascade	1 (1)
Glide	0 (0)
Backwater	0 (0)

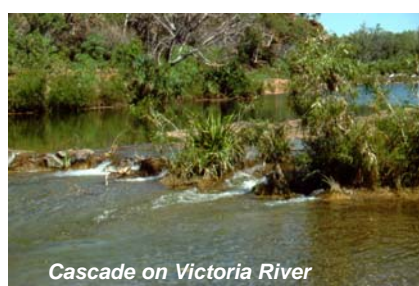
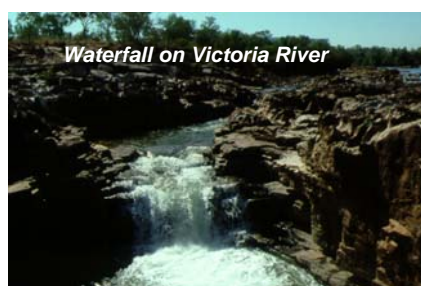
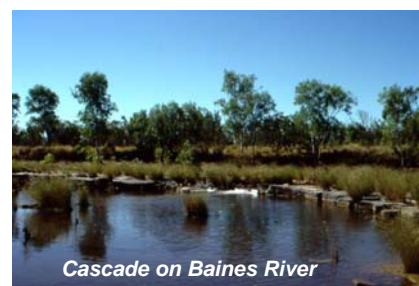
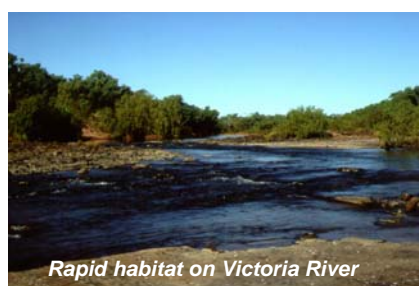
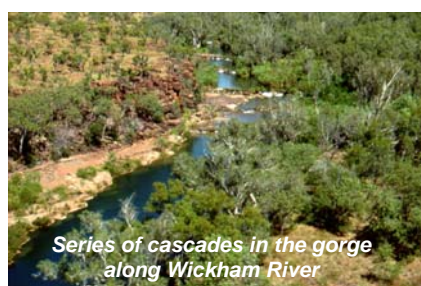
As the majority of the surveys were conducted during the dry season, the rivers and creeks (not fed by springs) were either completely dry (17% of sites) or had isolated pools (38%). The water level at time of sampling at other sites was recorded as moderate but less than the normal level (7% of sites), normal at water mark (22%) or high (1%). Tidal influences (eg high/low tide, incoming/outgoing tides) were recorded at 13% of sites located along the tidal reaches of the Victoria River.

The channel dimensions of each habitat type are 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 68% of the reach covered by this habitat type. Pools had an average length of 1,370.6m (range 30-11,500m), an average depth of 3.2m and an average width of 179.2m.

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	68.1 (24-100)	1,370.6 (30.0-11,500.0)	D 3.2 (0.2-19.4)	179.2 (4.5-5260.0)
Run	13.6 (1-42)	96.7 (7.0-300.0)	D 1.6 (0.4-3.4)	31.1 (3.0-101.0)
Riffle	34.6 (6-76)	599.2 (19.0-106.0)	D 1.7 (0.07-48.0)	36.2 (2.0-242.5)
Rapid	30.3 (5-75)	161.7 (30.0-375.0)	D 0.1 (0.08-0.2)	14.7 (11.0-18.0)
Cascade	11.0 (11-11)	40.0 (40.0-40.0)	H 0.3 (0.3-0.3)	3.5 (3.5-3.5)
Waterfall	6.5 (3-10)	10.0 (10.0-10.0)	H 11.5 (3.0-20.0)	5.5 (5.5-5.5)



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 20.6m (range 0.5-208m), an average height of 3.5 (0.3-15m) and an average slope of 18.9° (range 0.9-62.6°). The lower bank (ie below water mark), for all habitat types, had an average width of 8.3m (range 0.2-130m); an average height of 0.9m (range 0.1-6m); and an average slope of 28.7° (range 0.6-79°).

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	13.0 (1.0-155.0)	3.4 (0.3-15.0)
Run	5.2 (0.5-12.0)	1.0 (0.4-1.8)
Riffle	28.8 (1.0-208.0)	3.5 (0.4-9.6)
Rapid	67.5 (52-76.0)	6.3 (4.2-7.7)
Cascade	3.0 (2.0-4.0)	0.8 (0.3-1.3)
Waterfall	5.2 (2.0-7.0)	1.0 (0.3-1.4)
Overall Mean - All Habitats	20.6 (0.5-208.0)	3.5 (0.3-15.0)

88% of sites monitored had a moderate bank slope of between 30-60°. The remainder of slopes recorded included 56% low (10-30°), 8% steep (60-80°), 3% flat (<10°) and 1% vertical (80-90°).

The major bank shape recorded was convex and to a lesser extent concave. Other bank shapes recorded included a wide lower bench and stepped.

When the sites were assessed for their variability or diversity of channel habitat types, the majority (84%) of sites recorded either a high diversity or a very 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 High Diversity (9-10)	5 (7)
High Diversity (7-8)	57 (77)
Moderate Diversity (5-6)	3 (4)
Low Diversity (3-4)	7 (9)
Very Low Diversity (1-2)	2 (3)

Six of the nine sites assessed with low to very low channel type diversity were in the mid to lower tidal reaches of the Victoria and Bullo Rivers. These sites had uniform, tidal pools. The two sites with very low channel type diversity included pool habitats on the Armstrong and Angalarri Rivers.

Most site reaches assessed had two channel habitat types (77%), 12% of sites had only one habitat type, 8% had three, and 3% had four channel habitat types.

Sites recording moderate channel type diversity (4% of sites) were located on the East Baines and Wickham Rivers and on Stevens Creek. These reaches recorded some variety of habitats (ie two types) but pools dominated these reaches extensively with less than 10% of the reaches being occupied by riffles, runs or cascades.

Sites recording a high channel type diversity (77% of sites) had mostly two habitat types present although the proportion of the reach occupied by habitats other than pools was mostly between 10-30% or >30%, which increased the diversity ratings for these reaches.

Those streams recording reaches with a very high diversity of channel habitat types (7% of sites), were associated with rocky, steeper sections or sections where the number of habitat types recorded was three to four and the proportion of the reach occupied by non-pool habitats was either 10-30% or >30%.



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. 85% of the river banks were stable, 14% had limited instability, and one site had extensive instability. The extensive instability was recorded at Site 9a_4, Poison Creek on Mt Sanford Outstation.

This site was experiencing severe erosion due to the presence of cattle and, to a lesser extent, from the river crossing and vehicle access track. Even though most of the river banks in the catchment were considered stable, some form of erosion processes were recorded at 96% of sites, and aggradation was recorded at 1% of sites. Only two sites were considered absolutely stable.

Table 4.9 Bank Stability Ratings

Stability Category (Rating)	Number of Sites (% of banks)
Stable (81-100%)	60 (85)
Limited Instability (61-80%)	10 (14)
Moderate Instability (41-60%)	0 (0)
Extensive Instability (21-40%)	1 (1)
Extreme Instability (0-20%)	0 (0)
Dominant Process Recorded	
Aggradation	1 (1)
Erosion	68 (96)
Stable	2 (3)

A subjective assessment of the stability of the banks indicated that more sites recorded minimal to low overall bank instability (refer Table 4.10). A high proportion of sites were subjectively assessed as having low, low to moderate and moderate bank instability problems. Very few sites recorded 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 Banks (%)	
	Overall Instability	Susceptibility To Erosion
Minimal	11	12
Minimal to Low	2	2
Low	97	83
Low to Moderate	45	37
Moderate	45	41
Moderate to High	9	6
High	4	2

The location of instabilities along the banks, both lower and upper, is summarised in Table 4.11. Erosion was the dominant process affecting bank stability throughout the catchment and was recorded mostly at obstacles, irregularly, at floodplain scours, on outside bends and at seepage points. Aggradation along the banks was predominantly at obstacles.

Table 4.11 Location of Instability along Banks

Location of Instability	Percent of Sites (%)	
	Erosion	Aggradation
Bends - Outside	42	1
- Inside	7	3
Floodplain Scours	51	8
Obstacles	88	16
Seepage / Runoff Points	42	0
Irregular	53	5
All Along	0	0

Factors affecting bank stability are listed in Table 4.12. The instability recorded for river banks was attributed predominantly to high flow and stock. Other major factors affecting bank stability were infrastructure (ie roads, tracks, river crossings, culverts, bridges, etc), floodplain scours and areas where runoff was occurring. Only 7% of sites recorded no factors affecting bank stability.

Table 4.12 Factors Affecting Bank Stability

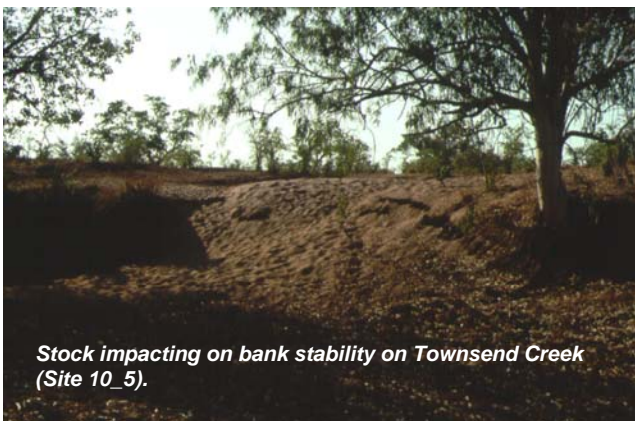
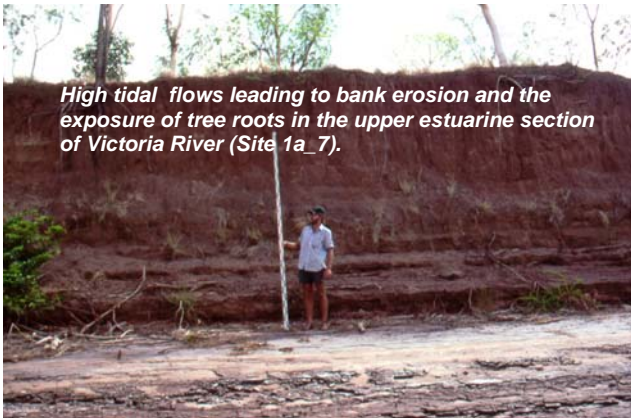
Factor	Percent of Sites (%)
High Flow	85
Stock	77
Roads/tracks, Crossings, Bridges	58
Floodplain Scours/Breakouts	51
Runoff	41
Vermin	14
Tidal Influence	9
People Tracks	5
Seepage	3
Clearing of Vegetation	1
Other	1

Lower banks were more stable than upper banks (Table 4.13). The average percent of the bank recorded as being stable was 94% for the lower bank and 85% for the upper bank. The majority of sites (84%) recorded $\geq 90\%$ of the lower banks as being stable, compared to 38% of sites having upper banks $\geq 90\%$ stable. The average percent of erosion occurring along the upper bank was 15%, though this varied from 0% to as high as 80%.

The only types of artificial bank protection measures recorded for all survey sites were fencing (along the river and/or at stock watering points), which occurred at 7% of sites, and gabions (1% of sites).

Table 4.13 Stability of Lower Banks Compared to Upper Banks

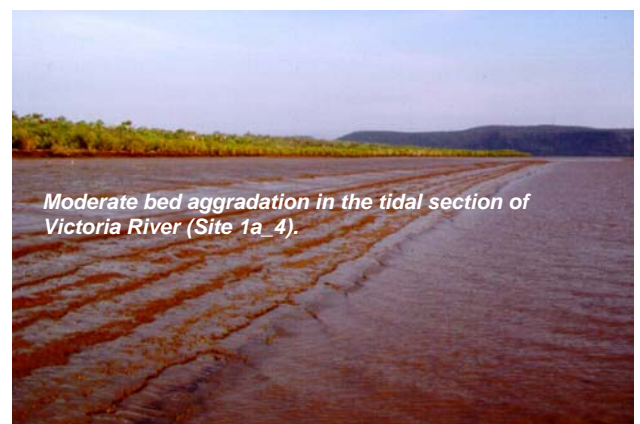
Stability Comparisons	Bank Location	
	Lower Bank	Upper Bank
Percent Sites (%) where:		
≥90% Stable	84	38
≥50% Stable	92	91
≥50% Eroding	0	1
≥50% Aggrading	0	0
Mean Percent Stable and Range (%)	94 (80-100)	85 (20-100)
Mean Percent Eroding and Range (%)	6 (0-20)	15 (0-80)
Mean Percent Aggrading and Range (%)	<1 (0-5)	1 (0-25)



The sites recording moderate bed aggradation were located on the Victoria (5 sites), Bullo (3 sites) and Camfield Rivers (3 sites), as well as Jasper Creek and Gordon Creek. Most of the Victoria River and Bullo River sites were tidal, and experience aggradation as sediments move through the estuary. Other sites, such as those on Camfield River and Gordon Creek, had relatively flat, uniform and shallow river beds with a large amount of sand and gravel. These sites were all near stock watering points and vehicle crossings, and had bank erosion, floodplain scouring and new channels forming. The site recording erosion problems was located on Poison Creek at the road crossing into Mt Sanford Outstation (Site 9a_4). Stock, and to a lesser extent the vehicle crossing and access track, have caused severe erosion of both the bed and banks at this location.

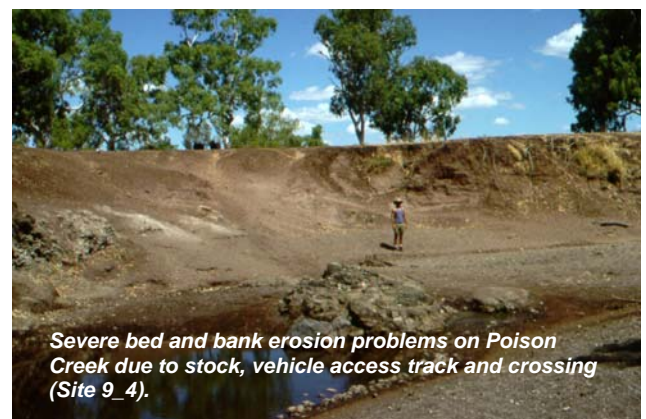
Table 4.14 Overall Bed Stability Ratings

Stability Category (Rating)	Number of Sites (%)
Stable (10)	60 (81)
Moderate Erosion or Aggradation (6)	14 (19)
Dominant Process Recorded	
Aggradation	13 (18)
Erosion	1 (1)
No process (bed stable)	60 (81)



4.4 Bed and Bar Condition and Stability

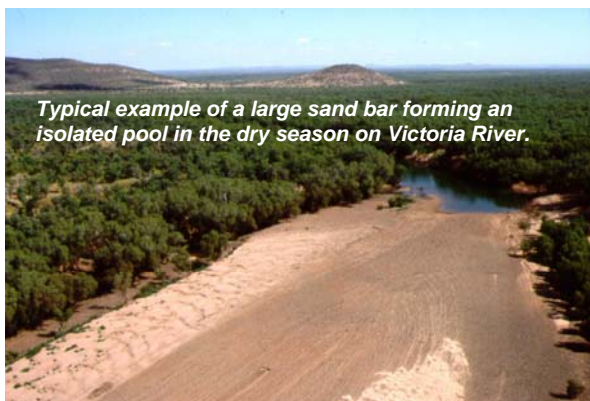
A summary of the overall bed stability throughout the catchment, based on a subjective assessment made in the field of whether the river bed is stable, moderately eroding or aggrading, or severely eroding or aggrading, is shown in Table 4.14 and Map 14. The majority (81%) of sites had stable river beds. The remaining sites recorded moderate bed aggradation (18%) or erosion (1%).



Bars were widespread (74% of sites). At sites where bars were present, 55% of bar types were encroaching vegetation bars, while a further 45% were alternate 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 averaged 18% of the bed, ranging to as high as 55%.

Table 4.15 Bar Types Recorded

Bar Type	Percent of Sites (%)	Percent of Bar Types (%)
Encroaching Vegetation	40	55
Alternate	33	45
High Flow Deposits	11	15
Point	11	15
Mid-channel Island	3	4
Around Obstacles	4	6
Channel Bar Plain	1	2



Gravel features recorded for the bed and bars showed that the gravel was mostly covered by algae or silt (90% of sites); and was composed of sub-angular (79%), rounded (23%) or angular (23%) material. The major shapes recorded for the gravel was disc-shaped (79% of sites), spherical (38%) or blade-shaped (10%). The bed compaction ranged from being packed but not armoured (41% of sites), having low compaction (34%), moderate compaction (28%), very low compaction (17%) to tightly packed and armoured (15%). 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.

Controls stabilising the bed included rock outcrops (65% of sites), fallen trees (14%) and structures like crossing and culverts (8%). No bed stabilising controls were recorded for 30% of sites.

The major factor considered to affect bed stability was grazing, which was recorded at 41% of the sites. Other processes affecting bed condition are listed in Table 4.16. No factors were found to be affecting bed stability at 45% of sites.

Table 4.16 Factors Affecting Bed Stability

Factor	Percent of Sites (%)
Agriculture or Grazing	41
Bank Erosion	12
Instream Siltation	4
Concentration of Flows	4
Bed deepening / lowering	3

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 8-14%.

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)	22	58	67
Small Sand (0.06-0.5mm)	13	13	22
Large Sand (0.5-2mm)	11	7	4
Small Gravel (2-5mm)	9	4	1
Medium Gravel (5-20mm)	7	3	1
Large Gravel (20-60mm)	8	3	1
Cobbles (60-300mm)	9	5	2
Boulders (>300mm)	21	8	3
Organic Material	14	9	8

Tables 4.18, 4.19 and 4.20 show the sediment sizes recorded for beds, lower and upper banks, respectively, for each habitat type. Pool habitats have a higher proportion of smaller bed sediments; runs and riffles have a range of bed sediment sizes; and rapids have a higher proportion of larger bed sediments. The sediments along the lower and upper banks for all habitat types consisted mainly of smaller sediment sizes, except rapids, which had boulders in the lower bank. Rock outcrops were recorded at 70% of sites and where present, they were mostly located in the bed, and to a lesser degree, the lower and upper banks.

Table 4.18 Bed Sediments Recorded for Each Habitat Type

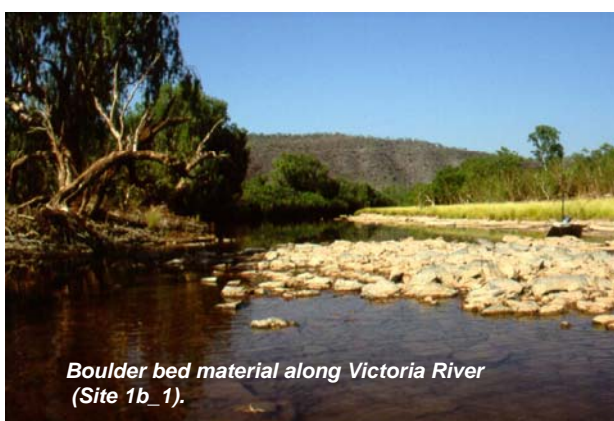
Sediment Size Classes		Mean Composition of Sediment Types for Beds (%)			
		Pool	Run	Riffle	Rapid
Fines / Clays	(<0.06mm)	31	8	12	0
Small Sand	(0.06-0.5mm)	18	3	8	1
Large Sand	(0.5-2mm)	12	4	11	3
Small Gravel	(2-5mm)	8	27	9	3
Medium Gravel	(5-20mm)	5	14	9	3
Large Gravel	(20-60mm)	5	5	11	8
Cobbles	(60-300mm)	4	23	15	21
Boulders	(>300mm)	18	18	24	62

Table 4.19 Lower Bank Sediments Recorded for Each Habitat Type

Sediment Size Classes		Mean Composition of Sediment Types for Lower Banks (%)			
		Pool	Run	Riffle	Rapid
Fines / Clays	(<0.06mm)	78	84	34	1
Small Sand	(0.06-0.5mm)	12	10	14	2
Large Sand	(0.5-2mm)	4	4	11	2
Small Gravel	(2-5mm)	1	3	6	2
Medium Gravel	(5-20mm)	1	0	5	2
Large Gravel	(20-60mm)	1	0	7	3
Cobbles	(60-300mm)	2	0	9	12
Boulders	(>300mm)	1	0	14	76

Table 4.20 Upper Bank Sediments Recorded for Each Habitat Type

Sediment Size Classes		Mean Composition of Sediment Types for Upper Banks (%)			
		Pool	Run	Riffle	Rapid
Fines / Clays	(<0.06mm)	78	72	55	14
Small Sand	(0.06-0.5mm)	18	5	25	76
Large Sand	(0.5-2mm)	3	8	5	5
Small Gravel	(2-5mm)	<1	1	1	0
Medium Gravel	(5-20mm)	<1	1	1	0
Large Gravel	(20-60mm)	<1	1	2	0
Cobbles	(60-300mm)	<1	10	5	5
Boulders	(>300mm)	1	1	5	0



4.6 Riparian Vegetation

The majority of sites (81%) 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 mangroves (10% of sites), *Eucalyptus* Wet Sclerophyl (5%), *Eucalyptus* woodland (3%) and *Lowland Monsoon* (1%).

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. The majority of the riparian vegetation was rated as having moderate cover and diversity (72% of sites), with the remaining 27% being rated as having high cover and diversity, and 1% (an estuary site) with low cover and diversity.

Table 4.21 Cover and Structural Diversity of Riparian Vegetation

Riparian Vegetation Category (Rating)	Number of Sites (%)
Very High Cover/Diversity (9-10)	0 (0)
High Cover/Diversity (7-8)	19 (27)
Moderate Cover/Diversity (5-6)	51 (72)
Low Cover/Diversity (3-4)	1 (1)
Very Low Cover/Diversity (1-2)	0 (0)



The average width of the riparian zone was 23m (range 0-155m). Averaged over both banks, only 1% of sites had a riparian zone width of <5m; 25% were between 5-10m; 30% between 11-20m; 17%

between 21-30m; 11% between 31-40m and 15% of sites had a riparian zone width of >40m. Map 16 shows the riparian vegetation width category for each site, averaged for both river banks. Those sites that recorded a riparian zone width of >40m were located on the Victoria, Bullo, East Baines, Wickham and Armstrong Rivers. The only site which had a riparian zone <5m was located on Giles or Wattie Creek.

The more common native species recorded at 10% or greater of sites are shown in Table 4.22. A full list of the riparian vegetation species recorded throughout Victoria River catchment is shown in Appendix D. *Eucalyptus camaldulensis* was the most widespread species recorded at 73% of sites. Other common overstorey species included the *Lophostemon grandiflorus*, *Terminalia platyphylla*, *Pandanus aquaticus* and *Ficus coronulata*.

The most widespread ground cover species was *Eriachne festucacea*, located at 38% of sites. Other common ground cover species included the *Achyranthes aspera*, *Cynodon dactylon* and *Heteropogon contortus*.

Mangrove species found along the Victoria River estuary included *Aegialitis annulata*, *Aegiceras corniculatum*, *Avicennia marina*, *Ceriops australis*, *Excoecaria ovalis* and *Lumnitzera racemosa*. The most widespread mangrove species was *Avicennia marina* recorded at 10% of sites, followed by *Excoecaria ovalis* (8%), *Aegialitis annulata* (5%) and *Aegiceras corniculatum* (4%).



The structural types recorded for the vegetation in the riparian zone, including both native and exotic species, are shown in Table 4.23. Forbs or herbs and regenerating trees (<2m) were present at 97% of sites, small (2-10m) trees and grasses were present at 95% of sites, and woody shrubs and medium (10-30m) trees were recorded at 93% and 90% of sites, respectively. There were no large trees (>30m) in the riparian zone at any of the sites, nor was there any salt marsh. Vines, rushes and sedges, mangroves and phragmites varied in their prevalence and distribution. Only 1% of sites had palms or ferns.

Table 4.22 More Common Native Riparian Vegetation

Plant Name – <i>Genus species</i>	Common Name	Structural Type	Percent of Sites (%)
<i>Eucalyptus camaldulensis</i>	River Red Gum	Tree	73
<i>Lophostemon grandiflorus</i>	Northern Swamp Box	Tree	64
<i>Terminalia platyphylla</i>	Wing-seed Terminalia	Tree	64
<i>Pandanus aquaticus</i>	River Pandanus	Tree	56
<i>Ficus coronulata</i>	Peach-leaf Fig	Tree	55
<i>Melaleuca leucadendra</i>	Cajaput	Tree	51
<i>Acacia holosericea</i>	Candelabra Wattle	Low tree / shrub	40
<i>Eriachne festucacea</i>		Grass	38
<i>Nauclea orientalis</i>	Leichhardt Tree	Tree	38
<i>Atalaya hemiglauc</i>	Whitewood	Low tree / shrub	36
<i>Eucalyptus microtheca</i>	Coolibah	Tree	36
<i>Excoecaria parvifolia</i>	Guttapercha Tree	Tree	36
<i>Achyranthes aspera</i>	Chaff-flower	Forb	35
<i>Ficus racemosa</i>	Cluster Fig	Tree	34
<i>Lysiphyllum cunninghamii</i>	Bauhinia	Tree	32
<i>Barringtonia acutangula</i>	Freshwater Mangrove	Low tree / shrub	31
<i>Flueggea virosa</i>		Low tree / shrub	29
<i>Cynodon dactylon</i>	Couch Grass	Grass	27
<i>Terminalia bursarina</i>	Bendee	Tree	26
<i>Cyperus vaginatus</i>	Stiff-leaf Sedge	Forb	19
<i>Heteropogon contortus</i>	Bunch Speargrass	Grass	18
<i>Chionachne cyathopoda</i>		Grass	16
<i>Sesbania formosa</i>	White Dragon Tree	Tree	16
<i>Cathormion umbellatum</i>		Low tree / shrub	14
<i>Eragrostis tenellula</i>		Grass	14
<i>Arundinella nepalensis</i>	Reedgrass	Grass	13
<i>Chara sp.</i>		Forb	13
<i>Ziziphus quadrilocularis</i>		Tree	12
<i>Avicennia marina</i>	White Mangrove	Mangrove	10
<i>Bothriochloa bladhii</i>	Forest Bluegrass	Grass	10
<i>Eucalyptus bella</i>		Tree	10
<i>Melaleuca argentea</i>	Silver Paperbark	Tree	10
<i>Phyllanthus reticulatus</i>		Low tree / shrub	10
<i>Strychnos lucida</i>	Strychnine Bush	Low tree / shrub	10



Table 4.23 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)*	90	16 (0-30)
Trees (2-10m)*	95	18 (0-40)
Regen. Trees (<2m)*	97	6 (0-13)
Woody Shrubs (<2m)*	93	6 (0-15)
Vines	73	4 (0-20)
Rushes and Sedges*	48	3 (0-12)
Phragmites*	5	<1 (0-8)
Forbs (or Herbs)*	97	5 (0-17)
Grasses*	95	29 (0-75)
Ferns*	1	<1 (0-5)
Mangroves*	10	2 (0-40)
Salt Marsh	0	0
Palms	1	< (0-12)

* Can be included as riparian and emergent aquatic vegetation

Assessment of the percentage cover of the surface area for each structural type in the riparian zone was also made (refer Table 4.23). Grasses provided the highest percentage cover of 29%, and trees between 2-30m provided 16-18% cover.

The percentage of the lower and upper bank length that was bare of vegetation cover was assessed, where overstorey comprised trees and shrubs greater than 1.3m tall, and understorey included grasses and other ground cover species. In general, the lower banks had a higher percentage of bare ground than the upper banks, with 92% (range 70-98%) of the overstorey and 93% (range 10-100%) of the understorey recorded as bare ground. The average bare bank on the upper banks was 71% (range 30-90%) for the overstorey and 66% (22-95%) for the understorey.

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. The rating takes into account the degree of invasion (or percentage cover) recorded for exotic species within the riparian zone. Exotic riparian vegetation species were widespread, being recorded at 79% of sites (refer Table 4.24). No exotic species were recorded at 21% of sites, whilst 45% of sites recorded between 1-15%. The remaining 34% of sites recorded >16% cover of exotic species. These sites were along the Victoria, Bullo, Baines and Wickham Rivers, and Jasper and Giles or Wattie Creeks.

Table 4.24 Cover of Exotic Riparian Vegetation

% Cover Category (Rating)	Number of Sites (%)
0 (10)	15 (21)
1 - 5 (8)	12 (17)
6 - 10 (6)	10 (14)
11 - 15 (4)	10 (14)
>16* (2)	24 (34)

* The maximum % cover recorded for exotic vegetation within the riparian zone, averaged for both river banks at a site, was 42%.

The mean total cover of exotic species in the riparian zone was 11% (with a range of 0-42%). The structural types and percentage covers recorded for the exotic vegetation are shown in Table 4.25. The most common exotic structural types were vines and forbs. The average percentage covers for the exotic vegetation was low with both vines and forbs averaging 4% cover. Exotic species that are declared as noxious within the Northern Territory were located at 58% of sites.

Table 4.25 Structural Categories Present in the Riparian Zone and Cover for Exotic Vegetation

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Trees (2-10m)	36	2 (0-20)
Woody Shrubs (<2m)	27	1 (0-9)
Vines	60	4 (0-20)
Forbs (or Herbs)	59	4 (0-15)
Grasses	11	1 (0-25)

The major exotic species recorded with their percentage covers are shown in Table 4.26 (also refer to Appendix D). Stinking Passion Flower (*Passiflora foetida*), a naturalised vine, *Parkinsonia aculeata*, and Noogoora Burr (*Xanthium occidentale*) were the three major species recorded throughout the catchment. They were recorded at 60%, 30% and 30% of sites, respectively. Maps 18, 19 and 20 show their cover and distribution. Other notable exotic species included Spiked Malvastrum (*Malvastrum americanum*), Rubber Bush (*Caloptropis procera*), *Hyptis suaveolens* and *Melochia pyramidata*.

Of the 19 different exotic species recorded, eight are declared noxious within the Northern Territory. *Parkinsonia aculeata* and *Xanthium occidentale*, two of the three most prevalent weeds in the Victoria River catchment, are noxious weeds, and were widespread, being recorded at one third of the sites assessed. Other noxious weeds recorded at a high proportion of sites include *Caltropis procera* and *Hyptis suaveolens*, both recorded at 12% of sites.

Table 4.26 More Common Exotic Riparian Vegetation

Plant Name - <i>Genus species</i>	Structural Type	Percent of Sites (%)	Mean Percent Cover and Range (%)
<i>Passiflora foetida</i> (Stinking Passion Flower)	Vine (climber)	60	6 (2-15)
<i>Parkinsonia aculeata</i> (Parkinsonia)*	Low tree / shrub	30	5 (1-10)
<i>Xanthium occidentale</i> (Noogoora Burr)*	Herb / forb	30	8 (2-12)
<i>Malvastrum americanum</i> (Spiked Malvastrum)	Herb / forb	13	2 (1-2)
<i>Calotropis procera</i> (Rubber Bush)*	Low tree / shrub	12	4 (2-5)
<i>Hyptis suaveolens</i> (Hyptis)*	Herb / forb	12	4 (2-5)
<i>Melochia pyramidata</i>	Herb / forb	12	2 (1-3)
<i>Acacia farnesiana</i> (Mimosa Bush)	Low tree / shrub	8	3 (2-5)
<i>Euphorbia hirta</i> (Asthma Plant)	Herb / forb	8	2 (1-2)
<i>Ricinus communis</i> (Castor Oil Plant)*	Shrub	8	7 (1-9)
<i>Cenchrus ciliaris</i> (Buffel Grass)	Grass	4	12 (2-25)
<i>Chloris inflata</i>	Grass	4	4 (2-5)
<i>Echinochloa colona</i> (Awnless Barnyard Grass)	Grass	4	8 (8-8)
<i>Sida acuta</i> (Spiny-head Sida)*	Herb / forb	4	4 (3-5)
<i>Acanthospermum hispidum</i> (Starburr)*	Herb / forb	3	4 (2-5)
<i>Cardiospermum halicacabum</i> (Balloon Vine)	Vine	3	8 (8-8)
<i>Sida cordifolia</i> (Flannel Weed)*	Herb / forb	3	5 (4-5)
<i>Aerva javanica</i> (Kapok Bush)	Herb / forb	1	2 (2-2)
<i>Urochloa mosambicensis</i> (Sabi Grass)	Grass	1	13 (10-15)

* Declared Noxious Weed within the Northern Territory



(Photo provided by Weeds Branch, DIPE)

4.7 Aquatic Vegetation

Two-thirds (66%) of sites assessed recorded the presence of aquatic vegetation as submerged, emergent or floating vegetation types. The average percentage of bare sites (ie no aquatic vegetation) was 89% (range 12-100%).

The cover and distribution of submerged, emergent and floating aquatic vegetation throughout the Victoria River catchment is presented in Maps 21, 22 and 23 respectively.

Most aquatic vegetation was present as emergent vegetation (59% of sites), with an average of 7% cover (range 0-40%). Submerged vegetation was present at 21% of sites and recorded an average cover of 3% (range 0-65%). Floating vegetation was more scattered in its distribution and was found at 6% of sites and recorded an average cover of 0.3% (range 0-5%). Table 4.27 shows the structural categories recorded for submerged, floating and emergent aquatic vegetation and their percentage covers.

Table 4.27 Structural Categories and Cover for Vegetation in the Aquatic Zone

Structural Category	Percent of Sites (%)	Mean Percent Cover and Range (%)
Submerged:		
- Filamentous algae	3	<1 (0-5)
- Chara / Nitella	14	2 (0-18)
- Herb like forms	3	1 (0-65)
- Myriophyllum	4	<1 (0-12)
Floating:		
- Water lilies	4	0.2 (0-5)
Emergent:		
- Phragmites*	3	<1 (0-5)
- Rushes / Sedges*	8	<1 (0-5)
- Pandanus*	20	4 (0-15)
- Melaleuca*	25	6 (0-10)
- Other shrubs/trees*	17	1 (0-40)
- Other ground covers*	13	<1 (0-25)

* Can be included as riparian and emergent aquatic vegetation

Major species recorded (at greater than 5% of sites) for submerged, floating and emergent vegetation and their percentage covers, where present, are shown in Table 4.28. No exotic aquatic vegetation species were recorded in the Victoria River catchment.

Table 4.28 Major Species and Cover Recorded for Aquatic Vegetation

Plant Name / Aquatic Zone*	Percent of Sites (%)	Mean Percent Cover and Range (%)
<i>Melaleuca leucadendra</i> (E)	21	6 (5-10)
<i>Pandanus aquaticus</i> (E)	18	8 (5-15)
<i>Chara sp.</i> (S)	14	12 (5-18)
<i>Avicennia marina</i> (E)	7	13 (5-28)
<i>Excoecaria ovalis</i> (E)	6	4 (3-5)
<i>Eriachne festucacea</i> (E)	6	10 (5-18)
<i>Aegialitis annulata</i> (E)	6	4 (3-5)
<i>Myriophyllum verrucosum</i> (S)	4	11 (10-12)
<i>Aegiceras corniculatum</i> (E)	4	8 (3-12)
<i>Cyperus victoriensis</i> (E)	3	5 (5-5)
<i>Cyperus vaginatus</i> (E)	3	5 (4-5)
<i>Melaleuca argentea</i> (E)	3	5 (2-8)
<i>Nymphaea violacea</i> (F)	3	4 (4-4)
<i>Cynodon dactylon</i> (E)	3	8 (5-10)
<i>Phragmites karka</i> (E)	3	5 (4-5)
<i>Muehlenbeckia florulenta</i> (E)	3	5 (5-5)
<i>Ceriops australis</i> (E)	3	4 (3-5)

* Zones include: S = Submerged F = Floating E = Emergent



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 4.29 and Map 24. 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 (62% of sites) or moderate cover and diversity (37%). One site on the Wickham River rated very high with regard to the cover and diversity. There were no sites with a rating of low or very low cover and diversity of instream and bank habitats.

Table 4.29 Cover and Diversity of Instream and Bank Habitats

Instream/Bank Habitat Category (Rating)	Number of Sites (%)
Very High Cover/Diversity (81-100%)	1 (1)
High Cover/Diversity (61-80%)	44 (62)
Moderate Cover/Diversity (41-60%)	26 (37)
Low Cover/Diversity (21-40%)	0 (0)
Very Low Cover/Diversity (0-20%)	0 (0)



An overall aquatic rating for all aquatic life was also assigned to each site surveyed (refer Table 4.30). This assessment is a subjective measure determined during field surveys and 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. The majority of sites rated as good (63%), with 6% rating very high or good to very high, and the remaining 31% rating poor to good, poor and very poor.

Table 4.30 Overall Aquatic Condition based on Subjective Ratings

Condition Category	Percent of Sites (%)
Very High / Pristine	3
Good to Very High	3
Good	63
Poor to Good	19
Poor	11
Very Poor	1

Instream and bank habitat types are summarised in Tables 4.31 and 4.32. The most commonly occurring instream cover types included branches, leaves and twigs, logs, tree roots, rock faces and permanent pools deeper than 1m. Stream bed cover provided from the banks was dominated by vegetation canopy cover, vegetation overhang less than 1m from the water, and root overhang. The canopy cover provided a mean width of 2.7m and occurred along a mean of 62% of the bank length.

Table 4.31 Instream Habitat Types

Instream Habitat Type	Percent of Sites (%)	Mean Percent Cover and Range (%)
Logs	90	7 (0-12)
Log Jam		
- <50% dense	7	0.3 (0-5)
- >50% dense	4	0.1 (0-5)
Branches	99	7 (0-12)
Branch Piles		
- <50% dense	23	1 (0-10)
- >50% dense	0	0
Leaves and Twigs	93	13 (0-80)
Macrophyte Fragments	3	0.1 (0-5)
Algal Clumps	37	2 (0-15)
Large Submerged Plants - Freshwater	1	1 (0-65)
Mangroves	10	1 (0-20)
Floating Vegetation	1	0.1 (0-4)
Emergent Vegetation	31	2 (0-20)
Tree Roots	89	8 (0-25)
Rock Faces	77	26 (0-100)
Permanent Pool >1m Deep	62	35 (0-100)
Built Structures/ Debris	13	0.5 (0-5)

Table 4.32 Bank Habitat Types

Bank Cover	Percent of Sites (%)	Mean Bank Length and Range (%)	Mean Width of Type and Range (m)
Canopy	100	62.4 (10-90)	2.7 (0.2-7.9)
Vegetation Overhang	100	26.5 (4-85)	2.1 (0.1-29)
Root Overhang	96	11.5 (0-80)	1.1 (0.0-29)
Bank Overhang	17	0.9 (0-10)	0.0 (0-0.3)
Built Structures	4	0.2 (0-4)	0 (0-2)



At the time of the survey 49% of sites had no passage for fish and other aquatic organisms; 35% were partly to very restricted; and 16% had good, or unrestricted passage. If the water level was normal, or at 'water mark', 100% sites had passage, 73% of sites had some form of restriction, and 27% 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 4.33:

- 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 4.33 Overall Condition Rating

Overall Condition Rating (%)	General Term Used to Describe Overall Condition	Number of Sites (%)
81-100*	Very High	9 (13)
61-80	High	62 (87)
41-60	Moderate	0 (0)
21-40	Low	0 (0)
0-20	Very Low	0 (0)

* 100% = Ideal, undisturbed or natural state

The results indicate that all of the sites recorded a high overall condition rating (87% of sites) or a very high overall condition rating (13%). No sites were rated as being moderate, low or very low condition. Map 25 shows the overall condition ratings for sites throughout the Victoria River catchment.

The average of the overall condition for all sites within each sub-section was ranked from highest to lowest, and the results are listed below:

1. Angalarri River
2. Armstrong River
3. Wickham and Humbert Rivers
4. Giles or Wattie Creek
5. Victoria River – upper catchment
6. Baines River
7. Jasper Creek
8. Victoria River – estuary
9. Gregory and Delamere Creeks
10. Battle Creek
11. Gordon Creek
12. Bullo River
13. Victoria River – below Jasper Creek
14. Camfield River
15. Victoria River – below Camfield River



5. SUB-CATCHMENT RESULTS

Maps 10-25 show the results for the condition and stability ratings and other attributes for the whole of the Victoria River catchment (refer Section 4). Figures 5.1-5.15 show each sub-section within the Victoria River catchment.

The Victoria River catchment has been divided into the following 15 major sub-catchments (shown in Map 6):

- Victoria River
 - Estuary
 - Below Jasper Creek
 - Below Camfield River
 - Upper Catchment
- Bullo River
- Baines River
- Angalarri River
- Gregory or Delamere Creeks
- Battle Creek
- Jasper Creek
- Wickham and Humbert Rivers
- Gordon Creek
- Armstrong River
- Camfield River
- Giles or Wattie Creek

The following information is presented for each of the sub-sections that have been grouped according to the major sub-catchments in the Victoria River catchment (listed above):

1. A map showing each sub-section.

Figures 5.1-5.15 show each sub-section within the Victoria River catchment. Each figure shows the location of sites, sample points and vegetation profiles within each sub-section. The location of longitudinal profile surveys (ie depth measurements along the streams' 'thalweg') is highlighted. Boundaries of nature parks and/or national parks and the location of towns and communities are also shown.

2. A chart summarising the results for the overall condition ratings for each sub-section.

Charts 5.1-5.15 show the overall condition rating score for sites within each sub-section. The six components that make up the overall condition rating are:

- 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

Each of the six components is rated out of 10 giving a final 'Overall Condition Rating Score' out of 60. 10 represents an ideal, undisturbed or natural state and 1 is very disturbed or unstable.

3. A summary of the major findings and issues within each sub-section.

**"Major" disturbances or exotic species means that they were recorded at $\geq 33\%$ of sites.
"Minor" disturbances or exotic species means that they were recorded at $< 33\%$ of sites.**

5.1 Victoria River

5.1.1 Victoria River Estuary

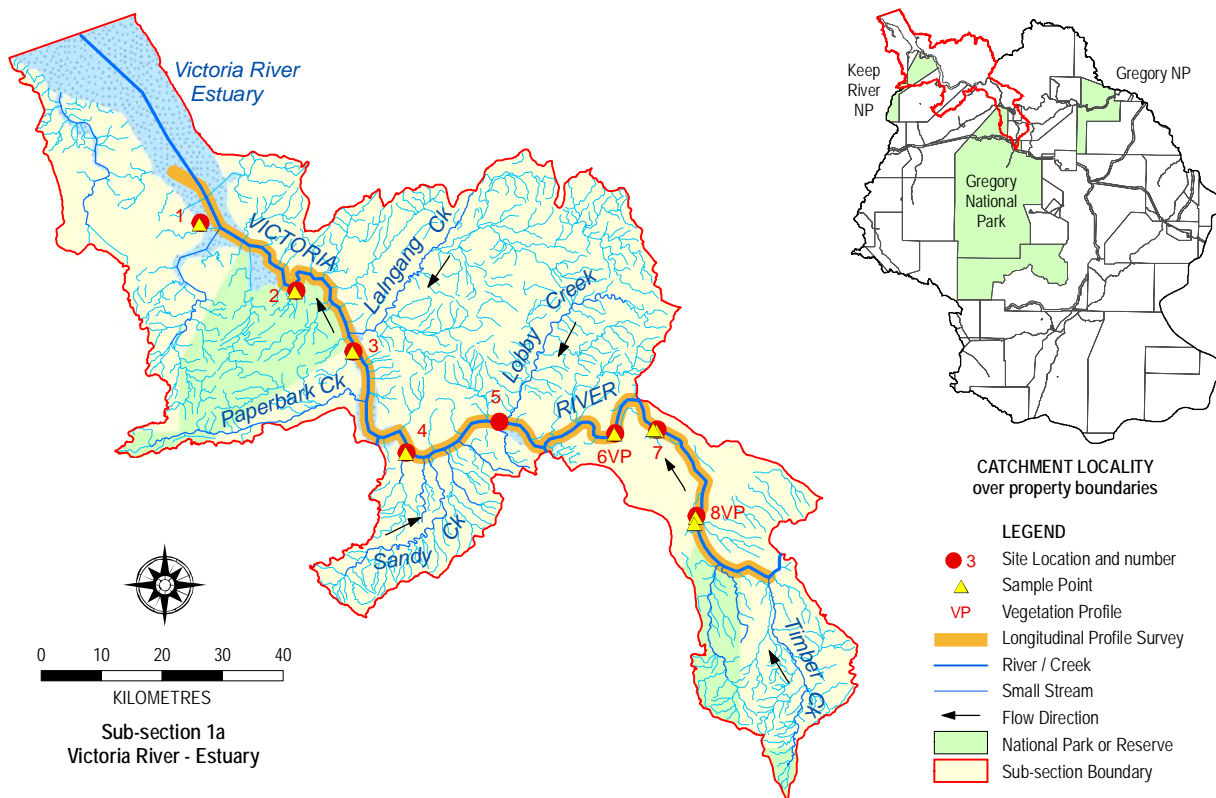
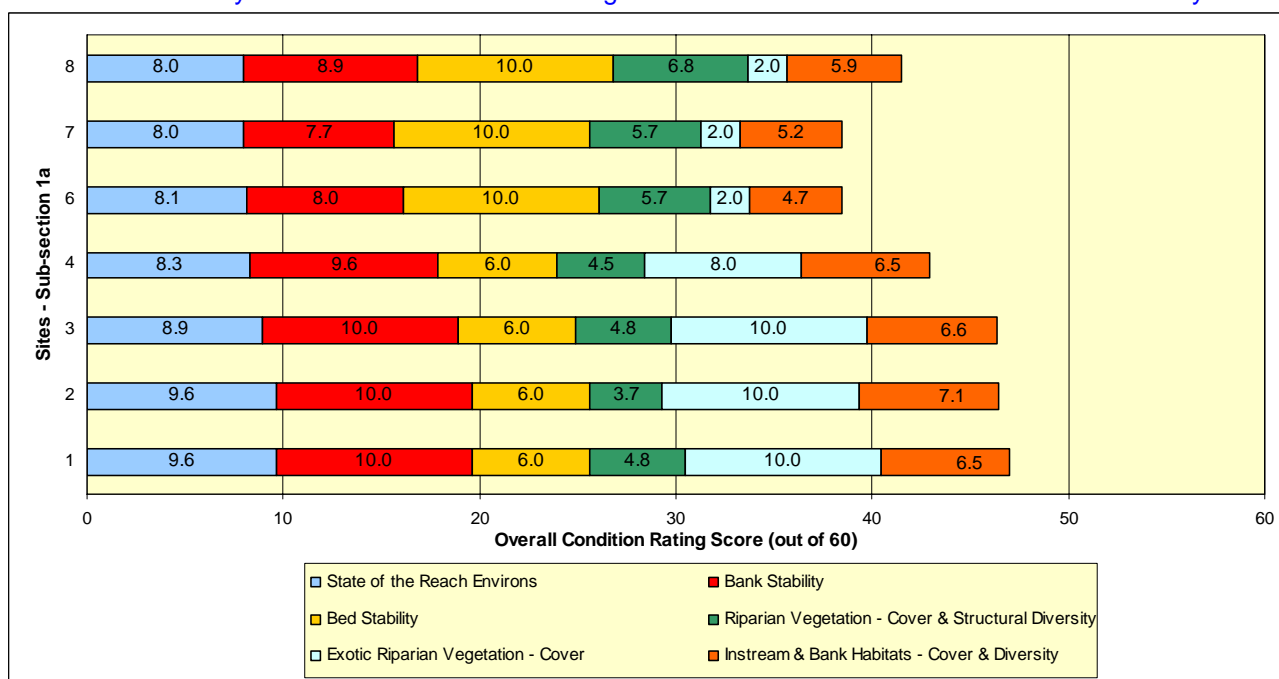


Figure 5.1 Locality Map of Sub-section 1a - Victoria River Estuary

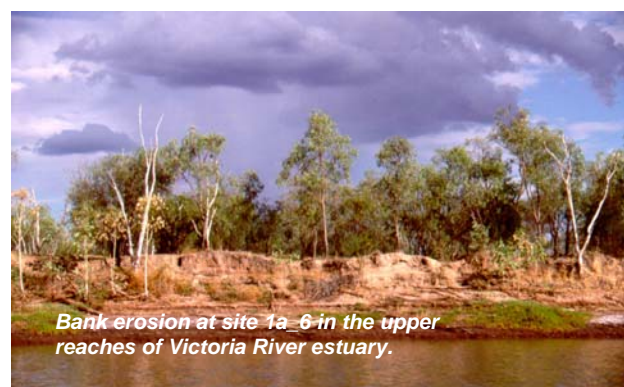
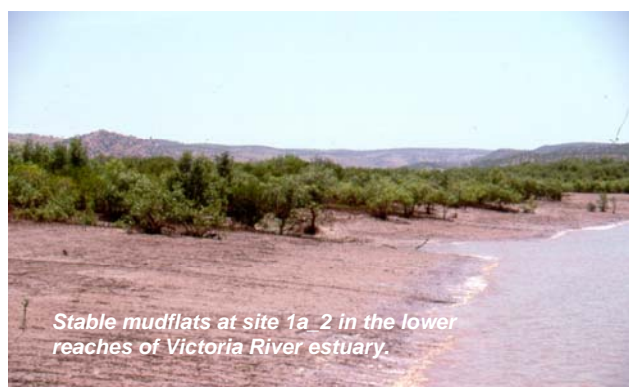
Sub-section 1a incorporates the tidal section of Victoria River, downstream from Saltwater Yards. Eight sites were located on this section of the River, only seven were fully assessed.

Chart 5.1 Summary of the Overall Condition Rating Score for Sub-section 1a – Victoria River Estuary



Summary of the major findings for Sub-section 1a – Victoria River Estuary

- Reach environs:** All reaches were rated as being essentially natural except for Sites 1a_7 and 1a_8 which had some modification due to grazing.
- Disturbances: Minor - grazing.
- Bank stability:** All sites were rated as having stable river banks except Sites 1a_6 and 1a_7 which had limited instability. The major process at these sites was erosion.
- Disturbances: Major - high flow/tidal influence, stock.
- Bed stability:** The upper estuary sites had stable beds. Sites 1a_1, 1a_2, 1a_3 and 1a_4, at the lower end of the estuary, were rated as moderately aggrading.
- Channel habitat types:** Pools were present at all sites. The only other habitat type recorded was riffles at 1a_7 (Skeg Rock) and 1a_8. Diversity of channel habitat types was low at the sites with only long pools, and high where riffles and pools were present.
- Riparian vegetation:** The cover and structural diversity rating for the riparian vegetation included high, moderate and low. Mangroves were the dominant vegetation community on the lower tidal section downstream of Angalarri River, whilst vegetation associated with freshwater streams was present at the upstream sites. The cover provided by overstorey vegetation (ie trees and shrubs greater than 1.3m tall) along the upper banks averaged 25% whilst ground covers averaged 22%. The mean width of the riparian vegetation was 43m (range 18-95m).
- Exotic riparian vegetation:** The level of exotic species invasion ranged from nil in the lower tidal section, to low (1-5% cover) in the tidal section upstream of the junction of Bullo River, and high (16-42% cover) at Sites 1a_6, 1a_7 and 1a_8 in the upper section of the estuary. [Note * = species declared noxious in NT]
- Major species: *Parkinsonia aculeata**, *Passiflora foetida*, *Xanthium occidentale**
 Minor species: *Malvastrum americanum*, *Calotropis procera**
- Aquatic vegetation:** All sites recorded the presence of emergent aquatic vegetation. The mangrove species, *Avicennia marina*, was the most widely distributed species.
- Instream and bank habitats:** The lower estuary sites were rated as having high cover and diversity of instream and bank habitats, whilst the upper estuary sites rated as moderate.
- Overall condition:** All sites were rated as having high overall condition.
- MAJOR ISSUES:** Weed invasion was high in the upper tidal reaches. Tidal influence and high flows, impacts from cattle and native fauna (eg Wallabies) were other factors contributing to disturbances. Low habitat diversity ratings can be attributed to the dominance of pools in the tidal section.



5.1.2 Victoria River – Below Jasper Creek

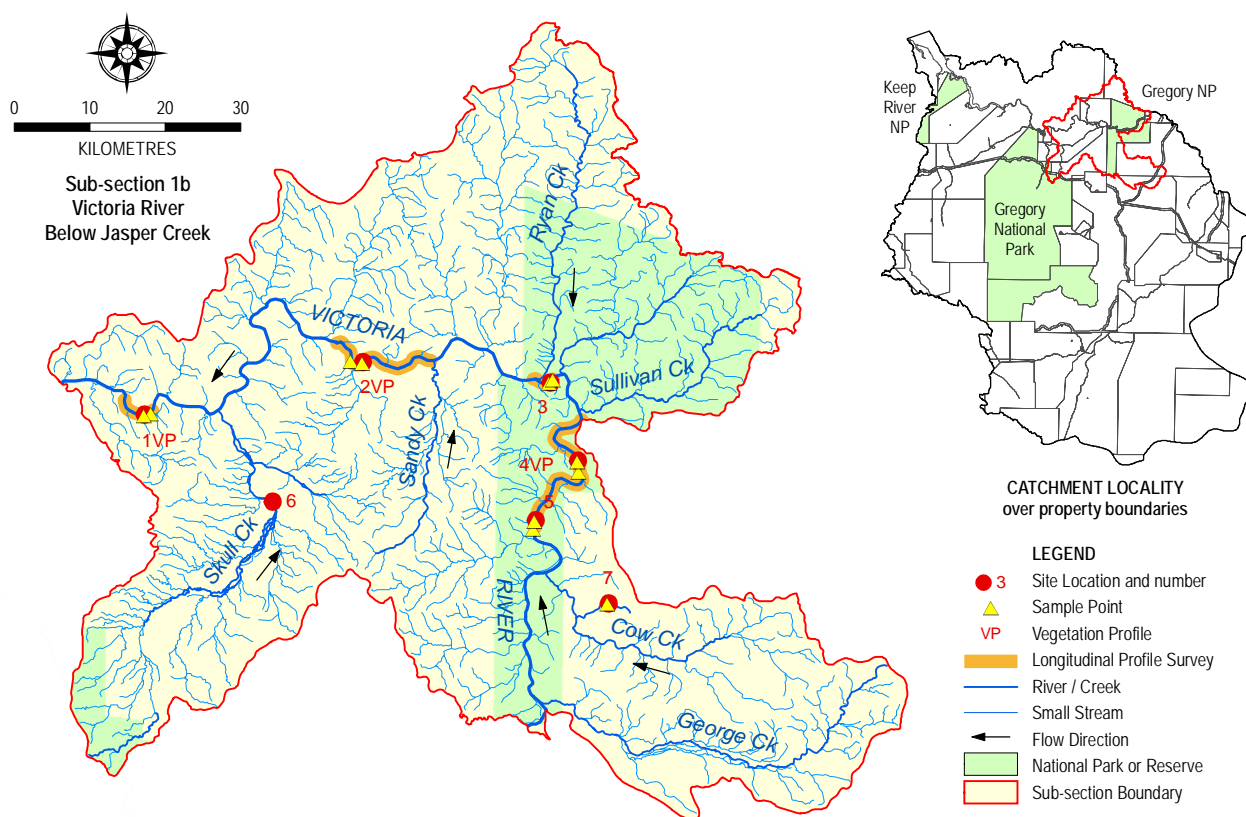
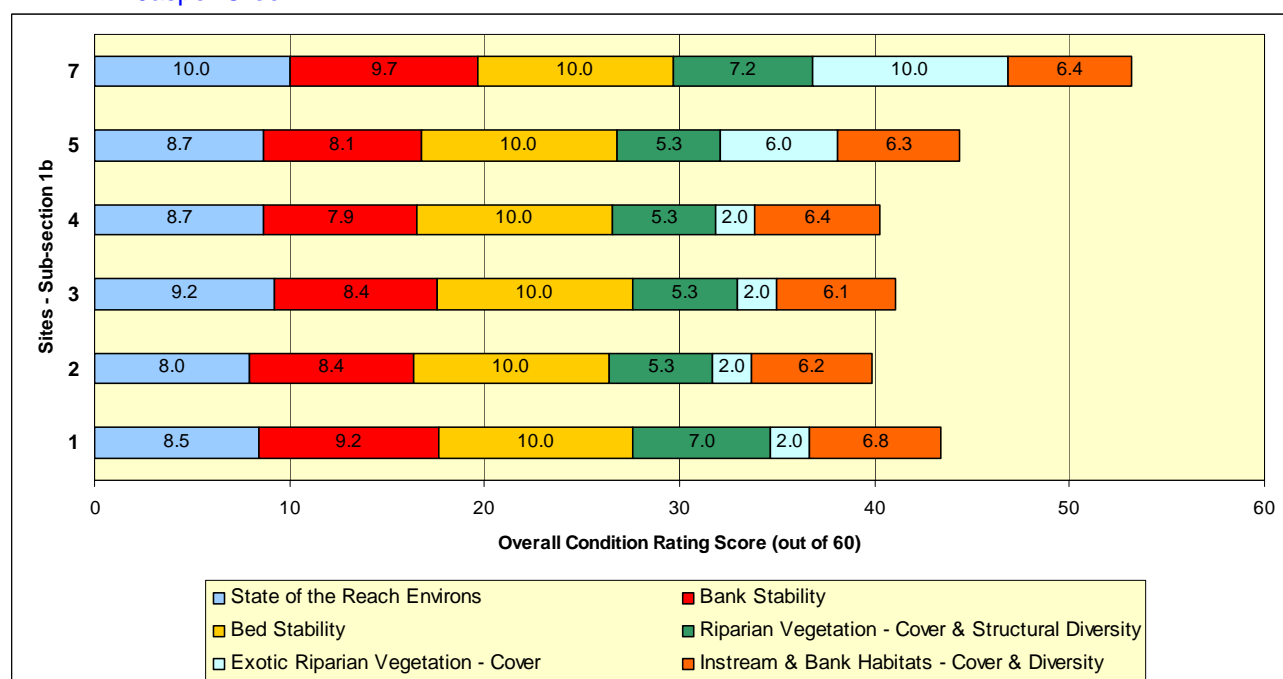


Figure 5.2 Locality Map of Sub-section 1b – Victoria River below Jasper Creek

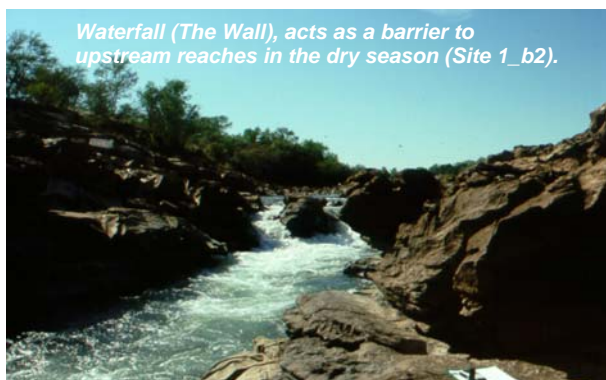
Sub-section 1b includes five sites on the Victoria River from upstream of Saltwater Yards to Jasper Creek, one site on Skull Creek and one site on an arm of Cow Creek. Of the seven sites, six were fully assessed.

Chart 5.2 Summary of the Overall Condition Rating Score for Sub-section 1b – Victoria River below Jasper Creek



Summary of the major findings for Sub-section 1b – Victoria River below Jasper Creek

- Reach environs:** Five of the six sites assessed were rated as essentially natural. Site 1b_2 had some modification due to stock access to the river.
- Disturbances: Major - grazing, roads/tracks
Minor - bridge/causeway, animal watering point
- Bank stability:** All sites were rated as having stable river banks except 1b_4 which had limited instability. The dominant bank process was erosion.
- Disturbances: Major - high flow, runoff, stock, vermin
Minor - seepage, bridge/causeway, floodplain scours
- Bed stability:** All sites were rated as having stable river beds. Rocky bars were present at all sites, averaging 19% of the bed surface, and up to 38% at 1b_1.
- Channel habitat types:** Pools and riffles were present at all sites. Other habitat types included a waterfall, a rapid, and runs. Diversity of channel habitat types rated as high to very high in this sub-section.
- Riparian vegetation:** The cover and structural diversity rating for the riparian vegetation ranged from moderate to high. Vegetation associated with freshwater streams was present at all sites. The cover provided by overstorey vegetation (ie trees and shrubs greater than 1.3m tall) along the upper banks averaged 38% whilst ground covers averaged 34%. The mean width of the riparian vegetation was 32m (range 17-46m).
- Exotic riparian vegetation:** No exotic species were recorded at Site 1b_7. The remaining sites all recorded the presence of exotic species ranging from low (1-5% cover), to high (16-42% cover). *Passiflora foetida* was recorded at 87% of sites, and *Xanthium occidentale** and *Ricinus communis** were recorded at 71% and 57% of sites, respectively. [Note * = species declared noxious in NT]
- Major species: *Passiflora foetida*, *Xanthium occidentale**, *Ricinus communis**
- Aquatic vegetation:** Four of the six sites recorded the presence of aquatic vegetation as emergent and submerged types. *Melaleuca leucadendra* was the most widespread species, occurring at 33% of the sites.
- Instream and bank habitats:** All sites were rated as having high cover and diversity of instream and bank habitats. The canopy cover along the bank averaged 71% of the bank length.
- Overall condition:** 1b_7 rated very highly overall, and the remaining sites all rated highly.
- MAJOR ISSUE:** High level of weed invasion along rivers that were located both inside and outside of Gregory National Park.



5.1.3 Victoria River – Below Camfield River

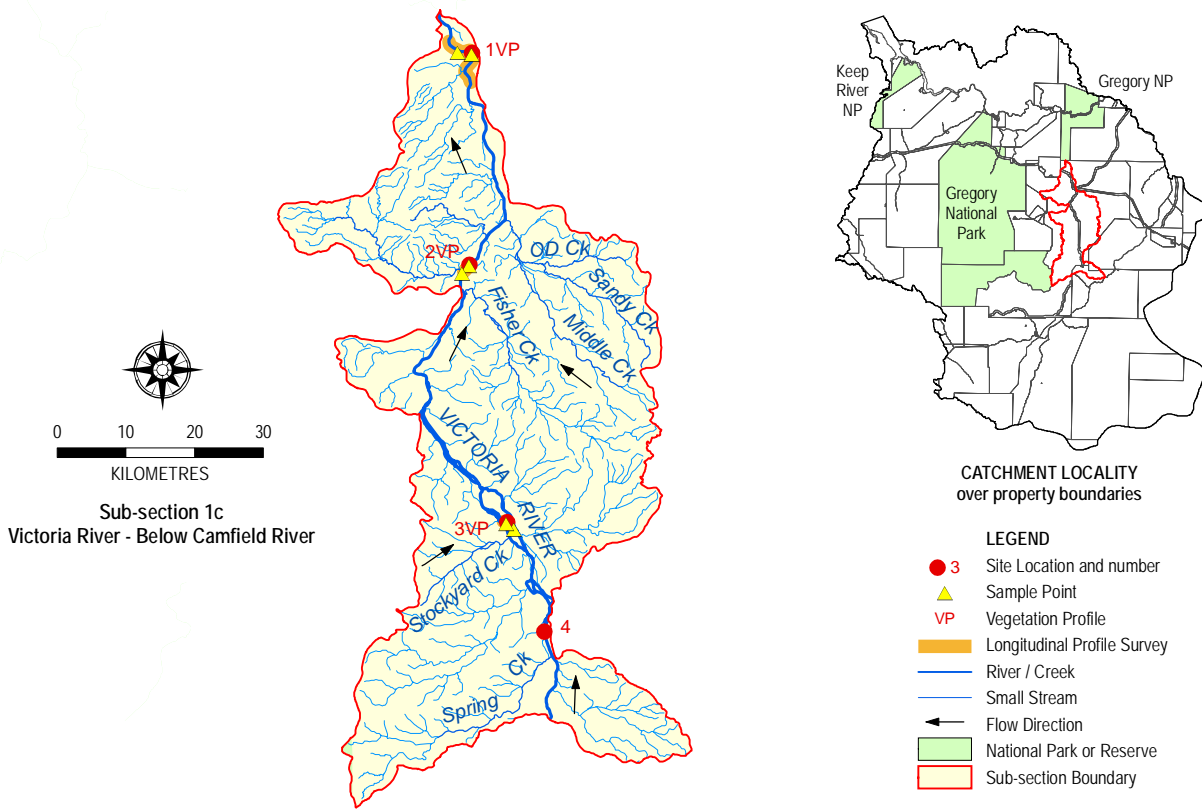
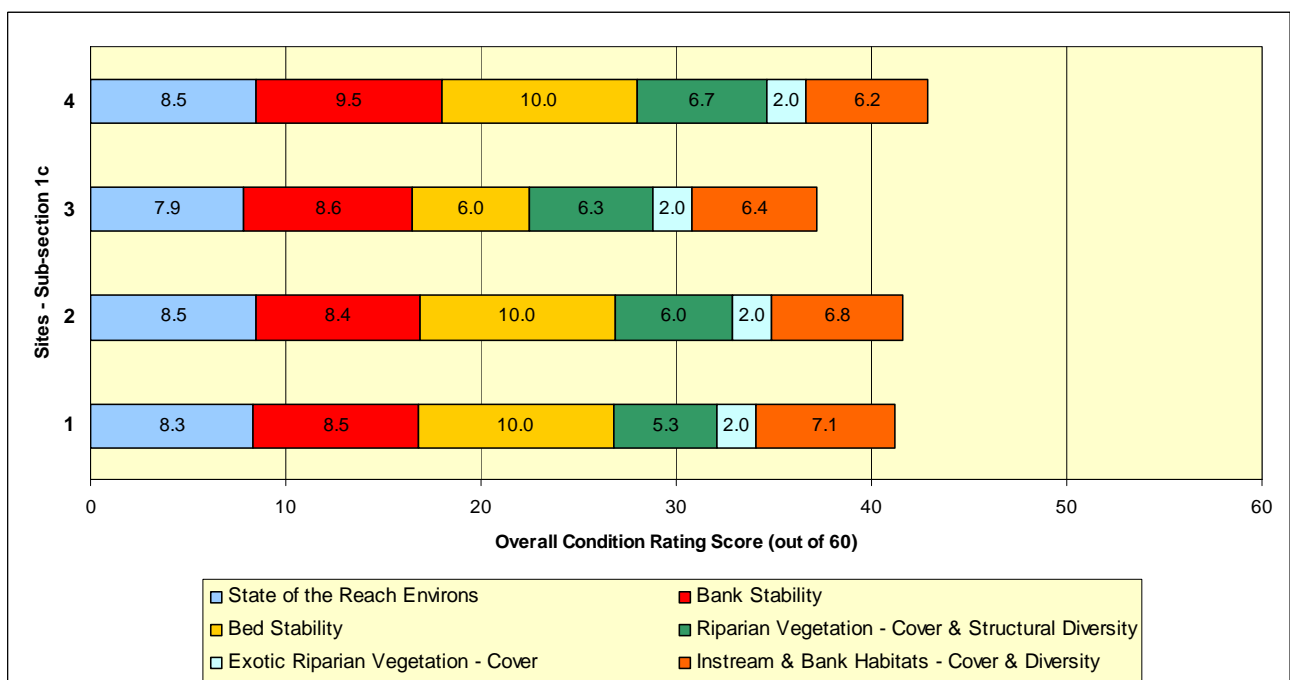


Figure 5.3 Locality Map of Sub-section 1c – Victoria River below Camfield River

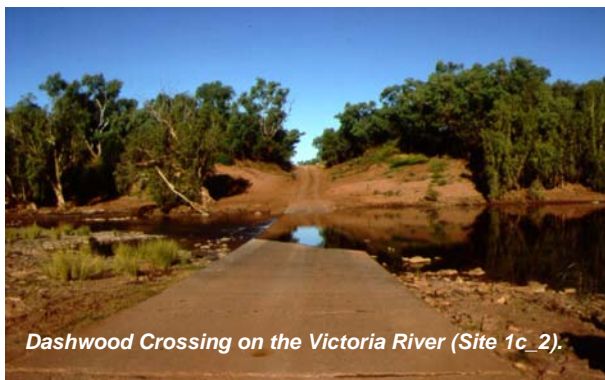
Sub-section 1c encompasses the Victoria River from Jasper Creek upstream to Camfield River. All four sites on Victoria River were fully assessed.

Chart 5.3 Summary of the Overall Condition Rating Score for Sub-section 1c – Victoria River – Below Camfield River



Summary of the major findings for Sub-section 1c – Victoria River below Camfield River

- Reach environs:** Three sites were rated as essentially natural whilst 1c_3 had some modification due to cattle access to the river.
- Disturbances: Major - road/track, grazing, causeway/crossing
 Minor - water extraction site, animal watering point
- Bank stability:** All sites were rated as having stable river banks.
- Disturbances: Major - high flow, runoff, stock, roads/tracks, floodplain scours
 Minor - people tracks
- Bed stability:** Three sites had stable river beds, and 1c_3 had moderate aggradation. All sites had large sand and gravel bars, covering an average of 36% of the bed surface, and up to 55% at 1c_3.
- Channel habitat types:** Pools were present at all sites, rapids and riffles were also present at some sites. Diversity of channel habitat types rated highly at all sites.
- Riparian vegetation:** The cover and structural diversity rating for the riparian vegetation was moderate at three sites, and high at one site. The cover provided by overstorey vegetation (ie trees and shrubs greater than 1.3m tall) along the upper banks averaged 36% whilst ground covers averaged 24%. The mean width of the riparian vegetation was 43m (range 26-60m).
- Exotic riparian vegetation:** All sites had a high level of weed invasion (16-42% cover), with three to four different species recorded at each site. *Passiflora foetida* and *Xanthium occidentale** were recorded at all sites, and *Parkinsonia aculeata** was recorded at half the sites. [Note * = species declared noxious in NT]
- Major species: *Passiflora foetida*, *Xanthium occidentale**, *Parkinsonia aculeata**
- Aquatic vegetation:** Aquatic vegetation was recorded at three of the four sites. *Melaleuca leucadendra* was the dominant species recorded at half the sites.
- Instream and bank habitats:** All sites assessed were rated as having a high cover and diversity of instream and bank habitats. The canopy cover along the bank averaged 66% of the bank length.
- Overall condition:** All sites rated highly overall.
- MAJOR ISSUES:** High level of weed invasion recorded at all sites, including noxious species. Some disturbance to reach environs due to stock and infrastructure like river crossings and tracks.



Dashwood Crossing on the Victoria River (Site 1c_2).



Riffle habitat on Victoria River (Site 1c_3).

5.1.4 Victoria River – Upper Catchment

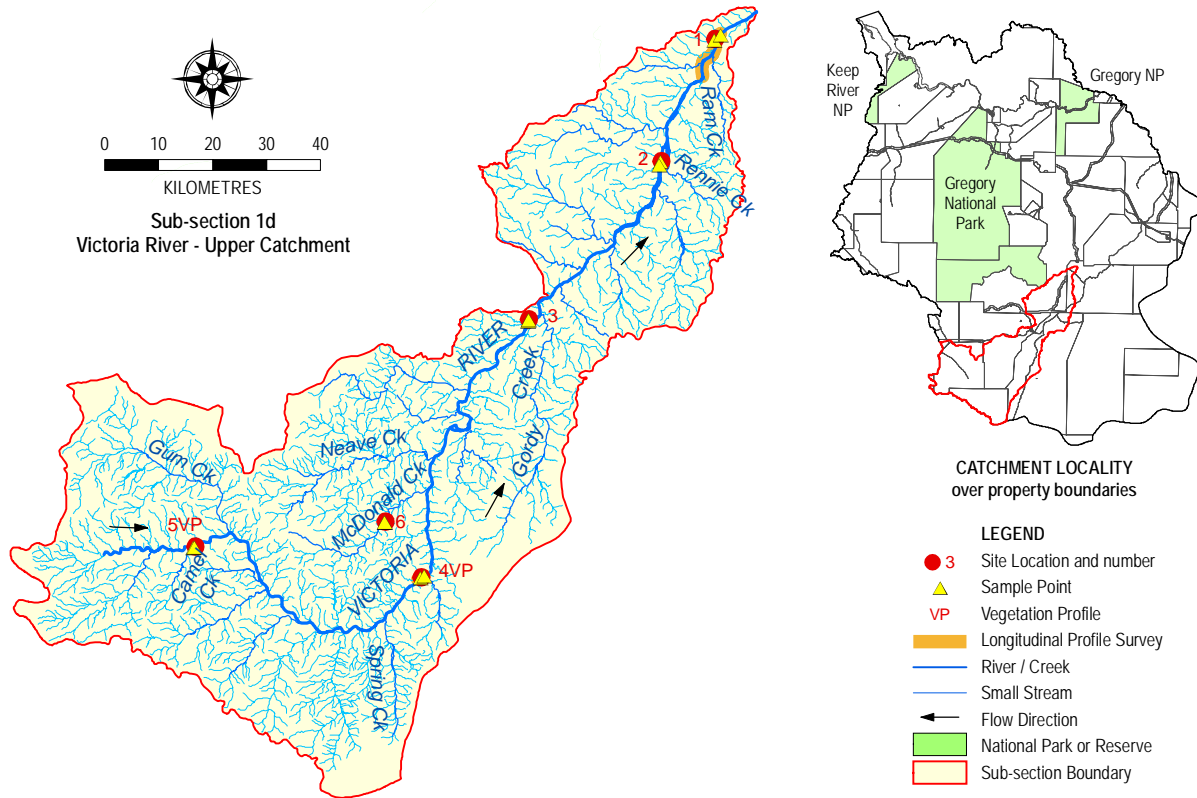
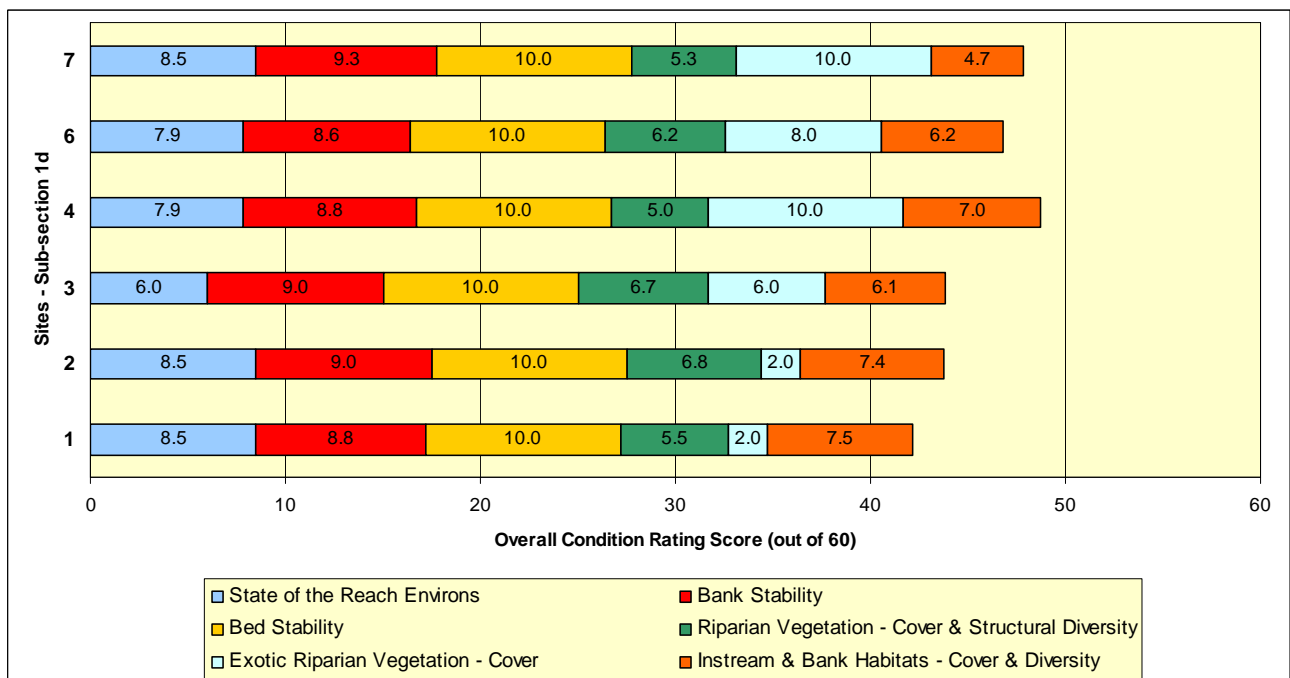


Figure 5.4 Locality Map of Sub-section 1d – Victoria River - Upper Catchment

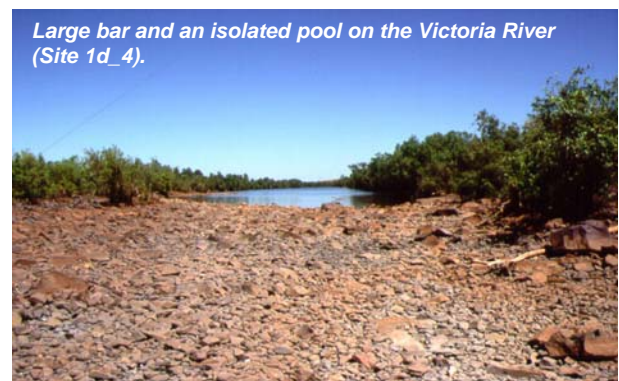
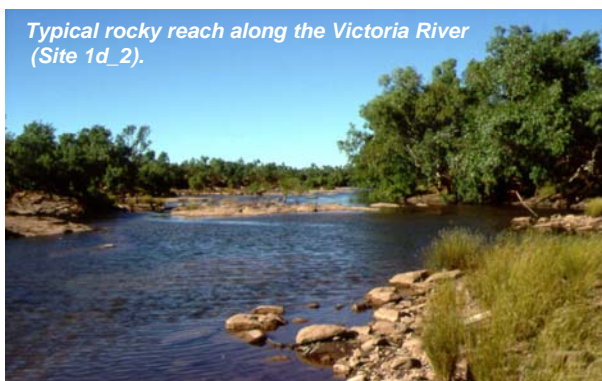
Sub-section 1d encompasses the upper reaches of the Victoria River from Camfield River, where four sites were located, along with one site on McDonald Creek. All six sites were fully assessed.

Chart 5.4 Summary of the Overall Condition Rating Score for Sub-section 1d – Victoria River – Upper Catchment



Summary of the major findings for Sub-section 1d – Victoria River – Upper Catchment

- Reach environs:** Three sites were rated as essentially natural. Sites 1d_4 and 1d_5 had some modification due to cattle and donkeys using the river corridor. Site 1d_3 at Kalkarindji had moderate modification due to the presence of the highway bridge crossing and people using the river for recreational activities.
- Disturbances: Major - roads/tracks, grazing, causeway/crossing
Minor - animal watering point, people
- Bank stability:** All sites were rated as having stable river banks.
- Disturbances: Major - bridge, stock, high flow, floodplain scours, runoff
Minor - vermin, people, roads/tracks
- Bed stability:** All sites were rated as having stable river beds, and had large gravel bars (up to 50% of the bed surface at 1d_5).
- Channel habitat types:** Pools and riffles were present at all sites. All sites were rated as having high diversity of channel habitat types.
- Riparian vegetation:** The cover and structural diversity rating for the riparian vegetation ranged from moderate to high. The cover provided by overstorey vegetation along the upper banks averaged 32% whilst ground covers averaged 26%. The mean width of the riparian vegetation was 5m on McDonald Creek, and 24m (range 14-45m) along the Victoria River.
- Exotic riparian vegetation:** No exotic species were recorded at McDonald Creek and at one site on the upper Victoria River. The level of invasion at the remaining sites included one site with low (1-5% cover), one site with moderate (6-10% cover), and two sites with very high (16-42% cover). [Note * = species declared noxious in NT]
- Major species: *Parkinsonia aculeata**, *Passiflora foetida*, *Acacia farnesiana*, *Malvastrum americanum* and *Acanthospermum hispidum**.
- Aquatic vegetation:** Submerged (eg *Chara* sp.) and emergent aquatic vegetation types, dominated by *Pandanus aquaticus* and *Melaleuca leucadendra*, were present at the Victoria River sites. No aquatic vegetation was recorded on McDonald Creek.
- Instream and bank habitats:** All of the Victoria River sites were rated as having high cover and diversity of instream and bank habitats. The McDonald Creek site was rated as moderate.
- Overall condition:** All sites were rated as having high overall condition, except 1d_4, which rated as very high.
- MAJOR ISSUES:** Disturbances to the Victoria River environment can be attributed to infrastructure and recreational activities near Kalkarindji. There is also a high level of weed invasion in the lower reaches of this sub-section of the Victoria River.



5.2 Bullo River

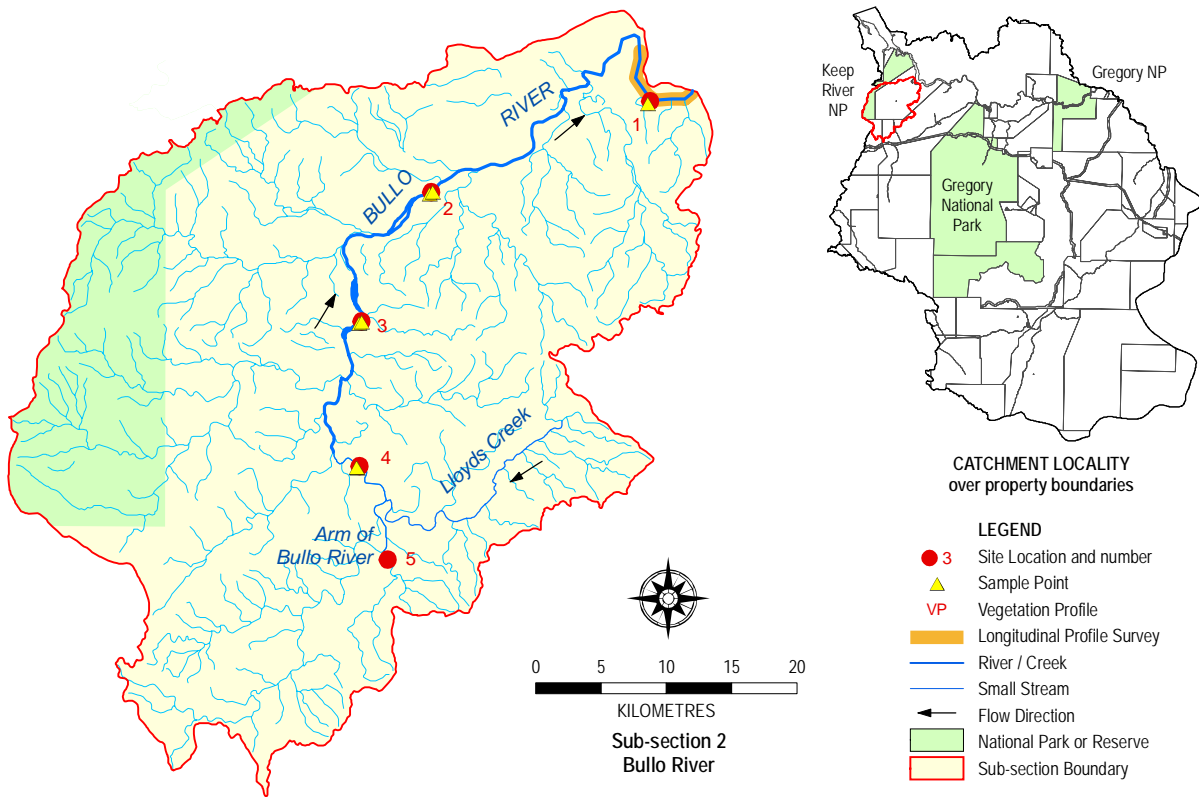


Figure 5.5 Locality Map of Sub-section 2 – Bullo River

Sub-section 2 includes the Bullo River and its catchment. Four sites were located on Bullo River and one site was located on a tributary of Bullo River. All Bullo River sites were fully assessed.

Chart 5.5 Summary of the Overall Condition Rating Score for Sub-section 2 – Bullo River

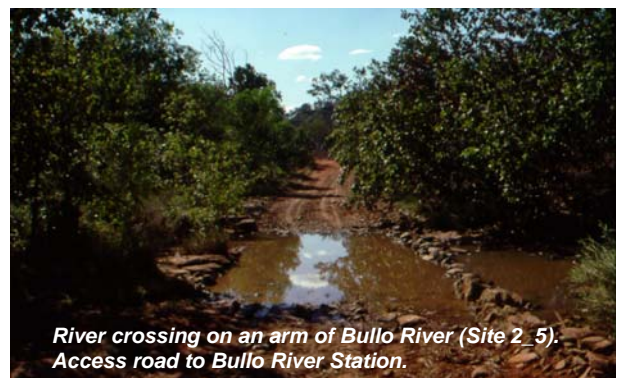


Summary of the major findings for Sub-section 2 – Bullo River

- Reach environs:** Three of the sites were rated as essentially natural, however 2_2 and 2_3 were rated as having some modification due to a cattle watering point nearby, and the presence of feral pigs.
- Disturbances: Major - roads/tracks, grazing, bridge/crossing
Minor - animal watering point
- Bank stability:** All sites were rated as having stable river banks, although the tides and buildup of mudflats were causing some bank instability problems at Site 2_1.
- Disturbances: Major - stock, high flow, tidal influence, roads/bridges
Minor - floodplain scours, runoff, vermin
- Bed stability:** The three most downstream sites on Bullo River recorded moderate aggradation of the river bed, whilst the upstream site (2_4) was stable. Large rocky bars were present in the mid reaches of Bullo River (up to 40% of the bed surface) and there were extensive mudflats in the tidal section.
- Channel habitat types:** All sites had pools, some sites also had riffles, and there was one run. All sites recorded a high channel type diversity except 2_1 which had low diversity, consisting of only a pool (in the tidal zone).
- Riparian vegetation:** The cover and structural diversity rating for the riparian vegetation ranged from moderate to high. The cover provided by overstorey vegetation (ie trees and shrubs greater than 1.3m tall) along the upper banks averaged 31% whilst ground covers averaged 34%. The mean width of the riparian vegetation was 35m (range 16-68m).
- Exotic riparian vegetation:** All sites recorded the presence of exotic species and the level of invasion was low (1-5% cover) at one site, moderate (11-15% cover) at two sites, and very high (16-42% cover) at one site. Up to five different species were recorded at some sites. [Note * = species declared noxious in NT]
- Major species: *Hyptis suaveolens**, *Sida acuta**, *Sida cordifolia**
- Aquatic vegetation:** All sites had aquatic vegetation, consisting predominantly of emergent vegetation and dominated by *Pandanus aquaticus* and *Melaleuca leucadendra*. Floating vegetation, *Nymphaea violacea*, was recorded at one site.
- Instream and bank habitats:** All sites had high instream bank habitat cover and diversity.
- Overall condition:** All sites had an overall condition rating of high.
- MAJOR ISSUES:** (1) High level of weed infestation along upper Bullo River. (2) Localised degradation due to infrastructure and access to rivers by stock and feral pigs. (3) Bank slumping due to tidal influence along lower Bullo River and bed aggradation along the mid to lower sections of Bullo River.



Mangroves at mouth of Bullo River (Site 2_1).



River crossing on an arm of Bullo River (Site 2_5).
Access road to Bullo River Station.

5.3 Baines River

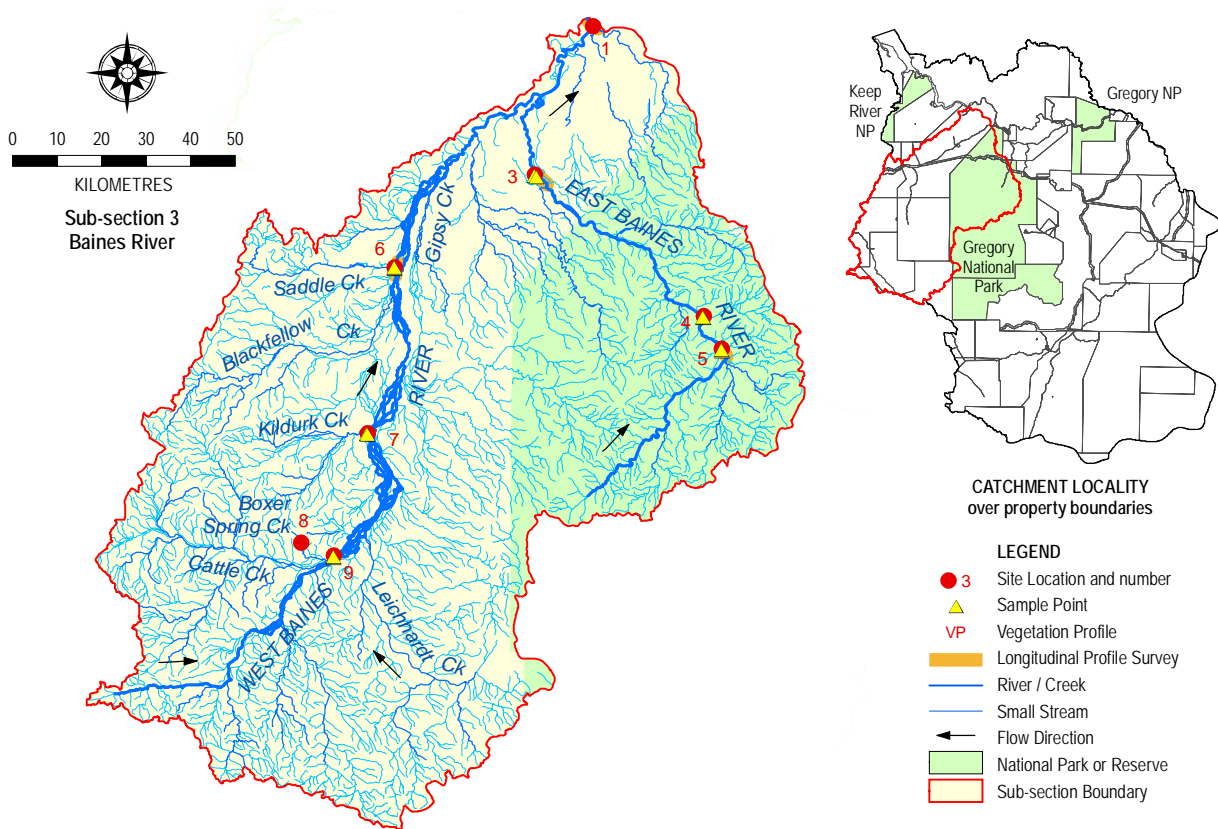
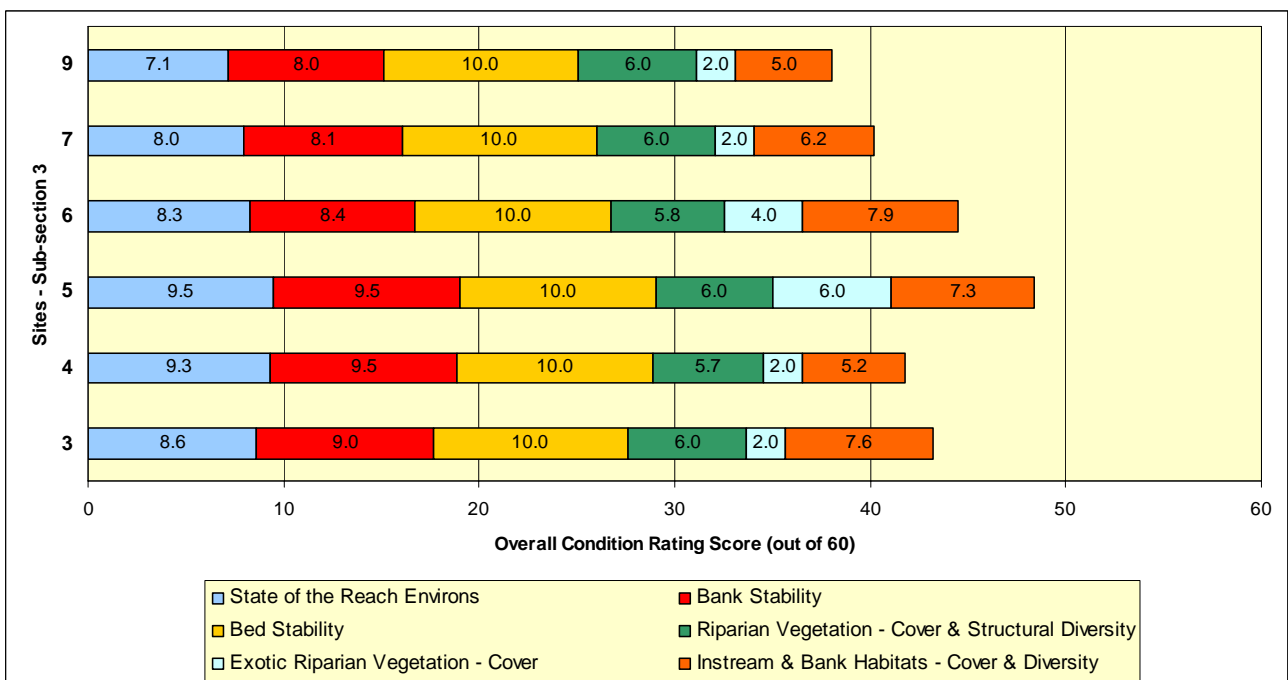


Figure 5.6 Locality Map of Sub-section 3 – Baines River

Sub-section 3 encompasses the Baines River catchment, including one site on the Baines River, two on the East Baines River, three on the West Baines River, and one site on each of Limestone and Boxer Springs Creeks. Of the eight sites in this sub-section, six were fully assessed.

Chart 5.6 Summary of the Overall Condition Rating Score for Sub-section 3 – Baines River



Summary of the major findings for Sub-section 3 – Baines River

- Reach environs:** All reaches were rated as having essentially natural reach environs, except for Sites 3_7 and 3_9 on West Baines River, which had some modification due to grazing activities, an animal watering point and floodplain erosion.
- Disturbances: Major - grazing, roads/tracks
Minor - bridge/culvert, weir, people, animal watering point
- Bank stability:** All sites were rated as having stable river banks except 3_9 which had limited instability with erosion as the dominant process.
- Disturbances: Major - high flow, runoff, stock, floodplain scours, bridge
Minor - vermin, clearing, people/tracks
- Bed stability:** All sites were rated as having stable river beds.
- Channel habitat types:** Pools and riffles were present at all sites. Other habitat types included a waterfall, a cascade, and a run. The channel type diversity rated between moderate to very high.
- Riparian vegetation:** The cover and structural diversity rating for the riparian vegetation was moderate at all sites assessed. The cover provided by overstorey vegetation (ie trees and shrubs greater than 1.3m tall) along the upper banks averaged 28% whilst ground covers averaged 41%. The mean width of the riparian vegetation was 20m (range 8-43m).
- Exotic riparian vegetation:** All six sites assessed recorded the presence of exotic vegetation. The level of invasion ranged from moderate (6-10% cover) to very high (16-42% cover).
[Note * = species declared noxious in NT]
- Major species: *Passiflora foetida*, *Xanthium occidentale** and *Calotropis procera**
- Aquatic vegetation:** Four of the six sites recorded the presence of aquatic vegetation including emergent, submerged and floating types. *Eriachne festucacea* was the most widely distributed species recorded at one third of sites.
- Instream and bank habitats:** Sites were rated as having either high or moderate cover and diversity of instream and bank habitats.
- Overall condition:** All sites rated highly overall, except 3_5, which rated very highly.
- MAJOR ISSUES:** High level of weed invasion, including noxious species, at all sites. Some disturbance to reach environs and banks along West Baines River by high flows, runoff, floodplain scours, stock and vermin.



5.4 Angalarri River

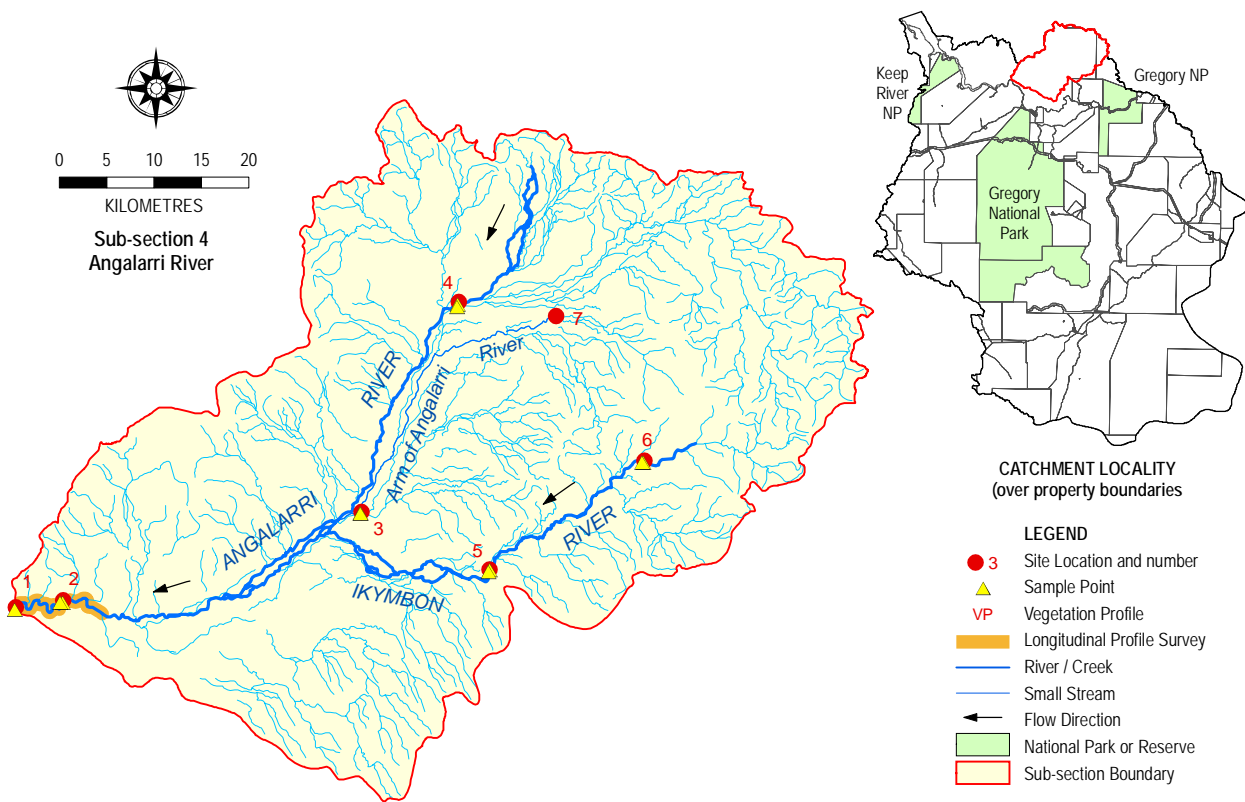
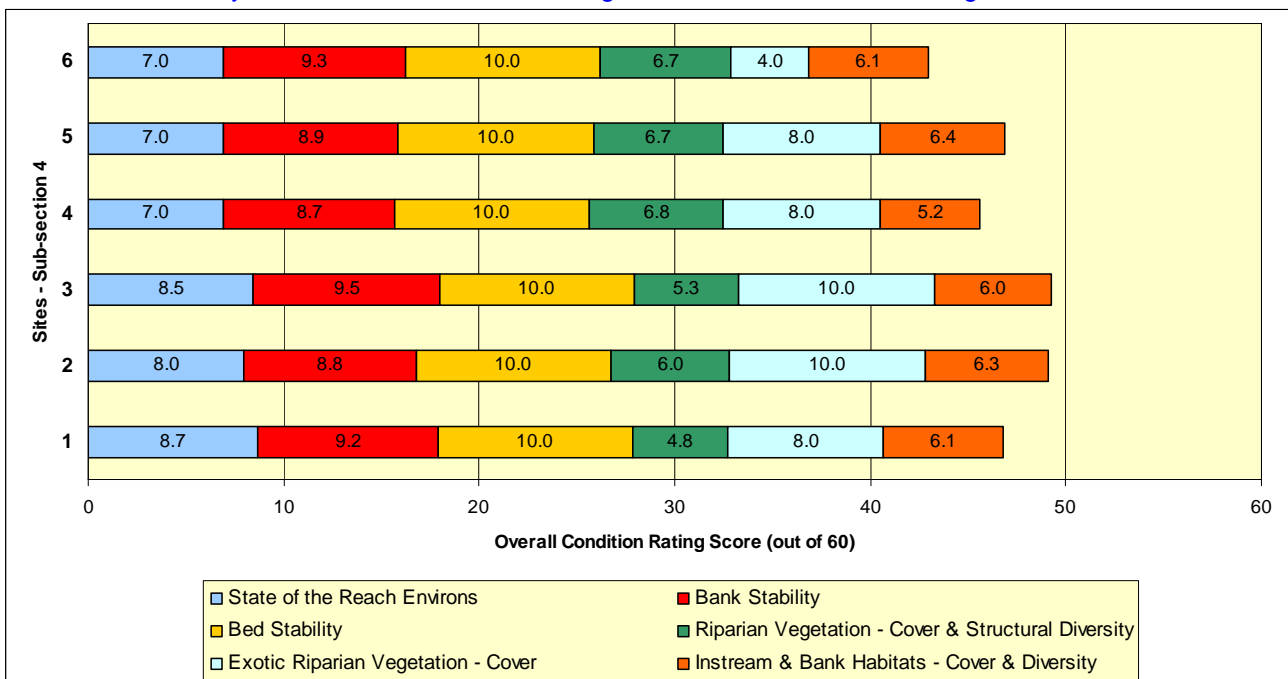


Figure 5.7 Locality Map of Sub-section 4 – Angalarri River

Sub-section 4 includes the catchment area of the Angalarri River. Seven sites were located in this sub-section, five on Angalarri, and two on Ikymbon River. Six sites were fully assessed.

Chart 5.7 Summary of the Overall Condition Rating Score for Sub-section 4 – Angalarri River



Summary of the major findings for Sub-section 4 – Angalarri River

- Reach environs:** Sites 4_1 and 4_3 were rated as being essentially natural. All other sites had some modification due to the presence of cattle and vermin (pigs, horses and donkeys).
- Disturbances: Major - grazing, animal watering point
Minor - road/track, boat ramp
- Bank stability:** All sites were rated as having stable river banks.
- Disturbances: Major - high flow, floodplain scours, stock, tidal influence
Minor - runoff
- Bed stability:** All sites were rated as having stable river beds. Rocky bars were only present on Ikymbon River, covering up to 50% of the river bed at Site 4_6.
- Channel habitat types:** All sites had pools and riffles, except 4_1, which had a pool only, resulting in a very low diversity rating. Diversity of channel habitat types rated high at all other sites.
- Riparian vegetation:** The cover and structural diversity rating for the riparian vegetation ranged from moderate to high. The cover provided by overstorey vegetation (ie trees and shrubs greater than 1.3m tall) along the upper banks averaged 29% whilst ground covers averaged 34%. The mean width of the riparian vegetation was 10m (range 5-20m).
- Exotic riparian vegetation:** Exotic species were recorded at four of the six sites assessed in this subsection. Where recorded, the level of invasion was low (1-5% cover), except on the upstream site on Ikymbon River, which had a moderate level of invasion (11-15% cover), including seven different species. [Note * = species declared noxious in NT]
- Major species: *Passiflora foetida*, *Melochia pyramidata*
Minor species: *Xanthium occidentale**
- Aquatic vegetation:** The only aquatic vegetation recorded in this subsection was mangrove species noted at two sites on the Angalarri River.
- Instream and bank habitats:** The sites were rated as having either high or moderate cover and diversity of instream and bank habitats. The canopy cover along the bank was moderate, averaging 56% of the bank length.
- Overall condition:** Sites 4_2 and 4_3 rated very highly overall. The other sites all rated highly.
- MAJOR ISSUES:** Impact on river banks and reach environs by presence of stock and vermin, particularly pigs, horses and donkeys. Moderate level of weed invasion on upper Ikymbon River.



5.5 Gregory and Delamere Creeks

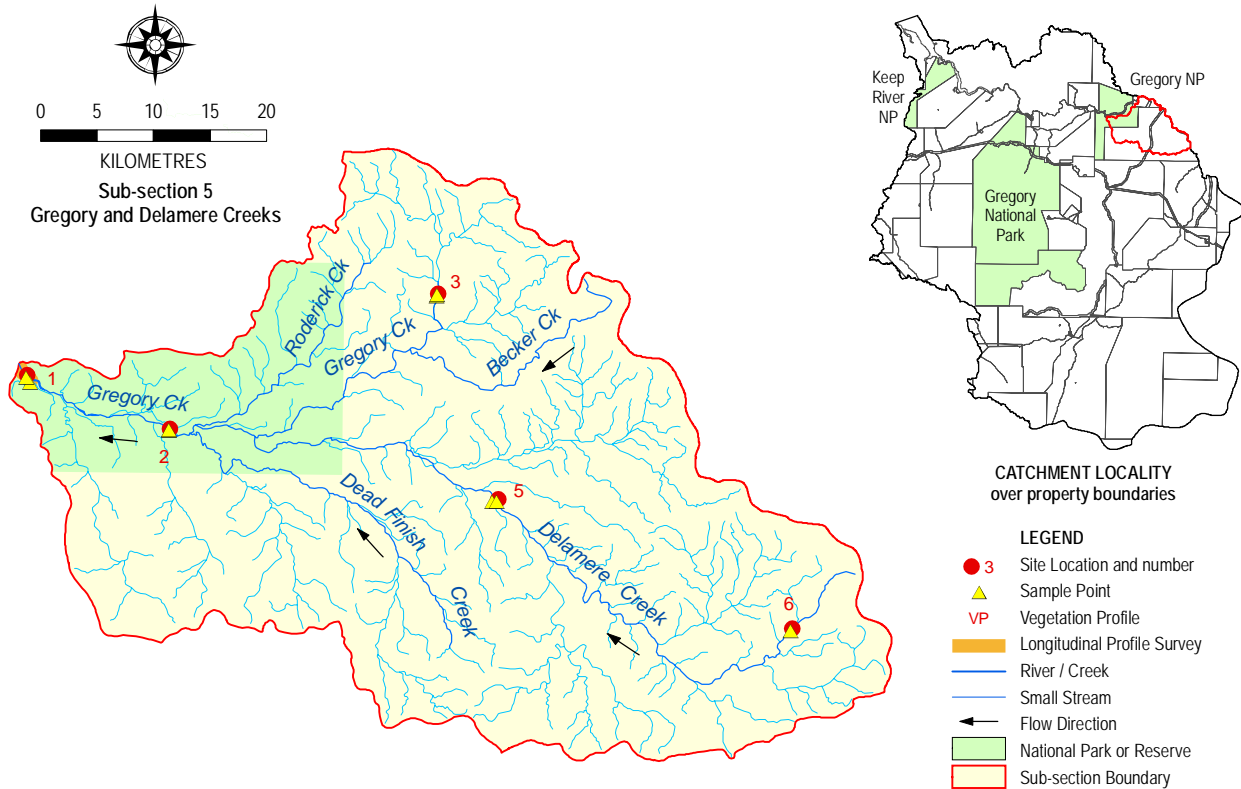
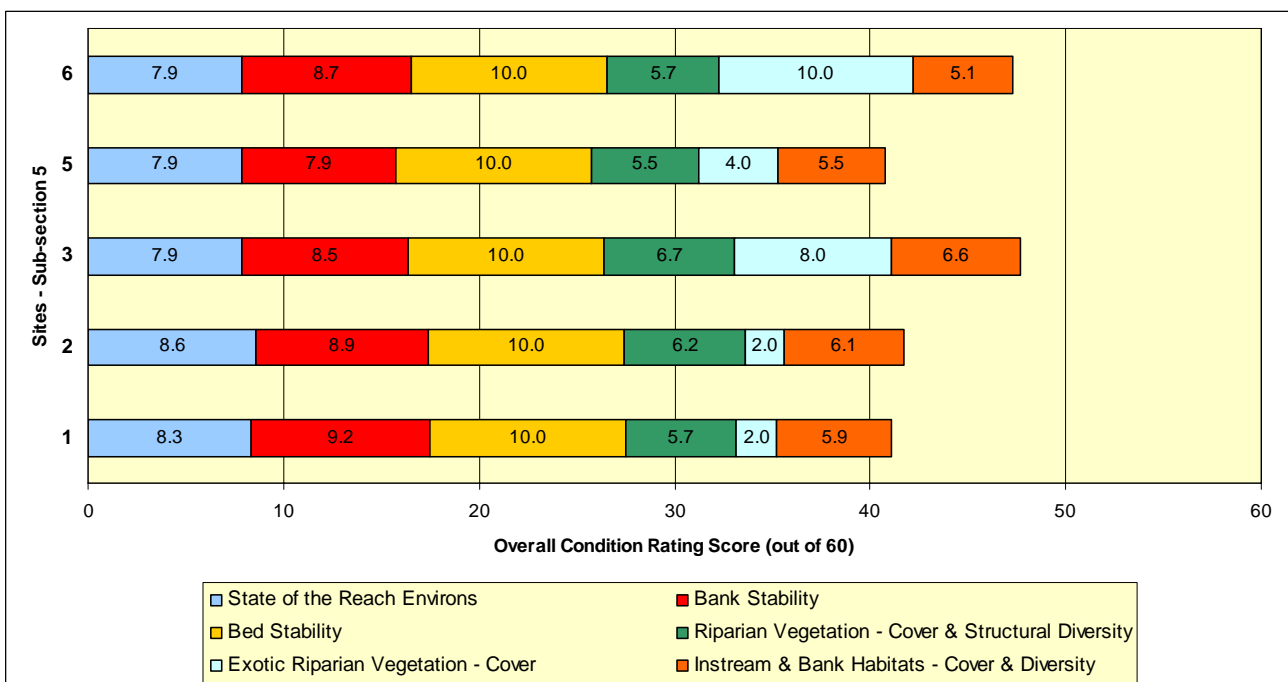


Figure 5.8 Locality Map of Sub-section 5 – Gregory and Delamere Creeks

Sub-section 5 covers the catchment area of Gregory and Delamere Creeks. Five sites were located within this sub-section, three on Gregory Creek and two on Delamere Creek. All sites were fully assessed.

Chart 5.8 Summary of the Overall Condition Rating Score for Sub-section 5 – Gregory and Delamere Creeks



Summary of the major findings for Sub-section 5 – Gregory and Delamere Creeks

- Reach environs:** Sites 5_1 and 5_2, within Gregory National Park, were rated as being essentially natural. The remaining three sites had some modification due to stock watering points, river crossings, and the presence of feral pigs.
- Disturbances: Major - grazing, watering point, roads/tracks, river crossings
- Bank stability:** All sites were rated as having stable river banks except 5_5 which had limited instability, with erosion as the dominant process.
- Disturbances: Major - high flow, stock, bridge/crossing, floodplain scours, vermin (eg pigs)
Minor - runoff
- Bed stability:** All sites were rated as having stable river beds.
- Channel habitat types:** Pools and riffles were present at all sites except 5_6, which had a pool only, resulting in a low diversity rating. Diversity of channel habitat types rated highly at all other sites.
- Riparian vegetation:** The cover and structural diversity rating for the riparian vegetation was moderate at all sites except 5_3, which was high. The cover provided by overstorey vegetation (ie trees and shrubs greater than 1.3m tall) along the upper banks averaged 33% whilst ground covers averaged 35%. The mean width of the riparian vegetation was 12m (range 5-21m).
- Exotic riparian vegetation:** Site 5_6 had no exotic species present. All other sites recorded the presence of exotic species in low (1-5% cover), moderate (11-15% cover) and very high (16-42% cover) levels of invasion. [Note * = species declared noxious in NT]
- Major species: *Passiflora foetida*, *Hyptis suaveolens**, *Parkinsonia aculeata**, *Xanthium occidentale**
- Aquatic vegetation:** Three sites recorded the presence of aquatic vegetation as emergent and submerged types. Emergent vegetation consisted of *Pandanus aquaticus* and *Melaleuca leucadendra*, and submerged vegetation comprised *Myriophyllum verrucosum*.
- Instream and bank habitats:** Two sites were rated as having high cover and diversity of instream and bank habitats, and the other three sites were moderate. The canopy cover along the bank was good, averaging 73% of the bank length.
- Overall condition:** All sites were rated as having a high overall condition.
- MAJOR ISSUES:** Stock, vermin and river crossings have caused erosion within and along the upper Gregory and Delamere Creeks. High level of weed invasion at sites within Gregory National Park.



5.6 Battle Creek

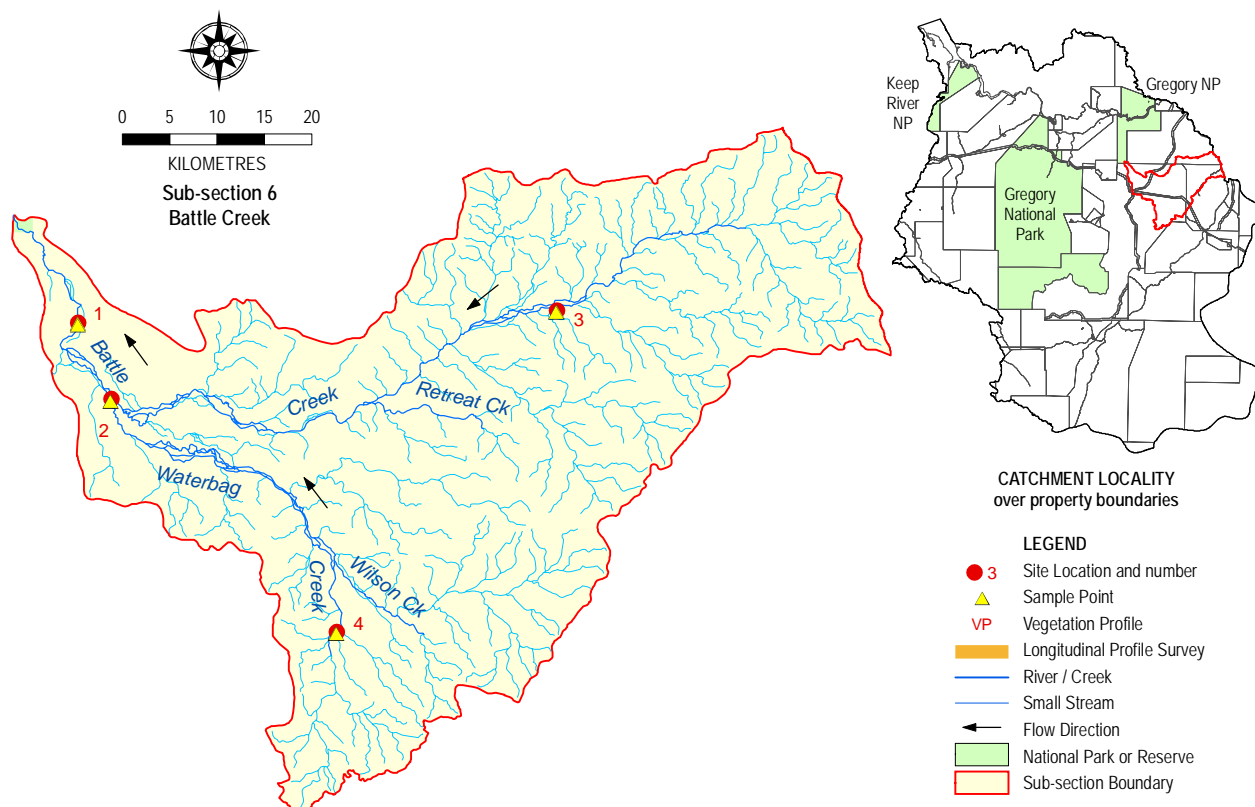
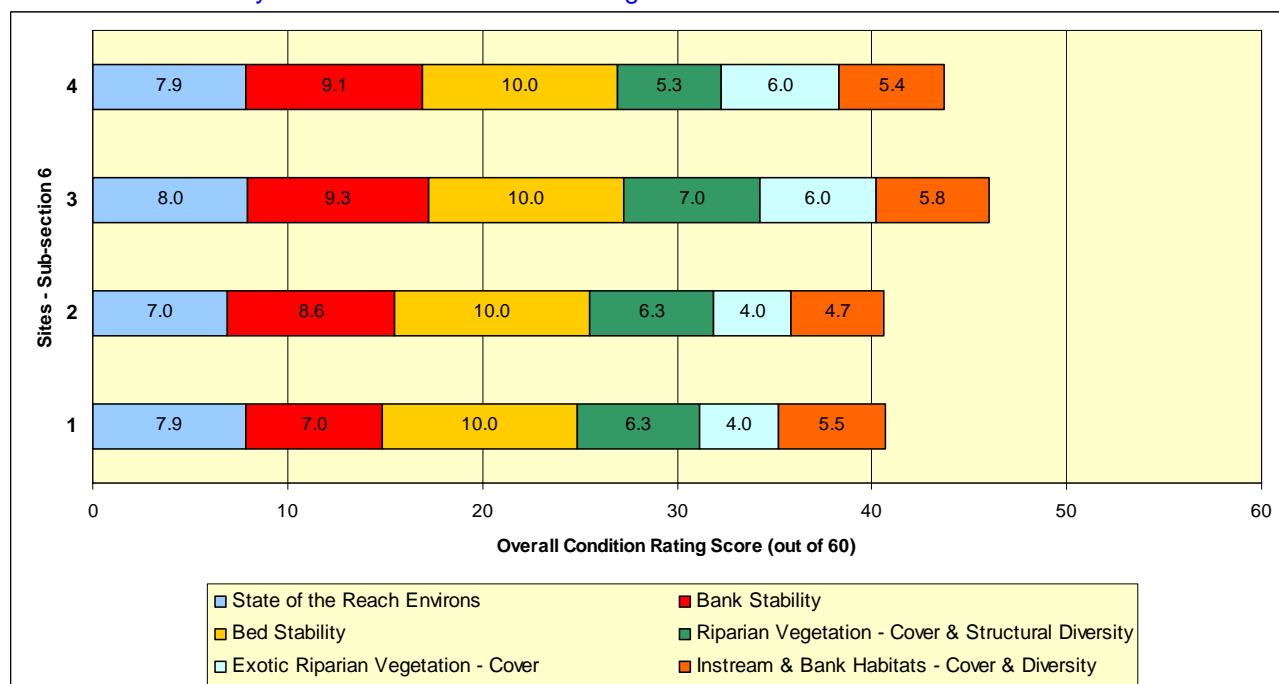


Figure 5.9 Locality Map of Sub-section 6 – Battle Creek

Sub-section 6 encompasses the catchment area of Battle Creek. Of the four sites located within this sub-section, three were located on Battle Creek and one site was located on Waterbag Creek. All four sites were fully assessed.

Chart 5.9 Summary of the Overall Condition Rating Score for Sub-section 6 – Battle Creek



Summary of the major findings for Sub-section 6 – Battle Creek

- Reach environs:** All four sites were rated as having some modification due to grazing and the presence of animal watering points.
- Disturbances: Major - grazing, animal watering points, roads/tracks, river crossings
- Bank stability:** All sites were rated as having stable river banks except 6_1, which had limited instability with erosion as the dominant process.
- Disturbances: Major - stock, high flow, floodplain scours, runoff, bridge/crossing
- Bed stability:** All sites were rated as having stable river beds.
- Channel habitat types:** Pools and riffles were present at all sites. Diversity of channel habitat types was rated as high.
- Riparian vegetation:** The cover and structural diversity rating for the riparian vegetation was moderate at all sites, except 6_3, which was high. The cover provided by overstorey vegetation (ie trees and shrubs greater than 1.3m tall) along the upper banks averaged 21% whilst ground covers averaged 45%. The mean width of the riparian vegetation was 11m (range 6-14m).
- Exotic riparian vegetation:** All sites recorded the presence of exotic species. The level of invasion was moderate (6-10% cover) on Waterbag Creek and at the upstream site on Battle Creek. The lower section of Battle Creek had a high level of weed invasion (11-15% cover). [Note * = species declared noxious in NT]
- Major species: *Passiflora foetida*, *Malvastrum americanum* and *Xanthium occidentale**
- Aquatic vegetation:** The only aquatic vegetation recorded was *Cyperus victoriensis*, recorded as emergent vegetation at two of the four sites.
- Instream and bank habitats:** Sites were rated as having moderate cover and diversity of instream and bank habitats. The canopy cover along the bank was moderate, averaging 38% of the bank length.
- Overall condition:** All sites rated highly overall.
- MAJOR ISSUES:** Stock access and watering points have caused localised trampling and subsequent bank erosion. Moderate to high level of weed invasion.



5.7 Jasper Creek

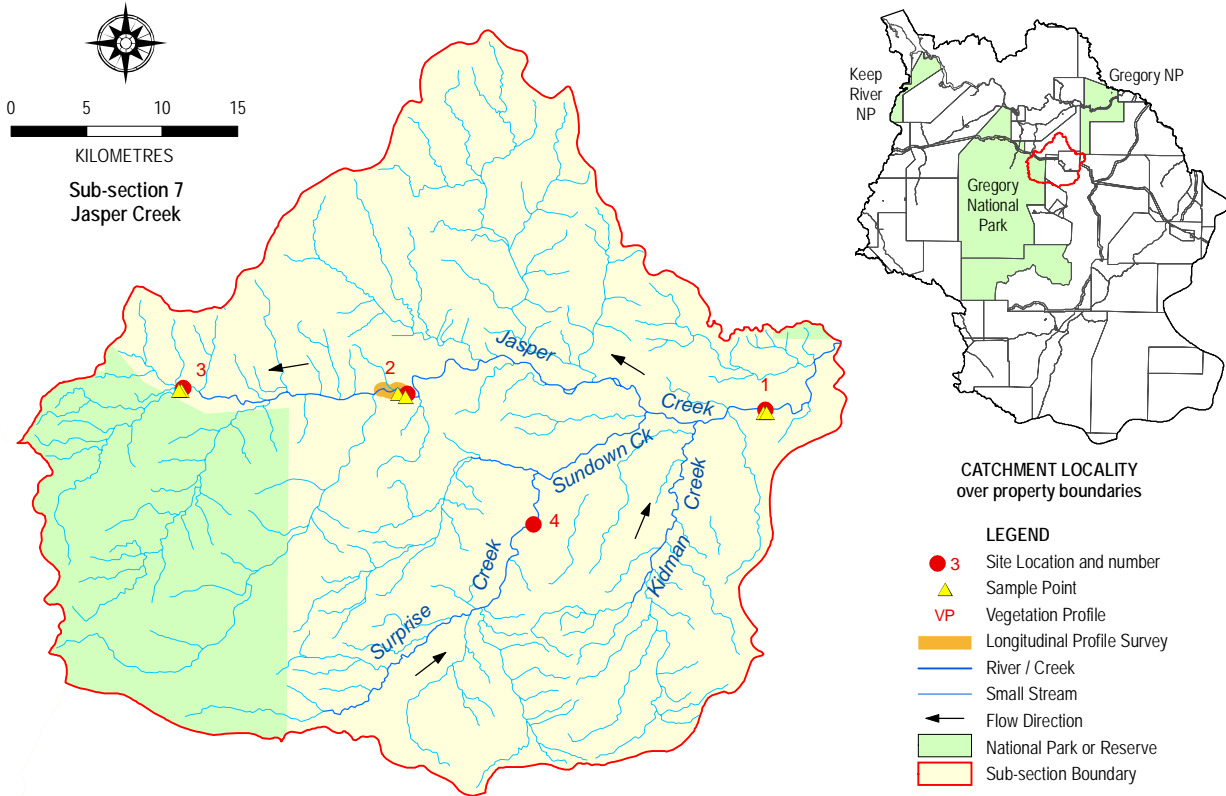
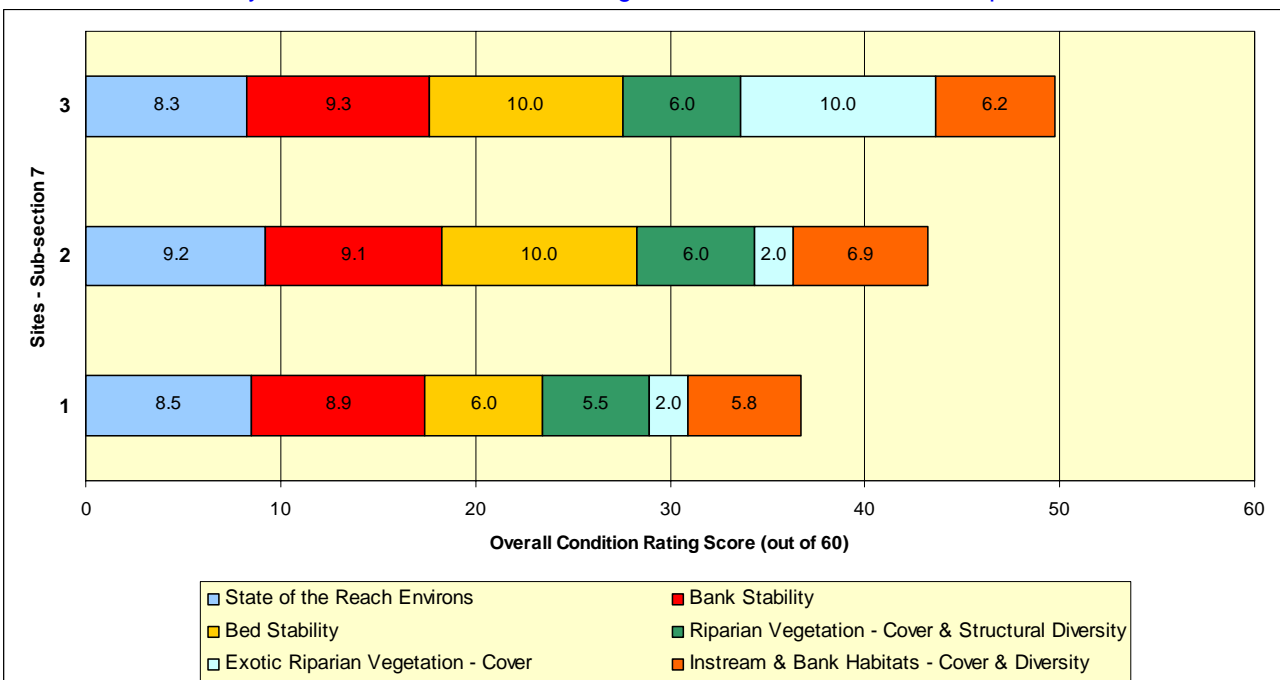


Figure 5.10 Locality Map of Sub-section 6 – Jasper Creek

Sub-section 7 includes the catchment area of Jasper Creek. Three sites were located on Jasper Creek, and were fully assessed. One site was located on Surprise Creek, and was not fully assessed.

Chart 5.10 Summary of the Overall Condition Rating Score for Sub-section 7 – Jasper Creek



Summary of the major findings for Sub-section 7 – Jasper Creek

Reach environs:	All reaches were rated as being essentially natural. Disturbances: Major - road/track, crossing/causeway, grazing Minor - people
Bank stability:	All sites were rated as having stable river banks. Disturbances: Major - high flow, bridge, stock Minor - floodplain scours, runoff, people tracks
Bed stability:	All sites were rated as having stable river beds except Site 7_1, which was found to have moderate aggradation and had sandy bars covering 15% of the bed surface.
Channel habitat types:	Pools and riffles were present at all sites. Diversity of channel habitat types was high.
Riparian vegetation:	The cover and structural diversity rating for the riparian vegetation was moderate at all sites. The cover provided by overstorey vegetation (ie trees and shrubs greater than 1.3m tall) along the upper banks averaged 23% whilst ground covers averaged 50%. The mean width of the riparian vegetation was 13m (range 6-25m).
Exotic riparian vegetation:	No exotic species were recorded at Site 7_3, however a very high level of invasion (16-42% cover) was recorded at the two downstream sites. [Note * = species declared noxious in NT] Major species: <i>Passiflora foetida</i> Minor species: <i>Euphorbia hirta</i> , <i>Xanthium occidentale</i> * and <i>Calotropis procera</i> *
Aquatic vegetation:	Emergent aquatic vegetation was recorded at all sites assessed. Species recorded included <i>Pandanua aquaticus</i> and <i>Melaleuca leucadendra</i> .
Instream and bank habitats:	Sites were rated as having either moderate or high cover and diversity of instream and bank habitats. The canopy cover along the bank was moderate, averaging 43% of the bank length.
Overall condition:	7_1 and 7_2 rated as high, and 7_3 very highly overall.
<u>MAJOR ISSUE:</u>	High level of weed invasion in the low to mid sub-section reaches assessed on Jasper Creek.



Passiflora foetida (Stinking Passion Flower) infesting banks on Jasper Creek (Site 7_2).



Jasper or Slatey Creek (Site 7_3). This site had an overall condition rating of very high.

5.8 Wickham and Humbert Rivers

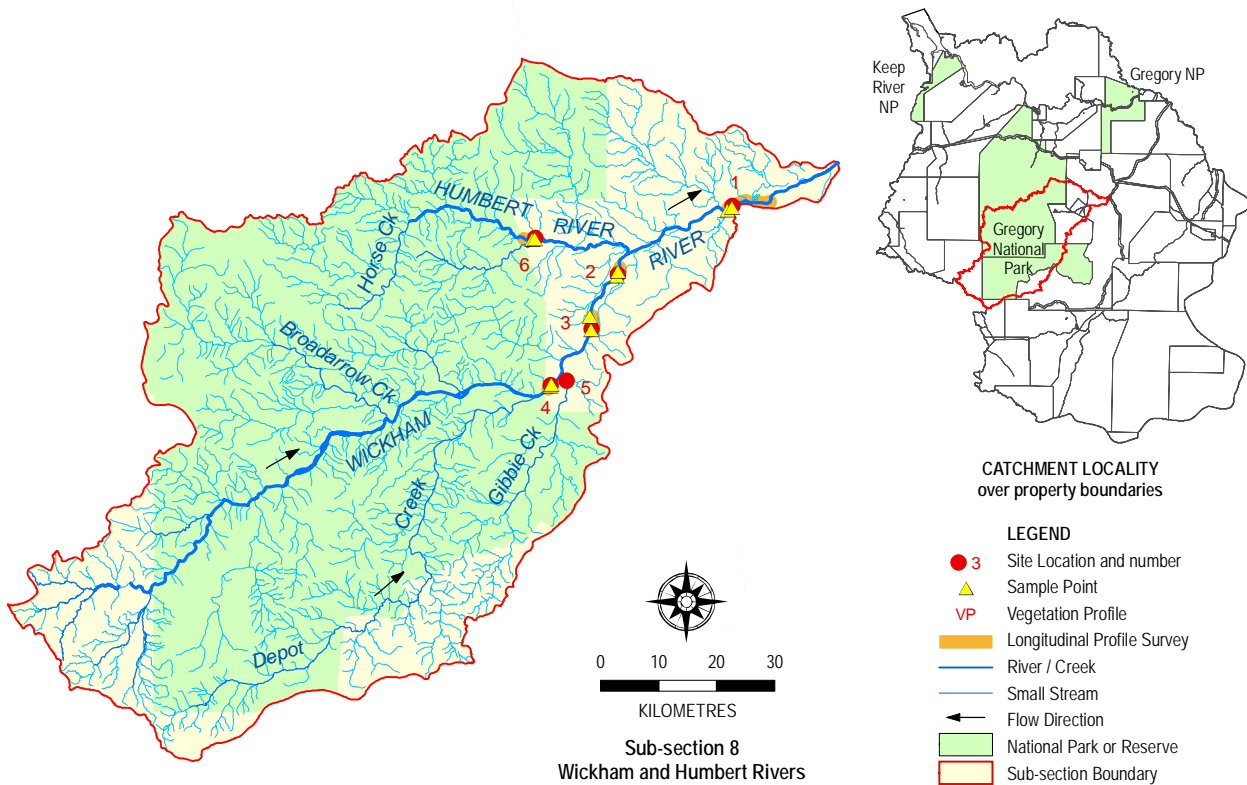
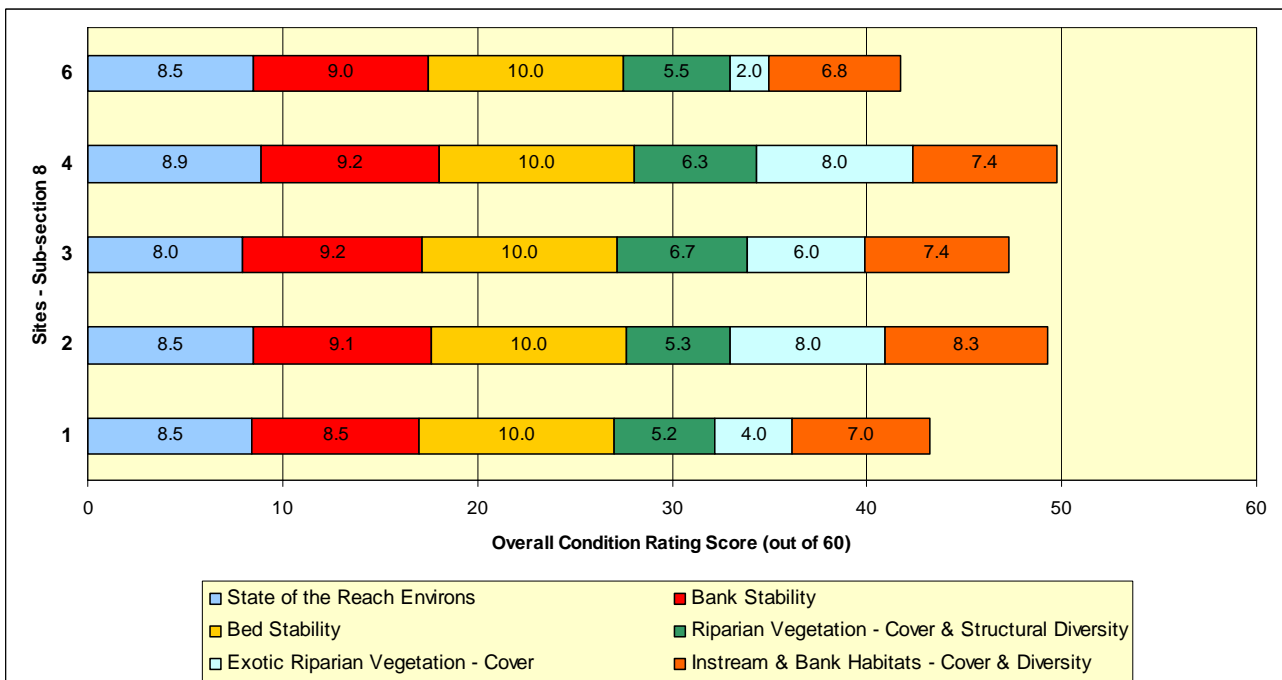


Figure 5.11 Locality Map of Sub-section 8 – Wickham and Humbert Rivers

Sub-section 8 includes the catchment area of the Wickham and Humbert Rivers. Six sites were located in this sub-section, four on Wickham River, one on Humbert River and another on Gibbie Creek. The five sites located on Wickham and Humbert Rivers were fully assessed. No sites were located in the upper reaches of the Wickham and Humbert Rivers within Gregory National Park.

Chart 5.11 Summary of the Overall Condition Rating Score for Sub-section 8 – Wickham and Humbert Rivers



Summary of the major findings for Sub-section 8 – Wickham and Humbert Rivers

- Reach environs:** All reaches were rated as being essentially natural except for Site 8_3 on Wickham River, which had some modification due to grazing and the presence of vermin (eg pigs and donkeys).
- Disturbances: Major - grazing, roads/tracks, crossing/causeway
Minor - animal watering point
- Bank stability:** All sites were rated as having stable river banks.
- Disturbances: Major - high flow, floodplain scours, stock, bridge/crossing
- Bed stability:** All sites were rated as having stable river beds. Gravel bars were present at all sites, covering up to 32% of the bed surface.
- Channel habitat types:** Pools and riffles were present at all sites. Diversity of channel habitat types rated highly at all sites in the middle reaches of Wickham and Humbert Rivers. Diversity rated moderately to very high at the two downstream sites on Wickham River.
- Riparian vegetation:** The cover and structural diversity rating for the riparian vegetation was moderate at all sites except 8_3, which was high. The cover provided by overstorey vegetation (ie trees and shrubs greater than 1.3m tall) along the upper banks averaged 32% whilst ground covers averaged 29%. The mean width of the riparian vegetation was 42m (range 11-89m).
- Exotic riparian vegetation:** All sites recorded the presence of exotic species and, where recorded, the level of invasion ranged from low (1-5% cover) to very high (16-42% cover). [Note * = species declared noxious in NT]
- Major species: *Passiflora foetida*, *Parkinsonia aculeata**
- Aquatic vegetation:** All sites recorded the presence of aquatic vegetation as either emergent, submerged or floating types. *Pandanus aquaticus* and *Melaleuca leucadendra* were the most prevalent species, recorded at 80% of sites.
- Instream and bank habitats:** All sites were rated as having high cover and diversity of instream and bank habitats except 8_2, which was very high. The canopy cover along the bank was good, averaging 79% of the bank length.
- Overall condition:** All sites rated highly except for 8_2 and 8_4, which had a very high overall condition rating.
- MAJOR ISSUES:** Widespread distribution of weeds, including four noxious species. Localised disturbances caused by the presence of feral animals like donkeys and pigs.



5.9 Gordon Creek

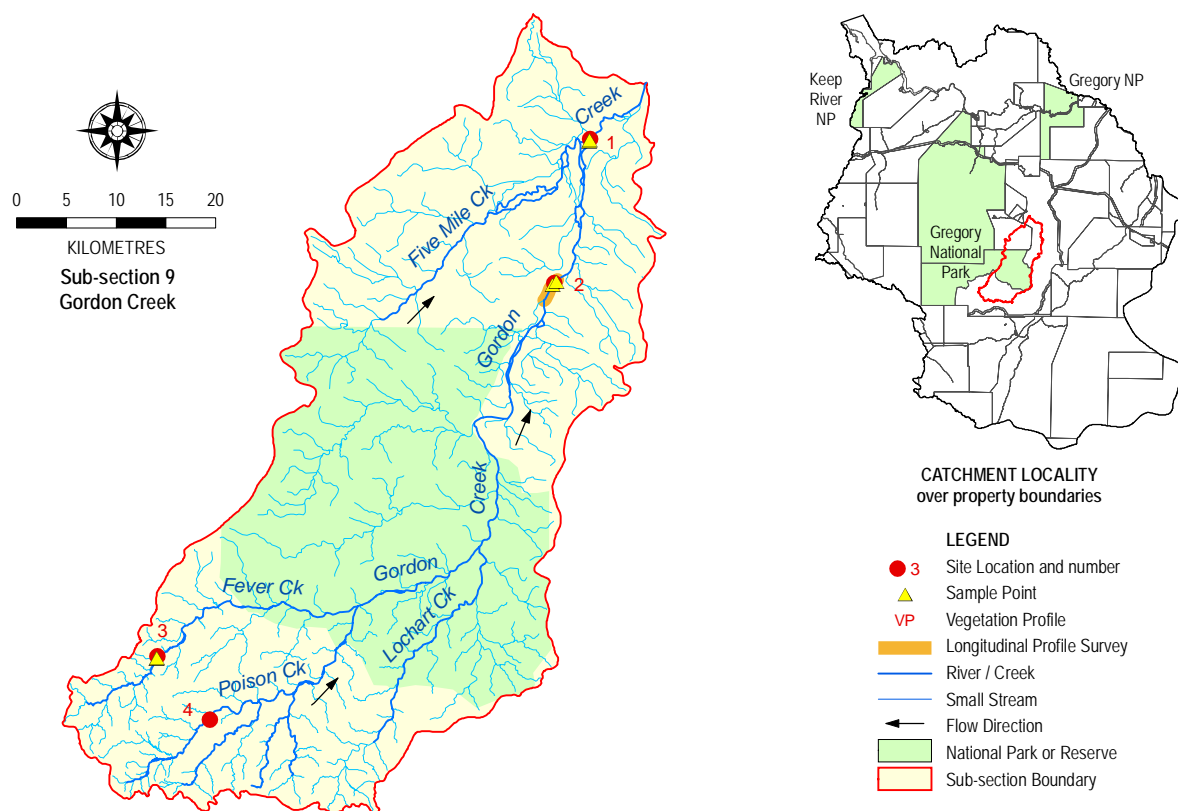
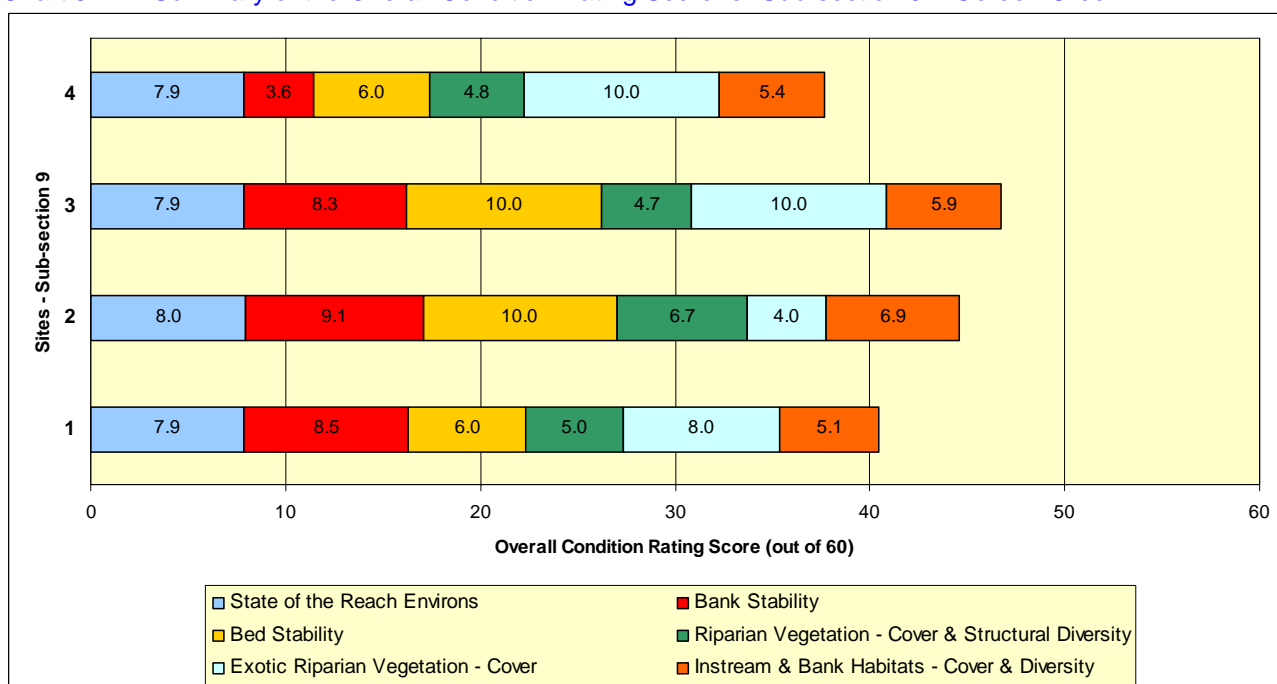


Figure 5.12 Locality Map of Sub-section 9 – Gordon Creek

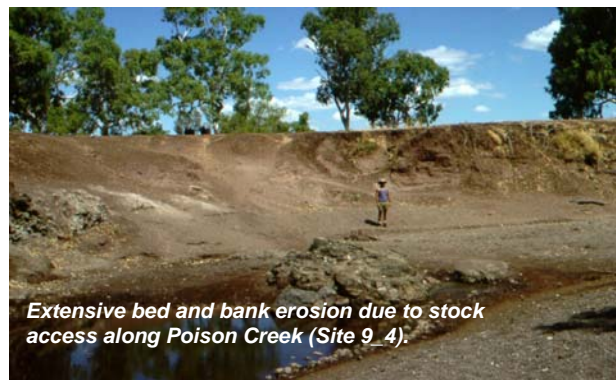
Sub-section 9 includes the catchment area of Gordon Creek, including two sites on Gordon Creek, one on Fever Creek and the other on Poison Creek. All four sites were fully assessed in this sub-section, except no sample points were defined, nor associated cross-sectional data collected, at Site 9_4.

Chart 5.12 Summary of the Overall Condition Rating Score for Sub-section 9 – Gordon Creek



Summary of the major findings for Sub-section 9 – Gordon Creek

- Reach environs:** All four sites were rated as having some modification due to cattle access, and erosion from tracks and river crossings.
- Disturbances: Major - grazing, roads/tracks, causeway/crossings, animal watering points
Minor - water extraction site, boat ramp
- Bank stability:** All sites were rated as having stable river banks except Site 9_4 on Gordon Creek. This site had extensive instability issues due to stock trampling the river banks and reach environs causing erosion problems, as well as the presence of a vehicle track and river crossing.
- Disturbances: Major - stock, high flow, floodplain scours, bridge/crossing, runoff
- Bed stability:** Site 9_1 on Gordon Creek had moderate bed aggradation, whilst Site 9_4 on Poison Creek had moderate bed erosion. All other sites had stable river beds. All sites had bars, ranging from 5-22% of the bed surface.
- Channel habitat types:** All sites recorded the presence of riffles and pools, and had a high diversity of channel habitat types.
- Riparian vegetation:** The cover and structural diversity rating for the riparian vegetation was either moderate or high. The cover provided by overstorey vegetation (ie trees and shrubs greater than 1.3m tall) along the upper banks averaged 25% whilst ground covers averaged 33%. The mean width of the riparian vegetation was 16m (range 5-36m).
- Exotic riparian vegetation:** The two sites on Gordon Creek recorded the presence of exotic species in low (1-5% cover) to moderate (11-15% cover) levels of invasion. No exotic species were recorded at the Fever Creek or Poison Creek sites
- Major species: *Passiflora foetida* and *Malvastrum americanum*
- Aquatic vegetation:** Emergent aquatic vegetation was recorded at two of the four sites assessed in this sub-section.
- Instream and bank habitats:** Sites were rated as having either moderate or high cover and diversity of instream and bank habitats. The canopy cover along the bank was moderate, averaging 58% of the bank length.
- Overall condition:** All sites rated highly overall.
- MAJOR ISSUES:** Impact of stock, tracks and river crossings on river banks, river beds and reach environments. Weed invasion along Gordon Creek.



5.10 Armstrong River

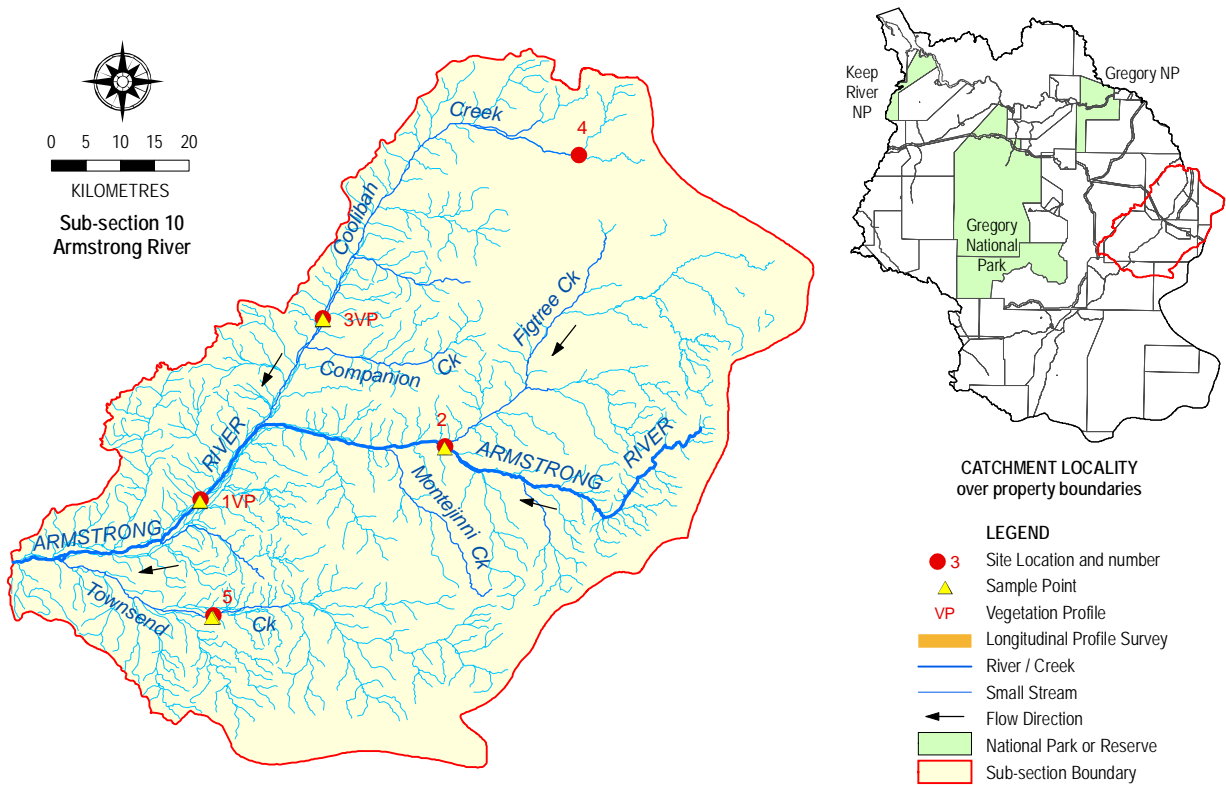
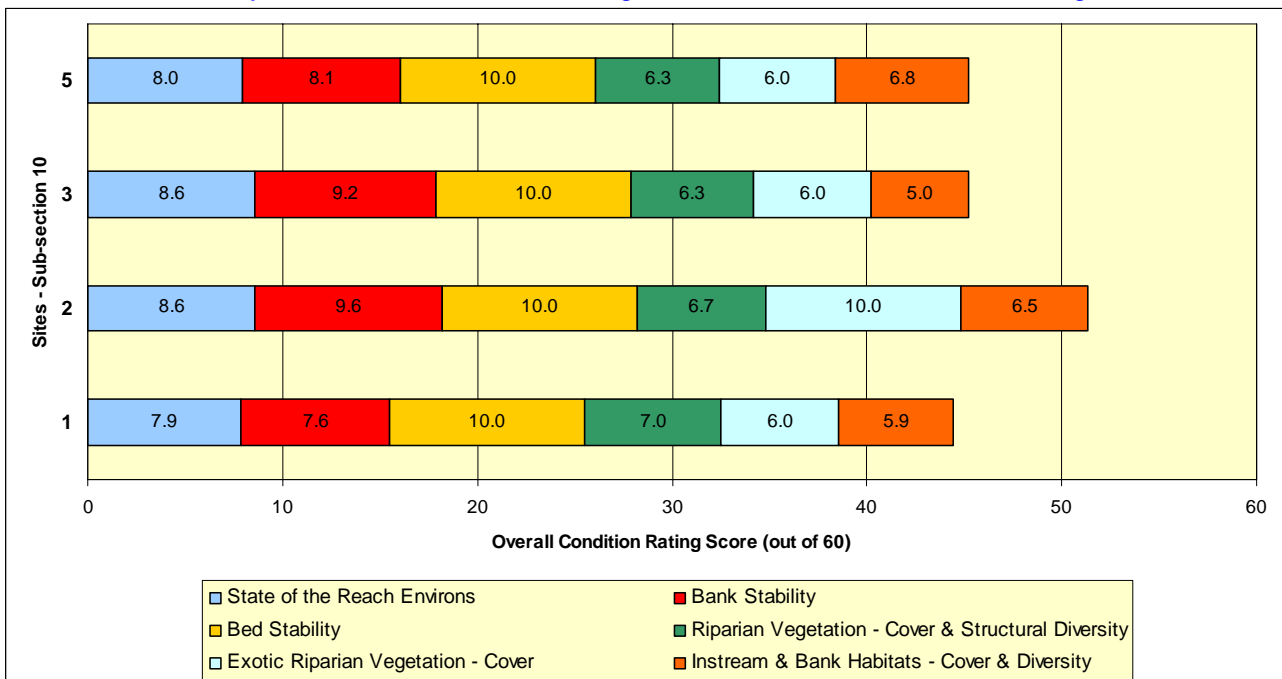


Figure 5.13 Locality Map of Sub-section 10 – Armstrong River

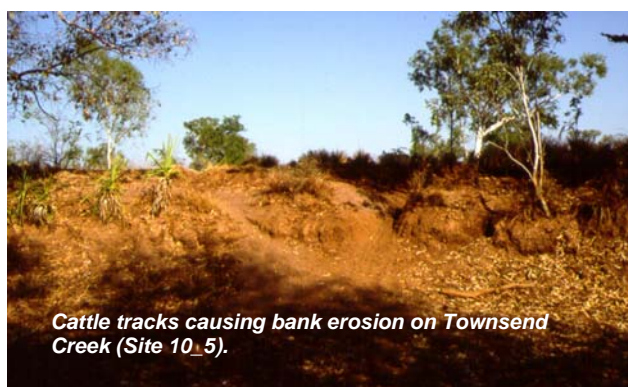
Sub-section 10 includes the catchment area of Armstrong River, covering two sites on the Armstrong River, two sites on Coolibah Creek, and one site on Townsend Creek. All sites, except for the Townsend Creek site, were fully assessed in this sub-section.

Chart 5.13 Summary of the Overall Condition Rating Score for Sub-section 10 – Armstrong River



Summary of the major findings for Sub-section 10 – Armstrong River

- Reach environs:** All sites were rated as being essentially natural except 10_1 and 10_5, which had some modification due to the presence of cattle and vehicle tracks.
- Disturbances: Major - grazing, roads/tracks, bridge/crossing, animal watering point
- Bank stability:** All sites were rated as having stable river banks except 10_1, which had limited instability due to the presence of stock and high flows.
- Disturbances: Major - high flow, floodplain scours, stock, bridge/crossing
- Bed stability:** All sites were rated as having stable river beds.
- Channel habitat types:** All sites had riffles and pools, except 10_2, which had only a pool, and therefore had a very low diversity rating. Diversity of channel habitat types rated high at all other sites.
- Riparian vegetation:** The cover and structural diversity rating for the riparian vegetation was high on Armstrong River and moderate on Coolibah and Townsend Creeks. The cover provided by overstorey vegetation (ie trees and shrubs greater than 1.3m tall) along the upper banks averaged 35% whilst ground covers averaged 29%. The mean width of the riparian vegetation was 19m (range 6-43m).
- Exotic riparian vegetation:** Three-quarters of sites recorded the presence of exotic species and, where recorded, the level of invasion was moderate (6-10% cover). No exotic species were recorded at Site 10_2 on Armstrong River. [Note * = species declared noxious in NT]
- Major species: *Passiflora foetida*
 Minor species: *Acacia farnesiana*, *Malvastrum americanum*, *Parkinsonia aculeata**
- Aquatic vegetation:** No aquatic vegetation was recorded at any of the sites in this sub-section.
- Instream and bank habitats:** Sites were rated as having either high or moderate cover and diversity of instream and bank habitats. The canopy cover along the bank was good, averaging 75% of the bank length.
- Overall condition:** Site 10_2 on Armstrong River rated very high overall condition. The remaining sites were all rated as high.
- MAJOR ISSUE:** The impact from stock along the river banks and river bed at all sites.



5.11 Camfield River

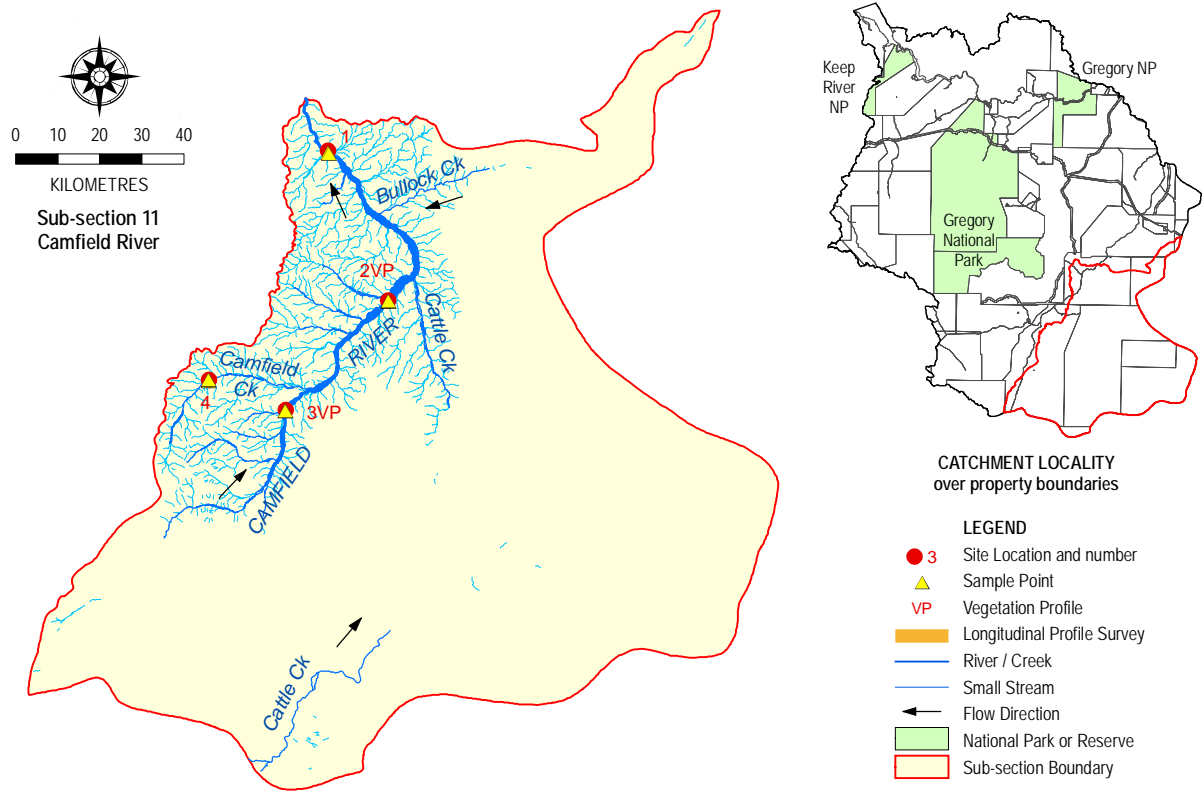
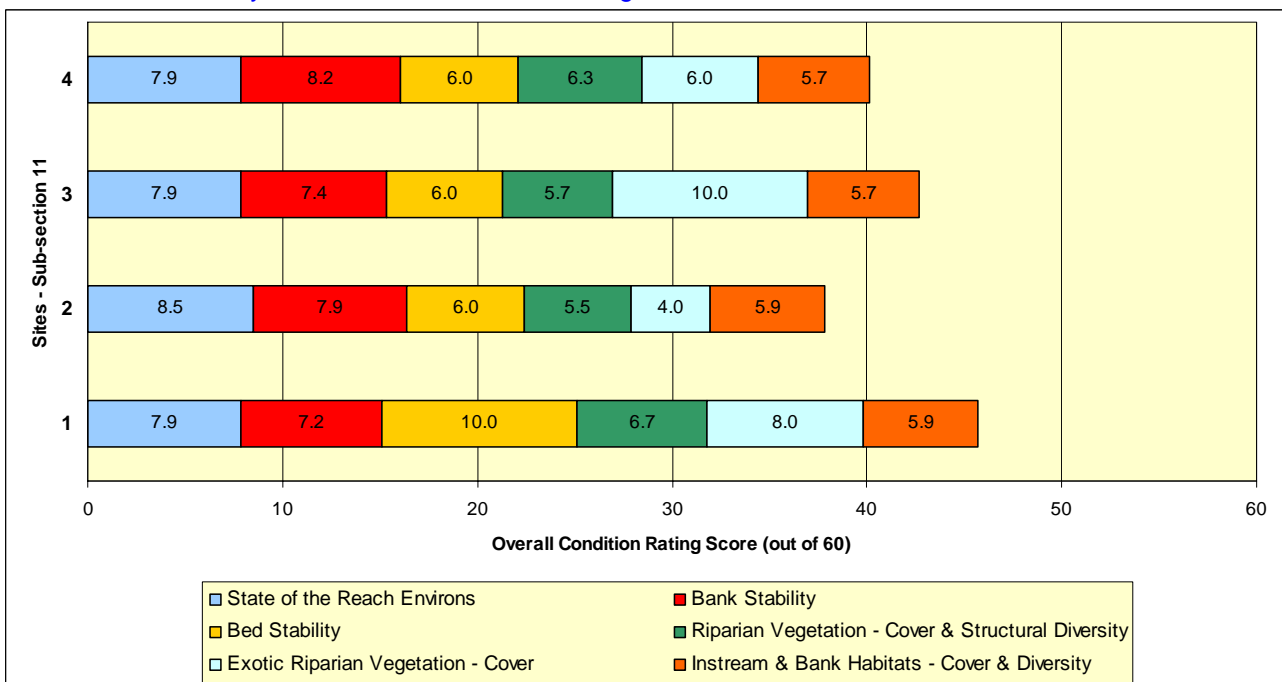


Figure 5.14 Locality Map of Sub-section 11 – Camfield River

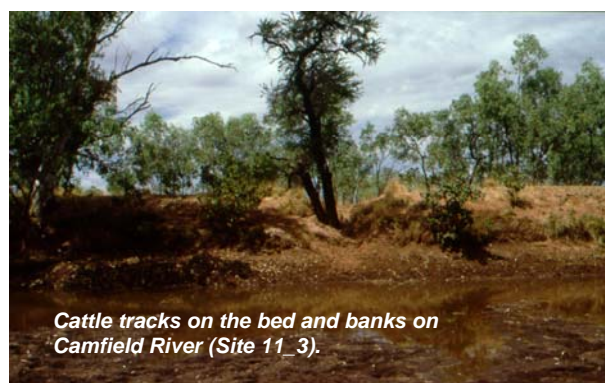
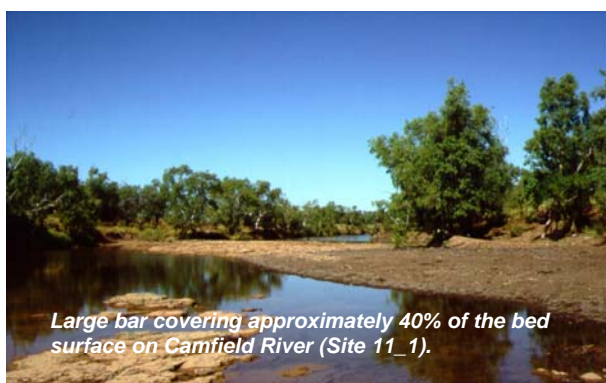
Sub-section 11 includes the catchment area of Camfield River. Four sites were located in this sub-section, three on Camfield River and one on Camfield Creek. All sites were fully assessed.

Chart 5.14 Summary of the Overall Condition Rating Score for Sub-section 11 – Camfield River



Summary of the major findings for Sub-section 11 – Camfield River

- Reach environs:** Three sites were rated as having some modification due to the presence of cattle tracks, river crossings, animal watering points and erosion from high flows and runoff. Site 11_2 on Camfield River was rated as essentially natural.
- Disturbances: Major - grazing, roads/tracks, bridge/crossing, animal watering points
- Bank stability:** All sites on Camfield River were rated as having limited instability, with erosion as the dominant process. Site 11_4 on Camfield Creek was rated as stable.
- Disturbances: Major - high flow, floodplain scours, bridge/crossing, tracks/roads, stock, runoff
- Bed stability:** Site 11_1 was rated as having a stable river bed. All other sites had moderate aggradation and recorded instream siltation as a factor affecting bed stability. Those channels were uniform in shape, being shallow, wide and relatively flat. Gravel bars were recorded at all sites, ranging from 8-40% of the bed surface.
- Channel habitat types:** All sites had both riffles and pools, and were rated as having high diversity of channel habitat types.
- Riparian vegetation:** The cover and structural diversity for the riparian vegetation was moderate and, in one instance, high. The cover provided by overstorey vegetation (ie trees and shrubs greater than 1.3m tall) along the upper banks averaged 29% whilst ground covers averaged 41%. The mean width of the riparian vegetation was 15m (range 5-33m).
- Exotic riparian vegetation:** No exotic species were recorded at Site 11_3. Exotic species were recorded at all other sites with levels of invasion ranging from low (1-5% cover), to high (11-15% cover).
- Major species: *Acacia farnesiana*
 Minor species: *Melochia pyramidata*, *Echinochloa colona*, *Passiflora foetida*
- Aquatic vegetation:** The only aquatic vegetation recorded in this sub-section was submerged *Chara* sp. located at Site 11_1 on Camfield River.
- Instream and bank habitats:** All sites were rated as having moderate cover and diversity of instream and bank habitats. The canopy cover along the bank was good, averaging 62% of the bank length.
- Overall condition:** All sites rated highly overall.
- MAJOR ISSUES:** Stock using the river environment to graze, shelter and water have caused extensive erosion and instability problems. Moderate river bed aggradation and issues associated with excessive instream siltation (eg loss of deeper pools).



5.12 Giles or Wattie Creek

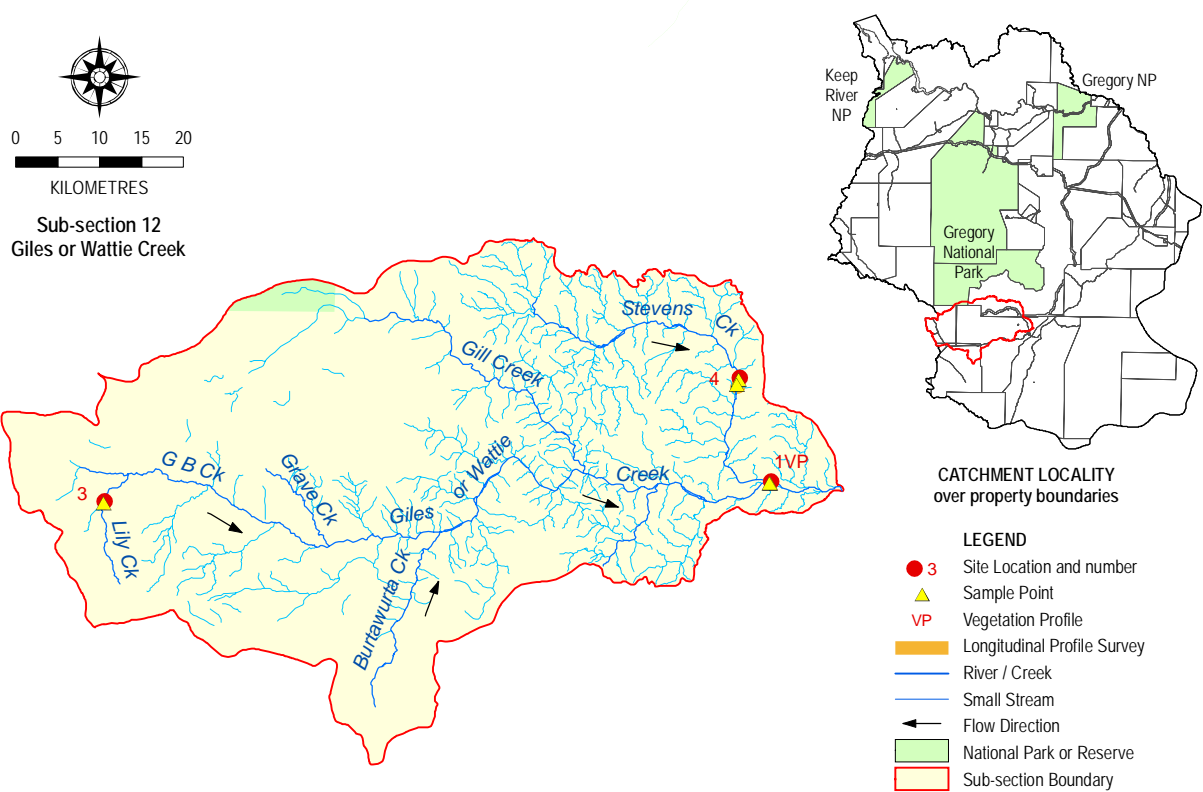
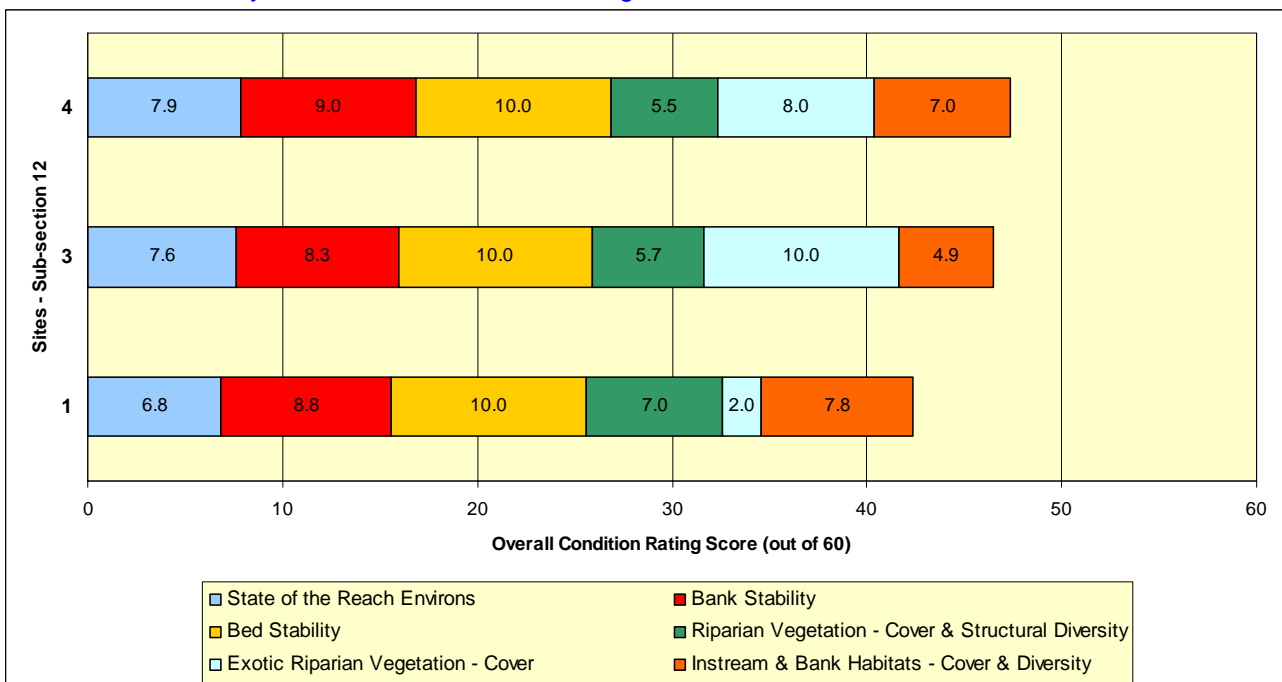


Figure 5.15 Locality Map of Sub-section 12 – Giles or Wattie Creek

Sub-section 12 includes the catchment area of Giles or Wattie Creek. Sites were located on Wattie Creek, Lily Creek and Stevens Creek. All three sites were fully assessed in this sub-section.

Chart 5.15 Summary of the Overall Condition Rating Score for Sub-section 12 – Giles or Wattie Creek



Summary of the major findings for Sub-section 12 – Giles or Wattie Creek

- Reach environs:** All reaches were rated as having some modification due to the presence of stock and infrastructure such as river crossings, fences and people tracks.
- Disturbances: Major - road/track, grazing, animal watering points
Minor - bridge/crossing, people tracks
- Bank stability:** All sites were rated as having stable river banks.
- Disturbances: Major - high flow, bridge/crossing, stock
Minor - Floodplain scours, runoff
- Bed stability:** All sites were rated as having stable river beds.
- Channel habitat types:** All sites had pool habitats plus either riffles or runs. Two sites had high diversity of channel habitat types, and one site had a moderate diversity rating.
- Riparian vegetation:** The cover and structural diversity rating for the riparian vegetation was high at one site, and moderate at the other two sites. The cover provided by overstorey vegetation (ie trees and shrubs greater than 1.3m tall) along the upper banks averaged 31% whilst ground covers averaged 46%. The mean width of the riparian vegetation was 8m (range 2-14m).
- Exotic riparian vegetation:** Exotic vegetation was recorded at two of the three sites in this sub-section. Wattie Creek had a very high level of invasion (16-42% cover) and Stevens Creek was recorded as low (1-5% cover). [Note * = species declared noxious in NT]
- Major species: *Melochia pyramidata*, *Cardiospermum halicacabum*, *Cenchrus ciliaris*, *Passiflora foetida*, *Acacia farnesiana*, *Calotropis procera**
- Aquatic vegetation:** Aquatic vegetation was recorded at two of the three sites in this sub-section. Submerged, emergent and floating types were all recorded.
- Instream and bank habitats:** Two-thirds of sites were rated as having high cover and diversity of instream and bank habitats, with the remaining Site 12_2 rating moderately. The canopy cover along the bank was good, averaging 62% of the bank length.
- Overall condition:** All sites were rated as having high overall condition.
- MAJOR ISSUES:** (1) Stock using the river environment to graze, shelter and water. (2) Localised erosion from river crossings, tracks and impacts from recreational activities in the river corridor. (3) Very high level of weed invasion along Wattie Creek.





6. SUMMARY – VICTORIA RIVER CATCHMENT

◆ *Reach Environs and Site Features*

Just over half the sites assessed were rated as having essentially natural reach environs, and the remainder had some modification. Only one site had moderate modification to the reach environs and no sites were assessed as having major or extreme modification. Generally, the sites with essentially natural reach environs had relatively low impact land uses, undisturbed vegetation and few local disturbances like grazing, infrastructure and concentration of animals at watering points.

Subjective disturbance ratings conducted in the field indicated that the majority of sites had low to very low levels of disturbance, and the remainder had low to moderate and moderate levels of disturbance. One site was reported to have moderate to high level of disturbance due to the presence of an access track and people using the river reach for recreational activities. No sites were highly, very highly or extremely disturbed.

The majority of land adjacent to stream reaches studied was under either freehold or leasehold tenure, including Aboriginal land. The major land use recorded adjacent to the streams was grazing, and to a much lesser extent, National Park. Grazing activity, roads/tracks, river crossings, and watering points for stock and feral animals were the three major disturbances to stream reaches.

◆ *Channel Habitat Types, Diversity and Dimensions*

Reaches studied averaged 2,238m in length and ranged from 50-20,300m. Pools and riffles were the dominant habitat types located throughout the catchment. Pools generally occurred with riffles and runs, and waterfalls were also associated with areas of steeper topography such as Limestone Gorge and Cow Creek. There were only three rapids recorded in the catchment, and one cascade. The majority of survey work was conducted during the dry season so many rivers and creeks were either completely dry or had isolated pools.

Channel type diversity assessed the number of different channel habitat types present and the proportion of the reach occupied by pools versus other habitat types. The majority of sites recorded a high diversity of channel habitat types and these mostly had two habitat types present. Sites with very high diversity usually had three to four habitat types, and were found in the steeper rocky sections of the catchment.

Very low and low diversity ratings were predominantly recorded in tidal sections where the pools were very long and uniform. Sites with moderate channel type diversity had two habitat types, of which pools dominated the reaches.

◆ *Bank Condition and Stability*

The majority of river banks throughout the catchment were considered stable, with a few (ie 10 sites) that had limited instability, and one site that was suffering from extensive instability due to stock and the presence of a vehicle crossing and track (Site 9_4 on Poison Creek). A subjective assessment of bank stability conducted in the field indicated that the majority of sites recorded low overall bank instability, however many sites had low to moderate and moderate bank instability, and some sites also had moderate to high and high levels of instability.

Though most river banks were rated as being stable, some form of erosion processes were recorded at the majority of sites, and aggradation was recorded at one site. Only two sites were considered absolutely stable. Lower banks were more stable than upper banks with an average of 94% of the lower bank considered stable, and 85% considered stable for the upper bank.

The major factors affecting bank stability were high flow and stock, and to a lesser extent, infrastructure (eg roads, tracks, crossings, bridges), floodplain scours, runoff and vermin. Smaller contributing factors included tidal influence, people tracks and clearing of vegetation. The only types of artificial bank protection measures recorded were fencing along the river and/or at stock watering points, which occurred at several sites, and gabions at one site.

◆ *Bed and Bar Condition and Stability*

A subjective assessment of the overall bed stability indicated that the majority of sites had stable river beds, while 13 sites recorded moderate bed aggradation and one site recorded bed erosion problems.

Moderate bed aggradation was located on Victoria River (5 sites), Bullo River (3 sites), Camfield River (3 sites), Jasper Creek and Gordon Creek. Most of the Victoria River and Bullo River sites were tidal, and experience aggradation as sediments move through the estuary. Other sites, such as those on Camfield River and Gordon Creek, had relatively flat, uniform and shallow river beds with a large amount of sand and gravel. These sites were all near stock watering points and vehicle crossings, and had bank erosion, floodplain scouring and new channels forming. The site recording erosion problems was located on Poison Creek at the road

crossing into Mt Sanford Outstation (Site 9a_4). Stock, and to a lesser extent the vehicle crossing and access track, have caused severe erosion of both the bed and banks at this location.

Bars were widespread and were recorded at nearly three-quarters of sites, averaging 18% of the bed and ranging to as high as 55%. Bars with encroaching vegetation and alternate bars were the two most prevalent bar types.

Nearly half of sites had no factors affecting bed stability, however at the remaining sites, the major factor affecting bed stability was grazing, with bank erosion, concentration of flows, instream siltation and bed deepening contributing to a lesser extent.

◆ *Bed and Bank Sediments*

A range of size classes, from clays to boulders, were recorded in the river bed and banks. Pool habitats had a higher proportion of smaller bed sediments; runs and riffles had a range of bed sediment types; and rapids had a higher proportion of cobbles and boulders. The sediments along the lower and upper banks for all habitat types consisted mainly of smaller sediment sizes (eg small sand and clays), except rapid habitats, which had boulders on the lower banks.

◆ *Riparian Vegetation*

All sites were assessed as having moderate to high cover and structural diversity for riparian vegetation except one estuary site, which rated as low. The average width of the riparian zone was 23m ranging up to 155m. Only one site on Giles or Wattie Creek recorded a narrow riparian width of less than five metres. 15% of sites had riparian widths of greater than 40m, including sites on the larger river systems: Victoria, Bullo, East Baines, Wickham and Armstrong Rivers.

A range of structural categories were present in the riparian vegetation except for tall trees >30m and salt marsh. Trees, shrubs, forbs and grasses were the most prevalent structural types (recorded at over 90% of sites). Grasses provided the highest percentage cover of all structural types, followed by trees and shrubs.

Eucalyptus camaldulensis was the most widespread native overstorey species, followed by *Lophostemon grandiflora*, *Terminalia platyphylla*, *Pandanus aquaticus*, *Ficus coronulata* and *Melaleuca leucadendra*. *Acacia holosericea* was the most common native shrub, and *Eriachne festucacea* the most common native grass species. The most common mangrove species was *Avicennia marina*, which was confined to sites in the Victoria River estuary.

Exotic species were widespread in the riparian vegetation, being recorded at over three-quarters of sites. A total of nineteen species were recorded, including eight that are declared noxious in the Northern Territory.

The maximum number of different exotic species recorded at any one site ranged from 0-7. The mean total cover of exotic species in the riparian zone was 11%, ranging from 0-42%. One-third of sites recorded the highest category for exotic species cover (>16%). These sites were along the Victoria, Bullo, Baines and Wickham Rivers, and Jasper, Giles or Wattie Creeks. Nearly half the sites had between 1-15% cover for exotic species and the remaining 21% of sites had no exotic species recorded in the riparian areas.

The most common exotic structural types were vines and forbs. *Passiflora foetida*, a naturalised vine, *Parkinsonia aculeata* and *Xanthium occidentale* were the three major species recorded throughout the catchment, recorded at 60%, 30% and 30% of sites respectively. *Passiflora foetida* was recorded in all sub-catchments, although generally had a low percentage cover (1-5%). *Parkinsonia aculeata* was recorded in most sub-catchments with 6-10% cover in all sections of the Victoria River, on West Baines River and Gregory and Delamere Creeks. *Xanthium occidentale* was also recorded in most sub-catchments, particularly in the lower reaches of Victoria River and West Baines Rivers, where percent cover is between 6-15%. Other noxious species recorded at a high proportion of sites included *Caltropis procera* and *Hyptis suaveolens*.

◆ *Aquatic Vegetation*

Two-thirds of sites recorded the presence of aquatic vegetation. Emergent aquatic vegetation was more widespread (59% of sites) than submerged vegetation (21%) and floating vegetation (6%). Emergent vegetation was recorded in all but two sub-catchments, Armstrong and Camfield Rivers. The most common emergent vegetation types included *Melaleuca leucadendra* and *Pandanus aquaticus*. Submerged vegetation was recorded in the Victoria, Baines, Camfield, Wickham and Humbert Rivers, and Gregory or Delamere and Giles or Wattie Creeks. The most prevalent submerged vegetation type was *Chara sp.* Floating vegetation was only recorded in very low densities in Bullo, Baines, Wickham and Humbert Rivers and Giles or Wattie Creek. There were no exotic aquatic vegetation species recorded.

◆ *Instream and Bank Habitats*

All but one site were rated as having moderate or high cover and diversity of instream and bank habitats. One site on the Wickham River had a very high cover and diversity. A subjective assessment of the aquatic environment was also undertaken and the results showed that over two-thirds of sites were rated as being in good to pristine condition, whilst nearly one-third of sites rated as being in poor to very poor condition.

The most commonly occurring instream habitat types included branches, leaves and twigs, logs, tree roots, rock faces and deep permanent pools. Vegetation overhang from riparian vegetation provided canopy cover for instream habitats and had a mean width of 2.6m occurring along 63% of the bank length on average.

At the time of survey fish passage was restricted at nearly half of the sites assessed due to the formation of isolated pools. It was concluded that fish passage would be restored in the wet season.

◆ *Overall Condition*

The overall condition rating is based on equally combining the ratings for the following six components:

- State of the reach environs;
- Bank stability;
- Bed stability;
- Cover and structural diversity of riparian vegetation;
- Cover of exotic riparian vegetation; and
- Cover and diversity of instream and bank habitats.

The majority of sites (87%) recorded a high overall condition rating whilst the remaining sites (13%) rated very high. Therefore, no sites were rated as being degraded overall. The sites that rated very highly overall were located on Angalarri River, Wickham and Humbert River, Victoria River below Jasper Creek, in the upper catchment of the Victoria River, Baines River, Armstrong River and Jasper Creek.



7. CONCLUSIONS, BROAD MANAGEMENT ISSUES AND RECOMMENDATIONS

In order of overall condition, if all sites within each sub-section are averaged and then ranked from highest to lowest, the sub-sections are listed below:

1. Angalarri River
2. Armstrong River
3. Wickham and Humbert Rivers
4. Giles or Wattie Creek
5. Victoria River – upper catchment
6. Baines River
7. Jasper Creek
8. Victoria River – estuary
9. Gregory and Delamere Creeks
10. Battle Creek
11. Gordon Creek
12. Bullo River
13. Victoria River – below Jasper Creek
14. Camfield River
15. Victoria River – below Camfield River

Even though all the rivers and creeks were assessed to be of high or very high overall condition, all sites had some degree of degradation. That is, no site rated very highly for every attribute assessed. The type of degradation ranged from exotic species invasion, lack of cover and structural diversity of riparian vegetation, lack of diversity of instream and bank habitats, disturbances to the reach environs, and bank and/or bed instability. Disturbance factors included grazing, roads and tracks, concentration of stock and/or feral animals at watering points, high flows, runoff, floodplain scours and breakouts, people, and, to a limited extent, tidal influence.

Of the six factors contributing to the overall condition rating for sites assessed, the major issues within the Victoria River catchment in order of priority are listed below:

1. High level of weed invasion (all 15 sub-sections)
2. Lack of cover and structural diversity of riparian vegetation (all 15 sub-sections)
3. Lack of diversity of instream and bank habitats (all 15 sub-sections)
4. Disturbance to reach environs (14 sub-sections)
5. Bank instability (8 sub-sections)
6. Bed instability (6 sub-sections)

The following section outlines the major issues and conclusions that can be drawn from the survey of the Victoria River and its tributaries.

1. High level of weed invasion

Weed invasion in the riparian zone was identified as the major issue affecting the condition of the Victoria River and its tributaries. Exotic vegetation species, particularly vines and forbs, were widely distributed throughout the catchment and were recorded in all sub-sections and over three-quarters of sites assessed. The degree of invasion, or extent, of weeds in the riparian zone varied significantly (ie from 0-42% cover), with nearly half the sites recording a level of greater than 10% cover.

Weeds are generally opportunistic species, and outcompete native species for light, space and nutrient, effectively displacing them in the river corridor. This can alter the structural diversity and biodiversity of riparian areas, and has implications for river health in terms of affecting bank stability, stream flows, water quality, the aesthetic appeal of an area, movement of animals and people, and increasing the fuel load for fires.

Mechanisms for weeds being introduced to the Victoria River catchment include spreading down rivers and creeks; people deliberately introducing species for shade or ornamental plants, or accidentally on the soles of their shoes or attached to clothing; birds and mammals (including stock and feral animals) carrying seed in tails or spreading through dung after eating fruits or transported in hay; or cars and trucks carrying seed on tyres or unwittingly packed into their equipment.

Once introduced, weeds generally colonise areas denuded of other vegetation such as heavily utilised areas around stock bores, cattle yards, river crossings, camping areas, boat ramps and washouts following high flows or flood events (they can also colonise and stabilise sand bars, altering stream morphology).

Impacts of weeds for land managers include loss of productivity on pastoral properties as grass species decline, and reduced recreational activities (eg fishing, camping, walking etc) in areas where access or aesthetic appeal is affected. River reaches with high levels of weed invasion were located on different land tenure including Aboriginal land, pastoral leases, National Parks and Department of Defence land, as well as in close proximity to infrastructure such as the Victoria Highway.

Plants can be 'Declared Weeds' under the NT *Weed Management Act 2001*, and landholders then have a legal responsibility to control them on land that they manage. Declared weeds are categorised into Classes A, B and C, depending on whether they need to be eradicated, their growth and spread is to be controlled, or they are not to be

introduced into the NT. All other plants growing in the wrong place are known as an environmental weed.

Passiflora foetida, the most prevalent weed species in the Victoria River catchment at the time this survey was conducted, is an environmental weed. It is a fast growing species which chokes out native vegetation, and is also suspected of poisoning stock. *Parkinsonia aculeata* is a Declared Weed (Class B), and is also a Weed of National Significance (WONS species). This species was introduced into Australia as a shade tree in the 1890s. It forms impenetrable thorny thickets blocking access to creek lines and rivers and excluding native species. It is a very hardy plant that can withstand long dry periods and seeds remain viable for many years. The other most prevalent weed in the catchment was *Xanthium occidentale*, also a Declared Weed (Class B). This species was reportedly imported into Australia with cotton seed and forms dense thickets along river systems. These three species, along with the other weeds identified in the catchment pose a serious environmental problem for the people responsible for managing land.

In general, controlling weeds along streams requires a whole of catchment approach, as 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. Therefore weed control strategies along the Victoria River and its tributaries needs a collaborative approach from all land owners and managers, making the best use of available resources such as equipment and technology. Public awareness is also important to prevent the spread of weeds to new areas.

Individual landholders are responsible for weed management on their land, and most properties undertake some form of weed control (eg spraying, burning, slashing etc). There have been several organised campaigns to combat the weed situation in the catchment in recent years. *Parkinsonia aculeata* was the target of a weed control program conducted by landholders with Natural Heritage Trust (WONS) funding and assistance from DIPE between 2002 and 2004. Ongoing programs include a Lions Tail Control Program funded by Heytsbury Beef Pty Ltd undertaken by the Caring for Country Unit, Timber Creek. There is a Devils Claw Festival, which is an annual event organised through NT Parks and Wildlife Service on Gregory National Park. There have also been committed control programs on a number of pastoral properties to manage devils claw which has significantly reduced the extent of the infestations. It is important that there is continued follow up to keep the devils claw contained.

The VRDCA are in the process of applying for funding through the Weeds Menace Program to undertake a *Barleria* Control Program, and DIPE are currently developing an Integrated Weed Control Program for the control of Bellyache Bush, which is on the boundary of the Victoria River catchment.

The Katherine Regional Weed Management Strategy 2005-2010, prepared by the Katherine Regional Weed Advisory Committee, advocates weed prevention as the key to weed management, as control can often be un-economic and sometimes even impossible to achieve. Land managers are encouraged to prepare property management plans to prevent the introduction of weeds, and to control the spread of weeds that are already present. The DIPE Weed Management Branch are currently facilitating a weeds risk assessment process to identify priority weeds for the Katherine Region and review the Declared Weeds list for the NT *Weeds Management Act*. Specific NT Species Management Plans will be prepared for each of these species. National Strategic Plans have already been prepared for all of the WONS species and these are available at the Katherine and Timber Creek Weeds Management Officers. It is envisaged that land managers and conservation groups such as the VRDCA will eventually provide weed distribution information to the Weeds Management Branch so that sub-catchment maps can be collated and strategic management plans be developed to assist land managers plan and prioritise on ground works.

The Weeds Management Branch of DIPE in Timber Creek or Katherine are the best contacts for further information on the status of weeds in the region and best mechanisms for their control.

2. *Lack of cover and structural diversity of riparian vegetation*

Cover and structural diversity for riparian vegetation was categorised as moderate for nearly three-quarters of the sites throughout all sub-sections within the Victoria River catchment, making this factor the second most significant issue in the catchment.

The only site that recorded a low cover and structural diversity was along the Victoria River estuary. The low rating for this site was due to the fact that there were only two estuarine species recorded (ie *Avicennia marina* and *Sesuvium portulacastrum*) and these provided poor cover. This demonstrates that cover and structural diversity can be poor due to natural conditions, and is not necessarily a reflection of poor river management.

The riparian vegetation was quite structurally diverse throughout the catchment with trees (between 2-30m), shrubs, forbs and grasses being recorded at more than 90% of sites assessed. The rating was reduced due to the variation between 0-75% cover for the different structural types. Grasses provided the highest cover, but this only averaged 29%, although it ranged up to 75% cover along some reaches. Trees (2-30m) provided an average cover of only 16-18%, although this ranged to as high as 40% cover.

In general, the lower banks had a higher percentage of bare ground than the upper banks which is possibly due to naturally occurring seasonal aspects. Continual high flows over the wet season and deposition of sediment during this period, or water availability or fires during the dry season may influence the occurrence of ground covers and, therefore, the structural diversity and covers recorded.

The study revealed that the riparian vegetation was relatively intact throughout the catchment, and had not been impacted upon by extensive clearing or development. Factors affecting the reaches in general, included grazing, roads and tracks, causeways and river crossings, stock and/or feral animal watering points and bridges or culverts. These factors could also be contributing to the lack of cover and structural diversity of the riparian vegetation found throughout the catchment.

River bank stability can also influence the condition of the riparian zone. Natural factors such as water availability, soil type, climate and location within the catchment can all influence the types of vegetation found in the riparian areas, as do external influences such as grazing, vehicular access, people access, water quality and infrastructure. The cover and structural diversity of the riparian vegetation varied between sites, even in instances when the stability of the river banks did not vary. More specific research would be required to determine the relationship between river bank stability and riparian vegetation in the catchment.

The average width of the riparian zone throughout the catchment was 23m, with a range of 0-155m. The width of riparian vegetation is usually a good indication of the 'natural' width, and can often be used as a guideline for planning and recommending appropriate buffer zone widths throughout a catchment. The larger the stream, the larger the band of vegetation required to buffer potential impacts. From this study however, it is apparent that riparian vegetation widths are influenced by other factors, as the larger stream orders do not have the largest riparian vegetation bands as would be expected.

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) – 31m (range 2-95m)
- Medium-sized streams (orders 3 and 4) – 22m (range 5-68m)
- Major streams (stream orders 5 and 6) – 20m (range 5-89m)

The greatest variation in riparian widths at any one site was recorded in the Victoria River estuary, where the left hand bank had 11m wide vegetation and the right hand bank had 155m of vegetation. This site was located on a bend in the river where the outside bend (left hand bank) was eroding, and there was accumulated sand and associated vegetation on the inside bend (right hand bank). Other factors that may be contributing to narrower than expected riparian widths on the larger stream orders include: grazing by stock, feral animals and other native species (eg wallabies) which can suppress regeneration of natural species; weed invasion out competing native species; naturally low rainfall and limited groundwater resources resulting in less moisture for plants to access further away from the stream.

Riparian zones are a vital link between land and water environments. Riparian vegetation performs many essential functions, including: the protection of river banks from erosion processes; acting as a buffer or filter for sediments; 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 is imperative that riparian areas be protected in the Victoria River catchment. Grasses and other low species, including regenerating shrubs and trees, are particularly susceptible to impacts from grazing, infrastructure and uncontrolled access points to the river (eg boat ramps, camp sites, etc).

There have been several attempts to fence off riparian areas in the catchment in the past, however seasonally high flows and large distances make the cost of repairs and maintenance prohibitive for many landholders. Relocating stock watering points off stream is another mechanism to restore and protect riparian areas. Riparian areas will continue to be degraded for as long as stock and feral animals have unlimited access to these fragile environments.

3. *Lack of cover and diversity of instream and bank habitats*

The ratings indicate that there is a lack of cover and diversity of instream and bank habitats at over one-third of sites located in all sub-sections. This is not considered to be a major issue in the Victoria River catchment though, as it is probably a natural feature of the landscape rather than a result of degradation.

The rating reflects 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. Instream habitat types were relatively diverse with branches, leaves, twigs, and logs being recorded at over 90% of sites. Bank habitat types were also quite diverse with canopy cover and overhanging vegetation being present at all sites. The cover provided by instream and bank habitats ranged substantially though and it is generally this component that reduced the rating.

Instream and bank habitats are important resources for instream fauna, including macro-invertebrates and fauna associated with the riparian vegetation. The results suggest that the instream and bank habitats were generally diverse and possibly provide habitat areas to support a diversity of fauna. More specific research would need to be undertaken to determine the value of instream and bank habitats in the Victoria River catchment for fauna species. It is possible that the results of this study could be used in collaboration with other fauna studies such as the 'Ausrivas Program' or the Purple-crowned Fairy-wren research project to determine the relationship between instream and bank habitats and fauna species, in this unique seasonally dry-wet environment.

The location of the reach within the catchment, and the geology and topography influences the diversity of instream and bank habitats and subsequently the aquatic vegetation, as the flow varies enormously throughout the year, and mechanical damage during high flows is often an annual event. Riparian vegetation varies depending on the location in the catchment, and this has implications on leaves, twigs and branches falling instream, occurrence of large rock faces, permanent water holes etc. The drying up of many sections of the rivers and creeks each year means that instream vegetation has a limited growing season and has to recolonise each year, compromising the integrity and perhaps also the quality of the habitat it provides.

Sites situated on lower stream orders (ie smaller rivers and creeks) generally had a lower cover and diversity of instream and bank habitat than sites situated on the higher stream orders and those in the lower sections of the catchment where there is permanent water.

Management suggestions for protection of instream and bank habitats are similar to those listed for the protection of riparian vegetation and include: removal of weeds, relocation of stock watering points off stream, and control of feral animals. In addition to these measures, instream and bank habitats are also affected by water quality and high flows, as well as potential impacts by recreational and commercial fishing operations and other people using the river to its detriment.

4. *Disturbance to reach environs*

Disturbances to reach environs were identified as an issue affecting the overall condition of the catchment. 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 was the major land use and disturbance factor recorded throughout the Victoria River catchment, followed by roads and tracks, river crossings and watering points for stock and feral animals. Just over half the sites that rated as essentially natural had relatively low impact land uses, undisturbed vegetation and few local disturbances. Nearly half of the sites that rated as having some modification recorded the presence of a local disturbance such as grazing, concentration of animals (including ferals) around a watering point, river infrastructure (eg tracks, crossings), people or floodplain erosion that reduced the rating from essentially natural.

Infrastructure can cause localised problems, with poor design and/or lack of maintenance leading to erosion and other impacts. It is important to properly locate crossings, avoiding outside bends or steep banks, and to target areas where the creeks are shallower, and have larger sediments along the bed such as gravels, cobbles or boulders. Tracks need to be designed to minimise the concentration of flows along their length, and a regular maintenance program needs to be implemented to avoid severe erosion. Another key consideration when locating infrastructure such as roads, bridges and cattle crossing points, is to disturb as little riparian vegetation as possible. For assistance with this issue the following would be useful references:

- *Victoria River District Road and Fenceline Erosion Control* (VRDCA, 2003) as a video and DVD;

- *Guidelines for the Construction and Maintenance of Formed Roads and Access Tracks in the Northern Territory* (Fulton, 2002);
- *Draft Erosion and Sediment Control Guidelines* expected to be released by the NT Government in early 2006; and
- *The Glove Box Guide to Tracks, Firebreaks and Fencelines*, a CD that was developed by the NT Government with NHT funding in 2002.

Landholders, managers and visitors need to be mindful of the individual actions that contribute to river degradation, and to implement steps to avoid further deterioration and actually promote the restoration and maintenance of the river corridor and reach environs. Any regional strategy should ensure that the riparian vegetation is protected, ad hoc access points and river crossings are restricted, necessary infrastructure is maintained, fencing and off-river watering points for stock are encouraged, feral animals are controlled, and that weed invasion of the riverine environment is managed. It is therefore important to undertake follow up assessments to determine the rate and direction of changes occurring in the catchment and manage the outcomes accordingly.

5. *Bank instability*

Although 85% of the sites were assessed as having stable river banks, only two sites were considered absolutely stable. Erosion, rather than aggradation, was the dominant process affecting bank stability throughout the catchment. Overall, bank stability was not identified as a major issue in the catchment. The stability of banks can also affect other features such as riparian vegetation and instream and bank habitats.

There was only one site with extensive bank instability and it was located on Poison Creek in the Gordon Creek sub-section. Stock was causing extensive impacts at this site, along with a track and river crossing.

High flows associated with the wet season was the most significant factor contributing to bank instability, followed by erosion of river banks by stock and feral animals accessing the rivers and creeks for water, shelter and food. As many of the rivers and creeks become isolated pools during the dry season, animals tend to concentrate around these areas if no other water points are available. As a result, trampling and grazing of the river banks and reach environs occurs. Infrastructure such as roads, tracks, crossings and bridges were identified as the third greatest threat to bank stability. The only other major cause of erosion identified in the catchment was floodplain scours and breakouts and runoff, both associated with high flows during the wet season.

The high level of bank stability recorded throughout the catchment is reflected in the fact that the riparian vegetation is relatively intact and disturbances are generally localised and infrequent. The only bank protection measures noted at the time of survey included fencing along the river and/or at stock watering points at 7% of sites, and one site which had gabions. If follow up surveys or anecdotal evidence indicated that there was a deterioration in the stability of the river banks in the future, fencing off riparian areas to exclude stock and feral animals would help riparian vegetation regeneration and stabilise banks. When fencing is done along river corridors, responsibility for management needs to be taken into account so that activities such as weed and feral animal control, and maintenance of fencing do occur.

Monitoring the proportion of bank lengths that are stable, eroding or aggrading can assist with detecting the extent of change in bank stability over time throughout a catchment. It is also possible to identify links between bank stability and any increase in the rate or extent of erosion or sedimentation that can be attributed to human activities within the catchment. There is currently a project examining riparian management and the rate of erosion in the catchment which will address some of these issues (McCloskey, in press).

6. *Bed instability*

Overall, bed stability was not identified as a major issue in the catchment as only 19% of sites recorded bed instability in the form of moderate aggradation, except one site where erosion was the dominant process.

In the lower catchment sites on Victoria River and Bullo River, sites experiencing aggradation were mostly located in the tidal sections, where sediments would be expected to accumulate before eventually being flushed out to sea. Bed aggradation was also found to be occurring in upstream areas. At these sites the river channel was relatively flat, uniform and shallow, and there appeared to be a large amount of sand and gravel. These upstream sites were all near stock watering points and vehicle crossings, and had bank erosion, floodplain scouring and new channels forming.

Site 9_4 on Poison Creek was the only site that recorded bed (and bank) erosion problems due to stock, and to a lesser extent a vehicle crossing and access track into Mt Sanford Outstation. The instability at this site is subsequently affecting the riparian vegetation and reach environment.

Where bed stability was identified as an issue, the major factor affecting it was grazing. Other, less significant factors included bank erosion, concentration of flows, instream siltation and bed deepening.



Recommendations

The Victoria River catchment was found to be in reasonably good condition at most sites assessed during the 1996 survey. A follow up survey would be required to enable landholders, managers, the Northern Territory Government and community groups to determine whether the catchment condition has improved or deteriorated over the last decade.

There were several common management issues raised during the discussion on each of the condition rating factors, and these can be taken to be the recommendations from this report:

- Be pro-active in river management as it is cheaper and easier to avoid a problem than to fix one, and target the cause of problems rather than the symptoms;
- Address weeds and feral animals in a strategic and effective way that is sustainable;
- Protect riparian areas through fencing and relocating stock watering points off stream, and ensuring tracks and river crossings are properly designed, constructed and maintained; and
- Approach catchment management issues as a community rather than individual basis, with co-operation and collaboration where possible.



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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°; and strong currents.

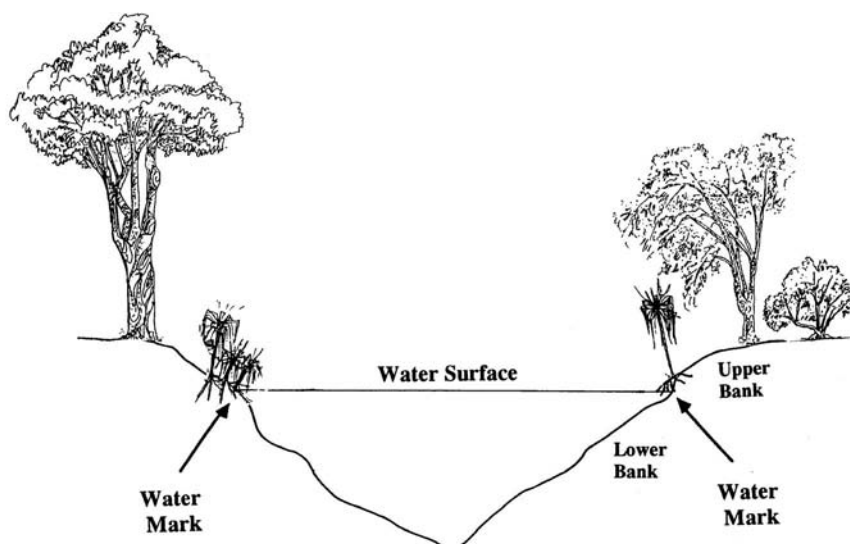
Catchment (river)	An area in which surface runoff collects and from which it is carried by a drainage system, as a river and its tributaries. Also known as drainage basin or watershed.
Causeway or Crossing	A road constructed across the bed of a stream. All stream flow goes over the road.
Channel	The whole area between the two high banks.
Channel Habitat Types	Waterfall, cascade, rapid, riffle, glide, run, pool or backwater
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).
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.
Geomorphic Province	An area of land having attributes of landform and/or soil and/or vegetation that differ consistently from those of other terrain, because of the direct influence of geomorphological landscape-forming process or processes operating there but not operating elsewhere at the same rate.
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°; 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.
Macroinvertebrates	Animals (eg insects, crustaceans, molluscs and worms) that do not have a backbone, are visible to the naked eye and, if aquatic, live in water. The number and variety of these animals found in a stream can give an indication of the relative levels of water pollution and can provide a means of assessing the ecological health of rivers.
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 <i>NT Noxious Weeds Act</i> 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 Habitat	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°; 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.
Riffle Habitat	A shallow area of a stream, often separating pools, characterised by a depth 0.1-0.3m; gradient 1-3°; 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 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°; 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.

Siltation	See 'Sedimentation'.
Site	Is a location on a river or creek where information is collected on the condition of the streams. 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.
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 <i>etc</i>) 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°.
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 <i>Ampelopteris prolifera</i>) and other vegetation (eg <i>Pandanus aquaticus</i>) 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: List of Sites
- Appendix B: Summary of Data Sheet Information
- Appendix C: Summary of the Condition and Stability Ratings
- Appendix D: Riparian Vegetation Species Recorded in Victoria River Catchment

Appendix A: List of Sites

Sub-section No. / Site No.	Tributary Name	Location Description
1a_1	Victoria River	Estuary - Approximately 9km downstream of Entrance Island (closest site to the mouth of the Victoria River)
1a_2	Victoria River	Estuary - Blunder Bay, approximately 3km upstream of Entrance Island
1a_3	Victoria River	Estuary - Holdfast Reach, approximately 17km downstream of Bullo River
1a_4	Victoria River	Estuary - Approximately 8km upstream of Bullo River junction
1a_5	Victoria River	Estuary - Downstream of Lobby Creek (approximately 9km downstream of Baines River)
1a_6	Victoria River	Approximately 15km upstream of Baines River junction, 7km downstream of Angalarri River
1a_7	Victoria River	Between Sandy Island and the junction of Angalarri and Victoria Rivers
1a_8	Victoria River	Downstream of Big Horse boat ramp near Sandy Island
1b_1	Victoria River	Approximately 5km upstream from Saltwater Yards on Fitzroy Station
1b_2	Victoria River	Upstream of Rockhole on Coolibah Station
1b_3	Victoria River	Downstream of public access point near Victoria River Roadhouse
1b_4	Victoria River	Approximately 10km upstream of boat ramp in Gregory National Park, upstream of Victoria River Roadhouse
1b_5	Victoria River	Approximately 24km upstream of public access point in Gregory National Park, upstream of Victoria River Roadhouse
1b_6	Skull Creek	At Victoria Highway crossing.
1b_7	Arm of Cow Creek	Downstream of water fall on an arm of Cow Creek
1c_1	Victoria River	Site on Victoria River Downs Station (accessed via Kidman Springs)
1c_2	Victoria River	Up and downstream of Dashwood Crossing on Victoria River Downs Station
1c_3	Victoria River	Upstream of river crossing on track to Coles Bore on Victoria River Downs Station
1c_4	Victoria River	Pigeon Hole Outstation
1d_1	Victoria River	Longreach Waterhole on Camfield Station
1d_2	Victoria River	At and downstream of river crossing on Mt Sanford Outstation, Victoria River Downs Station
1d_3	Victoria River	At and downstream of Buchanan Highway bridge at Kalkarindji
1d_4	Victoria River	At and upstream of crossing at Sambo Waterhole
1d_5	Victoria River	Upper catchment on Riveren Station
1d_6	McDonald Creek	At river crossing south of Kalkarindji on Daguragu Aboriginal Land
2_1	Bullo River	Bullo River Station on track into right hand bank
2_2	Bullo River	Approximately 10km upstream of Bullo River Homestead
2_3	Bullo River	Bullo Gorge on Bullo River Station
2_4	Bullo River	Bullo River Station, upstream of crossing and downstream of Big Knob waterhole
2_5	Arm of Bullo River	Bullo River Station, at creek crossing 5km downstream of Pinkerton Range
3_1	Baines River	2km upstream of junction with Victoria River
3_3	East Baines River	Upstream and downstream of Victoria Highway Bridge
3_4	Limestone Creek	Limestone Gorge (approximately 400m upstream of East Baines River junction)
3_5	East Baines River	Bullita Homestead, at and upstream of river crossing on Bullita Stock Route
3_6	West Baines River	1.5 - 2.5km upstream of Victoria Highway
3_7	West Baines River	Between Hurricane Hill Yards and Magdaba Yards
3_8	Boxer Springs Creek	Amanbidji Station
3_9	West Baines River	Upper catchment - Amanbidji Pastoral Co. (Kildurk Station)
4_1	Angalarri River	0.8km upstream of junction with Victoria River
4_2	Angalarri River	Approximately 7km downstream of Angalarri River crossing (access to Bradshaw Station)
4_3	Angalarri River	Approximately 3km upstream of junction with Ikymbon River on Bradshaw Station
4_4	Angalarri River	Mid-upper catchment site, approximately 29km upstream of Ikymbon River junction on Bradshaw Station
4_5	Ikymbon River	Upstream of Inukalen cataract on Bradshaw Station
4_6	Ikymbon River	Upper catchment site on Bradshaw Station
4_7	Arm of Angalarri River	Approximately 37km upstream of junction with Ikymbon River on Bradshaw Station

5_1	Gregory Creek	Approximately 2km upstream of junction with Victoria River in Gregory National Park
5_2	Gregory Creek	At river crossing in Gregory National Park near Sullivan Creek Camp
5_3	Gregory Creek	Upper catchment site, upstream of river crossing on Delamere Station
5_5	Delamere Creek	Upstream of river crossing on "Old Delamere"
5_6	Delamere Creek	At and downstream of river crossing before bore, approximately 6.5km south east of No.9 Bore on Delamere Station
6_1	Battle Creek	Approximately 3km from Larry's Lake on Victoria River Downs Station
6_2	Battle Creek	Upstream of river crossing going into Larry's Lake on Victoria River Downs Station
6_3	Battle Creek	On Killarney Station, upstream of boundary fence with Victoria River Downs Station
6_4	Waterbag Creek	Upstream of river crossing on road to Top Springs from Jasper Gorge
7_1	Jasper Creek	Upstream of creek crossing on Kidman Springs Research Station (boundary with Victoria River Downs Station)
7_2	Jasper Creek	At and upstream of boat launch site at Jasper Gorge camp site
7_3	Slatey or Jasper Creek	Upstream of crossing on road to Jasper Gorge
7_4	Surprise Creek	Upstream of creek crossing on Kidman Springs Research Station
8_1	Wickham River	Approximately 7km upstream of river crossing (by boat) on Victoria River Downs Station
8_2	Wickham River	Upstream of river crossing and gauge station on Humbert River Station
8_3	Wickham River	Johnston Waterhole on Humbert River Station
8_4	Wickham River	At and upstream of river crossing, approximately 3km upstream of junction with Gibbie Creek on Humbert River Station
8_5	Gibbie Creek	Humbert River Station
8_6	Humbert River	Humbert River Homestead river crossing and upstream
9_1	Gordon Creek	Upstream of crossing on Victoria River Downs Station
9_2	Gordon Creek	Above crossing on road to Pigeon Hole Outstation on Victoria River Downs Station
9_3	Fever Creek	Upstream of creek crossing on road to Mt Sanford Outstation, Victoria River Downs Station
9_4	Poison Creek	At road crossing on road to Mt Sanford Outstation, Victoria River Downs Station
10_1	Armstrong River	Downstream of road crossing near Ogden Bore on Montejinni Station
10_2	Armstrong River	Old Top Springs (upstream of Delamere Road crossing)
10_3	Coolibah Creek	Upstream of crossing on road to Jasper Gorge
10_4	Coolibah Creek	Delamere Road at creek crossing
10_5	Townsend Creek	Upstream of Buchanan Highway Crossing (50.4km from Top Springs)
11_1	Camfield River	At old Buchanan Highway river crossing on Camfield Station
11_2	Camfield River	At and upstream of river crossing near No. 22 Bore on Cattle Creek Station
11_3	Camfield River	Junjaminji waterhole, near Churgamidgee Bore on Wave Hill Station (riffle at river crossing and pool downstream)
11_4	Camfield Creek	Downstream of river crossing near No.17 Bore on Wave Hill Station
12_1	Wattie Creek	Upstream of river crossing on road to Dagaragu
12_3	Lily Creek	Upstream of crossing near No.18 bore on Limbunya Station
12_4	Stevens Creek	Upstream of river crossing on road to Mt Sanford Outstation (Blackgin Waterhole), Victoria River Downs Station

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 km²)
- 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:

<ul style="list-style-type: none"> Horticulture small crops/vines irrigated broadacre row crops grazing – sown pasture grazing – native – thinned intensive livestock urban manufacturing/processing urban park or reserve 	<ul style="list-style-type: none"> horticulture tree crops / fruit rainfed broadacre row crops grazing – native – cleared grazing – native – virgin timber urban residential national/environment park or reserve rural residential / hobby farm, other
---	--
- Local disturbance:

<ul style="list-style-type: none"> road/track causeway/river crossing/ford weir river works irrigation runoff/pipe outlet sewage effluent water point for stock/ferals dredging other mine none 	<ul style="list-style-type: none"> bridge/culvert boat ramp channelisation discharge pipe water extraction/pump grazing forestry activities sand/gravel mine people
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- 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°.
Cascade	Step height <1m; gradient 5-60°; strong currents.
Rapid	Depth >0.3m (guide only); gradient 3-5°; strong currents; and rocks break surface.
Riffle	Depth 0.1-0.3m (guide only); gradient 1-3°; moderate currents and surface unbroken but unsmooth.
Glide	Depth <0.1m; gradient 1-3°; small currents; surface unbroken and smooth.
Run	Depth >0.3m; gradient 1-3°; 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.1).
- Sketch and measurements for each bank – marking on the 'point of inflexion', upper bank and edge of riverine vegetation / riparian zone (refer Figure A.1).

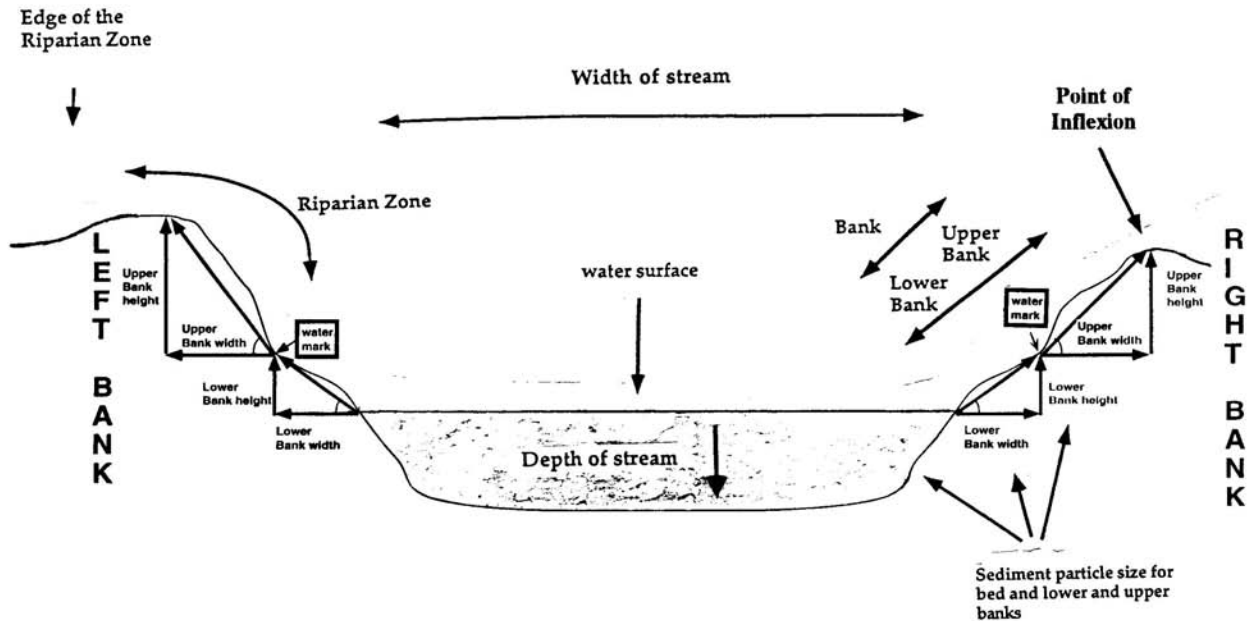


Figure A.1: Diagrammatic Representation of a River Channel Showing the Type of Information Collected During Cross-section Surveys

- Bank sediments for each bank, lower and upper, totalling 100%. Percentage of organic matter within sediment sample. Sediment size classes include:
 - finer (<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

- **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.2) 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

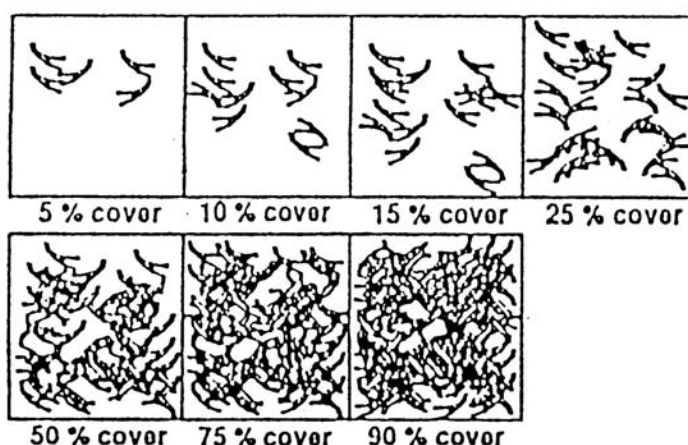


Figure A.2:

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.2) for:

submerged vegetation	(algae, Chara/Nitella, Vallisneria, Myriophyllum, Elodea and other herb-like forms)
floating vegetation	(water hyacinth, Azolla, water lilies and other floating vegetation)
emergent vegetation	(Phragmites, Typha, Para Grass, rushes/sedges, Pandanus, Melaleuca, other shrubs/trees and 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 1m² 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.
- 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.2) 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 and disturbance, are determined and then scaled between 0% and 100% (see listing below), before being multiplied by the weightings (ie 50%) and summed 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% - ie 100/14 * category number)	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	Aboriginal Land	(93%)
	Park or Reserve	(100%)	
Local disturbance categories: (scaled between 0% and 100% - ie 100/15 * category number)	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:

$$\text{State of the Reach Environs} = \text{Local disturbance x (50\%)} + \text{Land use x (50\%)}$$

• **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 (ie erosion or aggradation) is averaged for the river banks and the process recording the highest average represents the dominant direction of the change in condition prevailing at the site at the time of the survey.

$$\text{Bank Stability Rating} = (80\%) \% \text{ upper bank stable}^* + (20\%) \% \text{ lower bank stable}^* \\ (*\text{averaged for each bank})$$

- *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:

<i>Overstorey vegetation:</i>	trees >30m tall	(1)
	trees 10-30m tall	(2)
	palms	(3)
<i>Understorey vegetation:</i>	trees 2-10m tall	(4)
	mangroves	(5)
	woody shrubs <2m tall	(6)
	regenerating trees <2m tall	(7)
<i>Ground covers:</i>	vines	(8)
	rushes/sedges	(9)
	Phragmites	(10)
	Forbs/herbs	(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.2) 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 summed. That is, covers for growth forms 1 to 3, 4 to 7 and 8 to 14 (shown above) are summed. 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:

$$\text{sum of \% covers for overstorey} - (\text{sum of \% covers for overstorey} * \% \text{ of bare ground} * 15\%)$$

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”:

$$0.1 * \% \text{ cover for overstorey/understorey}^{(1)} \text{ UB} + 0.66 * \% \text{ cover for ground cover}^{(2)} \text{ UB}$$

(1) Called ‘overstorey bare’ in projects’ database

(2) Called ‘understorey bare’ in projects’ database

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 summed to give a rating out of 30 for each river bank at a site 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 along each river bank 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 formula below. Rating results for each bank are averaged for the site.

$$\text{Cover and Structural Diversity of Riparian Vegetation Rating} = \text{Foliage cover (A)} + \text{Structural diversity (B)}$$

- 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.2). 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

- Aquatic Vegetation ** (Maps 21, 22 and 23)

A condition rating for aquatic vegetation **has not been derived**, but rather the cover and distribution of submerged, emergent and floating aquatic vegetation and emergent aquatic vegetation are shown in Maps 21, 22 and 23 respectively.

• **Cover and Diversity of Instream and Bank Habitats ***

(Map 24)

The instream and bank habitat ratings are based on a combination of:

1. The cover (refer Figure A.2) 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 types 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 summed to give a final instream cover rating out of 15. Re-scale to 10.

(i) Organic Debris – Includes instream habitat types 1-6 listed above.

The covers are summed for these 6 types 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 types 7-11 listed above.

The covers are summed for these 5 types 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 types 12-15 listed above. Pools strongly influence this rating so are treated separately to the other habitat types.
- Add categories 12, 13 and 15 together (can be >100%)
 - 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:

- canopy cover
- vegetation overhang <1m from water surface
- root overhang
- bank overhang
- 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. Rating results for each bank are averaged for the site. The results for (i), (ii) and (iii) outlined below are summed 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%)
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• *Overall Condition ** (Map 25)

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 summed 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
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Appendix D: Riparian Vegetation Species Recorded in Victoria River Catchment

Plant Name – <i>Genus species</i>	Common Name	Status	Sub-sections where recorded
Trees, low trees and shrubs			
<i>Abutilon andrewsianum</i>		Native	1a
<i>Acacia ampliceps</i>		Native	1d
<i>Acacia colei</i>		Native	1d, 12
<i>Acacia difficilis</i>		Native	2
<i>Acacia farnesiana</i>	Mimosa Bush	Exotic	1d, 10, 11, 12
<i>Acacia holosericea</i>	Candelabra Wattle	Native	1a, 1b, 1c, 1d, 2, 3, 4, 5, 7, 8, 9, 10, 12
<i>Acacia leptophleba</i>		Native	1d, 12
<i>Acacia lysiphloia</i>	Turpentine	Native	12
<i>Acacia pellita</i>		Native	1b, 2, 3
<i>Acacia plectocarpa</i>		Native	4
<i>Acacia tumida</i>	Pindan Wattle	Native	2, 7
<i>Adansonia gregorii</i>	Baobab	Native	3, 4
<i>Aegialitis annulata</i> (M)	Club Mangrove	Native	1a, 2
<i>Aegiceras corniculatum</i> (M)	River Mangrove	Native	1a, 4
<i>Alectryon kimberleyanus</i>		Native	3
<i>Alstonia spectabilis</i>		Native	3, 7
<i>Antidesma ghaesembilla</i>	Murrungun	Native	3
<i>Atalaya hemiglaucula</i>	Whitewood	Native	1a, 1b, 1c, 1d, 2, 3, 4, 5, 6, 8, 9, 10
<i>Atalaya salicifolia</i>		Native	1c
<i>Avicennia marina</i> (M)	White Mangrove	Native	1a, 2, 4
<i>Barringtonia acutangula</i>	Freshwater Mangrove	Native	1b, 1c, 2, 3, 4, 5, 6, 7, 8
<i>Batis argillicola</i>		Native	1a
<i>Breynia cernua</i>		Native	12
<i>Buchanania obovata</i>	Wild Mango	Native	7
<i>Cajanus crassicaulis</i>		Native	1d, 7
<i>Cajanus reticulatus</i>		Native	1b, 2
<i>Calotropis procera</i>	Rubber Bush	Exotic*	1a, 3, 6, 7, 8, 12
<i>Calytrix brownii</i>		Native	4, 7
<i>Calytrix exstipulata</i>	Kimberley Heather	Native	1a
<i>Capparis sepiaria</i>		Native	2, 3, 4, 6, 10
<i>Cathormion umbellatum</i>		Native	1a, 1b, 2, 3, 4, 5
<i>Celtis philippinesis</i>		Native	6
<i>Ceriops australis</i> (M)	Long-fruited Spurred Mangrove	Native	1a
<i>Cressa cretica</i> (E)	Rosinweed	Native	2
<i>Crotalaria cunninghamii</i>	Parrot Pea	Native	2
<i>Crotalaria novae-hollandiae</i>	New Holland Rattlepod	Native	10
<i>Croton arnhemicus</i>		Native	1a
<i>Dichrostachys spicata</i>	Prickly Bush	Native	9, 10
<i>Dodonaea platyptera</i>		Native	4, 6, 8, 10
<i>Ehretia saligna</i>	Coonta	Native	1d
<i>Erythrina variagata</i>	Coral Tree	Native	6
<i>Eucalyptus bella</i>		Native	1b, 2, 3, 5, 10
<i>Eucalyptus brachyandra</i>	Tropical Red Box	Native	1a
<i>Eucalyptus brevifolia</i>	Snappy Gum	Native	12
<i>Eucalyptus camaldulensis</i>	River Red Gum	Native	1a, 1b, 1c, 1d, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
<i>Eucalyptus microtheca</i>	Coolibah	Native	1a, 1b, 1c, 1d, 3, 4, 6, 7, 8, 9, 10, 11

<i>Eucalyptus ptychocarpa</i>	Swamp Bloodwood	Native	5, 7, 8, 9
<i>Eucalyptus terminalis</i>	Northern bloodwood	Native	4, 7
<i>Excoecaria ovalis</i> (M)		Native	1a, 2, 4
<i>Excoecaria parvifolia</i>	Guttapercha Tree	Native	1a, 1c, 1d, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11
<i>Exocarpos latifolius</i>	Native Cherry	Native	3, 7
<i>Ficus coronulata</i>	Peach-leaf Fig	Native	1b, 1c, 1d, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
<i>Ficus leucotricha</i>		Native	1b, 3
<i>Ficus racemosa</i>	Cluster Fig	Native	1b, 1c, 1d, 2, 3, 5, 6, 7, 8, 9, 10, 12
<i>Flueggea virosa</i>		Native	1b, 1c, 1d, 3, 5, 6, 7, 8, 9, 10, 11, 12
<i>Gardenia</i> sp.		Native	1a
<i>Grevillea pteridifolia</i>	Fern-leaved Grevillea	Native	4
<i>Grevillea striata</i>	Beefwood	Native	4
<i>Grewia breviflora</i>		Native	2, 5, 8
<i>Grewia retusifolia</i>	Emu Berries	Native	2, 3, 4, 7, 10
<i>Gyrocarpus americanus</i>	Stinkwood	Native	6
<i>Hakea arborescens</i>		Native	5, 9, 11
<i>Halosarcia halocnemoides</i>		Native	1a, 1b
<i>Hibiscus panduriformis</i>	Yellow Hibiscus	Native	3
<i>Jasminum didymum</i>		Native	1d
<i>Lophostemon grandiflorus</i> (E)	Northern Swamp Box	Native	1b, 1c, 1d, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
<i>Lumnitzera racemosa</i> (M)	White-flowered Black Mangrove	Native	1a
<i>Lysiphyllum cunninghamii</i>	Bauhinia	Native	1d, 2, 3, 5, 6, 7, 8, 9, 10, 11
<i>Melaleuca acacioides</i>	Coastal Paperbark	Native	1a, 4
<i>Melaleuca argentea</i> (E)	Silver Paperbark	Native	1d, 2, 3, 4, 8, 11
<i>Melaleuca bracteata</i>	Black Teatree	Native	1d, 3, 11, 12
<i>Melaleuca leucadendra</i> (E)	Cajaput	Native	1a, 1b, 1c, 1d, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12
<i>Melaleuca minutifolia</i>		Native	12
<i>Melaleuca</i> sp.		Native	1b, 1c, 1d, 2, 8, 10
<i>Melaleuca viridiflora</i>	Green Paperbark	Native	2, 4
<i>Melastoma affine</i>		Native	1b
<i>Muehlenbeckia florulenta</i> (E)		Native	1a, 1b, 6
<i>Nauclea orientalis</i>	Leichhardt Tree	Native	1b, 1c, 1d, 2, 3, 5, 6, 7, 8, 9, 10, 12
<i>Pandanus aquaticus</i> (E)	River Pandanus	Native	1b, 1c, 1d, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
<i>Pandanus spiralis</i>	Screw Palm	Native	1b, 3, 4, 12
<i>Parkinsonia aculeata</i>	Parkinsonia	Exotic*	1a, 1b, 1c, 1d, 2, 3, 5, 6, 8, 9, 10
<i>Petalostigma pubescens</i>	Downy Cracker Bush	Native	2
<i>Phyllanthus maderaspatensis</i>		Native	3, 6, 7, 8
<i>Phyllanthus reticulatus</i>		Native	1b, 2, 3, 7, 8, 9
<i>Pouteria sericea</i>		Native	3
<i>Premna acuminata</i>		Native	2
<i>Pterocaulon sphacelatum</i>	Apple Bush	Native	1a
<i>Ricinus communis</i>	Castor Oil Plant	Exotic*	1b, 1c
<i>Salsola kali</i>	Prickly Saltwort	Native	1a, 2
<i>Santalum lanceolatum</i>	Plumbush	Native	9, 11, 12
<i>Sesbania formosa</i>	White Dragon Tree	Native	1d, 3, 5, 6, 9, 11, 12
<i>Sesbania simpliciuscula</i>		Native	6
<i>Sida spinosa</i>	Spiny Sida	Native	10
<i>Streptoglossa odora</i>		Native	4
<i>Strychnos lucida</i>	Strychnine Bush	Native	3, 4, 5, 6, 7
<i>Suaeda arbusculoides</i> (E)	Queensland Seablite	Native	1a, 2
<i>Syzygium eucalyptoides</i> ssp <i>eucalyptoides</i>	White Apple	Native	1b, 2, 3, 5, 8

<i>Tephrosia rosea</i>	Flinder's River Poison	Native	5, 6, 10, 12
<i>Terminalia bursarina</i>	Bendee	Native	1b, 1c, 1d, 2, 3, 4, 7, 8, 9, 11
<i>Terminalia erythrocarpa</i>		Native	1b, 2, 3, 8
<i>Terminalia grandifolia</i>	Nut Tree	Native	10
<i>Terminalia latipes</i>		Native	1a
<i>Terminalia platyphylla</i>	Wing-seed Terminalia	Native	1b, 1c, 1d, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
<i>Terminalia sp.</i>		Native	10
<i>Terminalia volucris</i>	Rosewood	Native	2, 3, 10, 11, 12
<i>Thespesia populneoides</i>	Portia Tree	Native	4
<i>Timonius timon</i>		Native	2
<i>Vitex glabrata</i>		Native	9
<i>Ziziphus quadrilocularis</i>		Native	1d, 3, 6, 7, 8, 10, 12
Forbs, grasses, ferns and vines			
<i>Acanthospermum hispidum</i>	Starburr	Exotic*	1d
<i>Achyranthes aspera</i>	Chaff-flower	Native	1a, 1b, 1c, 1d, 3, 4, 5, 6, 8, 9, 10, 11, 12
<i>Acundinella nepalensis</i>		Native	8
<i>Aerva javanica</i>	Kapok Bush	Exotic	1a
<i>Alternanthera augustifolia</i>	Narrow-leaf Joyweed	Native	1b, 5
<i>Alternanthera nodiflora</i>	Common Joyweed	Native	1a, 1b, 1c, 3, 4
<i>Aristida holathera</i>	Erect Kerosene Grass	Native	1a
<i>Arundinella nepalensis</i>	Reedgrass	Native	3, 4, 7, 8, 9, 10
<i>Blumea tenella</i>		Native	10
<i>Boerhavia schomburgkiana</i>		Native	1a
<i>Bothriochloa bladhii</i>	Forest Bluegrass	Native	1b, 1c, 3, 4, 6, 9, 10, 11
<i>Brachiaria reptans</i>	Fine Armgrass	Native	1a, 1b, 1c, 7, 9
<i>Cardiospermum halicacabum</i>	Balloon Vine	Exotic	1b, 12
<i>Cenchrus ciliaris</i>	Buffel Grass	Exotic	1a, 1d, 12
<i>Chara sp. (S)</i>		Native	1b, 1c, 1d, 1e, 3, 11, 12
<i>Chionachne cyathopoda</i>		Native	1b, 3, 5, 6, 8, 9, 10
<i>Chloris inflata</i>		Exotic	1a, 1d, 6
<i>Chrysopogon fallax</i>	Golden Beard Grass	Native	1d, 4, 11
<i>Crotalaria retusa</i>	Wedge-leaf Rattlepod	Native	1d, 2, 9
<i>Cymbi forme</i>		Native	2
<i>Cynanchum carnosum</i>		Native	4
<i>Cynodon dactylon (E)</i>	Couch Grass	Native	1a, 1b, 1c, 1d, 2, 3, 4, 5, 7, 9, 11, 12
<i>Cyperus bifax</i>	Downs Nutgrass	Native	1c, 6, 10, 11
<i>Cyperus dactylotes</i>		Native	11, 12
<i>Cyperus haspan (E)</i>		Native	1a
<i>Cyperus holosericea</i>		Native	4
<i>Cyperus javanicus</i>		Native	2, 4, 10
<i>Cyperus vaginatus (E)</i>	Stiff-leaf Sedge	Native	1d, 5, 6, 8, 9, 10, 11, 12
<i>Cyperus victoriensis (E)</i>		Native	1c, 6
<i>Cyperus viscidulus</i>		Native	4
<i>Dichanthium fecundum</i>	Curly Bluegrass	Native	1d, 3, 4, 6, 8, 9
<i>Dichanthium sericeum ssp polystachyum</i>		Native	6
<i>Dicliptera armata</i>		Native	9
<i>Echinochloa colona</i>	Awnless Barnyard Grass	Exotic	1a, 2, 11
<i>Eleocharis geniculata</i>		Native	2
<i>Enneapogon purpurascens</i>		Native	1a, 1d, 6, 9
<i>Eragrostis cumingii</i>	Cuming's Lovegrass	Native	1a, 2, 4
<i>Eragrostis tenellula</i>		Native	1b, 1c, 1d, 3, 5, 6, 7, 11

<i>Eriachne festucacea</i> (E)		Native	1b, 1c, 1d, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12
<i>Eriocaulon setaceum</i> (E)		Native	1b
<i>Eulalia aurea</i>		Native	4, 5, 7, 10, 11, 12
<i>Euphorbia coghlanii</i>	Sandhill Caustic Weed	Native	1c, 5
<i>Euphorbia hirta</i>	Asthma Plant	Exotic	1c, 2, 3, 7, 8, 9
<i>Fimbristylis littoralis</i>		Native	4
<i>Fimbristylis microcarya</i>		Native	1b
<i>Flaveria australasica</i>	Yellow Twin Stem	Native	10
<i>Fuirena ciliaris</i>		Native	4
<i>Gardenia lunata</i>		Native	1d
<i>Germainia truncatiglumis</i>		Native	1b
<i>Glinus lotoides</i>		Native	1b, 3, 7, 10
<i>Gomphrena canescens</i>	Batchelor's Buttons	Native	1d
<i>Gossypium australe</i>	Native Cotton	Native	1b
<i>Gymnanthera oblonga</i>		Native	3, 5
<i>Heliotropium sp.</i>		Native	1b
<i>Heteropogon contortus</i>	Bunch Speargrass	Native	1d, 2, 3, 4, 5, 6, 7, 9, 10
<i>Heteropogon triticeus</i>	Giant Speargrass	Native	2
<i>Hygrophila angustifolia</i>		Native	4
<i>Hyptis suaveolens</i>	Hyptis	Exotic*	2, 3, 5, 7, 8
<i>Indigofera linifolia</i>	Native Indigo	Native	1d, 5, 6
<i>Ipomoea plebeia</i>	Bellvine	Native	2
<i>Ischaemum sp.</i>		Native	9
<i>Iseilema vaginiflorum</i>	Red Flinders Grass	Native	3
<i>Limnophila chinensis</i> (S)		Native	3
<i>Lindsaea ensifolia</i>	Common Wedge Fern	Native	1b
<i>Ludwigia octovalvis</i>	Willow Primrose	Native	4
<i>Maidenia rubra</i> (S)	Maidenia	Native	1d
<i>Malvastrum americanum</i>	Spiked Malvastrum	Exotic	1a, 1d, 3, 6, 8, 9, 10
<i>Melochia pyramidata</i>		Exotic	1b, 3, 4, 6, 11, 12
<i>Mitrasacme nummularia</i>		Native	1b
<i>Mnesithea rottboellioides</i>		Native	3, 4, 5, 8
<i>Myriophyllum verrucosum</i> (S)	Red Water Milfoil	Native	5, 8, 12
<i>Nelsonia campestris</i>		Native	2, 6, 8, 9, 11
<i>Neptunia gracilis</i>	Native Sensitive Plant	Native	6
<i>Nymphaea violacea</i> (F)		Native	2, 8
<i>Ophiuros exaltatus</i>		Native	6
<i>Panicum decompositum</i>	Native Millet	Native	1a, 3, 4, 12
<i>Panicum effusum</i>	Hairy Panic	Native	8
<i>Panicum mindanaense</i>		Native	2, 4
<i>Panicum trichoides</i>		Native	2
<i>Paspalidium distans</i>		Native	1c, 3, 4, 7
<i>Passiflora foetida</i>	Stinking Passion Flower	Exotic	1a, 1b, 1c, 1d, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
<i>Persicaria attenuata</i> (E)		Native	3
<i>Philydrum lanuginosum</i> (E)	Woolly Waterlily	Native	1b
<i>Phragmites karka</i> (E)	Tropical Reed	Native	1b, 2, 8
<i>Plectrachne pungens</i>	Curly Spinifex	Native	7
<i>Pseudoraphis spinescens</i> (E)	Spiny Mudgrass	Native	3
<i>Psoralea cinerea</i>	Annual Verbena	Native	1b
<i>Rotala sp.</i> (S)		Native	3
<i>Schoenoplectus litoralis</i> (E)		Native	2, 12

<i>Sesbania cannabina</i>	Yellow Pea Bush	Native	1a, 6
<i>Sesuvium portulacastrum</i> (E)	Sea Purslane	Native	1a, 2
<i>Setaria apiculata</i>	Pigeon Grass	Native	8
<i>Sida acuta</i>	Spiny-head Sida	Exotic*	2
<i>Sida cordifolia</i>	Flannel Weed	Exotic*	2
<i>Sorghum plumosum</i>	Plume Sorghum	Native	1b
<i>Sorghum sp.</i>		Native	3, 5, 7, 9
<i>Sporobolus virginicus</i> (E)	Sand Couch	Native	1a, 4
<i>Stemodia viscosa</i>		Native	1d, 3
<i>Themeda triandra</i>	Kangaroo Grass	Native	3, 4
<i>Tinospora smilacina</i>	Snakevine	Native	2
<i>Triodia pungens</i>	Gummy Spinifex	Native	1a
<i>Triumfetta parviflora</i>		Native	1a
<i>unidentified unidentified</i>		Native	1b, 1c, 6, 10
<i>Urochloa mosambicensis</i>	Sabi Grass	Exotic	3
<i>Urochloa sp.</i>		Native	8
<i>Xanthium occidentale</i>	Noogoora Burr	Exotic*	1a, 1b, 1c, 1d, 3, 4, 5, 6, 7, 8
<i>Xanthium sp.</i>		Native	1b
<i>Xerochloa imberbis</i>	Rice Grass	Native	1a

* Declared Noxious Weed within the Northern Territory

E Also recorded as emergent aquatic vegetation

F Also recorded as floating aquatic vegetation

S Also recorded as submerged aquatic vegetation

M Mangrove species



The following Maps appear in this section:

- Map 1 NT Drainage Divisions and Basins as defined by the Australian Water Resources Council
- Map 2 Locality Plan
- Map 3 Landform
- Map 4 Vegetation and Important Wetlands
- Map 5 Land Tenure and Land Use
- Map 6 Major Sub-catchments
- Map 7 Sub-sections
- Map 8 Stream Orders
- Map 9 Location of Sites
- Map 10 Local Land Tenure at Sites
- Map 11 State of the Reach Environs
- Map 12 Channel Type Diversity
- Map 13 Bank Stability
- Map 14 Bed Stability
- Map 15 Cover and Structural Diversity of Riparian Vegetation
- Map 16 Width of Riparian Vegetation
- Map 17 Cover of Exotic Riparian Vegetation
- Map 18 Cover and Distribution of *Passiflora foetida*
- Map 19 Cover and Distribution of *Hyptis suaveolens*
- Map 20 Cover and Distribution of *Parkinsonia aculeata*
- Map 21 Cover and Distribution of Submerged Aquatic Vegetation
- Map 22 Cover and Distribution of Emergent Aquatic Vegetation
- Map 23 Cover and Distribution of Floating Aquatic Vegetation
- Map 24 Cover and Diversity of Instream and Bank Habitats
- Map 25 Overall Condition

The maps published in this report were compiled using software ArcGIS 9.2, by Natural Systems Division, Department of Infrastructure, Planning and Environment (DIPE), Katherine.

DATA SOURCE

Catchment boundaries:	The Victoria River catchment and sub-section boundaries were delineated for the Top End Waterways Project in 1996 using 1:100,000 and 1:250,000 topographic map sheets taking into account contour lines and spot heights.
Cadastre (property boundaries):	Land Information Division, DIPE, Darwin
Roads:	Land Information Division, DIPE, Darwin
Park boundaries:	Parks and Wildlife Service, DIPE, Darwin
Rivers, creeks:	Copyright © Commonwealth of Australia, Geoscience Australian (2005)
Water resource data:	HYDSYS database, Natural Resources Division, DIPE, Darwin

Where data source is not noted above it will be provided on the relevant map.