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Tropical Rapid Appraisal of Riparian Condition Version 1 (for use in tropical savannas)

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Summary

- The Tropical Rapid Appraisal of Riparian Condition (TRARC) is a visual assessment of the riparian zone using simple indicators of condition. It is designed to be user-friendly for the non-specialist and is best suited to savanna streams with a well defined channel and a distinct riparian zone and is not designed for estuaries or for floodplains adjacent to the riparian zone.
- An index of condition is derived from 24 *indicators* which are grouped into four *sub-indices*: (1) PLANT COVER, the amount of cover provided by all the vegetation; (2) REGENERATION, the amount of native plant regeneration; (3) WEEDS, the cover of exotic weeds relative to native plants and (4) EROSION, the amount of bank erosion. Also, an index of PRESSURE is derived from six *indicators* which help identify the likely causes of change in condition.
- This guideline provides step by step instructions for undertaking a TRARC assessment.
- The TRARC Version 1 described here is preliminary and subsequent iterations will be refined through further research and extensive field validation in different river types.

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Background

Riparian zones can be broadly defined as the land that adjoins or directly influences a body of water (Price & Lovett 2002) which includes the riverbank and the land immediately alongside it, as well as floodplains and the areas surrounding lakes and wetlands. For rivers and streams, the riparian zone has been defined as the area from the low water mark of the stream channel to the portion of the terrestrial landscape where the vegetation may be influenced by elevated water tables or flooding (Naiman & Decamps 1997). Riparian zones are widely acknowledged as important elements of the landscape because they influence the flows of energy and nutrients across the terrestrial and aquatic ecosystems (Naiman & Decamps 1997), perform functions that help to maintain aquatic ecosystems (Pusey & Arthington 2003), and provide a range of ecosystem services (Lovett et al. 2004). For example, riparian vegetation slows water flow and helps stabilise stream banks; provides food, shade and habitat for terrestrial and aquatic plants and animals; and filters sediments, nutrients and pollutants before they enter the stream (Naiman & Decamps 1997). Being located at the interface of the terrestrial and aquatic ecosystems, riparian zones are potentially valuable indicators of catchment condition (Rapport et al. 1998).

The tropical savannas of northern Australia cover approximately 25% of the continent and are dominated by Eucalypt woodlands with a continuous grassy understorey (Mott et al. 1985). This sparsely vegetated savanna landscape is dissected by thin green strips of riparian vegetation fringing the creeks and rivers. Although the riparian zones occupy only a small proportion of the savanna landscape, they make a disproportionately large contribution to the biodiversity, cultural and economic values of northern Australia (e.g. Douglas & Pouliot 1997, Woinarski et al. 2000). Riparian zones are also a focus for much activity related to development in tropical savannas, including grazing, agriculture and tourism, and they are vulnerable to disturbances such as weed invasion, feral animals, fire, overgrazing and erosion (Burrows 2001, Choquenot et al. 2001, Douglas & Pouliot 1997, Grice 2001).

It is essential that tropical riparian zones are managed wisely to avoid the degradation that has become so common in temperate regions of Australia. Savanna land managers have recognised this, and the past decade or so has seen increasing interest in riparian management. Maintaining and improving the condition of riparian zones is listed as a priority in several regional natural resource management (NRM) plans (e.g. Northern Gulf Resource Management Group, Burdekin Dry Tropics Board) and there has been substantial investment in riparian fencing programs in catchments such as the Burdekin, Victoria and Roper Rivers (e.g. Burrows 2001). However, determining the effectiveness of such programs requires a suitable method for assessing change in riparian condition over time. Because there are relatively few technical experts available to cover this vast and often remote region, riparian assessments are likely to be undertaken by volunteer non-professionals, such as land managers, many of whom will have limited time and resources. Hence there is a need for a riparian assessment method that can be undertaken quickly, repeatedly and inexpensively by trained non-experts across the tropical savannas.

Several tools have been developed to enable people with limited scientific training to rapidly asses riparian condition, either on its own (e.g. Jansen et al. 2005, Werren & Arthington 2002) or as part of a broader assessment of river health (e.g. Victoria Department of Sustainability and Environment 2006, Costelloe 2005). The Rapid Appraisal of Riparian Condition (RARC) (Jansen et al. 2005) was developed for creeks and rivers in south-eastern Australia and has been widely applied in catchments in New South Wales, Victoria and South Australia. Its use as an indicator of riparian condition has been validated by comparisons with cattle stocking rates, bird communities and litter decomposition (Jansen et al. 2005). We trialled the RARC on creeks and rivers across the tropical savannas of northern Australia and recognised a need to modify it to be more suitable for northern Australia. We propose the use of a new method, termed the Tropical Rapid Appraisal of Riparian Condition (TRARC). The TRARC is based on the RARC but includes *sub-indices* from two other riparian assessment tools: A Rapid Assessment Protocol for Riparian Vegetation (Werren & Arthington 2002) developed for Queensland's rivers; and the Waterway Foreshore Assessment Tool for Pilbara and Kimberley (Department of Water 2006). The TRARC has also been influenced by the Index of Stream Condition (Victoria Department of Sustainability and Environment 2006) and Quantifying the Health of Ephemeral Rivers (Costelloe 2005) methodologies.

The TRARC has now been trialled with a variety of land managers in Queensland and the Northern Territory and there is widespread interest in using it across the region. The TRARC methodology provides savanna land managers with a simple and consistent way of assessing the features of the riparian zone that are likely to affect its ecological function and to identify management actions that can maintain or improve the condition of the riparian zone. Undertaking TRARC assessments encourages land managers to spend time in their riparian zones, identifying current or potential threats and considering the effects of their management practices. In its current form, the TRARC is designed for site-scale (<10 km of river length) assessments of the current condition of a riparian zone. Repeated measurements over time can help land managers to monitor the outcomes of management practices such as riparian fencing or weed management. It is also anticipated that use of the TRARC will encourage discussions between land managers and scientists about how best to manage and monitor savanna riparian zones.

We recently completed the first stage in the development of the TRARC. This Technical Guideline describes Version 1 of the TRARC methodology and provides land managers with detailed instructions on how to apply it. It also identifies the knowledge gaps and research required for further development of the TRARC.

What is the Tropical Rapid Appraisal of Riparian Condition (TRARC)?

The TRARC is a multi-metric index of riparian condition. It is comprised of 24 *indicators* which are grouped into four *sub-indices* which can be combined to derive an index of riparian condition. Table 1 lists these *indicators* and their relationship to the main ecological functions performed by riparian zones as defined by Naiman and Decamps (1997). The four *sub-indices* help to identify the general components that contribute to the condition of a site. In summary, they describe:

1. The amount of cover provided by all the vegetation (PLANT COVER).
2. The extent of native plant regeneration (REGENERATION).
3. Weed cover relative to native plant cover (WEEDS).
4. The amount of bank erosion (EROSION).

Information on vegetation condition should only inform decision-making when used alongside other information such as the potential threats to an area (Gibbons & Freudenberger 2006). To help interpret the condition score and to identify factors that have the potential to change riparian condition, the TRARC also includes six *indicators* which are assessed to derive an index of PRESSURE. This index includes both anthropogenic factors and natural features that make the riparian zone more vulnerable to change (e.g. steep banks and fine bank sediments).

Table 2 lists the common pressures on tropical riparian zones, the likely effects of these pressures, and how these relate to the *indicators* assessed in the TRARC to derive the PRESSURE index. Although not included in PRESSURES, the WEEDS *sub-index* should also be examined when considering the potential for a change in condition.

Table 1. Functions of the riparian zone as defined by Naiman and Decamps (1997) and *indicators* used in the TRARC to assess these.

Functions performed by riparian zone	Elements that performs these functions	Indicators used in TRARC
Bank stabilisation	– Plant roots – Bank sediment size – Bank slope – Fallen trees and logs	– Plant cover – Canopy continuity – Bank erosion (exposed tree roots, slumping, gullying, undercutting) – Exposed soil – Bank sediment size – Bank steepness – Logs
Water flow reduction	– Fallen trees, logs, branches and leaves – Standing vegetation	– Logs – Organic litter – Plant cover
Trapping of plant propagules; filtering of sediments, nutrients and pollutants from upslope	– Fallen trees, logs, branches and leaves – Ground cover plants	– Logs – Organic litter – Understorey and grass cover
Organic input to stream	– Fallen fruit, branches and leaves	– Plant cover – Logs – Organic litter
Creation and maintenance of aquatic and terrestrial plant and animal habitats and biodiversity (including refuge and landscape connectivity)	– Fallen trees, logs, branches and leaves – Standing vegetation	– Logs – Organic litter – Plant cover – Canopy health – Canopy continuity – Large trees – Tree size classes – Tree regeneration – Weeds

Table 2. Common pressures on tropical riparian zones, the likely impacts of these on the riparian zone and the *indicators* used in the TRARC to assess these.

Pressure	Impact	Indicators used in TRARC
Fire	– Reduced riparian width – Death of sensitive and juvenile plants – Reduced canopy cover – Increased sediment and nutrient inputs to stream – Reduced litter inputs to stream	– Fire
Overgrazing and feral animals	– Trampling and compaction of soil – Reduced grass cover – Bank destabilisation and increased erosion – Death of adult trees from ringbarking and uprooting – Transport of weed seeds – Death of juvenile plants through grazing, trampling and uprooting – Disturbance of instream substrate – Increased nutrient and sediment input and poorer water quality	– Animals (managed and unmanaged)
Impoundment	– Reduced wet season flood intensity and frequency – Increased dry season flow – Reduced episodic recruitment events – Reduced flushing of instream sediment slugs – Creation of instream sandbars and braided channels – Alter structure and abundance of riparian vegetation	– Flow regime: large dams
Instream structures (weirs, bridges, culverts)	– Creation of back-flow eddies downstream of structures – Increased water height upstream of structures – Bank erosion	– Instream structures
Tree clearing	– Increased sediment and nutrient inputs to stream – Increased surface water runoff and flooding – Reduced habitat for native animals – Decreased canopy cover – Increased weed invasion – Increased infiltration to ground water basin – Increased erosion potential	– Tree clearing
Weeds (exotic species)	– Smothering of native plants – Competition with native plants for light, water and nutrients – Increased fire fuel loads (grass) – Reduced plant biodiversity – Reduced habitat for native animals – Increased refuge for feral animals	– Weeds
Erosion	– Loss of bank material, vegetation and habitat – Increased sediment input to stream – Reduction of bank stability	– Bank stability
Human activities and structures	– Reduced plant cover and regeneration – Increased path for weed dispersal – Increased erosion mechanisms – Increased risk of fire	– Other

Assessment tools developed for rapid use by non-professionals typically require minimal species identification and are often based on recording the presence or absence of attributes, or assessing attributes in terms of broad abundance classes, rather than continuous measures (Gibbons & Freudenberger 2006). The *indicators* which make up the four condition *sub-indices* and the PRESSURE index are listed in Table 3, along with a summary of how each is assessed. The TRARC is not based on detailed botanical information, though knowledge of the local weeds is required. Each *indicator* in the TRARC is given a score between 1 and 5, with higher numbers implying better condition (or greater pressure). Detailed scoring categories for each *indicator* and how to calculate the *sub-index* scores are presented in the *User's guide* (pages 10–28).

Table 3. Summary of how each of the TRARC indicators are assessed. *Indicators* are grouped into the four CONDITION *sub-indices* and the PRESSURE index.

Sub-indices and their *indicators*	Assessment (each given a score of 1–5)
PLANT COVER	
– Canopy cover	Percentage cover of trees >5 m tall
– Canopy continuity	Percentage of longitudinal bank covered with trees >5 m tall
– Midstorey cover	Percentage cover of vegetation 1.5–5 m tall
– Understorey cover	Percentage cover of vegetation <1.5 m tall
– Grass cover	Percentage cover of grass
– Organic litter	Percentage cover of leaves and fallen branches <10 cm diameter
– Logs	Abundance of logs >10 cm diameter
REGENERATION	
– Canopy health	Appearance of canopy health
– Large trees	Abundance of trees with trunk diameter >30 cm
– Tree size classes	Variation in tree trunk width
– Dominant tree regeneration	Abundance of juveniles 0.3–3 m
– Other tree regeneration	Abundance of juveniles 0.3–3 m
WEEDS	
– Canopy weeds	Proportion of weed versus native canopy cover
– Midstorey weeds	Proportion of weed versus native midstorey cover
– Understorey weeds	Proportion of weed versus native understorey cover
– Grass weeds	Proportion of weed versus native grass cover
– Organic litter weeds	Proportion of weed versus native organic litter cover
– High impact weeds	Presence of listed weed species
– High impact weed distribution	Distribution pattern of listed weed species within the riparian transect
EROSION	
– Exposed soil	Percentage cover of exposed soil/sand/ash
– Exposed tree roots	Extent of exposed roots due to erosion
– Slumping	Combined width of slumps
– Gullying	Combined width of gullies
– Undercutting	Combined width of undercuts
PRESSURE	
– Bank stability	– Bank slope – Instream structures: abundance of human-built instream structures – Dominant and maximum bank sediment size
– Animals: managed and unmanaged	Extent of impact due to managed animals (e.g. stock) and unmanaged animals (e.g. feral pigs)
– Fire	Time since fire and spatial impact of fire
– Tree clearing	Proximity of clearing to river bank and width of clearing
– Flow regime	Reduction of plant regeneration due to large dams
– Other	Extent of damage from human built structures and activities

Application of the TRARC

So far, the TRARC has only been applied in a limited number of catchments, primarily to test the methodology in sites with contrasting conditions (Figure 1). Trials have targeted sites influenced by a range of management regimes, including pastoral, conservation and urban land uses. In collaboration with Greening Australia Northern Territory's 'Water for Life Program', the TRARC has been trialled with a cross section of northern Australia's diverse land management community, including indigenous, conservation, pastoral and government land and water managers, and community interest groups (Dixon et al. 2006, Schenkel 2006).

Trials in the Burdekin and Haughton catchments near Townsville, Qld (Figure 1 and Figure 2) focused on assessing the disturbance around 200 waterholes due to cattle activity. An early version of the TRARC was used, supplemented with floristic data, bank erosion measures and counts of cow pat densities. Results showed that with an increase in cow pat density there was a corresponding decrease in TRARC scores (Dowe et al. 2004, Dowe 2004), indicating a functional relationship between cattle density (as indicated by cow pat density) and riparian condition. These trials also identified the need to include bank stability as an indicator and to modify the weeds and regeneration indicators to better reflect the current condition of each site.

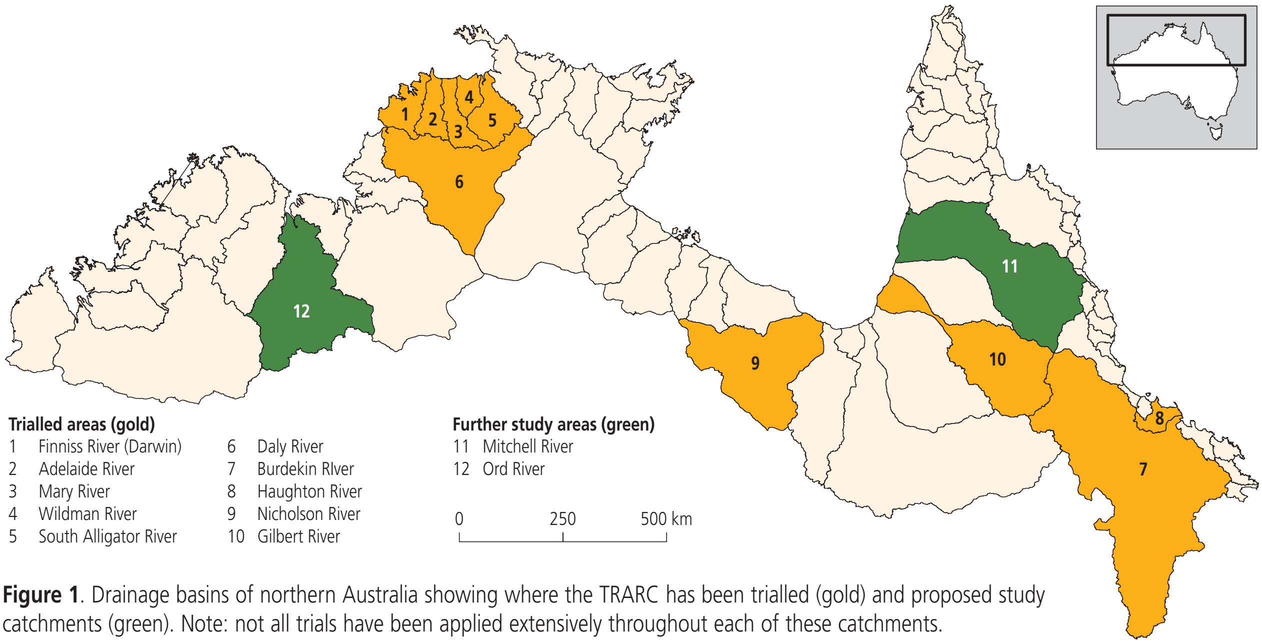


Figure 1. Drainage basins of northern Australia showing where the TRARC has been trialled (gold) and proposed study catchments (green). Note: not all trials have been applied extensively throughout each of these catchments.

Image source: Geoscience Australia <http://www.ga.gov.au/products>

Figure 2. Trials in the Burdekin catchment, Qld. Photo above: site with a low TRARC score. Note the limited regeneration of dominant trees, high weed numbers, low canopy cover, and evidence of slumping and gully erosion. Photo on right: site with a high TRARC score. Note the high regeneration of dominant trees in all size classes, absence of weeds, high canopy cover and no erosion. However, this site does have some fire damage.

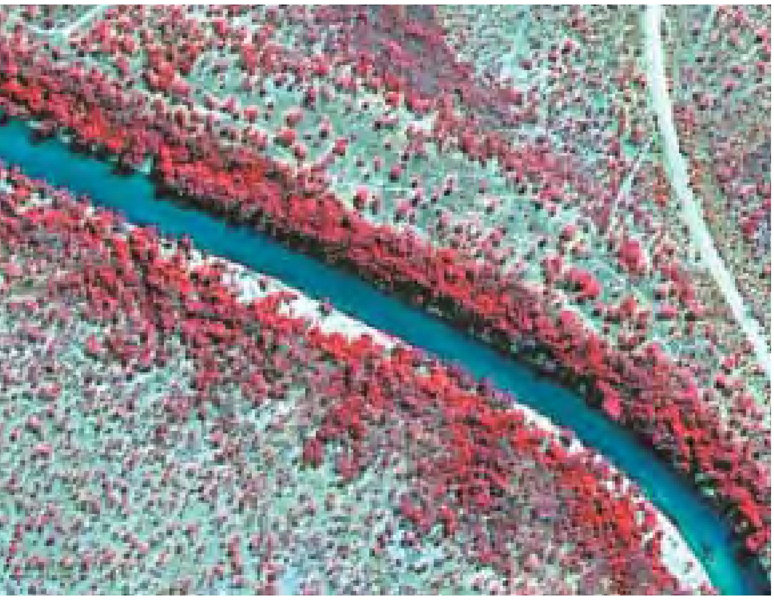


Figure 3. 'QuickBird' image subset of the Daly River presented as a false colour composite using the near-infrared, red, and green spectral bands. Riparian areas with dense vegetation have a high near-infrared reflectance, hence appearing red on the image. Image: Kasper Johansen.

Figure 4. User-variability was determined to improve the reliability of the TRARC and give confidence in its results.

In the Daly River and South Alligator River catchments in the Northern Territory, TRARC results were compared to measurements from high-spatial-resolution 'QuickBird' satellite imagery (e.g. Figure 3). Several *indicators* used by the TRARC could also be measured from the remote imagery and a strong correlation was found between on-ground and image-derived measurements. Therefore, image-based assessment of condition may be extrapolated to longer stretches of the riparian zone (e.g. 200 km) without requiring additional on-ground measurements (Johansen et al. University of Queensland, in prep.). Further studies are currently in progress to determine the possibilities of scaling-up from on-ground site assessments to catchment-scale remote sensing assessments.

Around the Darwin region, several studies have examined the variability in TRARC scores between different users. It is essential that people are able to collect similar results at the same site so that there can be confidence in data sets collected over time by different operators (Figure 4). The studies showed that in most cases trained non-specialists obtained similar results to each other (as also found by Jansen et al. 2004 in *RipRap*, vol. 26), and to those collected by a specialist. These trials identified the need for modifications to some of the TRARC scoring categories and training procedures to help reduce the amount of variability between users (Ian Dixon, unpublished data).

Limitations and further development of the TRARC

Australia's tropical savannas contain a wide variety of river types (Brooks et al. 2005). The TRARC has been used successfully on streams ranging from 1st to 9th order, but all streams and rivers had a single, well-defined channel with a distinct riparian zone dominated by trees, and canopy cover was greater than 75% in the absence of disturbance. The TRARC is not designed for estuaries or for floodplains adjacent to the riparian zone and is yet to be tested in other types of tropical rivers, such as systems with anastomosing (braided) channels (Figure 5).

The TRARC is a multi-metric index which is comprised of a number of summary metrics (*sub-indices*) that are combined to derive a single index of riparian condition. Multi-metric approaches are commonly used for assessing vegetation condition (e.g. Parkes et al. 2003) and river health (e.g. Morton Bay Waterways and Catchment Partnership 2001) and they are appealing because they provide an integrated summary based on a number of different measures that may influence condition. However, the limitations of these approaches have been well documented (e.g. Suter 1993, Norris & Hawkins 2000). In particular, caution must be exercised when interpreting the final index score. For example, although two sites may have the same index score, they may have very different *sub-index* scores indicating very different management needs. Similarly, the index score for a site may not change between repeated measurements even though the *sub-index* scores may change dramatically. So it is always advisable to consider the *sub-index* scores (or even the *indicator* scores) when interpreting the final index of condition. The combined index score may be best suited to larger-scale (regional) assessments of a large number of sites, but this should only be undertaken after careful consideration of the range of reference conditions likely to be encountered at these larger scales (discussed below).

Development of the TRARC has led to agreement on the choice of appropriate indicators for assessing riparian condition in tropical savannas and a consistent way of measuring these in the field. In its current form the TRARC is designed for site-scale (<10 km of river length) assessments of the condition of a riparian zone. However, further development — such as defining reference conditions for specific areas — will broaden the potential application of the TRARC, and when combined with spatial modelling and/or remote-sensing, large-scale assessment of riparian condition may be possible across the vast savanna landscape.

Although there is no clear agreement on the definition of either river health or vegetation condition (e.g. Karr 1999, Gibbons & Freudenberger 2006), reference conditions are generally used as the benchmark for assessment of condition. Reference conditions can be defined as the conditions that would be expected at a site with no or minimal influence from modern human society (Karr 1999). There are a number of possible ways to determine the appropriate reference condition (e.g. Bailey et al. 2004). The current version of the TRARC does not explicitly consider variation in the reference condition across large scales. Instead, it adopts a generic approach based on the values of indicators that we have commonly encountered, or would expect to encounter in sites with minimal human disturbance, particularly disturbances that have arisen following European colonisation, such as the introduction of weeds, cattle and feral animals. For some indicators, such as weeds, the choice of reference values is clear-cut, as we would expect no weeds in the reference condition. For other indicators, such as canopy cover, the situation is less clear and we based our ratings on expert opinion. While this appears to be suitable for the catchments where the TRARC has been trialled so far, we acknowledge that the current scoring system will need to be rescaled before valid comparisons can be made between sites that may vary in reference condition. Therefore it is advised that scores should not be compared across larger scales until appropriate reference conditions have been established. Determining the range of natural variation both spatially and temporally, and understanding what drives this natural variation so that it can be distinguished from anthropogenic influences, are key knowledge gaps that need to be addressed in future versions of the TRARC.

The *Users guide* describes an interim method for combining the *sub-index* scores to derive the final index. This is a relatively simple approach, but further research is required to determine the best approach. For example, further research may suggest that particular *indicators* or *sub-indices* require different weightings. Interpreting the final index and assigning this to a condition rating also requires a larger-scale assessment to determine the range of values and how these differ across a range of sites with differing levels of anthropogenic impact. The condition ratings given in the *Users guide* are likely to be refined as more data are acquired.

Figure 5. An example of an anastomosing river. The TRARC may need modification for complex rivers such as this. Photo Andrew Brooks.

User's guide

The following pages provide detailed instructions on how to complete the TRARC for your sites of interest. Score sheets (pages 29–34) should be photocopied and stapled together before assessing the sites. The score sheets can also be downloaded separately from <www.rivers.gov.au> and from the savanna land managers site <http://savanna.cdu.edu.au>. The *User's guide* to split into three steps:

Step 1: Site selection
Step 2: Site assessment
Step 3: Data analysis

Step 1. Site selection

Before applying the TRARC, the user must clearly define the objectives of the study and then ensure that the sampling design is appropriate to meet these objectives. This may require advice from an expert with experience in statistical design and analysis. It is worth seeking assistance with this step to ensure that you are allocating your time and effort most efficiently and that you will be able to answer the questions that you are interested in.

The number of TRARC transects (see below) will be determined by the objectives and the time and resources that are available. Ideally, a pilot study should be conducted to determine the number of transects required to characterise a site with a known level of precision. These transects should be selected randomly to avoid common characteristics that occur near easily accessible sites (e.g. weeds and tracks are more common near roads).

Generally speaking, the following methods describe what to assess and how to assess a 100 m length of riparian zone — the standard TRARC transect. The basic sampling unit for a TRARC assessment, termed a *transect*, is essentially a 100 m long and 5–20 m wide stretch of riparian zone running parallel to the channel (Figure 6). The width of the *transect* is variable and is determined by the width of the riparian zone. For the purposes of the TRARC, the width of the riparian zone is defined as the area from the edge of the channel (toe of bank or low-flow water level) to where there is a distinct change in vegetation (from streamside vegetation to savanna or floodplain vegetation) and change in landform (from channel and bank characteristics to surrounding landscape topography), (Figure 7). From our trials, we have found that the TRARC is most suited to the area immediately adjacent to the stream channel (within 20 m). This area should be the focus of the assessment, although the user may wish to repeat the procedure at parallel intervals away from the stream. We have only found it necessary to use multiple parallel *transects* on very large rivers where the bank has a number of distinct benches, each with a distinct vegetation type. The location and width of each *transect* for these situations are as follows:

~ **Option 1**. If the vegetation and landform is uniform in appearance, then the centre of the *transect* should be positioned within 10 m of the edge of the channel and run parallel to the primary stream channel, roughly following its path (Figure 6). If the riparian width is less than 20 m, then the *transect* width should match the riparian width. If the riparian width is greater than 20 m, then the *transect* should be capped at a 20 m width but remain adjacent to the channel edge.

~ **Option 2**. If the riparian zone has more than one distinct vegetation type (e.g. on benched banks), then a *transect* should be positioned through the centre of each different vegetation type (Figure 6), even if the vegetation type does not follow the path of the primary stream channel at a uniform distance. Only one *transect* is required within each different type regardless of its width. There is no limit to how many distinct vegetation types the user should select. If the distinct vegetation type is less than 20 m, then the *transect* width should match the width of the vegetation type. If the vegetation type is greater than 20 m wide, then the *transect* should be capped at a 20 m width. The width of each distinct vegetation type should be recorded before commencing the assessment, as these widths will be used in analysing the data later.

Along each 100 m *transect*, three *points* (A, B and C) are positioned 50 m apart at the start, middle and end of the *transect* (Figure 6). Some *indicators* are scored at each of these *points* and others are measured over the entire length of the *transect*. Further details are described in **Step 2**.

Each *transect* should be located in an area with a consistent management regime and with similar vegetation and stream characteristics. For example, a *transect* should not cross from grazed land into a national park or shift from a single channel river into a swamp. If accessible, both left and right banks of the stream should be measured and these should be assessed as separate *transects*. It may be necessary

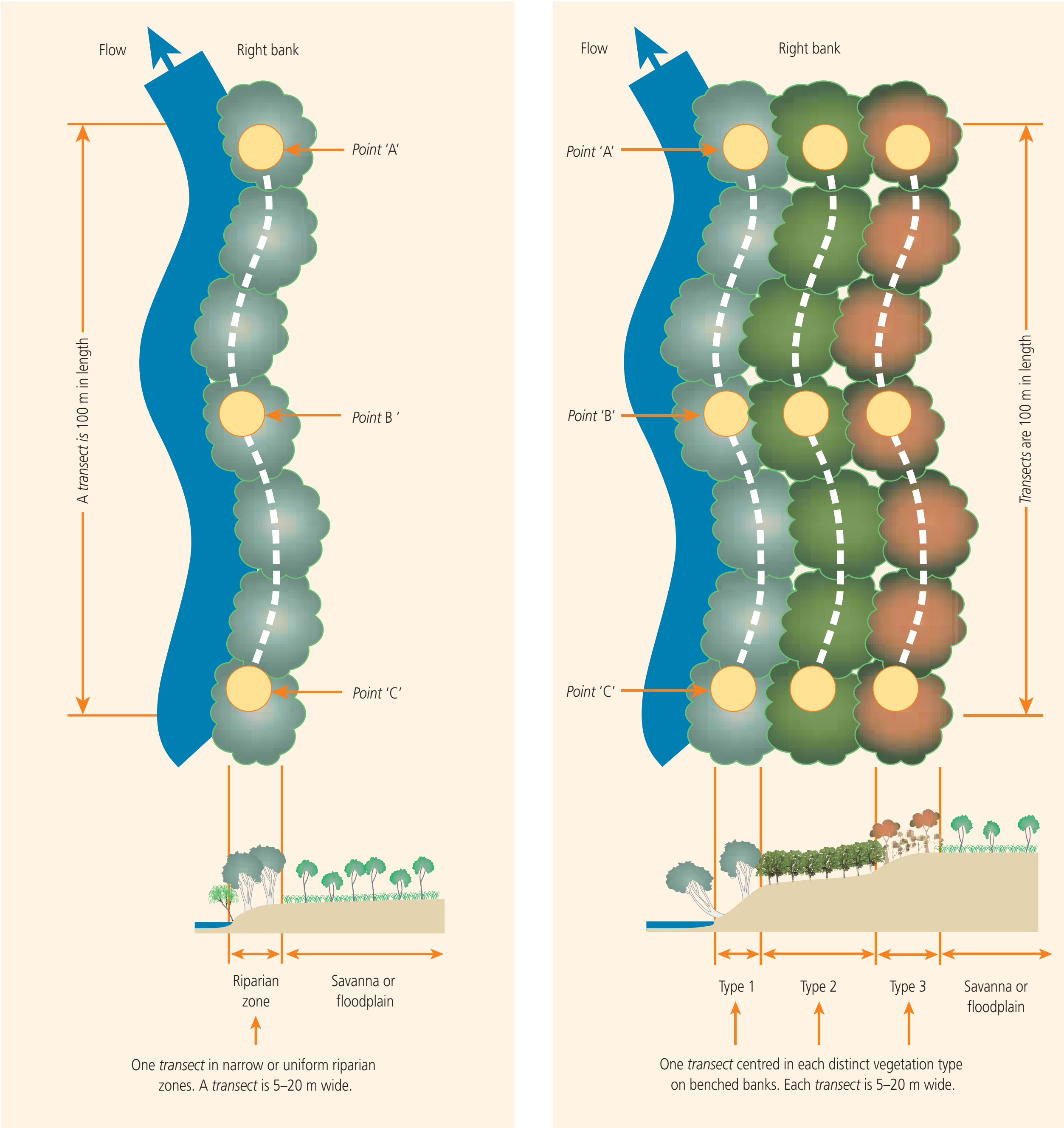


Figure 6. Two examples of the layout of TRARC *transects* showing the use of one *transect* in uniform riparian areas (left image) and the use of multiple parallel *transects* in riparian areas with distinct vegetation types (right image). Each *transect* is aligned down the centre of each distinct vegetation type and spans its width to a maximum of 20 m. Three vegetation types are shown here but there is no limit to the number of types the user should assess.

to use a single *transect* on one side of the stream and use multiple parallel *transects* on the other side if required.

The precise location of the *transects* should be recorded with a GPS (recorded in UTM) and/or marked out physically with steel pickets. A map with directions and landmarks should be drawn to assist in finding the site again in the future (see mud map example in the score sheets, page 30).

Assessment time will vary depending on the complexity of the area, but as a guide, each *transect* should take a trained pair of observers approximately 20 minutes. Therefore, if a site is to have three *transects* (one in each of three distinct vegetation types on one bank only), then at least one hour should be allowed to assess this area. Extra time should be allocated for travelling and placement of physical markers (e.g. steel pickets).

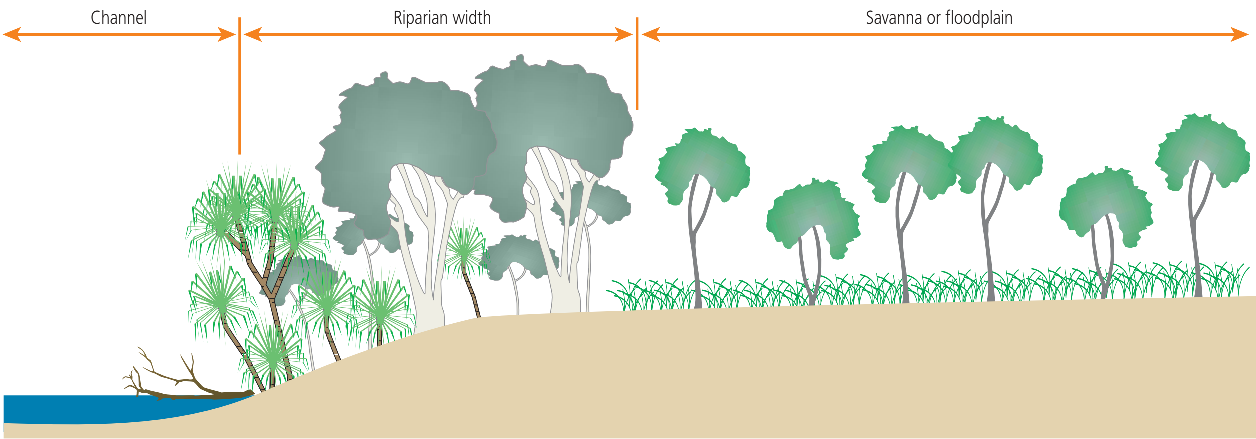


Figure 7. The riparian width is defined as the area from the edge of the channel to where there is a distinct change in vegetation and landform. This version of the TRARC is not designed for use in expansive floodplains or in complex channel systems.

Step 2. Site assessment

This section explains in detail how to assess the *indicators* on the score sheets (pages 29–34). Refer to the score sheets for scoring categories. To save time, the *indicators* on the score sheets are arranged in the order that you should assess them in the field. The descriptions in this step follow this same order. When arriving at a location to survey, make sure you accurately fill out the location details on the score sheet. All score sheets should be checked for missing information before leaving the area. Forgetting to score an *indicator* or record location details (such as photo numbers) may create unnecessary confusion if assessing many sites. For safety reasons and accuracy, it is recommended that you do not survey alone. This is particularly important in remote areas and where dangerous animals are present (e.g. snakes, crocodiles or buffalo). Having a second person to help make decisions should improve the reliability of your survey. If you have doubts about how to score a particular *indicator* in the field, make detailed notes about it and if possible, take several photos. You could then seek advice on the issue later and re-evaluate the score without having to go back to the site. Parts 1–10 of this section refer to the *indicators* that are assessed three times, once each at points A, B and C (Figure 6). Parts 11–24 refer to the *indicators* that are assessed once along the entire length of the *transect*.

1. Canopy cover

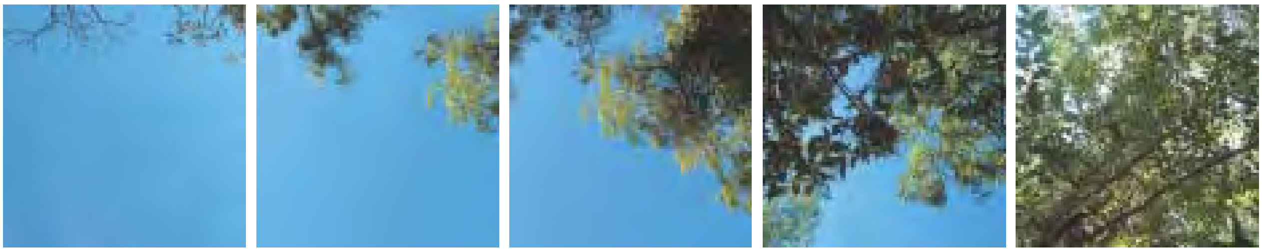
How much cover do the trees and tall shrubs (>5 m tall) provide?

Assess at the three *points* along the *transect*. When standing at *points* A, B and C, look directly above you (approximately 5 m radius). Assess how much of the sky is blocked by leaves and branches of native and weed species greater than 5 m tall. Figure 8 below shows examples of percentage canopy cover classes.

2. Canopy health

Do the trees and tall shrubs (>5 m tall) appear to be in good or poor health?

Assess at the three *points* along the *transect*. When standing at *points* A, B and C, look around you (approximately 20 m up and down the *transect*). Assess



<5% cover	5–25% cover	25–50% cover	50–75% cover	75–100% cover

Figure 8. Examples of five 'Canopy cover' categories.


Figure 9. Examples of canopy dieback and dead trees.

if the canopy is intact, or if it is showing signs of dieback (e.g. Figure 9). Scores should reflect the health of the majority of trees present. Care should be taken with deciduous trees and tall shrubs because natural leaf loss does not indicate poor health.

3. Tree size classes

Do the dominant native tree species (>3 m tall) have trunks with different thicknesses?

Assess at the three *points* along the *transect*. When standing at *points* A, B and C, select up to three tree species that are co-dominants for the area (approximately 20 m up and down the *transect*). These species may be different at each *point* along the *transect*. These species will also be used to assess the next *indicator*, 'Dominant tree regeneration'. Looking at just the trees of these species that are taller than 3 m, assess how much the trunks vary in thickness. To be consistent, you should compare the trunks at the same height from the ground: 1.3 m from the base or approximately chest height (Figure 10). Note: if multiple branching occurs lower than this height, make the visual measurement immediately below the first branching. If you allocate each tree to a distinct size class, how many groups do you see? There are five size classes to choose from: 1) <10cm; 2) 10–20 cm; 3) 20–30 cm; 4) 30–40 cm; and 5) >40 cm. To gain the maximum score for this *indicator*, any three of these five size groups need to be present. Some trees, such as Pandanus and palms, do not vary much in trunk thickness throughout their life. For these plants you should compare their heights instead of trunk thickness (Figure 10).

4. Dominant tree regeneration

Are there juveniles (<3 m tall) of the dominant tree species?

Assess at the three *points* along the *transect*. When standing at *points* A, B and C, select the same species as scored above in 'Tree size classes' and count the number of juvenile plants (0.3–3 m tall) around you (approximately a 5 m radius, Figure 11). Coppicing (regrowth from fallen trees or stumps) can be included as juveniles if they are <3 m tall.

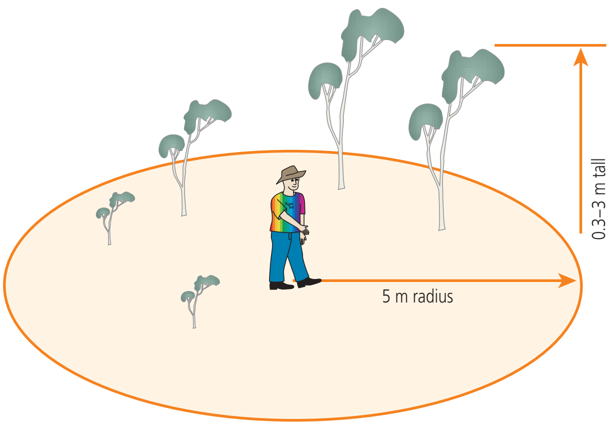


Figure 11. Juvenile plants (0.3–3 m tall) are counted within a 5 m radius area.

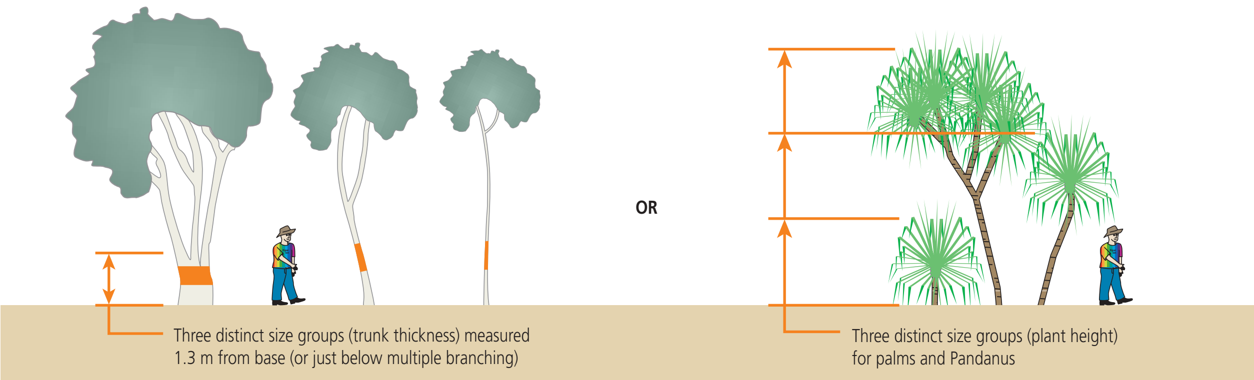


Figure 10. Examples of how to determine 'Dominant tree size classes'.

Figure 12. 'Other tree regeneration' is included even if the adult trees of that species are absent.

5. Other tree regeneration

How many juveniles (0.3–3 m tall) are there of other native tree species?

Assess at the three *points* along the *transect*. The previous indicator ('Dominant tree regeneration') only looked at the dominant native tree species. You may notice other native riparian tree species are regenerating even though the adult trees may not be present around the assessment *point* or even in the *transect*. 'Other trees' can be any native riparian tree species that grow in your region. For example, the canopy trees may be *Melaleucas* only, but you notice that there are some juvenile *Ficus* and *Syzygium* growing (Figure 12). Regeneration of these other riparian trees should be scored here. When standing at *points* A, B and C, look around you (approximately 5 m radius) and count the number of juveniles (0.3–3 m tall) of all other native riparian tree species (Figure 11).

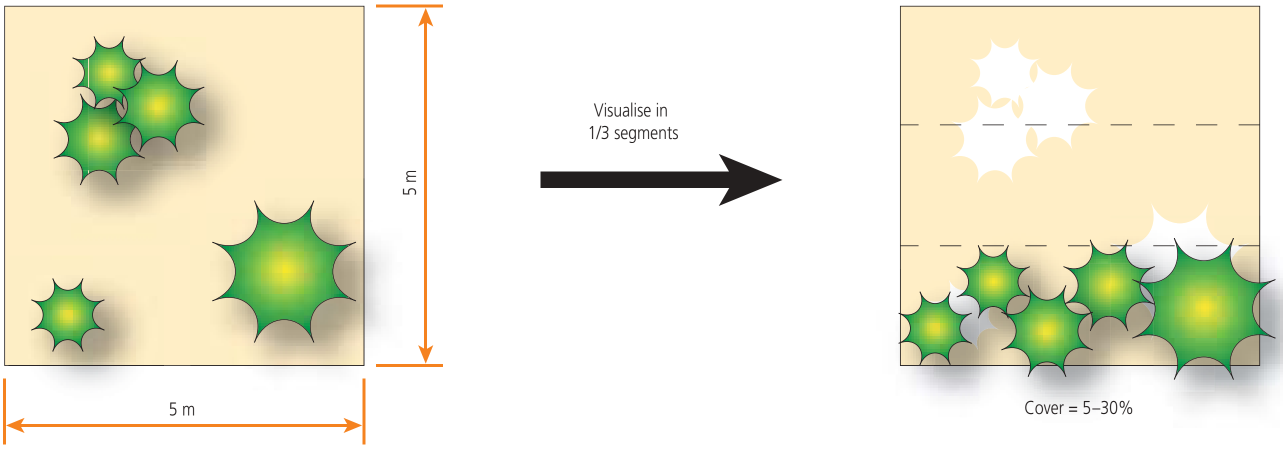
6. Midstorey, understorey, grass and organic litter cover

How much cover do midstorey, understorey, grass and litter provide?

For sections 6, 7 and 8 of the assessment, the same imaginary 5 x 5 m quadrat is used. A quadrat is located at each of the three *points* (A, B and C) along the *transect*. If assessing in pairs, it is helpful for each observer to stand at opposite corners of the quadrat to help mark its boundary. It is important to only look within this square when making the assessment. Estimate how much of the square would be covered by the following if viewed from above (see Figure 13):

1. **Midstorey** plants: native and weed species of shrubs and juvenile trees 1.5–5 m tall.
2. **Understorey** plants: native and weed species of shrubs, sedges, herbs, groundcovers and seedlings <1.5 m tall. Do not include grass.
3. **Grass**: native and weed grass species of any height.

Figure 13. Example of how to assess percentage cover within a 5 x 5 metre square.



4. **Organic litter**: leaves and sticks <10 cm diameter of native and weed species. Only include leaves and sticks that have been detached from plants. Include organic litter that is under shrubs and groundcovers.

Note: combined percentages for the three plant cover types and organic litter cover may total more than 100%.

7. Midstorey, understorey, grass and organic litter weeds

What proportion of the midstorey, understorey, grass and organic litter are weed species?

Assess at the three *points* along the *transect*. Using the same plants/litter that were assessed above in 'Midstorey, understorey, grass and organic litter cover', estimate the proportion of the plants/litter that are weed species versus native species within the 5 x 5 m square (Figure 14). Do not compare the numbers of individual plants, but compare their cover. List the most dominant weed species on the score sheet.

Note: the 'Canopy weeds' *indicator* is scored along the *transect* and is discussed later.

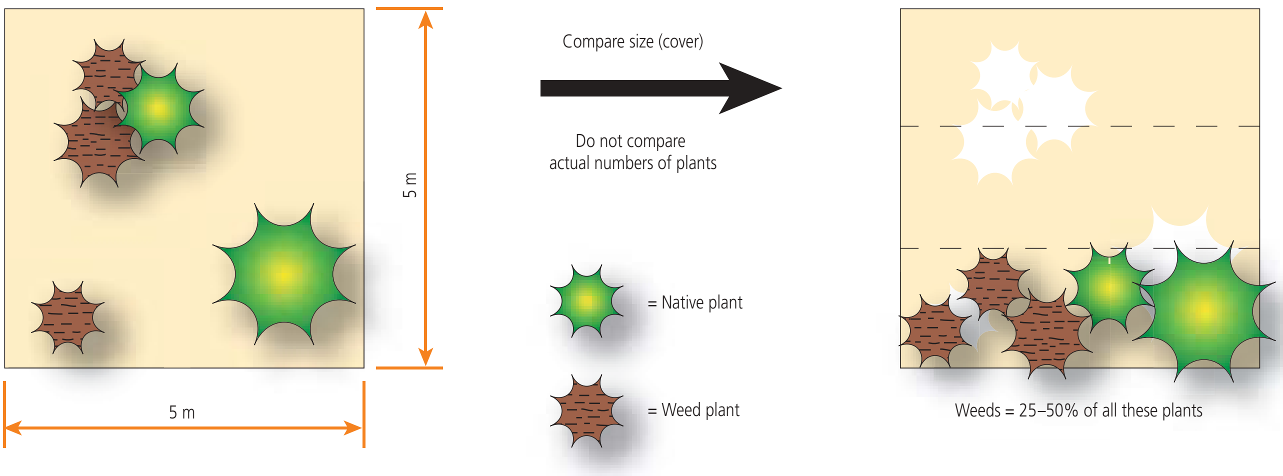
8. Exposed soil

How much of the ground surface is exposed soil, sand and ash?

Assess at the three *points* along the *transect*. Using the same imaginary 5 x 5 m square as 'Midstorey, understorey, grass and organic litter cover' at *points* A, B and C, estimate how much of the square would be covered by exposed soil, sand and ash if viewed from above. See Figure 15 for examples of cover. Do not include large natural rock formations, boulders, organic litter and plant roots.

Figure 15. Examples of three of the five 'Exposed soil' categories.

Figure 14. Example of how to compare the proportion of weeds versus native plants. Proportion is measured by their cover rather than number of plants.



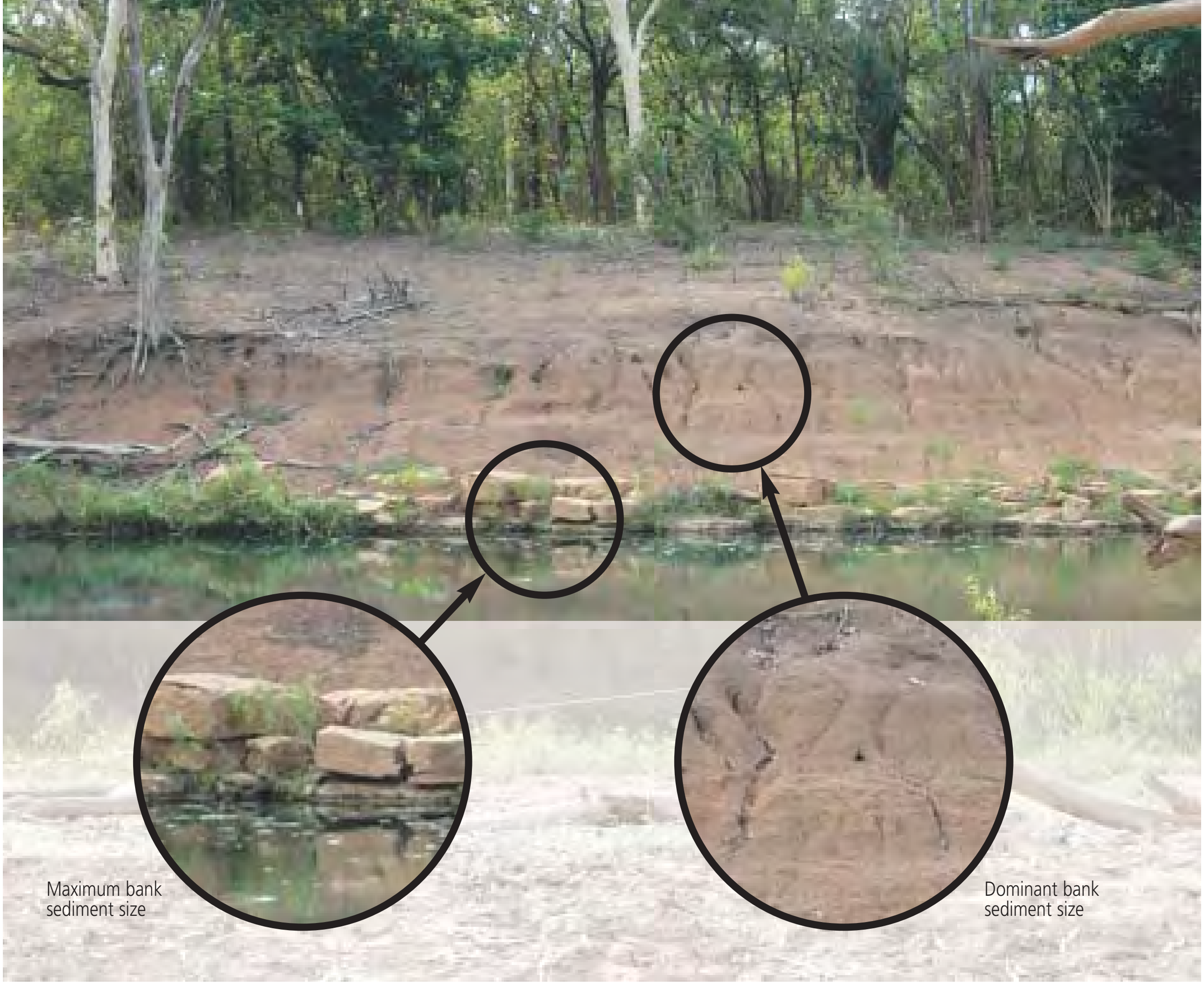


Figure 16. Examples of 'Maximum and dominant bank sediment size'.

9. Maximum and dominant bank sediment size

What is the maximum size of the bank sediment and what is the dominant size of the bank sediment?

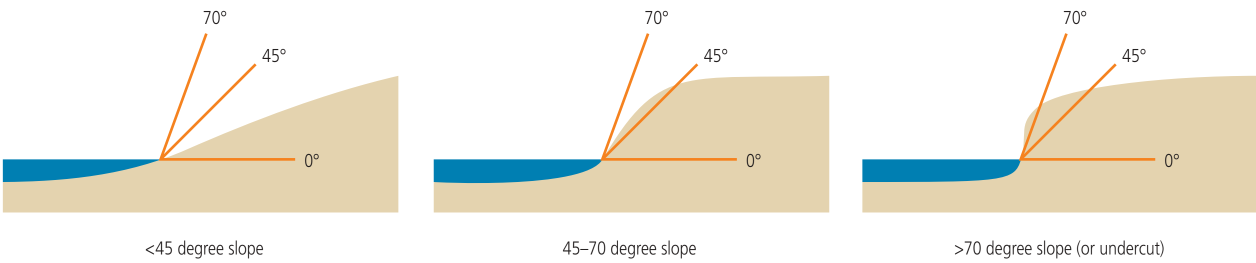
Sections 9 and 10 look at the bank features near the three *points* along the *transect*. When standing at *points* A, B and C, look up and down the height of the bank and determine both the **maximum** and the **dominant** bank sediment size (Figure 16): clay or silt (<0.064 mm); sand (0.064–2 mm); gravel (2–12 mm); pebbles (12–64 mm); cobbles, boulders or bedrock (>64 mm).

10. Bank slope

How steep is the bank?

Assess near the three *points* (A, B and C) along the *transect*. Estimate the average slope of the bank from top to bottom, or to water level (Figure 17). If using multiple parallel *transects* where benched (stepped) banks occur, only apply the score for the bank that you are currently assessing.

Figure 17. Examples of three 'Bank slope' categories.



So far, sections 1–10 have looked at *indicators* in and around the three *points* (A, B and, C). The remaining *indicators* (sections 11–24) are assessed along the length of the *transect* between these *points*. The *transect* should be parallel to the stream and follow its general path. As there are many elements to assess along the *transect*, you may wish to take notes half way, i.e. when you reach *point* B. Scores should then be assigned for the *transect* after assessing *indicators* at *point* C.

Figure 18. An example of a large tree with a trunk thickness greater than 30 cm. The clipboard resting on the tree is approximately 30 cm wide.

Figure 19. Fallen logs are included in the score if lying in the channel but still partly touching the bank.

11. Large trees

How many large native trees are there?

Assess along the *transect* (100 m long, 5–20 m wide). Only include live native trees that are within the *transect*. Count the number of trees that have a trunk diameter greater than 30 cm (Figure 18). To be consistent, trunk diameters should be estimated at a height of 1.3 m from the base, or approximately chest height (Figure 20). Note: if multiple branching occurs lower than this height, make the visual measurement immediately below the first branching. Do not include fallen, dead or weed trees. Keep a written tally in the box on the score sheet.

12. Logs

How many logs are there?

Assess along the *transect* (100 m long, 5–20 m wide). Count the number of fallen logs/trees that are greater than 10 cm in diameter and greater than 1 m in length. Include logs that have fallen into the channel but are partly on the bank (Figure 19). Keep a written tally in the boxes on the score sheet and separate into 'logs' (1-3 m in length) and 'large logs' (>3 m in length), (Figure 20). Choose the highest score for 'logs' or 'large logs'.

Figure 20. How to determine large trees, large logs and logs.

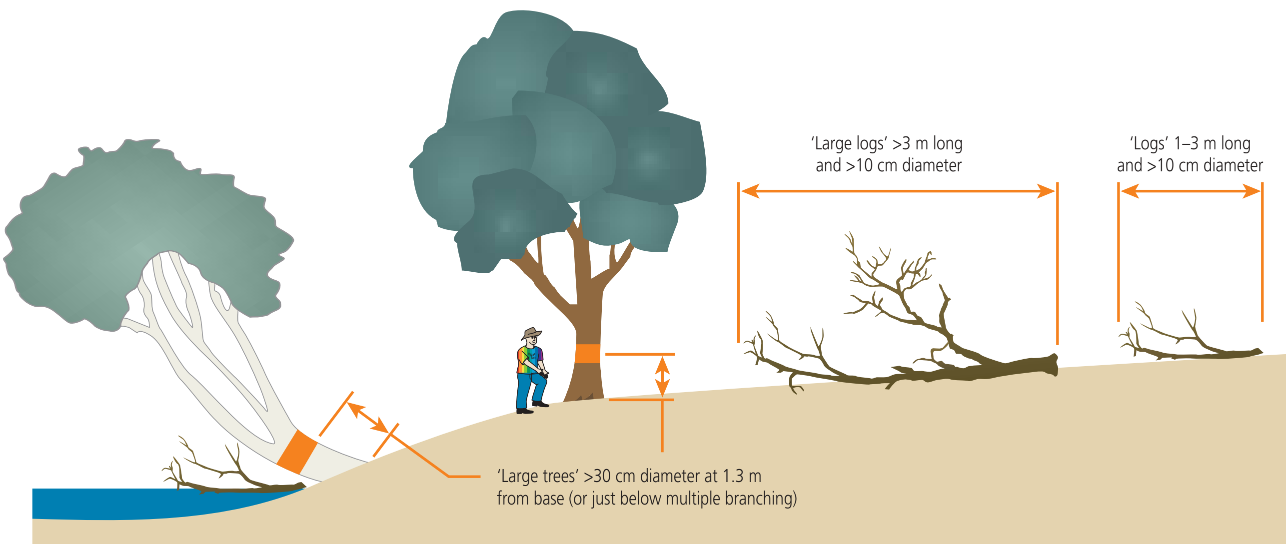


Figure 21. Examples of three high impact weed species: left, Noogoora Burr (*Xanthium strumarium*); middle, Mimosa (*Mimosa pigra*); and right, Mission Grass (*Pennisetum* sp.).

13. High impact weeds

How many high impact weed species are there?

Assess along the *transect* (100 m long, 5–20 m wide). Count the number of high impact weed species that you can see (e.g. Figure 21). The actual number of individual weed plants or their cover does not matter (this is assessed in 'High impact weed distribution'). Refer to the list of species on the score sheet and mark the boxes next to them if present in the *transect*. Note: the list of high impact weeds provided in this guideline may need to be modified for specific regions (this version is suitable for the 'Top End' of the Northern Territory and the Burdekin catchment in Queensland).

14. High impact weed distribution

What is the distribution pattern of high impact weed species?

Assess along the *transect* (100 m long, 5–20 m wide). Looking at the community of high impact weeds (as scored previously in 'High impact weeds'), take note on how regularly they occur and whether they occur as isolated individuals or dense patches (e.g. Figure 22). The diagrams shown below (Figure 23) are summaries of 13 distribution patterns. Refer to diagrams on the score sheet for the full range of descriptions and scores.

Figure 22. Dense cover of Wild Passionfruit (*Passiflora foetida*). Notice that it is smothering many native juvenile trees.

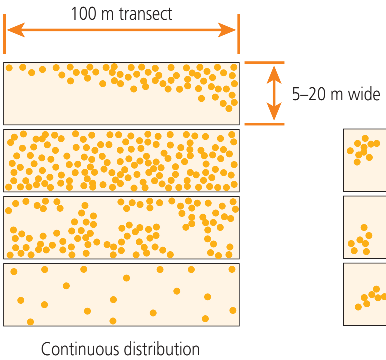
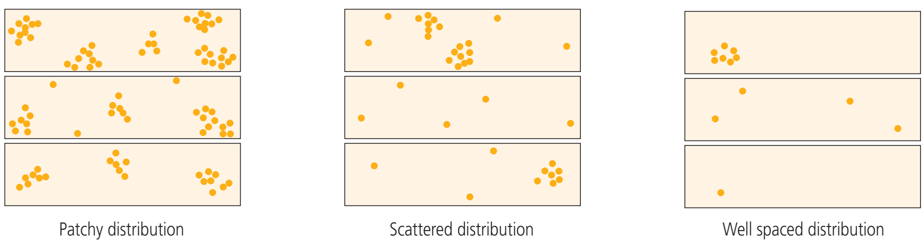


Figure 23. Summary distribution patterns of 'High impact weeds' within the *transect*.

Redrawn from www.cowsandfish.org.



15. Canopy weeds

What proportion of the canopy is due to weed species?

Assess along the *transect* (100 m long, 5–20 m wide). Estimate the proportion of the canopy plants (trees and tall shrubs >5 m in height) that are weed species versus native species within the *transect*. Make sure you compare their cover and not the number of individual plants (Figure 24). List the most dominant weed species on the score sheet. Canopy vines that are weeds should also be included.

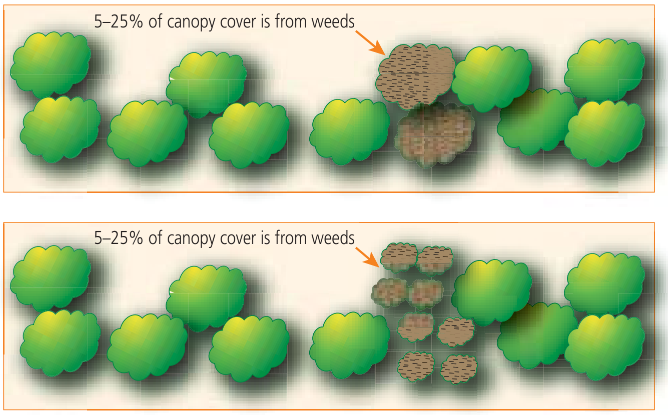


Figure 24. Two examples of evaluating the proportion of 'Canopy weeds'. In both examples, canopy weeds (brown coloured) make up 5–25% of all the canopy trees present. Proportion is measured by their cover rather than number of plants.

16. Canopy continuity

How much of the river bank has a continuous canopy along its length?

Assess along the *transect* (100 m long, 5–20 m wide). Look for gaps between the canopy trees (>5 m in height). If gaps between the trees' crowns are less than 5 m, then assume that this is a continuous canopy. Only look for gaps that are greater than 5 m between crowns and that span the width of the *transect* (Figure 25). Therefore, if there is a gap >5 m but it does not span the width of the *transect* then this section of the *transect* is considered to have a continuous canopy.

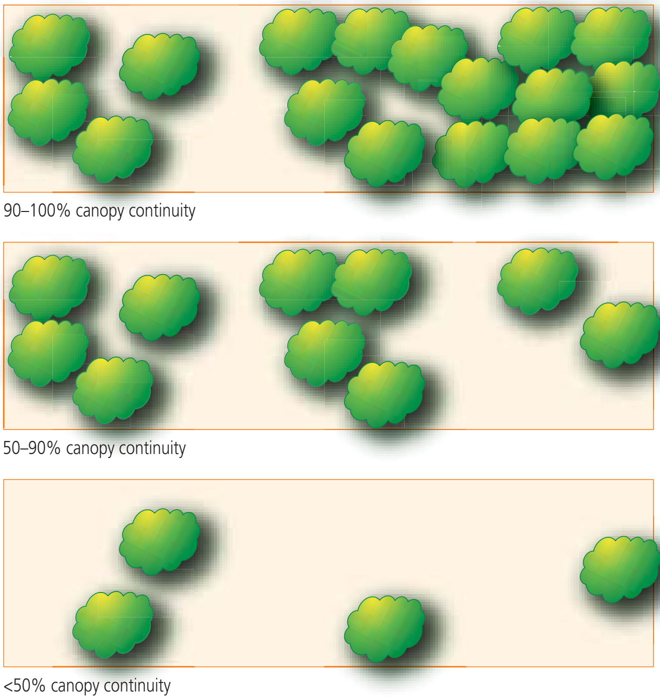


Figure 25. Examples of three 'Canopy continuity' categories: 90–100% (top); 50–90% (middle); and, <50% canopy continuity (bottom).

17. Exposed tree roots

To what extent have tree roots been exposed due to erosion?

Assess along the *transect* (100 m long, 5–20 m wide). Firstly, estimate the proportion of trees and tall shrubs with exposed tree roots within the *transect* (Figure 26). Roots must be greater than 20 mm in diameter and their exposure due to erosion. Do not include species with naturally exposed roots or aerial roots (e.g. Pandanus and Figs). Secondly, determine the average amount of roots exposed relative to the plant's circumference: less than one third; between one third to two thirds; or, greater than two thirds of the circumference exposed (Figure 27).

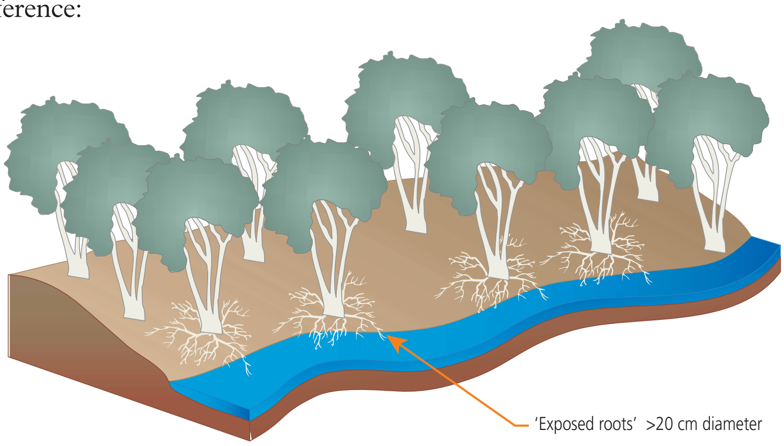


Figure 26. Example of 20–100% of trees with some exposed roots.

Figure 27. Examples of three categories of 'Exposed roots' relative to the tree's circumference.

18. Slumping, gullying and undercutting

How much of the river bank has eroded due to slumping, gullying and undercutting?

Assess along the *transect* (100 m long, 5–20 m wide). For each erosion feature, estimate the combined width of slumps, active gullies and undercutting within the *transect* (Figure 28 and Figure 29). Separate scores are given to each erosion feature. You may also wish to note the height and depth of each erosion feature (these are not included in the score). Active gullies are unstable and may be increasing in size. Stable or natural gullies may have vegetation, rocks or other structures supporting their walls and head (top of gully).

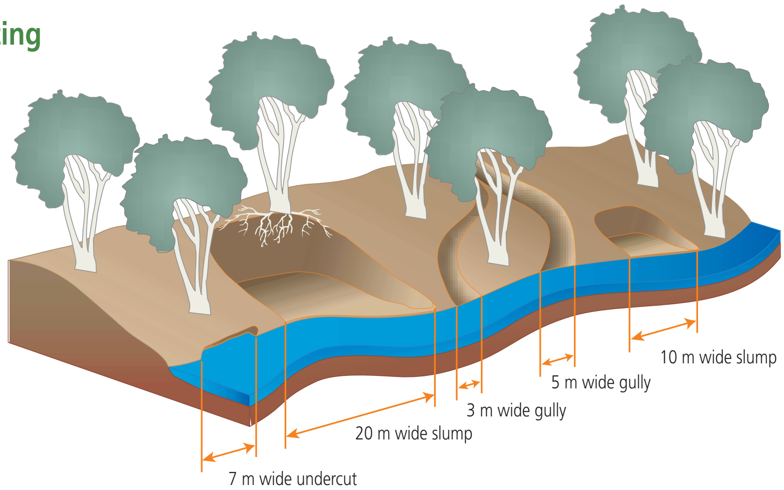


Figure 28. Combined widths of each erosion feature (measured within the 100 m long x 5–20 m wide *transect*): slumping = 30 m; gullying = 8 m; and undercutting = 7 m. A score is given to each of these erosion features.

Figure 29. Examples of the three erosion features measured in the TRARC: slumping of small bank (top left); slumping of large bank (top right); active (unstable) gully (bottom left); and, undercutting (bottom right).

Figure 30. Both managed and unmanaged animals can cause damage to riparian areas. For example, managed cattle (top left); unmanaged cattle and bank disturbance (top right); feral pigs (bottom left — photos Jim Mitchell); and feral pig disturbance (bottom right).

19. Animals: managed and unmanaged

What is the extent of damage to the vegetation, bank and channel due to managed and unmanaged animals?

Assess along the *transect* (100 m long, 5–20 m wide). Estimate the proportion of the *transect* that has been damaged by managed animals (stock or other farmed animals), and by unmanaged animals (wild cattle, pigs, donkeys, buffalo, horses, etc). Damage includes tree ringbarking, vegetation trampling, grazing, wallowing, soil compaction and track formation. Make a note on the score sheet if fences are present and whether they appear to be maintained and effective. If possible, also note what type of unmanaged animals are responsible for any damage (e.g. Figure 30).

20. Fire

How long has it been since a fire and how much vegetation was burnt?

Assess along the *transect* (100 m long, 5–20 m wide). Firstly, determine the time since the last fire (e.g. burnt this season, last season, or long ago). Studying the vegetation can help determine how long it has been since a fire has impacted the area (e.g. presence or absence of hanging dead material on Pandanus, Figure 31). If you are not certain about the time since the last fire, the following tips may help you:

~ **Dead grass**: if there is dead grass accumulated at the base of living grass (especially perennial grasses), then it probably has not been burnt for at least one year (one fire season).

~ **Young plants**: look at the youngest plants to see if they have fire damage (e.g. where young Pandanus is missing dead hanging leaves, Figure 31). If so, the fire has occurred since that plant's existence.

~ **Burnt bark**: over time, fire scars on tree trunks will diminish due to floods and regrowth. If bark still looks very scorched, then the fire was probably fairly recent.

Secondly, look to see how much of the survey area has been burnt (look for fire scars): how close to the stream did the fire come; and how high did the flames reach up the trees (Figure 31). Refer to the score sheet to select the appropriate score.

Figure 31. Examples of riparian fires: sensitive riparian plants can be killed by fire (top left photo); old fire scars up trunk (top right photo); recently burnt up to channel edge (bottom left photo); long unburnt vegetation — note unburnt dead leaves on old Pandanus (bottom right photo); and burnt juvenile plants can give an indication of time since fire (inset, bottom right photo).

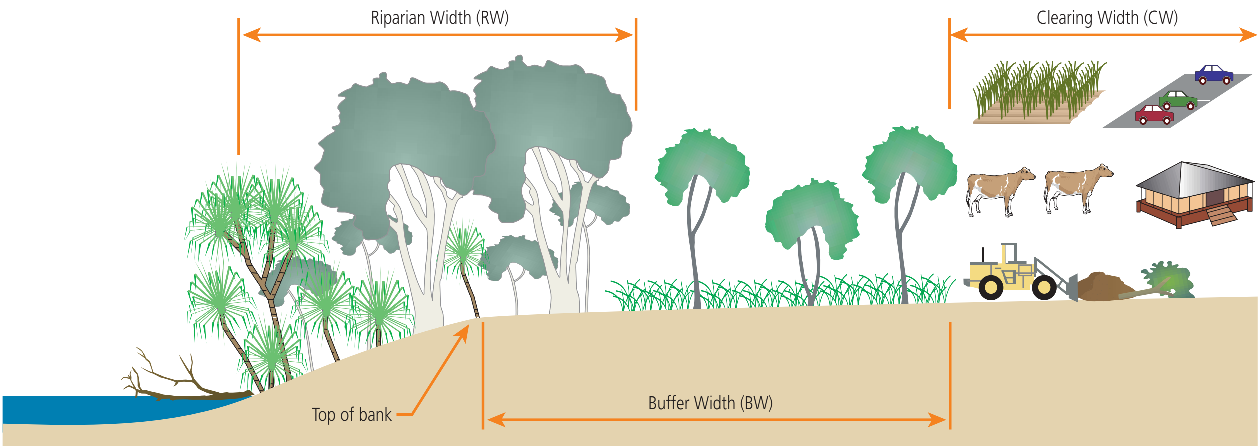


Figure 32. 'Tree clearing' is scored by a combination of riparian, buffer and channel widths

21. Tree clearing

How close is tree clearing to the top of the bank, and how wide is it?

This *indicator* is based on the Northern Territory's Land Clearing Guidelines (NRETA, 2006) and varies depending on stream order. Streams, creeks and rivers can be classified into hierarchical 'stream orders' depending on their size. A stream with no tributaries is a first order stream. When a first order stream joins another first order stream, it becomes a second order stream. Stream orders continue to increase when they join another stream of equal order. Stream order can be determined from maps and you should use the best available information for your region, e.g. 1:50,000 scale topographic map. Firstly, determine the type of your stream:

i. Drainage line or intermittent stream (1st, 2nd order streams)
ii. Creek (3rd, 4th order streams)
iii. River (5th order streams or greater)

Secondly, estimate the average *buffer width* along the *transect*. *Buffer width* is the uncleared vegetation measured from the top of the outermost bank to the nearest cleared land away from the waterway, or if no bank exists (drainage lines and wetlands) from the outer edge of the seepage line or maximum flood level (NRETA, 2006).

Thirdly, estimate the average cleared width relative to the average riparian width along the *transect* (Figure 32). *Cleared width* refers to areas that have had mass tree removal and the natural vegetation replaced with pasture, crops, or hard structures (e.g. for grazing, horticulture, car parks, roads, picnic grounds, camping and urban uses). *Riparian width* is measured from the edge of the channel (low flow) to where there is a distinct change in vegetation and landform. Refer to the score sheet to select the appropriate score. Note: if using multiple parallel *transects* (e.g. Figure 6), give the same 'Tree clearing' score to each *transect*.

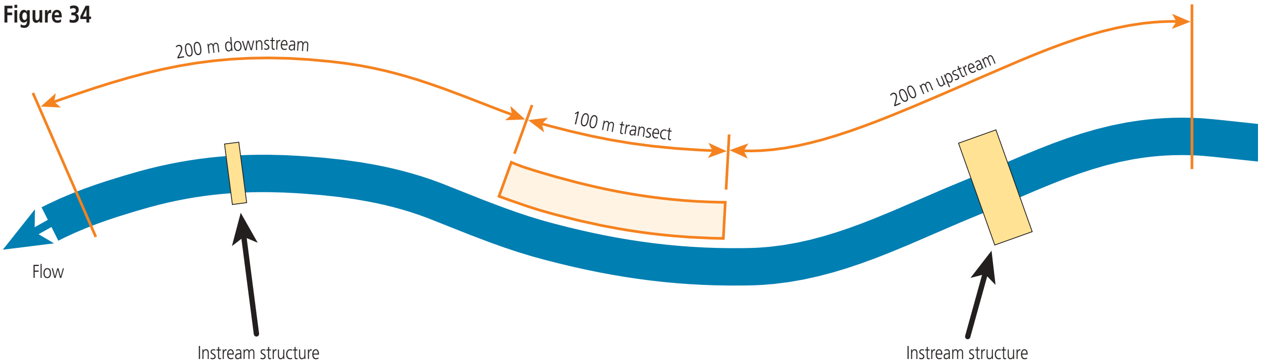
22. Flow regime: large dams

Have large dams had an effect on the vegetation's ability to regenerate?

If there is a large dam upstream used for irrigation, drinking water, power generation or recreation (e.g. Figure 33), the change in flow regime may have impacted on the riparian vegetation. If large seasonal flows have been blocked by the dam, tree regeneration high up the banks that rely on these floods will be less common and less successful. Assess if juvenile trees and seedlings are common or rare in areas that are high up the bank.

Figure 33. Ord River diversion dam, Kununurra WA. Photo Sean Lawrie.

Figure 34



23. Instream structures

Are there any human-built instream structures located upstream or downstream that affect the flow?

Count the number of human-built instream structures within 200 m upstream and downstream of the *transect* ends (including within the *transect*), (Figure 34). This includes bridges, culverts, weirs and dams. Note: if using multiple parallel *transects* (e.g. Figure 6), give the same 'Instream structures' score to each *transect*.

Figure 34. Human-built 'Instream structures' (as shown in figure above and photos below) are scored within 200 m upstream and downstream of the *transect*.

24. Other

How much impact has other structures or activities had?

Assess along the *transect* (100 m long, 5–20 m wide). Estimate the proportion of the riparian vegetation and banks within the *transect* that has been disturbed by any human-built structures or activities that have not been scored elsewhere. For example, sand mining, residential/urban development, slashed grass, 4WD tracks or crossings, boat ramps, bush camps, hard footpaths, walking tracks, recreation access (e.g. fishing site, swimming hole), gauging stations, pumps and pipes (Figure 35, photos below and opposite).

Water pipe.

Slashed grass.


Gauging station


Bike path


Swimming access


Bush camp


4WD crossing

Figure 35. Examples of 'Other' human activities and structures that can cause degradation to riparian areas. Sand mining (above).

Step 3. Data analysis

Methods to analyse the TRARC scores need to be both conceptually easy to understand and meaningful to management. Many data analysis techniques used in other rapid assessment methodologies are often characterised by simple additive and/or multiplicative calculations (Gibbons & Freudenberger 2006). Developing an appropriate analysis procedure requires a firm understanding of the importance that each *indicator* has in maintaining riparian condition and the interactions between these *indicators*. At this stage in the development of the TRARC, we acknowledge that further research is required to increase this understanding and refinements to the current data analysis procedure may be required. Therefore, the following procedure should be regarded as an interim version until further research and testing of data is undertaken.

To assist in analysing your data, an Excel spreadsheet is available to download from the websites <www.rivers.gov.au> or <http://savanna.cdu.edu.au>. Updated versions will also be available on these sites. The spreadsheet will automatically perform the calculations described below. However, the calculations can be performed manually with the aid of a calculator. The scores collected in the field need to be combined to derive summary scores for each condition *sub-index* and the PRESSURE index. These *indices* are most helpful for guiding management decisions. However, you may also wish to derive a CONDITION rating for each *transect*, which is the combination of PLANT COVER, REGENERATION, EROSION, and WEEDS. To do these calculations, four stages are required — as described below. Note: this process is for calculating scores for one *transect*. Deriving scores for sites with multiple parallel *transects* is explained at the end of this section.

Stage 1. Average *indicator* scores

a. *Indicators* that were scored at the three *points* along the *transect* are averaged into one number for each *indicator*. To calculate the average, sum the scores together and then divide by the number of scores that were summed (Equation 1).
b. Some *indicators* are then grouped before contributing to *sub-index* scores. There are two instances of this:
   i. 'Animals' = the average of 'Managed animals' and 'Unmanaged animals'.
   ii. 'Bank stability' = the average of 'Bank slope, 'Instream structures', 'Maximum bank sediment size' and 'Dominant bank sediment size'.

Equation 1. Calculation used to average scores.

$$\text{Average} = \frac{\text{Sum of scores}}{\text{Number of scores}}$$

Stage 2. Calculate *sub-index* scores

a. Group the *indicators* averaged in Stage 1 into five groups: four *sub-indices* (PLANT COVER, REGENERATION, EROSION, and WEEDS) and a PRESSURE index. See Figure 36 for these groupings.
b. Summary scores for each grouping are now calculated. With the exception of PLANT COVER, *sub-index* scores are the sum of its *indicator* scores. PLANT COVER is calculated differently as a greater emphasis (or 'weighting') is given to the 'Canopy cover' *indicator*. This is achieved by multiplying the 'Canopy cover' score with the sum of the other PLANT COVER *indicator* scores. Total scores are then converted to a score of 0–25 for PLANT COVER, REGENERATION, EROSION, and WEEDS or 0–100 for the PRESSURE index.
c. To convert the scores to lie between 0–25 or 0–100, two extra calculations are required. The first calculation is called 'range standardisation' which converts the score to 0–1 (Equation 2). The last calculation simply multiplies this score by 25 (for PLANT COVER, REGENERATION, EROSION, and WEEDS) or by 100 (for PRESSURE).

Equation 2. Three steps used to derive *sub-index* scores: Part 1, total the *indicator* scores ('a,b,c,d,e,f,g') for each grouping (see Figure 36 for names); Part 2, 'range standardise' this score ('X') to give a value between 0–1; Part 3, convert this value ('Y') to lie between 0–25 or 0–100. These three steps can be simplified into one equation for deriving each grouping score (as shown in Figure 36).

Part 1

Total PLANT COVER *indicators* (X)	= a x (b+c+d+e+f+g)
Total REGENERATION *indicators* (X)	= a+b+c+d+e
Total EROSION *indicators* (X)	= a+b+c+d+e
Total WEEDS *indicators* (X)	= a+b+c+d+e+f+g
Total PRESSURE *indicators* (X)	= a+b+c+d+e+f

Part 2

$$\text{'Range standardise' (Y)} = \frac{X - \text{(minimum score possible)}}{\text{(maximum score possible)} - \text{(minimum score possible)}}$$

PLANT COVER	= Y x 25
REGENERATION	= Y x 25
EROSION	= Y x 25
WEEDS	= Y x 25
PRESSURE	= Y x 100

At this stage in the data analysis, these *sub-index* scores should be studied because of the clarity with which specific management issues can be identified. If the user is assessing many sites within a catchment, it may also be useful to calculate a CONDITION rating. This is helpful in summarising the general CONDITION of many sites and when compared against the PRESSURE rating, sites of management priority may be identified. Defining sites of priority will depend on several circumstances, such as political, economic, cultural and environmental influences. However, when reviewing the data, the *sub-index* scores should always be considered before making management decisions.

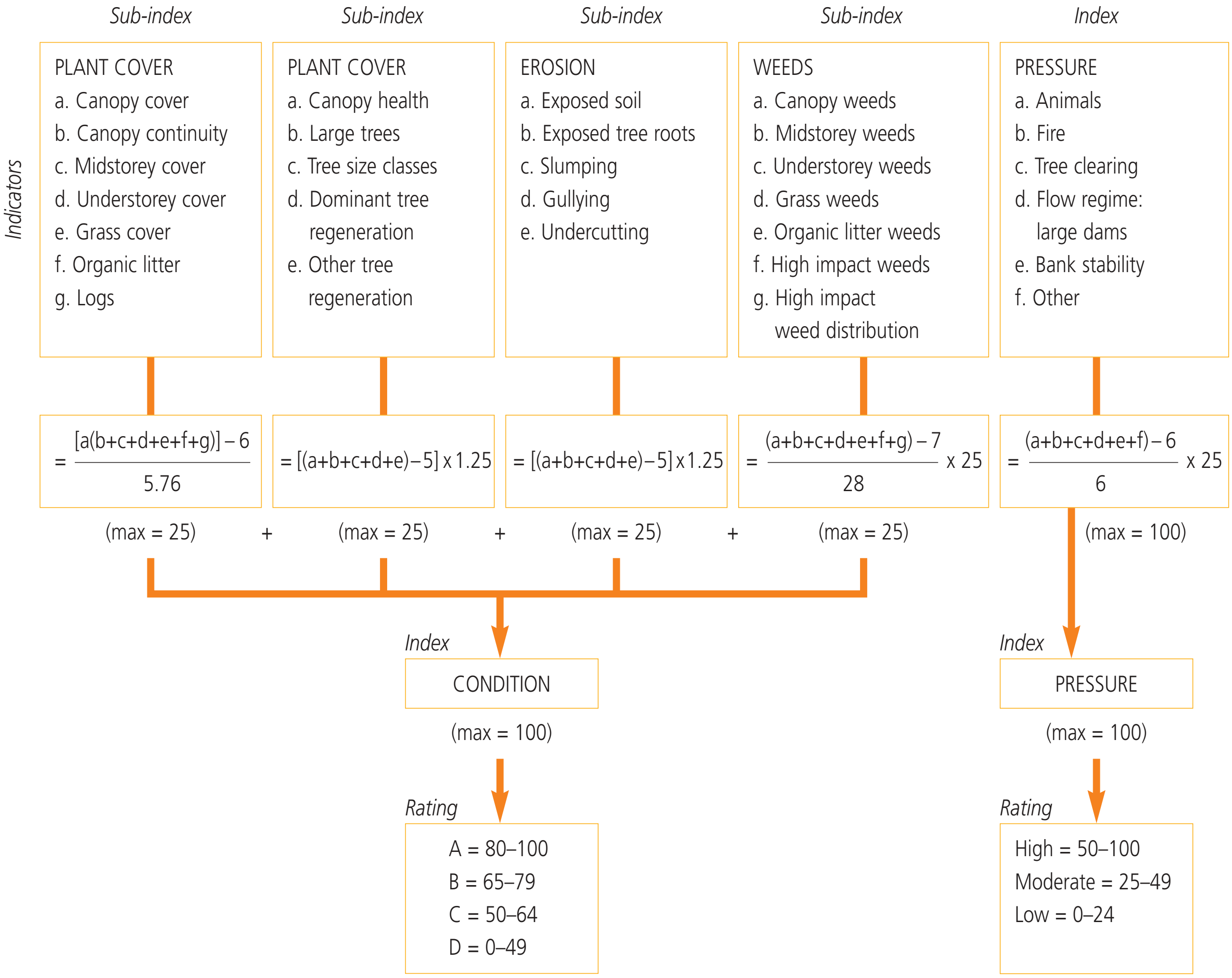
Stage 3. Calculate CONDITION index

The four *sub-indices* contribute to the CONDITION score (score range is 0–100). CONDITION = PLANT COVER + REGENERATION + EROSION + WEEDS.

Stage 4. Assign CONDITION and PRESSURE ratings

To help summarise the scores, the CONDITION index is assigned an A, B, C or D rating (A = 80–100, B = 65–79, C = 50–64, D = 0–49). The PRESSURE index is assigned a Low, Moderate, or High rating (Low = 0–24, Moderate = 25–49, High = 50–100) (Figure 36). Note: these assigned ratings are under trial by the developers of the TRARC and may be modified once more data is available to test.

Figure 36. Flow chart showing the process to calculate four *sub-indices*, a CONDITION index, a PRESSURE index and summary ratings. The equations shown are simplified from what is explained in Equation 2.



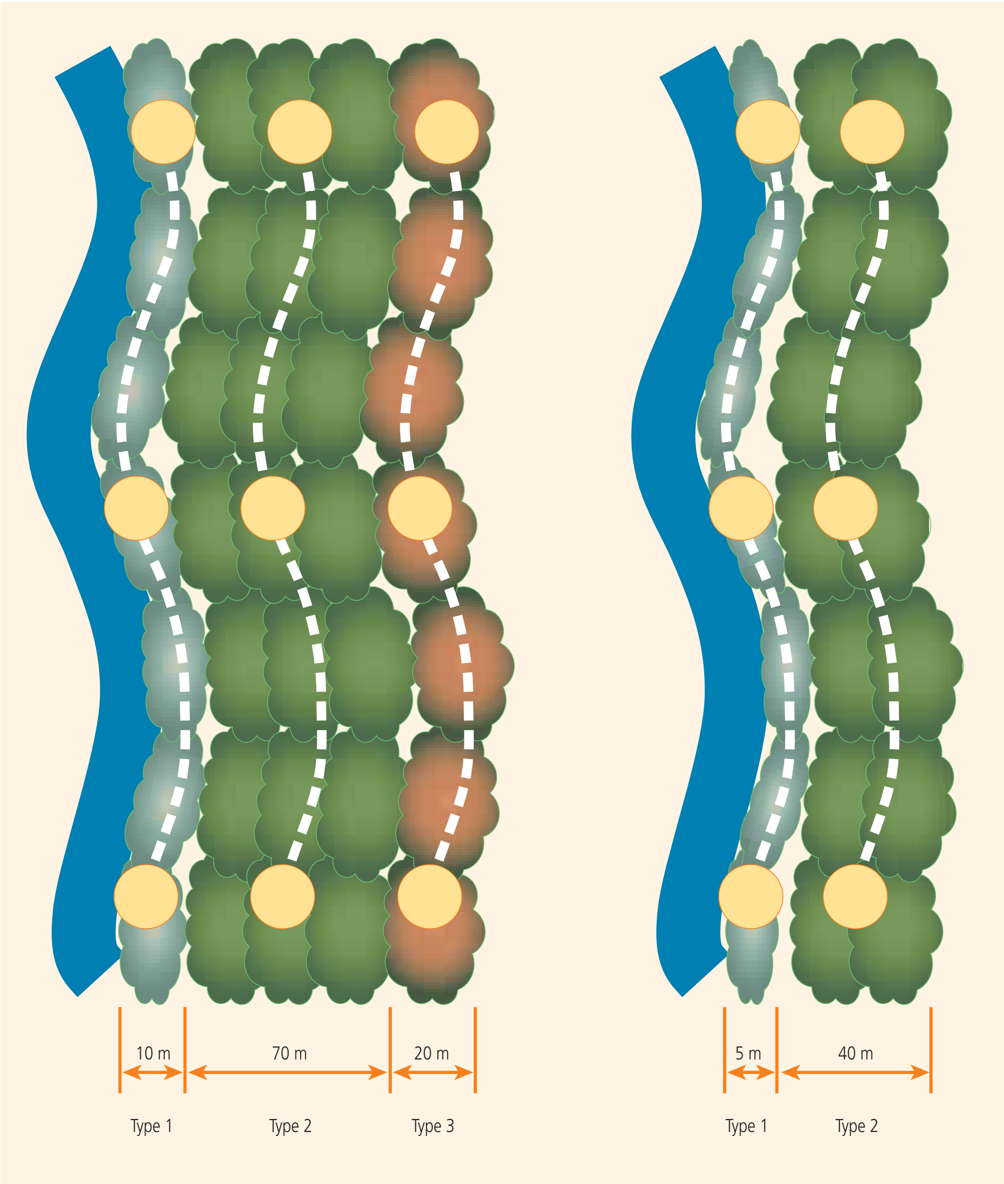


Figure 37. Two examples of multiple parallel *transects* where distinct vegetation types are present.

Example 1 (left): three vegetation types of varying widths with three *transects*.

Example 2 (right): two distinct vegetation types of varying widths with two *transects*.

When calculating overall scores, *transects* are 'weighted' in respect to the width of the vegetation type that it runs through.

Multiple parallel transects

If multiple parallel *transects* were used in areas with distinct vegetation types (as explained in Step 1: Site setup), overall scores can be derived for the site by combining each of the *transect's sub-index* scores. Firstly, follow the procedures outlined in Stages 1 and 2 above to calculate the *sub-index* scores for each *transect*. Secondly, as each vegetation type is likely to be of a different width, the *sub-index* scores for each *transect* need to be 'weighted'. This is done by working out how much of the total riparian width is occupied by each distinct vegetation type. The scores are then scaled accordingly. Once the overall scores are calculated for each *sub-index*, CONDITION and PRESSURE ratings can be assigned as in Stages 3 and 4 above.

Example 1. If a riparian zone was 100 m wide had three distinct vegetation types, thus three *transects*, and the width of each vegetation type was: Type 1, 10 m; Type 2, 70 m; and Type 3, 20 m (Figure 37); then the *transect* in Type 1 (10 m) would contribute to 10% of the overall score; Type 2 (70 m) would contribute 70%; and Type 3 (20 m), 20%.

Example 2. If a riparian zone was 45 m wide and had two distinct vegetation types: Type 1, 5 m; and Type 2, 40 m (Figure 37); then the *transect* in Type 1 would contribute to 11% of the overall score (because it occupies 11% of the total riparian width), thus the *transect* in Type 2 would contribute 89%.

Tropical Rapid Appraisal of Riparian Condition (TRARC). Version 1: August 2006

Tropical Savannas CRC — Cooperative Research Centre for Tropical Savannas Management

Australian Government — Land & Water Australia

http://savanna.cdu.edu.au

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Note: Read the *User guide* before using these score sheets. Circle most appropriate score.

Note: This number refers to the numbered items in the *User guide*

CANOPY COVER			1
% cover of trees and tall shrubs >5 m in height. Look directly above you (approx. 5 m radius). Include weeds	*Point*		
	A	B	C
<5%	1	1	1
5–25%	2	2	2
25–50%	3	3	3
50–75%	4	4	4
75–100%	5	5	5

CANOPY HEALTH			2
Canopy health of surrounding NATIVE trees and tall shrubs >5 m in height. Look around area (approx. 20 m up and down the *transect*). **Do not** include weeds	*Point*		
	A	B	C
Canopy very sparse/non-existent; shrubs and/or grasses common due to lack of canopy; dead trees may occur	1	1	1
Tree canopy sparse; individuals exhibit crown dieback; dead trees common	2	2	2
Canopy +/– sparse or lacking vigour; dead trees may be evident; minor crown dieback	3	3	3
Canopy slightly irregular and/or with some gaps; no/few dead trees	4	4	4
Tree canopy appears intact; no/few standing dead trees	5	5	5

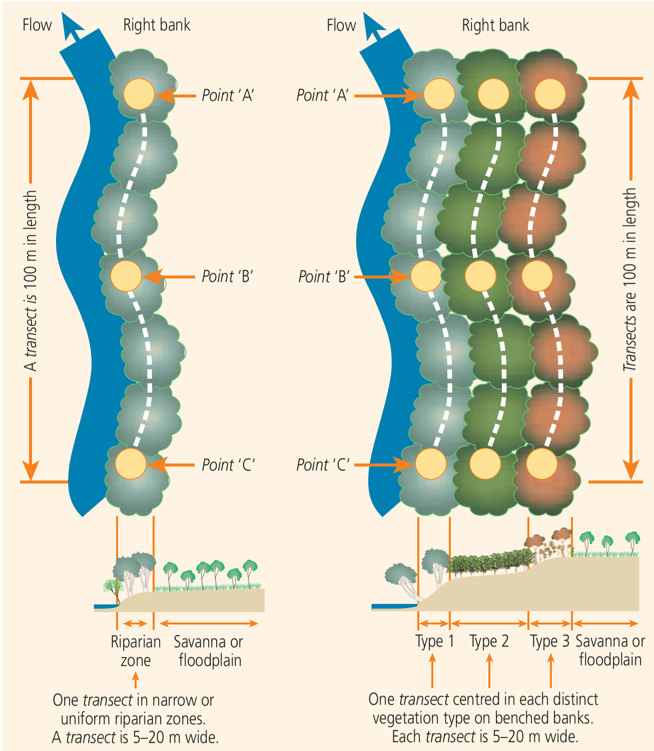
TREE SIZE CLASSES			3
Variation in trunk width/height of dominant native trees >3 m tall. Look around area (approx. 20 m up and down the *transect*). Do not include weeds. Size groups: <10 cm, 10–20 cm, 20–30 cm, 30–40cm, >40 cm	*Point*		
	A	B	C
No canopy, few trees or all same size group	1	1	1
2 distinct size groups	3	3	3
3+ distinct size groups	5	5	5

Choose a maximum of three species as co-dominants **OR** in tall closed forest with diverse species assess entire tree community

DOMINANT TREE REGENERATION			4
Number of juveniles 0.3–3 m tall of dominant tree species. Must be same species as measured in 'Tree size classes'. (Look within approx. 5 m radius)	*Point*		
	A	B	C
0	1	1	1
1–3	3	3	3
4+	5	5	5

OTHER TREE REGENERATION			5
Number of juveniles present that are common riparian species, even though adult individuals of these species are not dominant within the *transect*. (Look within approx. 5 m radius)	*Point*		
	A	B	C
0	1	1	1
1–3	3	3	3
4+	5	5	5

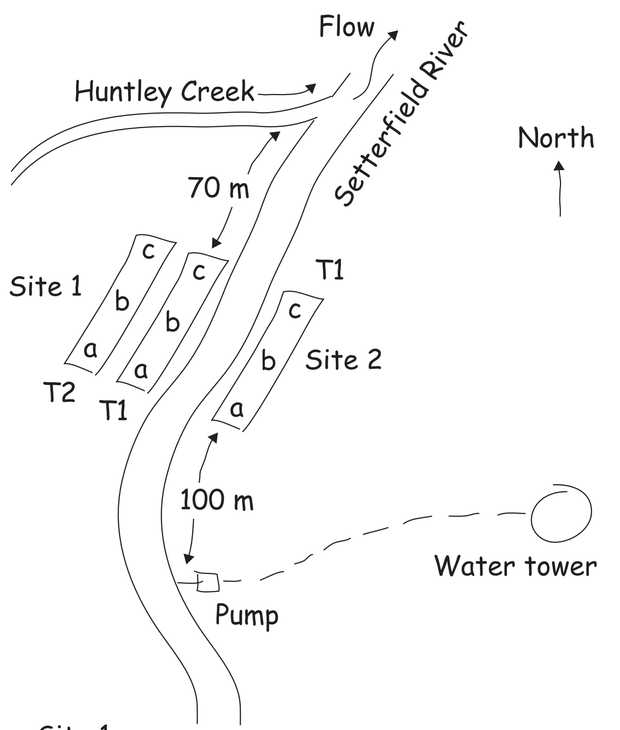
Date					
Stream name					
Site number					
Transect number					
Left / Right bank (when facing downstream)		Left		Right	
Assessor's name/s					
GPS (start of *transect*)					
GPS (end of *transect*)					
Average channel width (m) near *points* A, B, C	A	B	C	Ave	
Average riparian width (m) or width of distinct veg. type	A	B	C	Ave	
Photo numbers					



Mud map

Include the approximate distances from distinct landmarks to help others find this site in the future.

Example only, not to scale.



Site 1

Transect 1 (T1) is 5 m from channel
Transect 2 (T2) is 30 m from channel

Site 2

Transect 1 (T1) is 10 m from channel

MIDSTOREY COVER			6
% cover of shrubs and small trees 1.5–5 m in height (natives and weeds) (5 x 5 m square)	*Point*		
	A	B	C
<5%	1	1	1
5–30%	3	3	3
30–100%	5	5	5

NOTE: If no midstorey present, give WEEDS a score of 5.

MIDSTOREY WEEDS			7
What is the proportion of weeds (same 5 x 5 m square)	*Point*		
	A	B	C
75–100% weed plants	1	1	1
50–75% weed plants	2	2	2
25–50% weed plants	3	3	3
5–25% weed plants	4	4	4
<5% weed plants	5	5	5
List most dominant weed species			

GRASS COVER			6
% cover of grass of any height (natives and weeds) (5 x 5 m square)	*Point*		
	A	B	C
<5%	1	1	1
5–30%	2	2	2
30–60%	3	3	3
60–80%	4	4	4
80–100%	5	5	5

NOTE: If no grass present, give WEEDS a score of 5.

GRASS WEEDS			7
What is the proportion of weeds (same 5 x 5 m square)	*Point*		
	A	B	C
75–100% weed plants	1	1	1
50–75% weed plants	2	2	2
25–50% weed plants	3	3	3
5–25% weed plants	4	4	4
<5% weed plants	5	5	5
List most dominant weed species			

UNDERSTOREY COVER			6
% cover of shrubs, sedges, herbs and groundcovers <1.5 m in height (natives and weeds). Do not include grass (5 x 5 m square)	*Point*		
	A	B	C
<5%	1	1	1
5–30%	3	3	3
30–60%	5	5	5

NOTE: If no understorey present, give WEEDS a score of 5.

UNDERSTOREY WEEDS			7
What is the proportion of weeds (same 5 x 5 m square)	*Point*		
	A	B	C
75–100% weed plants	1	1	1
50–75% weed plants	2	2	2
25–50% weed plants	3	3	3
5–25% weed plants	4	4	4
<5% weed plants	5	5	5
List most dominant weed species			

ORGANIC LITTER			6
% cover of leaves and fallen branches <10 cm diameter, do not include ash (5 x 5 m square)	*Point*		
	A	B	C
<5%	1	1	1
5–30%	2	2	2
30–60%	3	3	3
60–80%	4	4	4
80–100%	5	5	5

NOTE: If no organic litter present, give WEEDS a score of 5.

WEED LITTER			7
What is the proportion of weeds (i.e., litter from weed plants) (same 5 x 5 m square)	*Point*		
	A	B	C
75–100% weed litter	1	1	1
50–75% weed litter	2	2	2
25–50% weed litter	3	3	3
5–25% weed litter	4	4	4
<5% weed litter	5	5	5
List most dominant weed species (litter)			

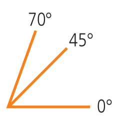
EXPOSED SOIL 8

% cover of exposed soil and ash. **Exclude** large natural rock formations, boulders, leaf litter and roots (5 x 5 m square)	*Point*		
	A	B	C
80–100%	1	1	1
60–80%	2	2	2
30–60%	3	3	3
5–30%	4	4	4
<5%	5	5	5
Tick box if mostly bedrock	☐	☐	☐

BANK STABILITY: Bank sediment size 9

Bank sediment size (near the three *points* A, B, C)	Maximum			Dominant		
	A	B	C	A	B	C
Clay or silt (<0.064 mm grain size)	5	5	5	5	5	5
Sand (0.064–2 mm grain size)	4	4	4	4	4	4
Gravel (2–12 mm grain size)	3	3	3	3	3	3
Pebbles (12–64 mm grain size)	2	2	2	2	2	2
Cobbles, boulders or bedrock (>64 mm grain size)	1	1	1	1	1	1

BANK STABILITY: Bank slope 10



Approximate bank slope (near the three *points* A, B, C)	*Point*		
	A	B	C
>70° slope (or undercut)	5	5	5
45–70° slope	3	3	3
<45° slope	1	1	1

LARGE TREES 11

Number of large trees (native and alive) with >30 cm trunk diameter when measured 1.3 m from base of trunk, do not include dead or fallen trees. (100 m *transect*)	SCORE
0	1
1–4	2
5–6	3
7–8	4
9+	5
TALLY	

LOGS 12

Number of logs* and large logs** (100 m *transect*)	SCORE
Absent	1
1–2 large logs OR <5 logs	2
3–4 large logs OR 5–9 logs	3
5–6 large logs OR 10–14 logs	4
7+ large logs OR 15+ logs	5
TALLY	

* LOGS (>10cm diameter and 1–3 m in length)

** LARGE LOGS (>10cm diameter and >3 m in length)

HIGH IMPACT WEEDS 13

Number of listed species (100 m *transect*)	SCORE
4 of listed species present	1
3 of listed species present	2
2 of listed species present	3
1 of listed species present	4
0 of listed species present	5

HIGH IMPACT WEED DISTRIBUTION 14

Description of weed distribution within 100 m *transect* (up to 20 m wide)	Distribution pattern	SCORE
Continuous dense distribution in a wet/dry zone		1
Continuous dense distribution		
Continuous distribution with some spaces		
Continuous distribution of well spaced plants		
Several well spaced patches		2
A few patches plus several scattered individuals		
A few patches		
A single patch plus several scattered individuals		3
Several scattered individuals		
A single patch plus a few scattered individuals		
A single patch		4
A few scattered individuals		
Rare		
No high impact weeds in *transect*		5

High impact weed species (for Top End, NT and Burdekin, Qld)

- ☐ *Andropogon gayanus* (gamba grass)
- ☐ *Calopogonium mucunoides* (calopo)
- ☐ *Centrosema molle* (centro)
- ☐ *Cryptostegia grandiflora* (rubber vine)
- ☐ *Hymenachne amplexicaulis* (olive hymenachne)
- ☐ *Hyptis suaveolens* (hyptis)
- ☐ *Ipomoea quamoclit* (morning glory)
- ☐ *Lantana camara* (lantana)
- ☐ *Leucaena leucocephala* (coffee bush)
- ☐ *Mimosa pigra* (mimosa, giant sensitive plant)
- ☐ *Panicum maximum* (guinea grass)
- ☐ *Parkinsonia aculeata* (parkinsonia)
- ☐ *Parthenium hysterophorus* (parthenium)
- ☐ *Passiflora foetida* (wild passion fruit)
- ☐ *Pennisetum* sp. (mission grass)
- ☐ *Ricinus communis* (castor oil plant)
- ☐ *Senna alata* (candle bush)
- ☐ *Stachytarpheta* spp. (snakeweed)
- ☐ *Urochloa (Brachiaria) mutica* (para grass)
- ☐ *Xanthium strumarium* (noogoora burr)
- ☐ *Ziziphus mauritiana* (chinee apple)

CANOPY WEEDS	15
Proportion of canopy plants (>5 m tall) that are weeds, including vines in the canopy (100 m *transect*)	SCORE
75–100% weed plants	1
50–75% weed plants	2
25–50% weed plants	3
5–25% weed plants	4
<5% weed plants	5
List most dominant weed species	

NOTE: If no canopy present, give WEEDS a score of 5.

CANOPY CONTINUITY	16
Proportion of *transect* length that has a canopy. Gaps between canopies must be >5 m and span the width of the *transect* (max 20 m). (100 m *transect*)	SCORE
<50%	1
50–90%	3
90–100%	5
Tick box if bedrock mostly causing gaps	☐

EXPOSED TREE ROOTS		17
Proportion of trees or tall shrubs with exposed tree roots (thicker than 20 mm) due to erosion. Do not include species with natural aerial roots (e.g. Pandanus and Figs). (100 m *transect*)	Average amount of plant's circumference with exposed roots (thicker than 20 mm)	SCORE
20–100% of plants	>1/3	1
	<1/3	2
5–20% of plants	>2/3	2
	1/3–2/3	3
	<1/3	4
5% of plants	>1/3	4
	<1/3	5

SLUMPING	18
Combined slumping width along 100 m *transect*	SCORE
20–100 m combined width	1
10–20 m combined width	2
5–10 m combined width	3
<5 m combined width	4
Slumps absent	5

GULLYING	18
Combined width of active, unstable gullies passing through 100 m *transect*	SCORE
20–100 m combined width	1
10–20 m combined width	2
5–10 m combined width	3
<5 m combined width	4
Gullies **absent** or **all with stabilised*** walls and head	5

*Stabilised by vegetation, rocks or other.

UNDERCUTTING	18
Combined length of undercutting along 100 m *transect*	SCORE
20–100 m combined width	1
10–20 m combined width	2
5–10 m combined width	3
<5 m combined width	4
Undercutting absent	5

ANIMALS: Managed	19
Extent of damage (tree ringbarking; vegetation trampling; grazing; wallowing; soil compaction; track formation; instream substrate disturbance) caused by managed animals (e.g. cattle). Do not include unmanaged animals here. (100 m *transect*)	SCORE
20–100% of ground or vegetation damaged	5
5–20% of ground or vegetation damaged	3
0–5% of ground or vegetation damaged	1
Tick box if fences are present and effective ☐ ; present but ineffective ☐ ; not present ☐	

ANIMALS: Unmanaged	19
Extent of damage (tree ringbarking; vegetation trampling; grazing; wallowing; soil compaction; track formation; instream substrate disturbance) caused by unmanaged animals (e.g. pigs, wild cattle, horses, donkeys, buffalo). Do not score managed animals (e.g. cattle) here. (100 m *transect*)	SCORE
20–100% of ground or vegetation damaged	5
5–20% of ground or vegetation damaged	3
0–5% of ground or vegetation damaged	1
☐ pig ☐ wild cattle/horse/donkey/buffalo ☐ other ______________________	

FIRE — 20

Time since fire	Average fire impact for *transect*	SCORE
Burnt in current/ most recent fire season	**Major impact**: canopy burnt and/or burnt up to channel edge	5
	Moderate impact: trunks charred but canopy mostly unburnt and not burnt up to channel edge	4
	Minor impact: some impact to riparian boundary or spot fire only	3
Burnt in previous fire season	**Major impact**: canopy burnt and/or burnt up to channel edge	4
	Moderate impact: trunks charred but canopy mostly unburnt and not burnt up to channel edge	3
	Minor impact: some impact to riparian boundary or spot fire only	2
Long unburnt (old fire scars)	—>	2
Little evidence of fire	—>	1

Notes for TREE CLEARING 21

* **Buffer width** is the uncleared vegetation measured from the top of the outermost bank to the nearest cleared land away from the waterway, **OR** if no bank exists (drainage lines and wetlands), from the outer edge of seepage line or maximum flood level.

** **Clearing width** refers to areas that have had mass tree removal (e.g. for grazing, horticulture, car parks, roads, picnic grounds, camping and urban uses).

*** **Riparian width** is measured from the edge of the channel (low flow) to where there is a distinct change in vegetation and landform.

TREE CLEARING — 21

Waterway type (pick one only)	Average buffer width (m)* for 100 m *transect* (measured away from waterway)	Average clearing width** compared to Average riparian width (RW)***	SCORE
Drainage lines and intermittent streams (1st, 2nd order)	<15	>RW	5
		<RW	4
	15–25	>RW	3
		<RW	2
	>25 or uncleared	any	1
Creeks (3rd, 4th order)	<25	>RW	5
		<RW	4
	25–50	>RW	4
		<RW	3
	50–75	>RW	3
		<RW	2
	75–100	>RW	2
		<RW	1
	>100 or uncleared	any	1
Rivers (5th order or greater)	<25	>RW	5
		<RW	4
	25–75	>RW	4
		<RW	3
	75–150	>RW	3
		<RW	2
	150–250	>RW	2
		<RW	1
	>250 or uncleared	any	1

FLOW REGIME: Large dams — 22

Large dam upstream and vegetation response to environmental flows (within 100 m *transect*)	SCORE
Large dam upstream and environmental flows ineffective at triggering recruitment events for plants high up bank: tree regeneration rare on high banks	5
Large dam upstream and environmental flows moderately effective at triggering recruitment events for plants high up bank: some tree regeneration on high banks	3
Large dam upstream and environmental flows effective at triggering recruitment events for plants high up bank: tree regeneration common on high banks	1
No large dam upstream	1

BANK STABILITY: Instream structures — 23

Human-built instream structures within 200 m upstream or downstream of *transect* (e.g. bridges, culverts, weirs, small dams)	SCORE
4+ instream structures	5
3 instream structures	4
2 instream structures	3
1 instream structures	2
No instream structures	1

OTHER — 24

Proportion of *transect* impacted by human structures or activities that have not yet been recorded. e.g. sand mining, residential/urban development, slashed grass, 4WD track or crossing, boat ramp, bush camp, hard footpath, walking track, fishing site, pumps, pipes, gauging station (100 m *transect*)	SCORE
50–100%	5
25–50%	4
10–25%	3
5–10%	2
<5%	1
Describe impact	

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Further information

For TRARC updates and a downloadable spreadsheet to calculate scores, visit the website <www.rivers.gov.au>. Other TRARC products and updates will be accessible through the Tropical Savannas CRC's 'Savanna Riparian Health' website accessible at <http://savanna.cdu.edu.au>. For further advice or information about the TRARC, please e-mail <trarc@cdu.edu.au>. Hard copies of this guideline are available for free from CanPrint Communications 1800 776 616.

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