Australian Government
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Australian Weeds Committee

A Field Manual

For Surveying and Mapping Nationally Significant Weeds

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and mapping
nationally
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weeds

NOTE: – all website links throughout this document were active at the time of publication.

– all terms highlighted in bold, italics and underlined are explained further in the Glossary

A field manual for surveying and mapping nationally significant weeds
Bureau of Rural Sciences

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Main photograph: Rubber vine (*Cryptostegia grandiflora*) infestation. Photo: Joe Vitelli, QLD DNRM
Inset top left: Boneseed (*Chrysanthemoides monilifera* ssp. *monilifera*) infestation. You Yangs Regional Park, Vic.
Photo: Nick Pitsas, CSIRO
Inset top right: Athel pine (*Tamarix aphylla*) infestation. Photo: Colin G. Wilson
Inset bottom: Gorse (*Ulex europaeus*) infestation. Photo: Kate Blood

Foreword

Weeds are one of the major problems affecting Australia's natural ecosystems and agricultural vegetation. Weeds have major impacts on the health, safety, amenity, economic well-being and quality of life of Australians.

Weed research and control is expensive and competes with other land management activities for scarce resources. The Weeds of National Significance (WONS) are the weeds considered to currently pose the most serious threats at a national level. The WONS programme was initiated to set priorities and provide national coordination of research and management activities. Setting priorities requires data. It is anticipated that applying the procedures outlined in this manual will improve the consistency of national-scale data and help guide resource allocation.

The manual is aimed primarily at land managers, land management agencies and research organisations. Complementary guidelines to assist communities and landholders to map weeds and develop local weed management plans have been prepared by the Cooperative Research Centre for Australian Weed Management.

This manual is based on collecting the minimum information agreed by the Australian Weeds Committee (AWC) as core attributes for monitoring the distribution and spread of WONS. It explains in detail the data collection and quality assurance procedures necessary to obtain information in a systematic way. Following these procedures will ensure that data collected are precise, comparable and repeatable and hence enable planners and policy-makers to draw objective conclusions about weed distribution and spread over time.

While the agreed WONS are the first priority, the manual can and should also be used as a conceptual model for the assessment of other weeds. The manual will be a valuable tool for weed eradication and containment programs, and for monitoring the performance of weed control in general.

Dr Cliff Samson
Executive Director
Bureau of Rural Sciences

Acknowledgements

Weeds experts from around Australia met in July 2003 and agreed that a manual for surveying and mapping WONS was needed. The 'attributes' (infestation site details) to be included were subsequently discussed with State and Territory representatives at workshops held between November 2003 and February 2004. Volunteers were sought from the workshops to field test the draft manual. Numerous suggestions and sources for the content of the manual were made during and after the workshops.

In particular, the contribution of State and Territory weed management and research programs, WONS coordinators and those who field tested the manual is gratefully acknowledged.

Seven of the 13 core attributes were endorsed by the Australian Weeds Committee (AWC) as a suitable national standard for mapping weeds (AWC meeting number 10, 2005). All 13 core, and the two optional attributes are recognised as relevant for on-ground, project scale monitoring.

The Australian Government's Natural Heritage Trust funded development of the manual.

Contents

1. Introduction

1.1 Why assess weeds?

The purpose of this manual is to provide standardised, systematic weed assessment procedures, applied across all land tenures. States and Territories require reliable weed infestation data to establish policy and allocate resources.

Decision-makers need comprehensive and objective data on weed distribution and spread to set priorities and measure outcomes of weed research and control.

Systematic records of weed infestations can help support understanding of:

- what weed is found, where and when;
- changes in area and density over time; and
- the effect of land management practices and weed management programs.

"You can't manage what you can't measure"

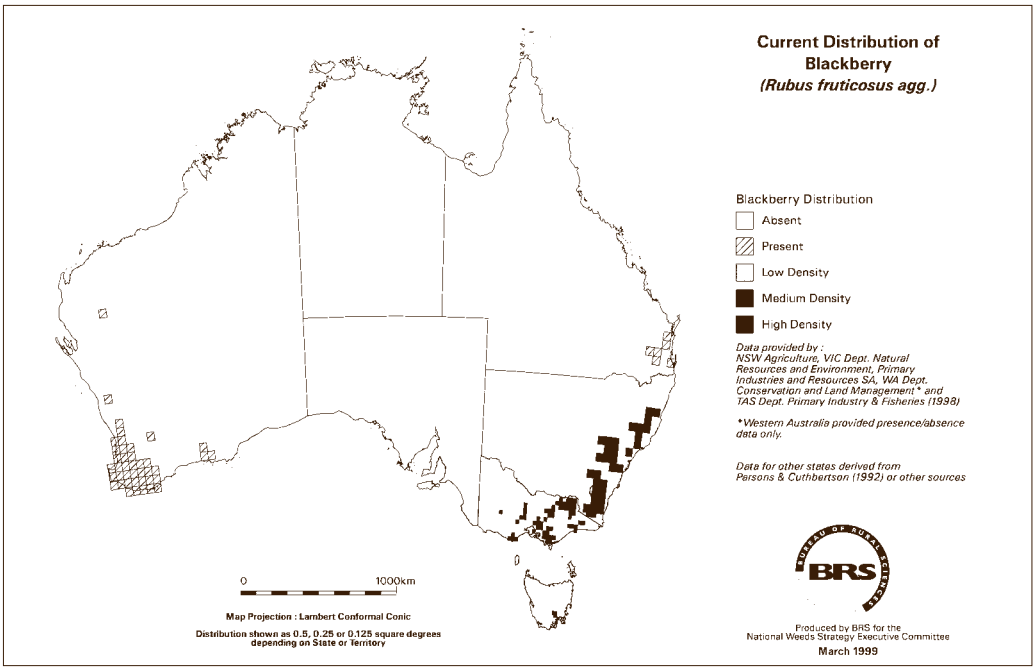


Figure 1 – Example distribution map From Thorp and Lynch (2000)

For example, the map in Figure 1 illustrates the presence of blackberry in southeastern and southwestern Australia. Control plans can be focussed in this region. When updated mapping shows weed spread or contraction, control efforts can be channelled accordingly.

This information has different uses at local (Figure 2), regional, and national levels; for example, to provide:

- priorities for on-ground work;
- information to support funding applications for weed control and research;
- data for mapping and modelling; and
- a basis for reporting procedures, such as those required by environmental management systems, the Montreal process and the National Monitoring and Evaluation Framework administered through the National Land and Water Resources Audit.

Figure 2 – Weed distribution information is important for planning effective control strategies. In this photo, hymenachne (*Hymenachne amplexicaulis*) is being aerial sprayed in the Hinchinbrook Shire, QLD. Photo: Matthew Buckman, Hinchinbrook Shire Council.

For each of the 20 WONS (Table 1), there are national strategies to manage infestations and spread.

For further information on development and progress of these strategies, visit the WONS species of interest at the Weeds Australia website (http://www.weeds.org.au/natsig.htm).

Table 1 – The inaugural list of Weeds of National Significance (WONS)*

Common Name	Scientific Name
Alligator weed	*Alternanthera philoxeroides*
Athel pine	*Tamarix aphylla*
Bitou bush (boneseed)	*Chrysanthemoides monilifera*
Blackberry	*Rubus fruticosus* agg.
Bridal creeper	*Asparagus asparagoides*
Cabomba	*Cabomba caroliniana*
Chilean needle grass	*Nassella neesiana*
Gorse	*Ulex europaeus*
Hymenachne	*Hymenachne amplexicaulis*
Lantana	*Lantana camara*
Mesquite	*Prosopis* spp.
Mimosa	*Mimosa pigra*
Parkinsonia	*Parkinsonia aculeata*
Parthenium weed	*Parthenium hysterophorus*
Pond apple	*Annona glabra*
Prickly acacia	*Acacia nilotica ssp. indica*
Rubber vine	*Cryptostegia grandiflora*
Salvinia	*Salvinia molesta*
Serrated tussock	*Nassella trichotoma*
Willows except weeping willows, pussy willow and sterile pussy willow	*Salix* spp. except *S. babylonica, S.* X *calodendron and S.* X *reichardtiji*

* Source: Thorp and Lynch 2000.

This manual is designed to guide survey and mapping of current and future WONS. While mapping WONS is the first priority, this manual can and should also be used as a model for the assessment of other weeds.

1.2 What information to record?

The minimum information (or 'attributes') needed to identify and monitor a weed site is listed in Table 2. Weed experts from around Australia contributed to the determination of these attributes, as documented in previous Bureau of Rural Sciences publications, including Thackway et al. 2003 and 2004 (http://www.daff.gov.au/brsweeds*). Seven of the 15 attributes were endorsed by the Australian Weeds Committee (AWC meeting number 10,

*NOTE: All website links throughout this document were active at the time of publication.

2005) as a baseline for national weed mapping standards. The AWC further agreed that the first 13 core attributes were appropriate for on-ground, local-scale monitoring, with attributes 14 and 15 being optional. See Appendix 1 for further details of the attributes.

The scope of this manual covers both national and regional mapping scales. The number of attributes of importance is dependent on the scale and resolution of the intended mapping application.

For example:

- **Regional, state and national-scale** attributes describing weed distribution and density are required for a range of purposes including national planning and policy. Monitoring at this scale is described as '***surveillance monitoring***'*. The attributes relevant for surveillance monitoring as endorsed by the AWC are highlighted in Table 2.
- **On-ground, project to local-scale** attributes describing treatment and precise location are required for weed management. Monitoring at this scale is described as '***investigative monitoring***'. All 15 attributes are relevant for investigative monitoring.

All 15 attributes are suitable for integration into Geographic Information Systems (***GIS***).

Table 2 – What to record for each weed site. The attributes relevant for surveillance monitoring as endorsed by the AWC are highlighted*.

Groups of information	What to record
What, when, who, why?	1. Data record number (core)* 2. Name of weed (core)* 3. When was the site assessed (date format; dd-mon-yyyy) (core)*
	4. Who assessed it? (core) 5. Purpose of visit (core)
Where?	6. Place name or locality (core)
	7. Latitude (Northing) (core)* 8. Longitude (Easting) (core)*
	9. Precision of latitude and longitude (core)
How much?	10. Area or length of plot, transect or polygon assessed (core)
	11. Cover or density of area, transect or polygon assessed (core)*
Other information	12. Treatment (types of control and/or eradication) (core)*
	13. Comments (core) 14. Number of records for the site (optional) 15. Land use category (optional)

Detailed methods for collecting attribute data are outlined in Section 3.2 — Steps for data collection.

*All terms highlighted in bold, italics and underlined are explained further in the Glossary

At a weed management level, maps developed from the methods described form the cornerstone for aggregating regional data up to a national scale.

The *Introductory Weed Management Manual* prepared by the Cooperative Research Centre (CRC) for Australian Weed Management (http://www.weeds.crc.org.au/) provides guidelines to assist regional communities and landholders to survey weeds and develop local weed management plans.

2. Which method for which weed?

Use the same methods to collect WONS core attribute data wherever possible. Consider the following factors when choosing a survey method.

• Plant form/habitat

Use remote sensing, or techniques such as aerial survey or aerial photography, for severe infestations, larger more conspicuous plants or where less precise data are adequate. Aerial survey may be appropriate for large infestations or for weeds occurring in large, open tracts of land such as rangelands or grasslands, or along waterways. Apply ground-based techniques for less conspicuous weeds, especially if it is essential to locate every plant.

• Sampling timing, frequency and intensity

Different weeds require different time intervals between sampling and different intensities of sampling. For example, for a weed that spreads widely and rapidly it may be essential to locate even a small outbreak before it produces seeds or propagules. Examples are weeds such as serrated tussock and salvinia. In this instance, use an assessment method that can be applied frequently and that locates small patches of inconspicuous plants. Less frequent and less precise methods can be used to assess woody weeds that spread relatively slowly such as willows. Annual weeds will need to be assessed during their peak season. For example assess winter annuals in winter and spring annuals in spring. For national surveys, five-year intervals between surveys are considered appropriate. Survey timing may coincide with control efforts, or surveys may be undertaken when flowering, seeding or germination is taking place to assist in identification of the weeds. For subsequent surveys of the same site, revisit at the same time of year.

• What method is already being used?

Most organisations already have survey procedures in place, such as ***Weed Watcher*** in Western Australia, ***PestInfo*** in Queensland and ***RETICLE*** in Tasmania. Aerial survey of weed species has been undertaken for some time in the Northern Territory. Refer to your local government agricultural or environmental agency (see 'Links and contacts'), or the relevant ***WONS coordinator*** for more information regarding methods currently used.

Ensuring consistent methods may be all that is required to improve data collection. The methods described in this manual aim to guide nationally consistent collection of core attribute data. These methods should be integrated with any existing survey methods so that WONS core attribute data are collected and weed infestations can be mapped on a national scale.

Growth form and habitat of current WONS species, as well as survey methods and timing are outlined in Table 3. This table illustrates the need for different approaches depending on the growth form and seasonality of a species. The Cooperative Research Centre (CRC) for Australian Weed Management website (http://www.weeds.crc.org.au/) provides WONS factsheets for further information. The strategic plans for all WONS species, and management guides for some species, are available at the Weeds Australia website (http://www.weeds.org.au/natsig.htm).

Table 3 – WONS growth form, habitat, corresponding survey methods and timing

WONS form/habitat	Survey methods and season
Alligator weed (Fig 3, p 14) (*Alternanthera philoxeroides*) emergent aquatic/terrestrial	• on-ground (or aerial survey severe infestations) • spring to autumn — temperate regions (flowering season); winter to early summer — tropical regions (flowering season) • frequent surveys due to rapid spread • may be useful to survey post-flood
Athel pine (Fig 10, p 39) (*Tamarix aphylla*) tree; arid to semi-arid rangelands/riparian	• aerial survey or on-ground to distinguish from native she-oaks • Athel pine has white-pink flowers which are conspicuous in summer
Bitou bush (*Chrysanthemoides monilifera* subsp. *rotundata*) sprawling shrub; coastal dunes and headlands, coastal forests Boneseed (Fig 6, p 30) (*Chrysanthemoides monilifera* subsp. *monilifera*) upright shrub; coastal dunes, woodlands, open forests	• on-ground annually to monitor seedlings and prevent seed set • aerial survey of severe infestations including ground survey of forested areas • survey all year — best during peak flowering April to June • on-ground annually to monitor seedlings and prevent seed set • survey when in peak flower (late winter to spring); survey for seedlings after main autumn germination
Blackberry (*Rubus fruticosus* agg.) bramble; various habitats	• on-ground (or aerial survey of severe infestations and open areas) • easier to locate when in leaf (spring to autumn — also when foliar spray is most effective)

Table 3 (Continued)

WONS form/habitat	Survey methods and season
Bridal creeper (*Asparagus asparagoides*) creeper; mallee, forest, heath	• on-ground • from July when in peak shoot production to September when flowering is starting
Cabomba (*Cabomba caroliniana*) submerged aquatic	• on-ground • frequent surveys due to rapid spread • survey in summer when all infestations are likely to be flowering • there are new innovations in hydroacoustic detection and mapping of submerged weeds
Chilean needle grass (*Nassella neesiana*) grass; pasture, grasslands	• on-ground • September to December when flowering to distinguish from other grasses
Gorse (*Ulex europaeus*) shrub; various habitats, grazing and bushland	• on-ground (or aerial survey during spring flowering) • survey all year but the main flowering period is in spring (all States and ACT) and autumn (mainly Tasmania and Victoria)
Hymenachne (*Hymenachne amplexicaulis*) emergent aquatic or terrestrial; dams, waterways, wetlands and neighbouring agricultural areas	• aerial or on-ground survey or by boat • survey all year but access may be difficult during the wet season
Lantana (*Lantana camara*) thicket shrub; bushland, pastures	• on-ground, aerial survey or remote sensing • monitor controlled infestations for new seedlings post-summer • flowers are the best long-range identifier and can emerge year-round but mostly after seasonal rain
Mesquite (*Prosopis* spp.) shrub or tree; various habitats	• aerial survey of known infestations • on-ground to distinguish from other prickle bushes • monitor seedling germination after seasonal rainfall
Mimosa (*Mimosa pigra*) large shrub or tree; NT wetlands	• aerial or on-ground • observe germination at the start and end of the wet season
Parkinsonia (*Parkinsonia aculeata*) large shrub or tree; semi-arid zone rangelands and wetlands	• aerial survey of known infestations • on-ground to distinguish from other prickle bushes • monitor seedling germination after seasonal rainfall

Table 3 (Continued)

WONS form/habitat	Survey methods and season
Parthenium (*Parthenium hysterophorus*) fast growing annual or short lived perennial; crops, pastures and disturbed sites	• aerial survey severe infestations, otherwise on-ground • frequent surveys due to rapid spread • plants are easier to distinguish following rainfall events
Pond apple (*Annona glabra*) small to large tree; tropical and sub-tropical wetlands, waterways and coastal environments	• aerial survey large infestations, otherwise on-ground or by boat • survey any time of year • plants are easier to distinguish during late winter-dry season when leaves are yellow (aerial survey at this time)
Prickly acacia (*Acacia nilotica* ssp. *indica*) small tree; grasslands, waterways, woodlands	• aerial survey of known infestations • on-ground to distinguish from other prickle bushes • monitor seedling germination after seasonal rainfall
Rubber vine (*Cryptostegia grandiflora*) shrub or climber; waterways, woodland and rainforest	• aerial survey severe infestations and in open areas, or on-ground • survey following rainfall — germinates after rain and more readily on waterways or riverbanks
Salvinia (*Salvinia molesta*) floating fern; rivers and streams	• aerial survey severe infestations, otherwise on-ground • frequent surveys due to rapid spread • infestations establish and spread following rainfall
Serrated tussock (*Nassella trichotoma*) grass; pasture, grasslands	• on-ground, or aerial survey of severe infestations • in autumn or early spring most grasses dry off and serrated tussock remains green • purple flowers and seedheads form in spring to early summer • seedlings in summer
Willows except weeping willows, pussy willow and sterile pussy willow (*Salix* spp. except *S. babylonica, S.* X *calodendron* and *S.* X *reichardtiji*) deciduous tree or shrub; riparian zones, windbreaks and ornamental plantings	• aerial survey or trunk counts on-ground all year • distinctive with or without leaves • survey flowering species in September to November to identify plants with catkins which will set seed

Figure 3 – Alligator weed (*Alternanthera philoxeroides*) should be surveyed regularly as it spreads rapidly through waterways. Photo: Graham Prichard, Port Stephens Council, NSW.

3. Recording and reporting methods

3.1 Before heading into the field

A field data sheet (page 25) has been developed to record weed information for a particular site, on a particular day. An example of a completed form (a field entry of the attributes) is on pages 26 and 27. Print this summary and data sheet for easy reference in the field. If paper assessment sheets are used, attributes 1–6 may be recorded before printing copies, leaving only the site-specific information to be completed in the field.

Alternatively, if a computer (for example a palm-top) is used in the field it can be set up to apply all or some of this information automatically. For example, Global Positioning Systems (***GPS***) can be linked to mobile ***GIS*** applications such as ***ArcPad***, and have capacity for integration of images, maps, aerial photos and site-specific information. These data can be further integrated into larger ***GIS*** systems. Queensland's ***PestInfo*** system is an example of a ***GIS*** enabled system. ***PestInfo*** includes the WONS core attribute set and is therefore suitable for adoption by other States and natural resource management agencies.

Satellite images and ***topographic maps*** can be downloaded from Geoscience Australia, or local and State government agencies (see 'Links and contacts'). These can be automatically integrated into ***GIS*** for use in the field and subsequent mapping.

3.2 Steps for data collection

Attribute 1. Data record

Use the same monitoring approach each time for a particular weed in each region or State so that consecutive assessments can be compared.

A data record identifies the weed information collected for a particular site on a particular day. Comparison of data records for the same site but different day enables changes in weed area, ***cover*** and/or ***density*** to be detected. Allocate a data record number according to your existing numbering system. If a numbering system is not already in place, a suggested format is the date, an associated survey or site number and species code. For example for Blackberry (*Rubus fruticosus*) data collected on 23 July 2005, the data record number might be: 230705_1_Rf.

Defining the site

The 'site' may be:

- individual weeds or a small patch of weeds (***point***); or
- a larger patch of weeds or paddock, farm, catchment or any other identifiable piece of land or water (***polygons***); or
- a ***transect***, line or strip (such as a roadside, stream bank or stream).

Other points to consider when defining a site are outlined below.

- **Can you see it?** What you can see depends on your vantage point — ground, vehicle or air. Define a site that you can see clearly enough to assess weed cover across all of it.
- **One site: one weed:** there may be two or more weeds growing together. Prepare a separate record for each weed, even if the assessments are done at the same time.
- **Where to put boundaries?** As a rule of thumb, divide an infestation into separate sites if there is a gap of around 200 metres or more (may be reduced in less open country) between weed plants or where there is a useful and obvious boundary within an infestation. For example, it may be useful to identify sites separated by a property boundary, drainage line or road that may later become useful in management or further monitoring. Wherever practical, select boundaries that can be related readily to map sheet features, such as property boundaries or topography.

Divide an infestation into separate sites if there is a significant gap between weed plants or where there is a useful and obvious boundary within an infestation.

- **Large area? Varying densities? Then *stratify* for accuracy:** It is difficult to assess an infestation if the ***cover*** varies widely across the infestation. Rather than assessing the infestation as one site, a more accurate measure can be achieved by dividing the infestation (by eye) into a number of separate sites each of which has relatively uniform cover. Each site can then be assessed separately. This is referred to as ***stratifying*** the site.

Attribute 2. Name of weed

Record both the scientific and common names of the weed species and any subspecies or variety names if applicable. Refer to Table 1 for correct common and scientific names for the WONS. 'WEEDeck', the national pocket guide to weed identification and the weed identification tool on the Weeds Australia website, provide identification resources and contacts. Interactive CD ROMs (Figure 4) for identifying declared plants and for identifying native and introduced blackberry subspecies are also available (refer to the Weeds Australia and the Centre for Biological Information Technology websites in 'Links and contacts'). If unsure of the correct name of the weed species, collect samples or take photographs and send them to a herbarium for identification. Even if certain of the identification of a species, submit a specimen from large infestations or from small new infestations to your state herbarium if possible. This documentation can be critical for future research. The Australian National Herbarium website provides information on collection and submission of specimens (see 'Links and contacts' for herbaria and other identification resources).

Figure 4 – Interactive CD ROMs are available for identifying declared plants and blackberry species from the Centre for Biological Information Technology (http://www.cbit.uq.edu.au/software/).

Attribute 3. Day-month-year

Record the assessment date so that changes over time can be detected and assessed. In general, sites under control programmes should be surveyed at least annually to accurately monitor infestation spread. Ideally, for comparison of sites that are being revisited, return visits should be at similar times. For example revisit a site during flowering, to identify weeds more easily (see Section 2 — 'Which method for which weed?').

Infestation sites need to be monitored regularly when annual weed species are present. Check the flowering season, seed dormancy and means of spread and adopt methods accordingly. For example, summer flowering species would be difficult to detect in early winter. However, dead material from previous flowering may remain and can give clues as to infestation extent.

For consistency between data records and to facilitate searching in a database context the format agreed to record the inspection date is day/month/year in the format DD-MON-YYYY. For example, 12 December 2003 is: 12-Dec-2003. Using three letters (rather than numbers) for month prevents confusing day with month.

Attribute 4. Source of data

Identify the agency and/or area of responsibility as well as the name of the data collector. This will allow follow-up of data records for research and data analysis.

Attribute 5. Purpose of visit

Collecting data for mapping weeds may not be the only purpose of weed survey. Record any other activities being undertaken at the site. The site visit may be part of an ongoing monitoring process of a suspected infestation site, a visit for weed control or it may be a ***ROTAP***, ***Ramsar*** listed or heritage site. This attribute identifies site characteristics which may be listed in another database.

Attribute 6. Place name or locality

Identify and record the closest town, city or geographic feature to the infestation site. State this attribute in the format: distance and direction from place name/locality. The place or locality name provides a quick way to identify the location and a mechanism to check the ***latitude*** and ***longitude***.

Attribute 7. Northing (latitude) and Attribute 8. Easting (longitude) at centre of site

State the following details (Table 4) when completing your location information. It should be possible for someone else to visit the site and locate where you made your observations.

Identify location by the ***coordinates*** of the centre of the site.

Provide:

- ***latitude*** and ***longitude*** (***geographic coordinates***) in decimal degrees (with six significant figures), or
- ***easting*** and ***northing*** (***cartesian coordinates***) in metres (with three significant figures or as displayed in your ***GPS***).

Determine your ***coordinates*** from either a ***topographic map*** (map grid reference) or global positioning system (***GPS***). Double check manual recordings as these form the basis for common mistakes.

Table 4 – Coordinates details to collect from map or GPS

Coordinates details determined from a map (this information is on the legend of your map):	Coordinates details determined from GPS (this information can be found under the 'properties' or 'settings' menus within your GPS device):
Map sheet number — part of title.	***Datum*** — GDA94/WGS84 is recommended. Note what is used.
Name — part of title.	***Projection*** — UTM is usual (equivalent to MGA94).
Scale — given in legend of map.	
Datum — GDA94 is recommended. Described in legend of map.	
UTM ***Zone*** — if ***eastings*** and ***northings*** are quoted.	UTM Zone — UTM zones are 49–56 in Australia.
Edition	

If necessary, use the 'Comments' field of the data sheet.

See the glossary at the back of the manual and the Geoscience Australia website in the 'Links and contacts' section for more details.

Attribute 9. Precision of latitude and longitude

If recording latitude and longitude, note whether coordinates were determined by:

- ***GPS*** (record the type or make and model of the system and note the accuracy)
- map reading
- prior records (such as a permanent sample plot record), or
- another method.

To achieve necessary accuracy, six significant figures must be recorded i.e. six figures after the decimal, if using decimal degrees. If quoting ***easting*** and ***northing***, record ***coordinates*** to the nearest metre. Some WONS, such as aquatic weeds may not be visible from a distance, so coordinates to the nearest metre are highly desirable.

Attribute 10. Area

Record the estimated area of the site in hectares. One decimal place is adequate for reporting WONS at a landscape level. The perimeter of a site can be delineated using a map, map overlay, aerial photo or other remotely sensed image. Area can be estimated in various ways, some of which are outlined below:

- Geographic Information System (***GIS***).
- ***Planimeter***, or other similar device.
- Survey: use boundary bearings and lengths, for example Figure 5.
- Length by width: determine the centre of the site and multiply the average length by the average width, ensuring the measurements are taken at right angles. A compass may be handy for this method.
- Area calculations: for example, area of a circle = 3.1416 x radius^2 (i.e. πr^2) if the site is roughly circular, determine the centre and calculate the area from the average radius.
- Use the whole paddock, allotment or property, the areas of which may be shown on a ***cadastral plan***.
- Dot grid: overlay a grid (Appendix 2) on the map. Use the accompanying table to calculate the on-ground area occupied by a grid cell according to your map scale.
- Add a separate sheet for non-point locations needing multiple ***coordinates*** and refer to this sheet in the 'Attribute 10. Area' or 'comments' field of the datasheet. Examples include ***polygons***, ***transects***, ***GPS*** waypoint lists, photo references or aerial photos.

Figure 5 - Measuring bridal creeper (*Asparagus asparagoides*) near Bridgetown, WA.
Photo: H. Spafford Jacob, CRC AWM, UWA.

Attribute 11. Cover/density

Weed ***cover*** or ***density*** is the estimated percentage of the site occupied by the weed, whether assessed by actual surface area occupied (for example for aquatic plants, grasses and herbs), projected canopy cover (for vines, tall shrubs and trees), or number of stems per hectare (trees). This information illustrates changes in severity of weed infestations across the landscape over time. Different methods for measuring density are outlined in Appendices 3–5. The results from field trials that compared different methods for measuring density are in Appendix 3. Note the method used in the comments field of the data sheet. Use the same method in consecutive assessments so they can be compared. Weed cover classes for monitoring WONS are outlined in Table 5, with equivalent Queensland Annual Pest Distribution Survey classes in Table 6.

Table 5 – WONS Density classes

Terrestrial and aquatic weeds	
Class number	Class description
1.	absent
2.	less than 1%
3	1% to 10%
4	11% to 50%
5.	greater than 50%
6.	present (density unknown)
7.	not known (or uncertain)
8.	not assessed

Additional optional classes for aquatic weeds	
Class number	Class description
9.	scattered
10.	100% covered

Use the ‘not known’ class if there is a significant risk that a weed is present but was not observed, as an incorrect recording of ‘absent’ would be undesirable. The ‘not assessed’ class is to distinguish absence of data from absence of weeds. ‘Present’ or ‘absent’ may be the only practical options for some weeds. The ‘less than 1%’ class is suitable for some infestations in rangelands. ‘Scattered’ or ‘100% covered’ classes can be used for aquatics, where infestation spread is very rapid. For some free-floating aquatics, ‘present (density unknown)’ may be most appropriate, depending on water flows and the rate of movement downstream. Conversions from some currently used survey classes to the WONS classes are outlined in Appendix 4.

Table 6 – Density classes and equivalent QLD Annual Pest Distribution Survey classes

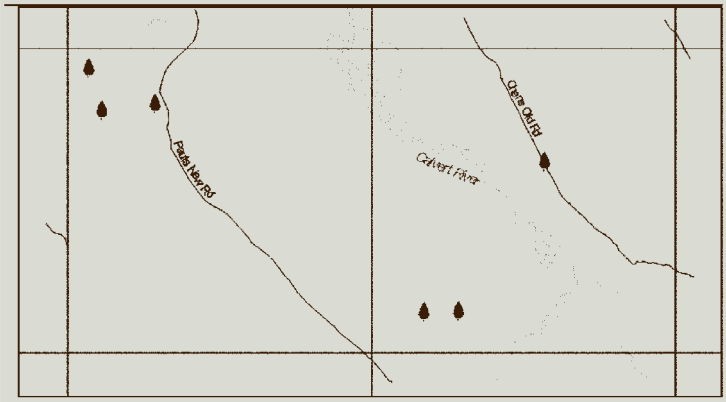
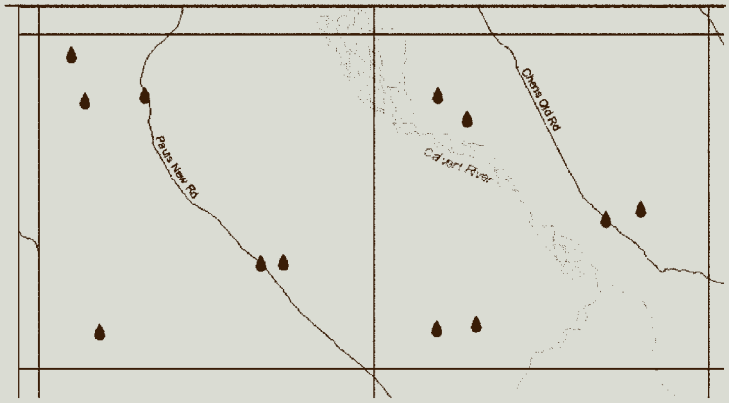
WONS density classes	Equivalent QLD APDS density class (weed occurrence denoted by ♦)
2. less than 1%	 Occasional and localised — confined to a specific extent of the defined area and infestations are of a low density
3. 1% to 10%	 Occasional and widespread — present in most or all of the survey area and infestations generally of a low or scattered density

Table 6 – Density classes and equivalent QLD Annual Pest Distribution Survey classes (*continued from previous page*)

WONS density classes	Equivalent QLD APDS density class (weed occurrence denoted by ▲)
4. 11% to 50%	 a) Common and localised — confined to specific parts of the survey area and the infestations are generally of medium density b) Common and widespread — present in most or all of the survey area and infestations are generally of a medium density
5. > 50%	 a) Abundant and localised — confined to specific parts of the survey area and infestations generally of a high density b) Abundant and widespread — present in most of or all of the survey area and infestations generally of a high density

Attribute 12. Treatment

If the infestation has been treated, note the area treated, method used and when. For example, was it sprayed, burned, chipped or hand pulled, was a combination of methods used or a biological control agent released? If it has not been treated or you don't know whether it has been treated, say so.

Attribute 13. Comments

Include comments that may be of use for mapping, planning and management, such as:

- Factors that may affect the adequacy of the record — such as whether access or vision was limited or which method of assessment was used for ***cover***/***density***.
- Stage of development — that is, the most advanced reproductive stage of any weed plant on the site. For example if most plants are flowering, but one or two plants have dropped seed, then the stage of development would be recorded as 'seed dropped'.
- Percentage of population at each life stage — for example seedlings, juveniles, adults. A subjective assessment but useful for control strategies and planning monitoring surveys.
- Age of infestation — how long the weed has been present at that site. Infestations in early stages of establishment are more eradicable.
- Source of infestation.
- Number of plants in infestation.
- Topography, access and other limitations to weed control.
- ***Photopoints*** — photograph of the site for future monitoring. Refer to Appendix 5 and the 'Links and contacts section' for details.
- Add a separate sheet for non-point locations needing multiple ***coordinates*** and refer to this sheet in the 'Attribute 10. Area' or 'comments' field of the datasheet. Examples include ***polygons***, ***transects***, ***GPS*** waypoint lists, photo references or aerial photos.

Attribute 14. Number of records

If you know that the weed you are assessing on the site, or an overlapping site, has been assessed previously, then note the other records. This will help link records and enable change to be monitored.

Attribute 15. Land use category

If you record land use, then the Australian Land Use Mapping (***ALUM***) classification is recommended. This classification system has five primary categories for land and a sixth category for water. The primary and secondary categories are listed in Appendix 6.

Refer to pages 26 and 27 for a summary of the recommended procedures for reporting each attribute.

3.3 Implementing the attributes — What to do with the information?

For WONS, the final vital step is to submit the records to the data custodian. Refer to the Weeds Australia website (http://www.weeds.org.au/natsig.htm/) for data custodian contact information and the relevant ***WONS coordinator***.

Data records can be collated from multiple regional sources and stored in a range of places and systems to show the distribution and ***cover*** of a weed/s for a broader region or state. Queensland's property or Shire-based Annual Pest Distribution Survey is an example of how this can be done. More information is available from the weed mapping links of the Queensland Department of Natural Resources, Mines and Water 'topics' website (http://www.nrm.qld.gov.au/topics/index.html). Some other States and Territories are implementing similar systems. The core attributes outlined in this manual provide a consistent standard so that these systems can be linked on a national scale.

This linkage is the first step towards collection of weed infestation data through a webpage interface such as Western Australia's '***Weed Watcher***' system (available from the 'weeds' link on the Department of Agriculture and Food Western Australia website http://www.agric.wa.gov.au/). The attribute fields described here could be completed from online forms and displayed automatically. Links to aerial photos, topographical maps and satellite images can be provided to aid survey with 'palm pilot' and ***GIS*** technology. Resultant national-scale weed infestation maps can be displayed online, and data collection and collation methods discussed through online forums.

Two or more pieces of information can be integrated in ***GIS*** systems to meet different purposes. For example, area and ***density*** displayed with treatment reflect the effect of management strategies. More complex analysis to support management plans can be achieved by combining GIS layers such as threatened species, heritage sites and weed corridors.

3.4 Quality assurance

To ensure accuracy and avoid errors, the WONS mapping procedures:

- Use a minimum number of core attributes, making data collection more practical.
- Propose a single data custodian for collation of records to help ensure consistency and provide a second layer of scrutiny for all records.
- Allow for the selection of assessment methods that suit the species, and minimise variation in results by using the same methods for consecutive assessments.
- Allows for the use of aids, such as ***GPS***, ***photopoints***, diagrams and standardised measurement techniques (Appendix 3) to ensure accuracy and consistency.

Consultation with colleagues on the implementation of the WONS mapping procedures will ensure consistent methods and improve accuracy further.

Field Data Sheet

(see example on next page)
Available from http://www.weeds.org.au/natsig.htm/

Attribute	Data entry
1. Data record	Record number: (new record sheet for different weed species or site)
2. Name of weed	Common name:
	Genus:
	Species:
	Sub-species:
	Variety:
	Hybrid:
3. Day-month-year	DD-MON-YYYY: __ __ - __ __ __ - __ __ __ __
4. Source of data	Name:
	Agency/ employer:
5. Purpose of visit	
6. Place name or locality	Distance and direction FROM place name:
7. Northing (Latitude) at centre of site	Decimal Degree S: or __ __ __ __ __ __ __ metres S Zone: **If using GPS complete the following** Projection: Datum:
8. Easting (Longitude) at centre of site	Decimal Degree E: or __ __ __ __ __ __ metres E **If using a map complete the following** Mapsheet name: Mapsheet number: Scale of map 1: Edition: Coordinate system: Datum:
9. Precision of latitude and longitude	
10. Area	__ __ __ . __ Hectare/s, if transect only __ __ __ __ __ metres **NON-POINT LOCATIONS** – reference to attachment:
11. Cover / density	Class or % cover/density
12. Treatment	
13. Comments	Age / life stage
*14. Number of records **	
*15. Land use category **	

** Optional attributes*

Field Data Sheet
Example

Attribute	DATA entry / attribute description	Field-type	Example
1. Data record	**Record number:** unique identifier for the site record allocated by collecting agency (new record sheet for different weed species or site)	number	**Record number:** IM0001
2. Name of weed	**Common name:**	character	**Common name:**Parthenium weed
	Genus: (any uncertainty recorded in the 'comments' field)	character	**Genus:** Parthenium
	Species: (any uncertainty recorded in the 'comments' field)	character	**Species:** hysterophorus
	Sub-species: (if applicable)	character	
	Variety: (if applicable)	character	
	Hybrid: (if applicable)	character	
3. Day-month-year	**DD-MON-YYYY:** __ __ - __ __ _ - __ __ __ collection/observation date in the format DD-MON-YYYY	date	**DD-MON-YYYY:** 20-May-2004
4. Source of data	**Name:** name of collector	character	**Name:** Joe Bloggs
	Agency/ employer: organisation of collector /where the record is derived		**Agency/ employer:** Bureau of Rural Sciences
5. Purpose of visit	reason/s site was chosen	character	monitoring site treated in 2003
6. Place name or locality	**Distance and direction FROM place name:** plain language description of location	character	**Distance and direction FROM place name**: 4km NE of Civic, Canberra
7. Northing (Latitude) at centre of site	**Decimal Degree S: or metres S** Latitude in decimal degrees or Cartesian coordinates, taken from the centre of the infestation. Coordinates to nearest metre or to six significant figures for decimal degrees. **Zone:** State the zone of the location if Cartesian coordinates **If using GPS complete the following** **Projection: Datum:** Projection and datum information can be found under the 'properties' or 'settings' menu within your GPS device	number	**Decimal Degree S:** or 6092697mS **Zone:** Z55 **Example entry from GPS:** **Projection:** UTM **Datum:** GDA94

example

Example

Attribute	DATA entry / attribute description	Field-type	Example
8. Easting (Longitude) at centre of site	**Decimal Degree E: or metres E** Longitude in decimal degrees or Cartesian coordinates, taken from the centre of the infestation. Coordinates to nearest metre or to six significant figures for decimal degrees. **If using a map complete the following** **Mapsheet name:** **Mapsheet number: Scale of map 1:** **Edition: Coordinate system: Datum:**	number	**Decimal Degree E:** or 696561mE **Example entry from map:** **Map sheet name:** ACT region **Mapsheet number:** ACT Special **Scale of map** 1:100,000 **Edition:** 4th **Coordinate system:** UTM **Datum:** GDA94
9. Precision of latitude and longitude	Precision of location measurement. Method used to derive location information. For example type of GPS and accuracy, topographic map or other method.	number	Estimated from 1:100,000 map to road intersection, site estimated 30m from there
10. Area	**__ __ __ . __ Hectare/s,** Area of the site in hectares to one decimal place. if transect only __ __ __ __ __ metres For infestations measured by transect, the length in metres **NON-POINT LOCATIONS – reference to attachment**: Note any additional references for non-point locations	number	0.1 Hectare/s If transect only __ __ __ __ __ metres
11. Cover / density	**Class or % cover/density** classes: 1.absent; 2.< 1%; 3.1% to 10%; 4.11% to 50%; 5.> 50%; 6. present (density unknown); 7.not known; 8.not assessed. Aquatics classes: 9. scattered or 10. 100% covered	number	**Class** 3 (1% to 10%) or % cover/density
12. Treatment	Type/s of control and/or management applied. "No treatment" should also be recorded.	character	physical removal
13. Comments	**Age / life stage** or other useful information including: density measurement method; factors affecting the adequacy of the record; additional references for non point locations; observations of the site.	character	**Age/ life stage** flowering Thriving around horse stables Density measured by proportion method
*14. Number of records **	*Number of records for the weed being assessed at the site or overlapping site, if known.*	*number*	*unknown*
*15. Land use category **	*Land use/s observed at the site; select from Australian Land Use and Management Classification land use categories.*	*character*	*1.1 Nature conservation*

** Optional attributes*

Glossary

NOTE: All website links throughout this document were active at the time of publication.

ALUM — Australian Land Use and Management — Land use classification system (www.brs.gov.au/landuse/classification). See Appendix 6 for ALUM classifications.

ArcPad — Personal Digital Assistant (PDA) mobile GIS system. Integrates GIS, lightweight hardware, GPS and wireless communication. ArcPad is just one of many such systems.

Cadastral Plan — a map showing the position of land ownership boundaries.

Cartesian coordinates — coordinates expressed in metres as eastings (x-axis) and northings (y-axis) derived from the distance a point is from an origin (zero value) of the x and y axes. The x-axis represents a line running in the west–east direction, and the y-axis in the south–north direction. The x-axis (easting) value is always quoted first. See the Geoscience Australia website in the 'Links and contacts' section for more details.

Coordinates — two values providing a reference to a point on the ground in the north-south and east-west direction.

Cover or density — the number of plants per hectare or % cover a weed occupies over the ground or % canopy cover. See Appendices 3–5 for more details.

Datum — the parameters used to define the basis of coordinate systems. For the WGS84 and the GDA94 datum, the origin of the coordinate systems corresponds with the centre of the earth. The origin of the coordinate systems of the AGD66 and AGD84 corresponds with a point around 200 metres away from the centre of the earth. This was to allow for the ellipsoid in the former systems to be a best-fit estimate of the earth's shape around the Australian continent. The earth-centred systems were introduced to better suit the increasing use of GPS derived coordinate measurements. See the Geoscience Australia website in the 'Links and contacts' section for more details.

Easting — vertical grid lines running from left to right (west to east).

Geographic coordinates — coordinates expressed in decimal degrees as latitude and longitude derived from angular lines running east-west and north-south on the earth's surface (GDA94, WGS84). See the Geoscience Australia website in the 'Links and contacts' section for more details.

GIS — Geographic Information System — a computer software system within which spatial information can be captured, stored, manipulated, displayed and analysed.

GPS — Global Positioning System — a satellite based navigation system.

Investigative monitoring — monitoring at the on-ground, project or local scale.

Land use category — a descriptor of land use according to the Australian Land Use Mapping (ALUM) classification system. See Appendix 6 for ALUM classifications.

Latitude — a measure of the angular distance a point on the earth's surface is north or south of the equator (0˚ latitude). The North Pole is expressed as 90˚north, the South Pole as 90˚ south.

Longitude — the angular distance the meridian of a point on the earth's surface is east or west of the prime meridian (0˚ longitude). The prime meridian is aligned through Greenwich, England, and is used to determine east and west.

Northing — horizontal grid lines running from bottom to top (south to north).

PestInfo — (Queensland Pest Data Management System) a Geographic Information System designed for mapping the distribution of weeds and pest animals.

Photopoints — permanently marked sites at which photographs are taken and vegetation or soil information collected. See Appendix 5 and the 'Photopoints' subheading in the 'Links and contacts' section for more details.

Planimeter — A mechanical or electronic device used to measure areas of irregular shapes or maps. The device has an arm that can be extended and rotated to trace the region of interest.

Point — in spatial terms, a single location (X, Y coordinates) that represents a geographic feature too small to be displayed as a line or area. An entity with a location in space but with no extent.

Polygon — a closed plane shape formed by the union of three or more straight lines. In computer graphics a multisided object treated as a single entity which can be linked to conditions or attributes.

Precision — description of the level of detail used to take a measurement.

Projection — a mathematical formula used to depict the earth's spherical surface on to a flat map surface. A Universal Transverse Mercator (UTM) projection of the GDA94 geographic coordinates produces the Cartesian coordinates Map Grid of Australia 1994 (MGA94). See the Geoscience Australia website in the 'Links and contacts' section for more details.

Qualitative — descriptive measurement — may not include discrete values.

Quantitative — numerical measurement — has discrete values.

Ramsar — The Ramsar Convention on Wetlands is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. It was adopted in the Iranian city of Ramsar in 1971 and came into force in 1975. The Convention's member countries cover all geographic regions of the planet see http://www.ramsar.org/ for more information.

RETICLE — the Tasmania GIS weed mapping database.

ROTAP — Rare or Threatened Australian Plant — a classification list developed by the CSIRO. Accessible from the CSIRO publication website: http://www.publish.csiro.au/nid/18/pid/173.htm.

Stratify — to divide an area of interest into sections to be analysed separately.

Surveillance monitoring — monitoring at the regional, State to national scale.

Topographic map — a map type showing a limited set of features with elevation and landform a minimum component of the display. Examples are contour or elevation maps. Topographic maps are used for reference or navigation maps.

Transect — a line used to survey the vegetation (or substrate) across a given area.

Weed Watcher — a web-based interface for finding or reporting a weed, hosted by the Department of Agriculture and Food Western Australia.

WONS coordinator — the person appointed to a specific WONS species to oversee implementation of the goals and actions of the National Weeds strategy. Coordinates and disseminates information on WONS control methods and funding sources. WONS coordinators are listed on the Weeds Australia website: http://www.weeds.org.au/ .

Zone — For mapping purposes the earth is divided into a series of zones to allow minimum distortion in projecting the earth onto a flat surface when using a Cartesian coordinate system. The Australian mainland is covered by seven zones; 49 to 56. See the Geoscience Australia website in the 'Links and contacts' section for more details.

Figure 6 - Boneseed (*Chrysanthemoides monilifera*) infestation. Photo: Nick Pitsas, CSIRO.

Appendix 1

Table of core attributes

Highlighted* national attributes represent those attributes required for monitoring and reporting at regional, State and national levels i.e. '***surveillance monitoring***' as endorsed by the Australian Weeds Committee[1].

Attribute	Description
1. Data record*	Unique identifier for the site record. Allocated and maintained by data custodian.
2. Name of weed*	Common name[2], genus, species, sub-species, variety, hybrid. Any uncertainty on naming recorded in the 'comments' field.
3. Day/month/year*	Collection/observation date or the date the survey commenced. Prefer DD-MON-YYYY, e.g. 12-DEC-2001 as this format is less error-prone than pure numeric dates.
4. Source of data	Name of collector or institution, identifies either personal contact details or the name of the institution where the record is derived.
5. Purpose of visit	Reason/s site was chosen. For example, to assess type and extent of WONS prior to treatment or monitoring to determine effectiveness of management action after treatment.
6. Place name or locality	Plain language description of location e.g. '10km west of Bourke'. Provides a useful cross-check against specified geocode (latitude and longitude).
7. Latitude*	Latitude in degrees, minutes and seconds. Prefer decimal degrees or MGA94 coordinates with zone and datum noted — for GPS entries.
8. Longitude*	Longitude in degrees, minutes and seconds. As for latitude.
9. Precision of latitude and longitude	Precision of measurement in locating the site. Measured in metres. Records how the latitude/longitude was determined (GPS, topographic map or estimated).
10. Area[3]	Area of the infestation measured in hectares. Area of the infestation defined by the outside boundary. For infestations measured by transect, indicate length of transect (in metres).

Attribute	Description
11. Cover/density*	Density measured by class intervals. Prefer data that records raw density as a percent. For rapid survey, density data may be collected as classed data e.g. 51-100% cover = dense.
12. Treatment/s*	Type/s of control and/or management being used to treat infestation. Management could include subcategories of mechanical, chemical, biological. No treatment should also be recorded.
13. Comments	Comments at the time of the survey. Qualifications and factors likely to affect the adequacy of the record. e.g. inadequate time spent. Anecdotal observations of the site or photograph/s.
14. Core site number of records	Number of records for the site or overlapping site. Records multiple sites spatially or multiple visits over time. May be left blank.
15. Land use category	Land use/s observed at the site according to agreed national classification. Select from Australian Land Use and Management Classification land use categories.

1. The seven highlighted* attributes were endorsed by the Australian Weeds Committee (AWC meeting number 10, 2005) as a baseline for national weed mapping (***surveillance monitoring***) standards. The AWC further agreed that all 15 attributes were appropriate for on-ground, local-scale monitoring (***investigative monitoring***).

   The attributes are published in:

   Thackway R., McNaught I. and Cunningham D. (2004). *A national set of core attributes for surveying, mapping and monitoring Weeds of National Significance*. In Sindel B.M. and Johnson S.B. (eds.) *Weed management: Balancing people, planet, profit*. 14th Australian Weeds Conference papers and proceedings, Charles Sturt University, Wagga Wagga. 6–9 September, 2004. pp 690–693. Weed Society of New South Wales and Council of Australian Weed Societies.

2. Common name for 'investigative monitoring' will be based on the standard common name in use for the jurisdiction where the work is being undertaken. For 'surveillance monitoring' an agreed national common name will be established, with naming uncertainty included in the comments field.

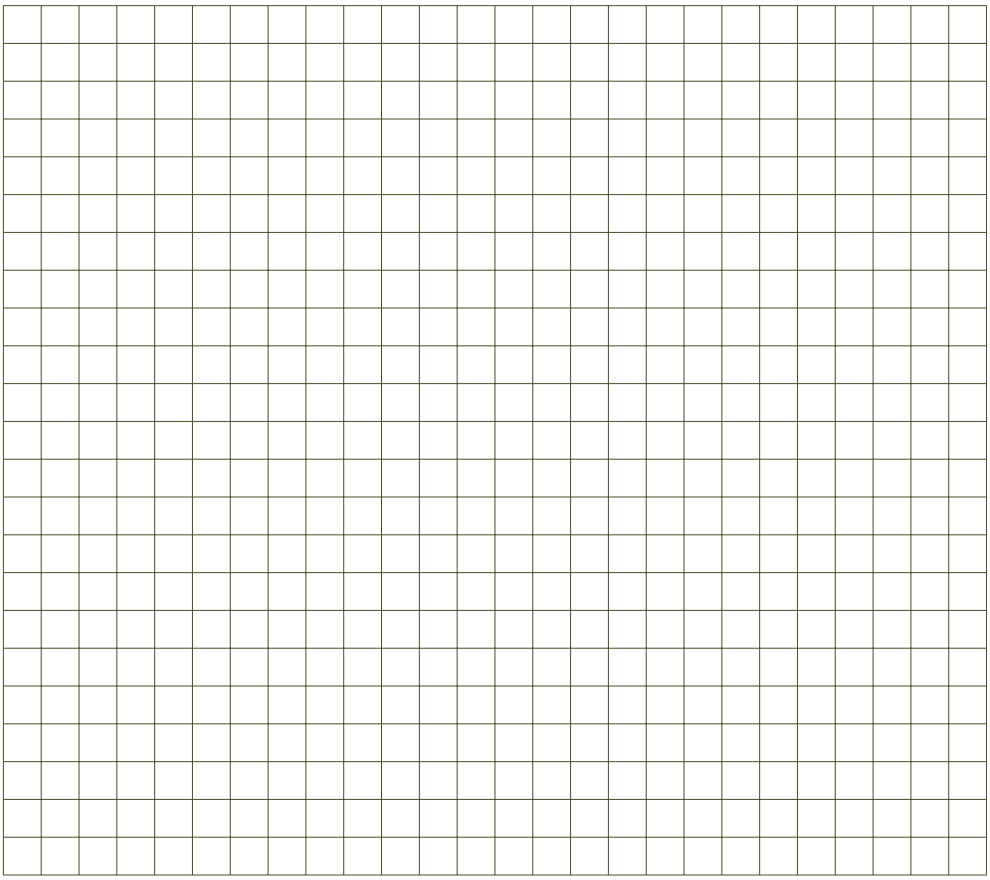
3. While all 15 attributes can be computed using GIS software, the area attribute can be used to link the attributes with polygons.

Appendix 2

Dot grid for calculation of area

Photocopy the grid on the following page onto an overhead transparency and overlay onto zones of your map to calculate the area of each zone.

Scale	Area of one cell	Scale	Area of one cell	Scale	Area of one cell
1:100	0.25m^2	1:800	16m^2	1:5000	625m^2
1:200	1m^2	1:1000	25m^2	1:10,000	2500m^2
1:500	6.25m^2	1:2000	100m^2	1:25,000	15,625m^2 or 1.56 ha



From the Introductory Weed Management Manual, CRC for Australian Weed Management

Appendix 3

Density calculation methods

All of the following methods can be applied to a paddock, farm, catchment, grid unit (depending on size), strip or transect. The methods described below yield a measure of either percentage cover or plants per hectare. Two other methods are also outlined.

Calculating percentage cover

Proportion of site or transect — usually assessed by eye and by selecting a category or range, eg, 0% to 10%; 10% to 50% and so-on, see Figure 7). A variety of charts have been developed to assist with visual assessment (an example is shown in Figure 8). It may be possible to convert ***qualitative*** descriptions to proportions, as discussed in Appendix 4.

Advantages/Disadvantages to assessing density by proportion methods include:

- can be used to calculate statistical outputs
- more labour-intensive to apply
- subjective.

Figure 7 - Serrated tussock (*Nasella trichotoma*) 50% density infestation estimated by visual proportion methods. Photo: Sherryl Broderick, NSW DPI.

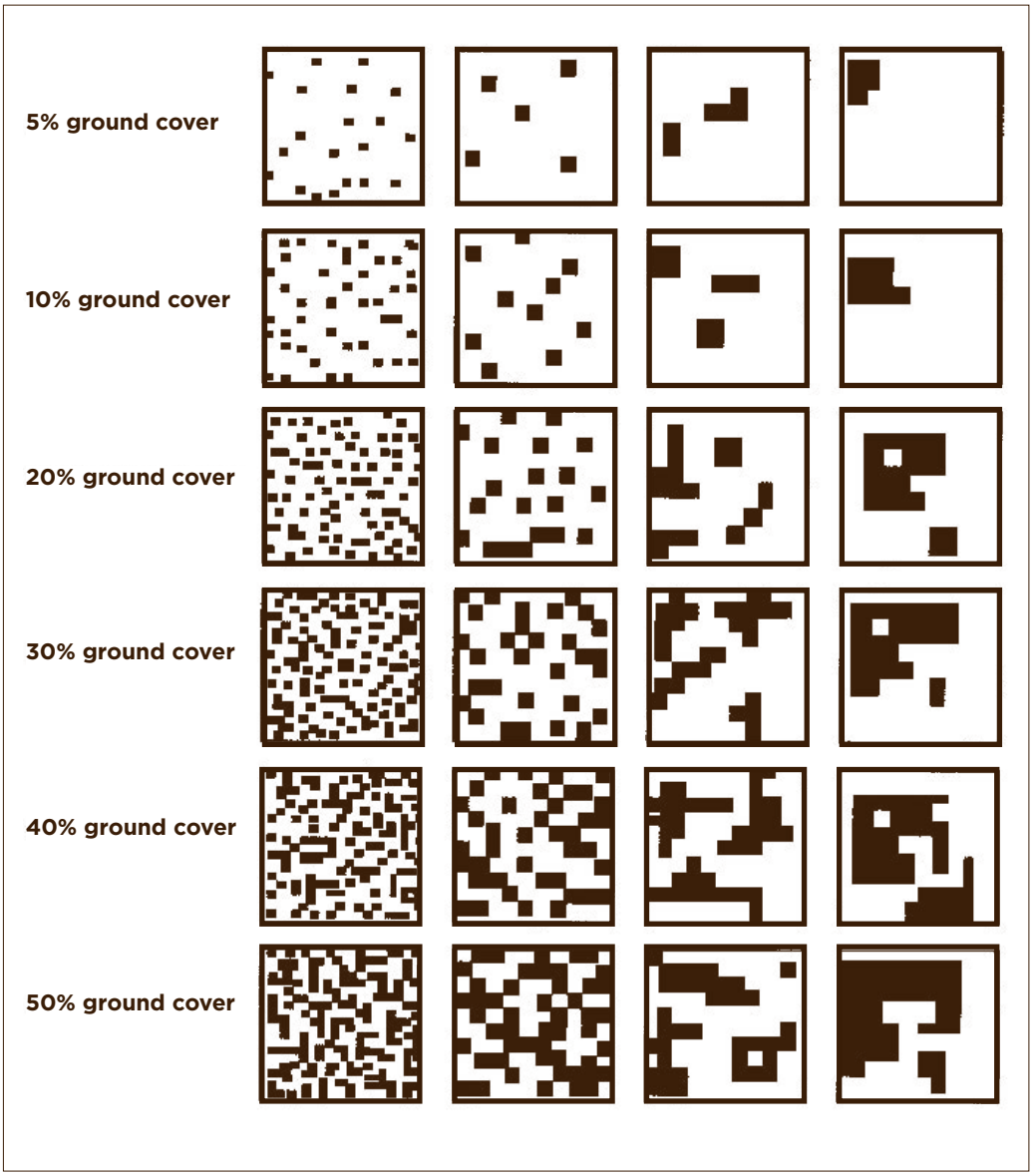


Figure 8 – Distribution of ground cover to assist in determining percentage cover.

Source: Bayley (2001)

Transects — Assess presence or absence at points along parallel transects; calculate density as percentage of the points where the weed is present. Lay parallel transects a set distance apart and sample points a set distance apart along each transect. For example 'step point' or 'point boot' methods, where the boot tip at each step is a sample point. A sample point with a weed is a 'yes'. The proportion of sample points with a weed is an estimate of the density.

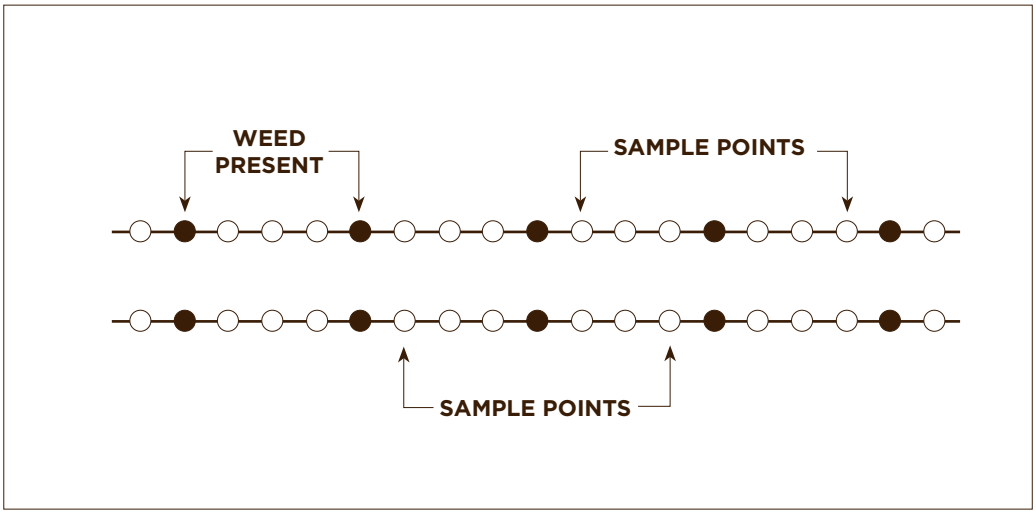


Figure 9 – Schematic diagram of transect sample point proportion assessment

In Figure 9, the proportion of sample points with a weed is 10 of 38 sample points. The density is 10/38 or 26%.

Transect sampling can be done by air, vehicle or on foot. Mimosa (*Mimosa pigra)* is mapped over broad areas in the Northern Territory from the air by assessing density at 20-second flying time intervals. The odometer on a four-wheeled vehicle may provide an efficient way to locate sample points at 100-metre or greater intervals.

The CRC for Australian Weed Management suggest transects from 10 to 50 metres apart for use in developing local weed management plans. A wider spacing is likely to be more practical for mapping WONS at a landscape level.

Endpoints — Randomly throw a stick onto the site from the same point a set number of times (greater than 100 for a more reliable result) and record the number of times the stick lands at a weed. This method is only suitable for low growing species in open terrain. Calculate percentage cover from the number of times the stick lands on a weed as a proportion of the total number of throws.

Calculating plants per hectare

Triangular Tessellation — Assess number of plants per hectare at points along transects. This can be done using the 'Triangular Tessellation' method described below. This method provides a statistically valid estimate of the average density (plants per hectare) of the site.

Advantages/Disadvantages to assessing density by transect or triangular tesselation methods include:

- the data is derived from less subjective methods
- labour intensive.

Density estimation by triangular tessellation — For weeds that can be individually identified, the density (number per hectare) can be estimated by measuring the distances between the three weeds closest to a sample point. Sample points can be located on transects, as described above.

This method is based on the theory that the triangle between the three closest weeds represents the area occupied by half a plant. The density is then:

$$\text{density per hectare} = \frac{10{,}000}{2(\text{area of triangle})}$$

It is not necessary to calculate the area of the triangle or the density — simply use Table 7. Measure the distance in metres between the three closest weeds. These are the triangle side lengths. Read off the density per hectare for the nearest combination of side lengths. This is the estimated density at the sample point; estimated density for the site is the average density for all sample points.

Table 7 – Density (plants/hectare) by distance (metres) between three closest weeds to a sample point

Side 1	Side 2	Side 3	Density (plants/ hectare)
0.5	0.5	0.5	46,188
0.5	1	1	20,656
0.5	1.5	1.5	13,522
0.5	2	2	10,079
0.5	2.5	2.5	8,040
0.5	3	3	6,690
0.5	4	4	5,010
1	1	1	11,547
1	1	1.5	10,079
1	1.5	1.5	7,071
1	1.5	2	6,885
1	2	2	5,164
1	2	2.5	5,264
1	2.5	3	4,270
1	3	3	3,381
1	4	4	2,520
2	2	2	2,887
2	2.5	2.5	2,520
2	3	3	2,182
2	3	4	2,016
2	4	4	1,768
2	4	5	1,721
2	5	5	1,291
2	5	6	1,316
2	6	6	1,021
2	7	7	1,068
2	7	8	845
2	8	8	899
2	9	9	722
2	9	10	611
2	10	10	503
2.5	2.5	2.5	1,848
2.5	2.5	3	1,667

Side 1	Side 2	Side 3	Density (plants/ hectare)
2.5	2.5	4	1,667
2.5	3	3	1,467
2.5	3	5	1,755
2.5	4	4	1,053
2.5	4	6	1,377
2.5	5	5	826
2.5	5	6	815
2.5	5	7	1,136
2.5	6	6	682
2.5	6	7	684
2.5	6	8	968
2.5	7	7	581
2.5	7	8	590
2.5	7	9	844
2.5	8	8	506
2.5	8	9	519
2.5	8	10	748
2.5	9	9	449
2.5	9	10	463
2.5	9	11	672
2.5	10	10	403
3	5	5	699
3	6	6	574
3	7	7	488
3	8	8	424
3	9	9	376
3	10	10	337
5	5	5	462
5	6	6	367
5	7	7	306
5	8	8	263
5	9	9	231
5	10	10	207

From Dignan and Fagg (1997)

Contact the Bureau of Rural Sciences (BRS) for a spreadsheet version of this table. Visit the 'Weeds' section of the BRS website www.brs.gov.au for contact details.

Other methods

Presence/absence — Not strictly a measure of density, but is used in some survey methods. When related to other attributes, this measure can indicate infestation extent.

Measurement of area covered — This may be practical for weeds that occur in more or less continuous patches with ground cover exceeding 50%. See 'Attribute 10. Area'.

Figure 10 - Athel pine (*Tamarix aphylla*) infestation along the Finke River in central Australia. Photo: Colin G. Wilson.

Appendix 4

Density conversions and a density measurement comparison

Conversion between WONS and other density classes

Where other scales or classes are in use and it is decided to retain them, convert those classes into the proposed WONS classes when aggregating into regional reports. An example of how different approaches to classifying density may be converted is shown below in Table 8. Only proposed classes 3, 4 and 5 are shown because it is assumed the others will be consistent.

Table 8 – Weed density class conversion

Current classes[1]	Current classes[2]	Current classes[3]	Current classes[4]	Current classes[5]	WONS classes
scattered individual plants	occasional	rare or isolated	single plants and clumps	light	3. 1% to 10%
scattered patches with isolated plants interspersed	common	marginal	partially accessible thickets	medium	4. 11% to 50%
large dense infestations	abundant	core	impenetrable thickets	heavy	5. 51% to 100%

1. Source: Campbell (1977).

2. Source: Queensland Annual Pest Distribution Survey system.

3. Source: Regional Weed Management Plan — Serrated Tussock 2004–8.

4. Source: method used for rating lantana infestations (Andrew Clark pers comm.).

5. Source: Gerrand (2000) – abundance categories of bitou bush. Density classes outlined in the Chilean Needle Grass Strategic Plan are similar (low, medium, high; ARMCANZ 2000).

Conversion from plants per hectare to percentage classes and vice versa

Conversion from plants per hectare to percentage and vice versa may be calculated. Take an average diameter measurement of a single weed in your sample area. This will vary based on species and age class. It is a more appropriate method for trees and regularly shaped species, rather than for vines or species with a trailing growth habit. The average diameter of a weed can be utilised for conversions according to the following formulae:

$$\text{PERCENTAGE COVER} = \left[\frac{n \times d}{10{,}000}\right] \times 100$$

$$\text{PLANTS PER HECTARE} = \frac{\left[\frac{\%\ \text{cover}}{100}\right] \times 10{,}000}{d}$$

WHERE: n = number of plants per hectare
d = average plant diameter (metres)

Note there is an indeterminable margin of error when the subjective proportion method is used. Therefore it is not possible to undertake conversions between proportion and transect (or area) percentage methods.

Comparison of density calculation methods

Different methods used for measuring density at the same site can yield different density values. Sherryl Broderick (National Serrated Tussock Coordinator), Roger Smith (Orange Council Weeds Manager) and Neil Boyd (Orange Council Weeds Inspector) undertook a field trial to provide a basis for calibrating this difference for serrated tussock. Their methods and results are described below.

Methods

Density categories were chosen to reflect the following standard density thresholds for optimum control of serrated tussock:

- 1–15% cover — control by promoting background competition and spot spraying
- 15–50% cover — control by promoting competition and broadacre chemical control
- > 50% cover — requires broad acre treatment and re-sowing where arable.

Ground cover examples of the whole visual field were used to match visual observations. This is as per the proportion method described in Appendix 3.

Point boot records were taken at one metre intervals, along two 100-metre transects, taken 10 metres apart (200 samples in 0.3 hectares). Triangular tessellation was used to record the plant density per hectare every five metres along two 100-metre transects, placed 10 metres apart. The average crown area of a tussock plant was not recorded in this trial, but could be used to convert plants per hectare to a percentage groundcover.

Results

Photos taken at the trial site with measurements attained by each density measurement method are in Figure 11. The visual assessments were probably over-estimated due to the number of dead plants on this property. Dead plants were actively excluded from tessellation or point boot counts. The two transects at the 50% visual assessment ran through a clearing at the 65 metre mark. The visual assessment was made of the whole landscape beyond the clearing. Cover estimates were 5% less than using the visual observations for 15% and 30% density.

Visual 50%; point boot 28%; 24,973 plants per hectare

Visual 15%; point boot 10%; 9,426 plants per hectare

Results for the third density category were visual 30%; point boot 24% and 24,716 plants per hectare

Figure 11 – Photographs of NSW serrated tussock infestation assessment sites and accompanying densities attained by different assessment methods. Photos: Sherryl Broderick, NSW DPI.

Appendix 5

Photopoints

Photopoints are a photographic record of changes at a site over time. A marker is used to identify the exact location at which a photo of the site is taken. This marker is revisited in subsequent years to monitor changes. The procedure is as follows:

- Use a star picket to mark the location from which the photo will be taken.
- Record the location of this point with GPS or mapsheet according to the instructions for attributes 7 and 8.
- Use a camera post around 1.5 metres high to rest the camera on. This post may also be the location marker star picket if the height is appropriate.
- Place another marker, 10 metres in the direction of the infestation/photo area so that the photo direction is aligned north-south to avoid glare or shadow.
- Label the second marker with the date and identification number, large enough to be pictured in the photograph.
- Use the same camera on each occasion, use colour film (or digital) and a camera suitable for outdoor use.
- Revisit at the same time of year, but frequently enough to monitor infestation change.

See 'Photopoints' in the 'Links and contacts' section at the back of the manual for further information.

Density may also be estimated by calculating the percentage of the photo area occupied by the weed.

The following example of calculating density this way was provided by Chris Moore, from the Parks and Recreation Department, Launceston City Council.

Methods and Results

Photopoints were taken — consecutive photos taken from the photopoints are shown in Figure 12. Mapinfo was used to determine the percentage area occupied by the weed in each photo by tracing over the weeds and doing a calculation as a percentage of the entire area of the photo. This procedure is easy to measure and recreate for any situation.

Cataract Gorge Reserve

Willow control in the South Esk River below the Main Walk.

15/02/02: 41% weed coverage

11/3/03: 16% weed coverage

Kings Bridge Reserve

Weed removal and revegetation of the riverside area.

03/06/02: 59% weed coverage

6/3/03: 8% weed coverage

Figure 12 – Photos taken in 2002 and then in 2003 from established photopoints with corresponding weed densities calculated as a percentage of the photo area. Photos: Chris Moore, Launceston City Council, Tasmania.

Appendix 6

Australian Land Use Mapping Classification

The Australian Land Use Mapping Classification ('ALUM'; Bureau of Rural Sciences 2002) is recommended when assessment of WONS includes land use. The ALUM classification was developed in collaboration with Commonwealth, State and Territory agencies involved in land use mapping. The primary and secondary levels in the current (version 6) classification are:

1. Conservation and natural environments
   - 1.1 Nature conservation (nature reserves, National Parks, other legally protected areas)
   - 1.2 Managed resource protection (land other than nature conservation reserves managed for biodiversity or landscape values, water catchments, traditional indigenous use)
   - 1.3 Other minimal use (defence land, stock routes, remnant native vegetation, rehabilitation)

2. Production from relatively natural environments
   - 2.1 Grazing natural vegetation (essentially intact native vegetation used for grazing)
   - 2.2 Production forestry (native forest and vegetation managed for timber or other production)

3. Production from dryland agriculture and plantations
   - 3.1 Plantation forestry
   - 3.2 Grazing modified pastures
   - 3.3 Cropping
   - 3.4 Perennial horticulture (plants living more than two years)
   - 3.5 Seasonal horticulture (plants living less than two years)
   - 3.6 Land in transition (land use unknown, degraded, abandoned or under rehabilitation)

4. Production from irrigated agriculture and plantations
   - 4.1 Irrigated plantation forestry
   - 4.2 Irrigated modified pastures
   - 4.3 Irrigated cropping
   - 4.4 Irrigated perennial horticulture (plants living more than two years)
   - 4.5 Irrigated seasonal horticulture (plants living less than two years)
   - 4.6 Irrigated land in transition (evidence of irrigation but land use unknown)

5. Intensive uses
    - 5.1 Intensive horticulture (shade houses and glass houses)
    - 5.2 Intensive animal production (for example, feedlots and piggeries)
    - 5.3 Manufacturing and industrial
    - 5.4 Residential
    - 5.5 Services (commercial areas, schools, recreation areas, defence and research facilities)
    - 5.6 Utilities (including powerlines)
    - 5.7 Transport and communication (including roads and railways)
    - 5.8 Mines, quarries and tailings areas
    - 5.9 Waste disposal and treatment (including landfill sites)

6. Water
    - 6.1 Lake
    - 6.2 Reservoirs, dams, evaporation basins and effluent ponds
    - 6.3 River
    - 6.4 Channel or aqueduct
    - 6.5 Marsh or wetland
    - 6.6 Estuary and coastal waters

Links and contacts

NOTE: All website links throughout this document were active at the time of publication.

Weeds Australia — National Weeds Strategy, national weeds search engine and outline of WONS species — http://www.weeds.org.au/

Cooperative Research Centre for Australian Weeds Management — http://www.weeds.crc.org.au/

WONS/ weeds fact sheets

Department of the Environment and Heritage links to CRC for weed management WONS factsheets http://www.deh.gov.au/biodiversity/invasive/weeds/wons.html

Queensland Government Department of Natural Resources, Mines and Water (2005) Weed and Pest Animal Management Weeds of National Significance website http://www.nrm.qld.gov.au/pests/weeds/wons/index.html

CRC for weed management (2003) weed management guides for individual species and publications listings http://www.weeds.crc.org.au/weed_management/indiv_species_a.html

Weeds mapping

Queensland Department of Natural Resources, Mines and Water - Pestinfo: A GIS-based weed mapping and database software system used extensively by Queensland local government sector. Website: http://www.nrm.qld.gov.au/pests/maps/mapping_systems_pestinfo/

Department of Agriculture and Food Western Australia — Weed Watcher: A GIS-based web mapping interface that facilitates community weeds mapping. Available from the pests, diseases and weeds link of the Department of Agriculture and Food Western Australia website: http://www.agric.wa.gov.au/

Department of Primary Industries and Water Tasmania — Reticle: Available from the community weed management/weed mapping network links of the DPIWE Tasmania weeds website: http://www.dpiwe.tas.gov.au/inter.nsf/ThemeNodes/SLEN-5NU68G?open

Topographic maps and satellite images

Topographic map 1:250,000 — Available from the 'topographic maps' section of the 'topographic mapping' section of the Geoscience Australia website — http://www.ga.gov.au/nmd/products/maps/raster250k/#sales

Global map (roads, towns, rivers) — available from the 'free downloads' section of the 'maps, image, data and publications' section of the Geoscience Australia website: https://www.ga.gov.au/products/servlet/controller?event=GEOCAT_DETAILS&catno=48006

ACRES satellite imagery — Available from the satellite remote sensing (ACRES) link on the Geoscience Australia website — http://acres.ga.gov.au/intro.html

Survey methods

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Myers, J. H. and Bazely, D. R. (2003). *Some tools for studying plant populations*. Appendix in *Ecology and Control of Introduced Plants*, Cambridge University Press, United Kingdom.

Relevant government agencies

Australian Government:

Department of Agriculture, Fisheries and Forestry — Natural Resource Management
http://www.daff.gov.au/nrm

Department of Agriculture, Fisheries and Forestry — Bureau of Rural Sciences
http://www.brs.gov.au/

Department of the Environment and Heritage — http://www.deh.gov.au/

State Government:

Queensland Department of Natural Resources, Mines and Water — http://www.nrm.qld.gov.au/

Queensland Department of Primary Industries and Fisheries — http://www.dpi.qld.gov.au

Queensland Environmental Protection Agency/Queensland Parks and Wildlife Service — http://www.epa.qld.gov.au

New South Wales Department of Primary Industries — http://www.dpi.nsw.gov.au/

New South Wales Department of Environment and Conservation — http://www.environment.nsw.gov.au/

New South Wales National Parks and Wildlife Service — http://www.nationalparks.nsw.gov.au

Environment ACT — http://www.environment.act.gov.au

Department of Primary Industries Victoria — http://www.dpi.vic.gov.au/dpi/

Department of Sustainability and the Environment Victoria — http://www.dse.vic.gov.au/dse/index.htm

Department of Primary Industries and Water Tasmania — http://www.dpiwe.tas.gov.au/

Department of Water, Land and Biodiversity Conservation South Australia — http://www.dwr.sa.gov.au/

Department of Conservation and Land Management Western Australia — http://www.calm.gov.au/

Department of Agriculture and Food Western Australia — http://www.agric.wa.gov.au/

Northern Territory Department of Planning and Infrastructure — http://www.ipe.nt.gov.au/

Local Government:

Australian State, Territory and Local Governments — http://www.gov.au/

The Australian Local Government Association links to local governments — http://www.alga.asn.au/links/obc.php/

Photopoints

Machin, Tricia and Lucas, Sharn (2003) *Using Photopoints* leaflet available from the Patawonga and Torrens water catchment boards 'Our patch' community initiative website http://www.ourpatch.on.net/

Photopoints leaflet accessible from the 'Photopoints' section of the 'Monitoring' section of the Department of Water, Land and Biodiversity Conservation South Australia (Undated) — http://www.rangelands.sa.gov.au/photopoints.htm

Location information

'datums and coordinates' information from the 'geodesy and GPS' section of the Geoscience Australia website: http://www.ga.gov.au/geodesy/datums/aboutdatums.jsp

Geosciences Australia — 'place name search' with latitude and longitude under 'online tools': http://www.ga.gov.au/map/names/

GPS — A guide for users — Department of Sustainability and the Environment – 'land.vic.gov.au' surveying and geodesy website: http://www.land.vic.gov.au/land/lcnlc2.nsf/LinkView/254DE472A3EA6625CA256F560019D1B55D2B50AE85D40750CA256E4C001EC7B8

Weed identification

National Pocket Guide for Weed Identification ('Weedeck'). Web-based version available from the Weeds Australia website: www.weeds.org.au/weedeck.htm or hardcopy versions available from: http://www.sainty.com.au/framepg.html

Online interactive weed identification and information tool http://www.weeds.org.au/weedident.htm

Declared plants of Australia interactive weed identification CD ROM — available from the Centre for Biological Information Technology http://www.cbit.uq.edu.au/software

Blackberry — An identification tool to introduced and native Rubus. Interactive CD ROM available from the Centre for Biological Information Technology http://www.cbit.uq.edu.au/software

Common Weeds of Northern New South Wales Rainforests and Subtropical Rainforest Restoration manual: http://www.bigscrubrainforest.org.au/weeds.htm

Auld, B.A. and Medd, R.W. (1992). *Weeds: an illustrated botanical guide to the weeds of Australia*. Inkata Press, Melbourne.

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State herbarium contacts

Australian National Herbarium, Canberra (CANB) http://www.anbg.gov.au/cpbr/index.html

National Herbarium of New South Wales, Sydney (NSW) http://www.rbgsyd.nsw.gov.au/conservation_research/herbarium_and_services

National Herbarium of Victoria, Melbourne (MEL) http://www.rbg.vic.gov.au/research_and_conservation/herbarium

Northern Territory Herbarium, Darwin (DNA) http://www.nt.gov.au/nreta/wildlife/plants/

Plant Biodiversity Centre (State Herbarium of South Australia), Adelaide (AD) http://www.flora.sa.gov.au/

Queensland Herbarium, Brisbane (BRI) http://www.epa.qld.gov.au/nature_conservation/plants/queensland_herbarium/

Tasmanian Herbarium, Hobart (HO) http://www.tmag.tas.gov.au/Herbarium/Herbarium2.htm

Western Australian Herbarium, Perth (PERTH) http://science.calm.wa.gov.au/herbarium/

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