## CONTENTS

BACKGROUND ...............................................................................................................1

REFERENCES ..................................................................................................................2

DEFINITIONS AND ABBREVIATIONS ......................................................................3

PURPOSE ..........................................................................................................................7

WEED RISK MANAGEMENT OVERVIEW ...............................................................7

1. ESTABLISH THE WEED RISK MANAGEMENT CONTEXT ..........................8

2. IDENTIFY WEED RISK CANDIDATES ..........................................................10

3. ANALYSE AND EVALUATE WEED RISKS ..................................................11

4. ANALYSE AND EVALUATE FEASIBILITY OF COORDINATED CONTROL ......................................................................................................................15

5. DETERMINE WEED MANAGEMENT PRIORITIES .....................................17

6. IMPLEMENT WEED MANAGEMENT ACTIONS ........................................19

APPENDIX 1: EXAMPLE POST-BORDER WEED RISK ANALYSIS AND FEASIBILITY OF COORDINATED CONTROL SYSTEMS .........................20
BACKGROUND

Weeds cause significant economic, environmental and social impacts across a wide range of agricultural, natural and urban land use systems. The most cost-effective means to manage weeds is to prevent their arrival, and procedures for predictive weed risk assessment to screen plant imports at a country’s border have been developed (FAO 2005) and implemented (e.g., Pheloung et al. 1999). Post-border however, there are often a wide range of weed species at various stages of invasion (Williams 2003). For example, Australia has approximately 3,000 exotic weed species. Weed species differ in their impacts and there are limited government and community resources to target individual species in a coordinated manner. Hence weed species need to be prioritised for coordinated control programs by identifying those that pose the greatest future threats and which are most feasible to control.

Weed scientists in Australia and New Zealand have developed a post-border weed risk management protocol (HB 294:2006), based on the Australian/New Zealand Standard for risk management (AS/NZS 2004). This FAO Procedures document is based on the Australian/New Zealand protocol. Weed risk management (WRM) involves establishing the processes and structures to strategically determine and take action against high priority weed species. Post-border WRM refers to weed species which are already present in a country or region, or which are likely future incursions.

Post-border weed risk management (WRM) consists of six distinct stages. Stage 1 is establishing the WRM context in which goals, scope, stakeholders, resources and analysis methods are determined. Stage 2 is identifying weed risk candidates, drawing together an initial, wide list of plant species for consideration and applying simple criteria to screen these to a shorter list of species for formal analysis. Stage 3 is analysing and evaluating weed risks. Stage 4 is analysing and evaluating feasibility of coordinated control. Stage 5 is comparing weed risk and feasibility of coordinated control for various species to identify priorities for management actions (e.g., preventing entry, eradication, containment, research). Stage 6 is implementing weed management actions, based on the priorities determined above. Overarching these stages is the need for effective communication and consultation throughout the process. Monitoring and reviewing is essential to measuring the effectiveness of the WRM process and to allow for future improvements and reassessments as new information arises.

Post-border WRM can provide a decision framework for regulatory management of weeds within countries (e.g., legal restrictions on sale and movement of declared/noxious weeds and legal requirements for their control), for selecting species priorities for research into improved control techniques and for choosing species targets for eradication.

This procedure has been developed by Dr John Virtue of the Cooperative Research Centre for Australian Weed Management.
REFERENCES


DEFINITIONS AND ABBREVIATIONS

Note: As post-border WRM is not restricted in scope to regulated pests then some definitions below differ from those of the International Standards for Phytosanitary Measures (FAO 2002). Unless otherwise indicated, definitions below are from (HB 294:2006).

**consequence**  The outcome or impact of an event (AS/NZS 2004). Note that there may be a range of possible outcomes, ranging from positive to negative, associated with an event. In WRM, the overall consequences of a weed are a function of its impacts and potential distribution.

**containment** Application of phytosanitary measures in and around an infested area to prevent spread of a pest (FAO 2002).

A weed management approach that aims to prevent an increase in the current distribution of a weed, by using weed control procedures to reduce the density of existing infestations and limit the dispersal of propagules.

**coordinated control** A strategic, usually government-led, weed management program that takes into consideration all occurrences of a weed and involves the application of weed control procedures towards a specific end (e.g., eradication or containment).

**current distribution** The geographic area over which a weed can be found at present.

**dispersal** The movement of propagules across the landscape.

**eradication** The elimination of every single individual of a species, including propagules, from an area to which recolonisation is unlikely to occur (Myers et al. 1998).

**establishment** The perpetuation, for the foreseeable future, of a pest within an area after entry (FAO 2002).

**exotic** Not native to a particular country, ecosystem or ecoarea (applied to organisms intentionally or accidentally introduced as a result of human activities) (FAO 2002).

**feasibility of coordinated control** The ease with which effective coordinated control of a weed may be achieved. The higher the feasibility the lower the resources required to act.
impacts The (usually negative) economic, environmental and/or social effects of a weed. Impacts are considered on a per unit area basis (the overall consequence of a weed is a function of impacts and potential distribution). For the purposes of this document, impacts of a weed are considered to be distinct from the utility obtained from the same species when it is deliberately grown.

invasiveness A relative index measure of the likely rate of spread of a naturalised plant species, being a function of the species’ establishment, reproductive and dispersal abilities. Akin to the likelihood of spread.

invasive plant Naturalised plants that produce reproductive offspring, often in large numbers, at considerable distances from parent plants, and thus have the potential to spread widely (Richardson et al. 2000). Note that this definition does not include any potential impacts (hence the term invasive plant is not necessarily synonymous with weed).

land use The principal land management objective. In broad terms an objective may be primary production (e.g., agriculture), conservation, or human services (e.g., residential, water supply).

likelihood Used as a general description of probability or frequency (AS/NZS 2004).

naturalised plants Exotic plants that sustain self-replacing populations without direct intervention by people (or in spite of human intervention), usually close to parent plants, by recruitment from seeds or vegetative propagules (e.g., tillers, tubers, bulbs, fragments) capable of independent growth (Richardson et al. 2004).

noxious weed A weed declared under government legislation which landholders have a legal requirement to control and/or which cannot be legally propagated, harvested, imported, sold or otherwise moved.

potential distribution The geographic area that a weed could occupy if allowed to spread unhindered.

propagules Discrete units of reproduction, including both sexual (e.g., seeds) and vegetative (e.g., corms, bulbils, fragments) means.
risk  The chance of something happening that will have an impact (positive or negative) upon objectives. Risk is measured in terms of a combination of the consequences of an event and their likelihood. (AS/NZS 2004).

risk analysis  A systematic process to understand the nature of and to deduce the level of risk (AS/NZS 2004).

risk assessment  The overall process of risk identification, risk analysis and risk evaluation (AS/NZS 2004).

risk evaluation  The process in which judgements are made on the tolerability of the risk on the basis of risk analysis and taking into account factors such as socio-economic, legal and environmental aspects (AS/NZS 2004).

risk identification  The process of determining what, where, when, why and how something could happen (AS/NZS 2004). For this document, this relates to identifying which species should be considered as candidates for weed risk analysis.

risk management  The culture, processes and structures that are directed towards realising potential opportunities whilst managing adverse effects (AS/NZS 2004).

risk treatment  The process of selection and implementation of measures to modify risk (AS/NZS 2004). For WRM this relates to the analysis of feasibility of coordinated control and the implementation of an appropriate weed management strategy for each weed species considered.

spread  Expansion of the geographical distribution of a pest within an area (FAO 2002).

The extent to which infestations of a weed move across the landscape, measured on a distance or area basis.

stakeholders  Those people and organisations who may affect, be affected by, or perceive themselves to be affected by a decision, activity or risk (AS/NZS 2004).

weed  A plant that is growing where it is not wanted by humans (FAO 2002). Plants (not necessarily non-native) that grow in sites where they are not wanted and which usually have detectable, negative economic, environmental and/or social effects (Richardson et al. 2000). Hence weeds are plants that cause negative impacts.
**weed control**  Application of any of a number of methods (e.g., mechanical, chemical or biological) that are designed to reduce the density and reproductive output of *weed* infestations, so that *impacts* are reduced or mitigated.

**weed management**  A strategic, planned, long-term combination of a range of preventative hygiene procedures and active *weed control* tactics to minimise the *spread* and *impacts* of one or a range of *weed* species.

**WRA**  weed risk analysis.

**WRM**  weed risk management.
PURPOSE

This FAO post-border WRM procedures document complements and extends the previous document “Procedures for Weed Risk Assessment” (FAO 2005), which discussed resourcing and technical issues for predicting weed risk to enhance border quarantine. This document provides a generic guide to the development of a post-border WRM decision framework. It includes the key criteria that should be considered in assessing and comparing (i) weed risks posed by different plant species established in a geographic area, or likely to become so, and (ii) the feasibility of managing these species through coordinated control programs. This document is focused on the weed risks of naturalised plant species and does not take account of the potential benefits from deliberately growing such plant species. Objective procedures for resolving such conflicts of interest, often between economic use of a species as a crop versus its environmental impact as a weed, are still at an early stage of development. Nonetheless, species should not be excluded from WRM procedures on the basis of their usage or perceived value.

WEED RISK MANAGEMENT OVERVIEW

Figure 1 gives the basic elements of post-border weed risk management. There are six distinct stages in determining weed species priorities.

![Diagram](image.png)

**Figure 1** An overview of post-border weed risk management (from HB 294:2006).
Communication and consultation is vital throughout the WRM process to ensure stakeholder participation, understanding and support. Stakeholders include those who benefit and those who incur costs through implementing a coordinated approach to weed management. Stakeholders can be advocates for how decisions were made and why particular weed species are being targeted. A consultative team approach enables greater collection of information for use in the WRM process and a formal steering committee of stakeholder representatives to manage the process is strongly advised.

Monitoring and review of each stage of the WRM process is needed to ensure they are effective in achieving the outcomes sought from commencing the process. The degree of confidence in the results from the WRM process (i.e. a list of prioritised weed species) will depend on the technical merits of the methods used. Each stage of the WRM process should be recorded appropriately to demonstrate how decisions were made, enable internal monitoring of the process and allow for external review. Assumptions, methods, data sources, analyses, results and reasons for decisions should all be recorded (AS/NZS 4360:2004).

WRM is also a cyclic process and needs to be repeated at (say) five year intervals to ensure that priorities and WRM methodology remain up to date. Consideration needs to be given to advances in risk analysis techniques, changes in weed flora, improvements in weed control practices and significant changes in land use or resources available for weed management.

<table>
<thead>
<tr>
<th>1. ESTABLISH THE WEED RISK MANAGEMENT CONTEXT</th>
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<tbody>
<tr>
<td>Goal</td>
</tr>
<tr>
<td>Geographic and land use scope</td>
</tr>
<tr>
<td>Stakeholders</td>
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<tr>
<td>Policy and legislation</td>
</tr>
<tr>
<td>Resources available</td>
</tr>
<tr>
<td>Expected outcomes and outputs</td>
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<td>Risk &amp; feasibility assessment methods</td>
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<tr>
<td>Project management</td>
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Bringing stakeholders together at the commencement of the WRM process is needed to define the basic parameters within which weed risks must be managed and to set the expected outcomes and level of complexity for the rest of the process. The assessment processes to be used need to be agreed upon and a project steering committee formed.

The goal is the main reason for undertaking a WRM. It may be narrow, such as choosing which weed species to eradicate, or wide, such as categorising all weed species according to their most appropriate management action.
The geographic (e.g., local, regional, state, national) and land use (e.g., agricultural, natural, urban) scope that is being targeted for weed management needs to be defined. This is referred to as the “management area” in the remainder of this document.

The stakeholders will be largely determined by the goal and management area. They need to be engaged throughout the WRM process, but their input is particularly important in establishing the context. Potential stakeholders include governments and their weed management authorities, agricultural industries, community groups, scientific organisations and land managers (e.g. farmers, rangers).

Existing policy and legislation relating to weeds provide opportunities, constraints and obligations for weed management. Managing weed risk successfully may, for example, involve establishing a legal requirement to control a species using noxious weed laws, or developing and implementing an industry code of practice for hygiene measures.

The level of resources available for both the WRM process and subsequent weed management programs need to be established. Resources include funding, data, literature, expertise, time and commitment/support from stakeholders.

The above considerations will enable the defining of clear and achievable expected outcomes and outputs sought from undertaking the WRM process. For example, a medium-term outcome could be a 10% reduction in the extent of five priority weed species within a region within 10 years. An associated short-term output would be a technical report listing priority weeds for coordinated control programs for that region within 1 year.

There needs to be stakeholder agreement on the risk and feasibility assessment methods that will be used, prior to undertaking analysis of the candidate list of weed species. The various values and perspectives that different stakeholders bring to the WRM process need to be identified, broadly acknowledged and considered in choosing methods. A clear separation between the development and routine use of an analysis system minimises the potential for inherent bias.

Establishing a representative steering committee provides for effective WRM project management. In addition to adequate stakeholder representation, the steering committee should also have technical expertise in weed ecology, control and risk management. Roles, responsibilities, tasks, milestones and due dates should be formalised.
2. IDENTIFY WEED RISK CANDIDATES

<table>
<thead>
<tr>
<th>List current weeds</th>
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<tbody>
<tr>
<td>Detect new weeds</td>
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<tr>
<td>Review likely incursions</td>
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<tr>
<td>Select species for further analysis</td>
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</tbody>
</table>

A list of weed species for analysis is needed which meets the WRM context established in the previous stage. In some instances there will be a known list of weeds (e.g., a noxious weeds list) and one can quickly progress to the weed risk analysis stage. However, where there is a broad goal to identify all significant weed threats in a management area and recommend appropriate risk management actions, then considerable effort needs to be put into developing an accurate list of candidate species.

A list of current weeds is made by combining published weeds lists and botanical records of naturalised species for the management area. Surveys of stakeholders on weeds of concern should also be undertaken, providing a good means of communication and consultation about the WRM process.

Detecting new weeds present is vital if a goal of WRM is to eradicate new weed threats. This involves reviewing records of recent naturalisations and also seeking anecdotal observations by local persons with recognised expertise in identifying native and exotic plant species. In both cases the true identities of the species should be confirmed by a qualified botanist so that appropriate literature searches for weed risk analyses are undertaken. Ongoing investment in surveillance activities to detect new weeds is an integral part of effective weed risk management.

A review of likely incursions is needed if a goal of WRM is to prevent the introduction and/or establishment of major new weed threats in the management area. These include weed species and species with weed history or current weed status of their congeners that are naturalised in adjacent areas and have a high likelihood of dispersal into the management area. Also included are species with weed potential that may be being deliberately grown in the management area, such as garden plants.

To select species for further analysis the number of candidate weed species should be reduced by a simple screening process agreed upon by the steering committee. The criteria for including or excluding species will depend on the goal/s for undertaking WRM. For example, if the goal is a target list for eradication then any widespread weeds will be immediately out of consideration. For a broad goal of categorising all important weed species, the steering committee may screen out those that have been widely naturalised in the management area for many decades and which have not been singled out for targeted control by landholders. Randall (2002) provides an international collation of weed lists which can assist in screening species. Excluded species and the reasons for doing so should be documented.
3. ANALYSE AND EVALUATE WEED RISKS

<table>
<thead>
<tr>
<th>Define existing weed controls</th>
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<tr>
<td>Invasiveness criterion</td>
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<tr>
<td>- establishment</td>
</tr>
<tr>
<td>- reproduction</td>
</tr>
<tr>
<td>- dispersal</td>
</tr>
<tr>
<td>Impacts criterion</td>
</tr>
<tr>
<td>- competitive exclusion of other plants</td>
</tr>
<tr>
<td>- reduction in yield/biomass of other plants</td>
</tr>
<tr>
<td>- reduction in quality of products/services</td>
</tr>
<tr>
<td>- restriction of physical movement</td>
</tr>
<tr>
<td>- human and/or animal health</td>
</tr>
<tr>
<td>- altered ecosystem processes</td>
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<tr>
<td>Potential distribution criterion</td>
</tr>
<tr>
<td>- climate match</td>
</tr>
<tr>
<td>- soil tolerances</td>
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<tr>
<td>- susceptible land uses</td>
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<tr>
<td>Calculate risk score</td>
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<tr>
<td>Evaluate weed risk</td>
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</table>

Weed risk analysis (WRA) is the use of standard, technical criteria to determine the relative weed threats posed by different plant species. In general terms, risk analysis compares the likelihood and consequences of an event happening, to evaluate the degree of threat posed by the event (see AS/NZS 4360:2004). In the case of WRA, the "event" is the invasion of a new weed. The term "invasiveness" is often used instead of "likelihood". "Consequences" refers to the types of "impacts" a weed could have, and where these could occur (i.e., its "potential distribution"). Thus for determining weed risk the three key criteria are Invasiveness, Impacts and Potential Distribution.

For each WRA criterion, species are assessed on their potential under the current, routine weed management practices (which may or may not affect the weed of interest) and assuming no future government intervention. Hence it important to define existing weed controls for the management area (e.g., the standard use of herbicides, cultivation and/or physical control). The costs and effectiveness of specific, targeted control of weed species are taken account of when assessing feasibility of coordinated control.

The weed risks of particular plant species can vary between different land uses or ecosystems, due to differences in disturbance regimes, resource availability and weed management practices. Hence it may be appropriate to assess weed risk separately for different land uses.

The Invasiveness criterion gives a relative index of the rate of spread of a weed, the direct measurement of which is difficult and time-consuming. Three key factors are:
- **Invasiveness Factor 1 – Establishment ability.** Species that can readily establish amongst dense vegetation, such as an advanced crop or closed forest, are considered a higher weed risk. Those species that mainly establish after significant vegetation disturbance events, such as fire, cultivation, drought or extreme grazing pressure, are considered a lower weed risk.

- **Invasiveness Factor 2 – Reproductive ability.** The higher the rate of reproduction the greater the weed risk. Three sub-factors are time to sexual maturity, level of seed production (e.g., seed/m²/yr¹) and extent of vegetative reproduction (e.g., bulbs, tubers, root suckers, rhizomes, stolons).

- **Invasiveness Factor 3 – Dispersal ability.** Species with propagules (seed and/or vegetative) that are regularly moved long distances from parent plants pose a higher weed risk. Dispersal ability depends on the number of dispersal modes for a weed, their frequency of occurrence and the distance moved. The dispersal modes that should be considered are wind, water, flying animals, ground animals (including native, pests and livestock), deliberate human dispersal (i.e., species grown as crops, pastures and/or ornamentals), accidental human dispersal (e.g., attachment to clothing), vehicles (e.g., cars, farm machinery, boats) and produce contaminants (e.g., hay, grains, gravel).

The **Impacts criterion** considers the economic, environmental and social effects of weeds, these being the basis for such plant species being called ‘weeds’. It is difficult to value such impacts in monetary terms, due to the limited availability of data for many weeds and due to difficulties in economic valuation where natural ecosystems are concerned. Hence it is simpler to focus on the types of impacts a weed can have, and the magnitude of these. Impacts in this criterion are considered on a per unit area basis, and the magnitude of these impacts will often be related to the weed’s density or abundance. Total potential impacts are then a function of Impacts and Potential Distribution (at its simplest; impacts per unit area × total area). Six key factors are:

- **Impacts Factor 1 – Competitive exclusion of other plants.** Weeds that, through competition or allelopathy, significantly reduce establishment of desired plants (i.e. crops, pastures, indigenous vegetation) are a greater risk. In extreme cases certain weed species can form monocultures.

- **Impacts Factor 2 – Reduction in yield/biomass of other plants.** This considers the weed’s competitive effects on sizes of desired plants at harvest or maturity. This may be a reduction in grain, pasture, fruit or timber yields, or a reduction in biomass of native vegetation.

- **Impacts Factor 3 – Reduction in quality of products/services.** Examples of this impact include tainting of meat or milk, discoloration of drinking water, weed seed contamination of grains, hay or wool, and structural damage to roads and buildings. For natural ecosystems the main impact of concern is a decline in indigenous plant species diversity, reducing nature conservation, recreational and tourism values.

- **Impacts Factor 4 – Restriction of physical movement.** This could include restrictions on movement of water (in natural and man-made systems), of people (e.g., walking or using vehicles, machinery, boats) and animals (e.g.,
livestock access to pasture and water, native animal access to breeding sites). Weeds that form tall, dense, spiny thickets rate highly for this risk factor.

- **Impacts Factor 5 - Human and/or animal health.** This considers the likelihood of poisoning, allergic reactions and/or physical injuries from thorns or spines.

- **Impacts Factor 6 – Altered ecosystem processes.** Ecosystem processes that may be significantly changed by high weed densities include fire regimes (through various effects upon fire frequency and intensity), levels of nitrogen fixation, water supply and use, soil sedimentation or erosion and salt accumulation. In addition, weeds may provide habitats and/or food sources for pest animals or act as alternate hosts for plant pests and diseases.

Declines in animal abundance and vigour due to weed competition are correlated with Impact Factors 1 and 2, and hence not considered as separate impacts.

The **Potential Distribution** criterion considers the total area that a weed could occupy if it were to spread uncontrolled. The greater the Potential Distribution the greater the weed risk. It may be described in terms of area at risk (e.g., hectares), proportion of a region at risk (%) or proportion of a land use at risk (%). Potential distribution is ideally predicted using climate modelling overlaid with soil and land use tolerances in a Geographic Information System (GIS) framework:

- **Climate matching.** Climate modelling software such as CLIMEX can give good estimates of areas favourable for a weed, provided input data is based on a representative set of point locations of the current occurrence of the species in both its native and naturalised world range. At a minimum, potential distribution can be ranked by visually matching known overseas distribution to similar climatic zones within the management area using maps (FAO 1999). Climate modelling can be quite variable in the accuracy of predictions, due to limits of distribution data, the models themselves and whether factors other than general climate place significant limits on a species distribution (e.g., plant competition, pests and diseases). Potential distributions can also be significantly overestimated for species that are normally restricted to areas that remain damp, such as riparian and swamp habitats.

- **Soil tolerances.** Overlaying soil tolerances with climate-based predictions can significantly refine weed potential distributions. However, this is dependent on the availability of soil maps for the region of interest, and on knowledge of weeds’ soil tolerances.

- **Susceptible land uses.** Different weeds invade and impact in different land uses/ecosystems, due to differences in resource availability and disturbance regimes. When maps of these land uses are available then these can be overlaid with the climatic and soil tolerances to further refine potential distribution.

For aquatic weeds rainfall is generally irrelevant in predicting potential distribution, so only temperature parameters should be used in climate analysis. Soil tolerances are similarly mostly irrelevant. Temperature-based predictions need to be refined with geographic data on water bodies (e.g., rivers, swamps, canals, estuaries) to get a more
realistic outcome of area at risk. Further refinement based on hydrological properties (e.g., salinity, water depth, clarity) will be dependent on data availability.

A weed risk score is calculated by combining the three criteria into a decision framework, usually a semi-quantitative weed risk analysis system that calculates a relative score. Examples of systems in current use are listed in Appendix 1. In choosing a system it is important that the questions and scoring system follow a logical framework and have been adequately validated and peer-reviewed prior to formal use. The system should be transparent and with minimal subjectivity to ensure repeatable results.

Weed risk analyses are best done with a multi-disciplinary group of experts, bringing together knowledge and reaching a consensus on answering questions within the criteria. Ideally this group is (or has strong links to) the stakeholder committee overseeing the WRM process. This ensures transparency in the process, and fosters ownership of the results. Sources of species information include weed reference books and journals, floras, “CAB Abstracts” and web databases (see HB 294:2006 for a comprehensive list). The accumulated knowledge and observations of land, natural resource and weed managers is extremely useful when ranking the behaviour of species in the area of interest, particularly in the absence of published information.

The decisions and ratings of each weed for each question should ideally be documented and supported by cited references. Such quantitative methods can reduce potential bias arising from personal opinions of assessors, allowing for transparency and repeatability of the analysis. It also allows others undertaking WRM in a different management area to draw upon past WRAs and hence save time and effort. However, there will often be instances where expert opinion rather than literature will need to be drawn upon to analyse particular species and interpret data for particular management areas. An index or score for uncertainty (e.g., Robertson et al. 2003) should be considered separately to a score for weed risk. Species with many unanswered questions should be priorities for further monitoring and/or research, so their analyses can be completed in a timely manner.

Weed risk is evaluated by categorising weed risk scores into levels of weed risk (e.g., low, medium, high). The number of risk categories should reflect the degree of certainty in weed risk analyses. Cut-off scores should be agreed upon as part of setting the WRM context, as there is potential for bias if such cut-offs are determined post-WRA. However, there may be concerns within the steering committee about the performance of the WRA system used (e.g. a weed species ranking lower or higher than generally expected), insufficient consideration given to perceived values of particular land uses or sites, and/or legal or political constraints with particular species. The reasons for any changes to the risk categorisation of species, in conflict with results from the WRA system used, should be documented to maintain the transparency of decision-making.
Coordinated control programs aim to achieve eradication or containment of a weed within the management area, through locating and treating infestations, and restricting movement of propagules. This is most effectively done within a legal framework (e.g., noxious weed laws). In simple economic terms, the total cost of a successful coordinated control program will be a function of total area infested, annual control cost per unit area, and number of years required to achieve the desired level of control. However, quantitative data for such calculations are often lacking. For ranking feasibility of coordinated control the three key criteria are current distribution, control costs and duration of control effort.

For each feasibility criterion, species are now assessed in terms of their response to specific control measures. These targeted weed controls are defined (e.g., herbicide type, rate and method of application) so that their costs and effectiveness may be considered in analysing feasibility of coordinated control.

The Current distribution criterion describes the total known extent of the weed. Mapping of a weed’s present distribution in the management area is needed to accurately address this criterion. The smaller the size and number of infestations of a weed species the easier it is to achieve coordinated control. Three key factors are:

- **Current Distribution Factor 1 - Total area infested.** This is the area bounded by all known plants, summed for all known infestations. It includes all land uses in which the weed occurs within the region of interest. It also includes areas where it may be deliberately grown in gardens or on farms, with mass plantings for commercial or amenity use adding considerably to total area infested. Infested area may be described in terms of actual area (e.g., hectares),...
proportion of the region occupied (%) or proportion of the land use occupied (%).

- **Current Distribution Factor 2 - Number of infestations.** This is the number of distinct infestation sites that need to be independently searched and treated. Infestations may be separated by distance, barriers (e.g., a river), property/jurisdictional boundaries or different land types. Work effort increases with the number of infestations (e.g., frequent packing up of equipment, greater liaison effort with landholders).

- **Current Distribution Factor 3 - Accessibility of infestations.** This relates to travelling times to and movement within infestations, for searching and control activities. Two sub factors are the maximum distance between infestations and the ease of movement within infestations (e.g., limits due to slope, rockiness, dense vegetation and/or presence of water).

The **Control Costs criterion** considers expenses associated with searching for the weed, treating infestations, and achieving landholder involvement. Three key factors are:

- **Control Costs Factor 1 – Detectability.** Weeds that are difficult to detect will require a greater search effort. Two sub-factors are ease of locating new infestations and ease of locating individuals within a known infestation prior to reproduction. Both are dependent on how conspicuous the weed is amongst other vegetation, the weed’s height and its life cycle timing. If new infestations can’t be readily detected, or individuals can’t be found before reproduction, then feasibility of coordinated control will be lower.

- **Control Costs Factor 2 - Treatment of infestations.** Treatment of weed infestations using various control techniques (e.g., herbicides, physical removal) is the fundamental cost in coordinated control programs. Some weeds will require multiple treatments before being killed. Both operating and labour costs need to be considered, the latter being relatively high in situations where off-target damage must be limited (e.g. natural ecosystems).

- **Control Costs Factor 3 – Land manager involvement.** Coordinated control of weeds relies on cooperation and involvement by affected land managers (e.g. farmers with infestations of the weed). To achieve this requires expenses for extension/education, enforcement, project management and administration. The ease of motivating and coordinating land managers in an ongoing program will vary between land uses and regions, particularly in relation to their financial capacity to undertake weed control measures.

The **Duration criterion** is an index of how long a coordinated control program takes to achieve its desired goal. The longer this time period, the more expensive and less feasible it becomes. The weed's response is considered under targeted control measures (to make this distinct from the WRA Invasiveness criterion). There are four key factors:

- **Duration Factor 1 - Efficacy of targeted control.** This considers whether the targeted treatments costed in Control Costs Factor 2 kill all treated plants in an infestation. Efficacy may be less than 100% due to tolerance to or recovery from treatment, or incomplete application of a treatment.
• **Duration Factor 2 - Reproduction under targeted control.** There may still be reproduction (sexual or vegetative) within a weed infestation despite a coordinated control program being in place.

• **Duration Factor 3 – Propagule longevity.** This is the major determinant of the time to achieve eradication and relates to both sexual and vegetative propagules.

• **Duration Factor 4 - Ongoing dispersal.** Feasibility of limiting dispersal is low where a weed is primarily spread by natural means and/or where it continues to be deliberately grown as an agricultural, forestry, horticultural or garden plant. If public attitudes strongly favour the continued cultivation of a species, due to its commercial, cultural and/or aesthetic values, then control programs will be hindered.

The principles of calculating a feasibility of coordinated control score and its interpretation to evaluate feasibility of coordinated control are similar approaches to those discussed for assessing and evaluating weed risks. Appendix 1 lists example semi-quantitative systems to score and rank feasibility of coordinated control.

### 5. DETERMINE WEED MANAGEMENT PRIORITIES

| Compare weed risk versus feasibility of coordinated control |
| Identify priority species for management |

A comparison of weed risk versus feasibility of coordinated control will categorise and prioritise weed species for various treatment actions (Figure 2). A matrix with fewer categories for ranking is preferable where there has been a high degree of uncertainty in analyses. There will be a compromise between confidence in the analyses and the need to clearly distinguish weed species for deciding on priorities for management actions.
### Procedures for Post-Border Weed Risk Management

#### Feasibility of Coordinated Control

<table>
<thead>
<tr>
<th>WEED RISK</th>
<th>Negligible</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Negligible</strong></td>
<td>No action</td>
<td>No action</td>
<td>No action</td>
<td>Monitor</td>
</tr>
<tr>
<td><strong>Low</strong></td>
<td>Improve general weed management</td>
<td>Improve general weed management</td>
<td>Monitor</td>
<td>Monitor Protect priority sites</td>
</tr>
<tr>
<td><strong>Medium</strong></td>
<td>Targeted control</td>
<td>Targeted control</td>
<td>Protect priority sites</td>
<td>Prevent entry Contain regional spread</td>
</tr>
<tr>
<td><strong>High</strong></td>
<td>Targeted control (incl. biocontrol)</td>
<td>Targeted control (incl. biocontrol)</td>
<td>Prevent entry Contain regional spread</td>
<td>Prevent entry Regional eradication</td>
</tr>
</tbody>
</table>

**Figure 2** An example post-border weed risk management matrix with suggested management actions (from HB 294:2006).

**Priority species for management** will generally be those in the highest weed risk category. However, selecting between different management actions for the same level of weed risk is less straightforward, and will largely depend on the initial WRM context (i.e. goals, management area, resources, outcomes). A government agency may have the capacity to invest in research (including biocontrol), extension, containment and eradication programs. A regional committee may only be focused on weed species that fall into the eradication and containment cells at the bottom right of the matrix (Figure 2).
6. IMPLEMENT WEED MANAGEMENT ACTIONS

Prepare and implement treatment plans

This stage is the transition from strategic planning to operational planning, leading to active, ongoing coordinated control programs. Such programs may include quarantine, surveillance, enforced control, research and extension, depending on resources available and the weed risk management context. Treatment plans document how the chosen weed management actions will be implemented, and should include proposed actions, resource requirements and budgets, responsibilities, work schedules, performance measures (e.g., monitoring progress against milestones), reporting requirements and communication of procedures and outcomes (AS/NZS 4360:2004; HB 436:2004).

There will be instances where a group of weed species can be treated with similar management actions. The operational planning process should seek to combine efforts against these species in the interests of efficient use of weed management resources. Similarly, any conflicts in operational plans between weed species should be identified and resolved.
APPENDIX 1: EXAMPLE POST-BORDER WEED RISK ANALYSIS AND FEASIBILITY OF COORDINATED CONTROL SYSTEMS

Note that these systems precede the development of this FAO WRM Procedure.


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