Department of Sustainability and Environment

Wetland conceptual models: associations between wetland values, threats and management interventions

Version one

Kay Morris and Phil Papas

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Front cover photo: Sale Common, a freshwater wetland in Gippsland, Victoria (Johanna Laurent).

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1 Background and objectives

Background

The Victorian Waterway Health Program uses a risk-based approach to assist in setting priorities for the protection and restoration of Victoria's aquatic ecosystems, namely river reaches, wetlands and estuaries. This risk-based approach is implemented through the Aquatic Value Identification and Risk Assessment (AVIRA). AVIRA stores information on the environmental, social and economic values of river, wetland and estuary assets. For each asset, AVIRA stores information on the threats to these values and conducts an automated risk assessment for every value/threat combination. AVIRA outputs inform a prioritisation process which identifies the values of river, estuary and wetland assets which have priority for management intervention. Once the risk assessment is completed, the possible management interventions are evaluated to assist in identifying priorities for investment. This forms the basis of strategic planning and investment for waterways at the regional level, ensuring that the most appropriate and cost-effective management interventions are implemented to protect, maintain or improve river, estuary and wetland values.

The steps involved in this process are illustrated in Figure 1 and listed below.

Step 1: assess the relationships between individual wetland values and threats.
Step 2: assess the relationships between management interventions and threats.
Step 3: assess how much of a management action is required to deliver a particular outcome.

These three steps will enable waterway managers, including the catchment management authorities (CMAs) and Melbourne Water, to achieve the outcomes described below (Peters 2009).

- a more evidence based decision-making and planning process
- improved capacity to identify threats to assets, and opportunities for asset protection
- a pro-active management approach
- more effective allocation and use of resources
- improved stakeholder confidence and trust.

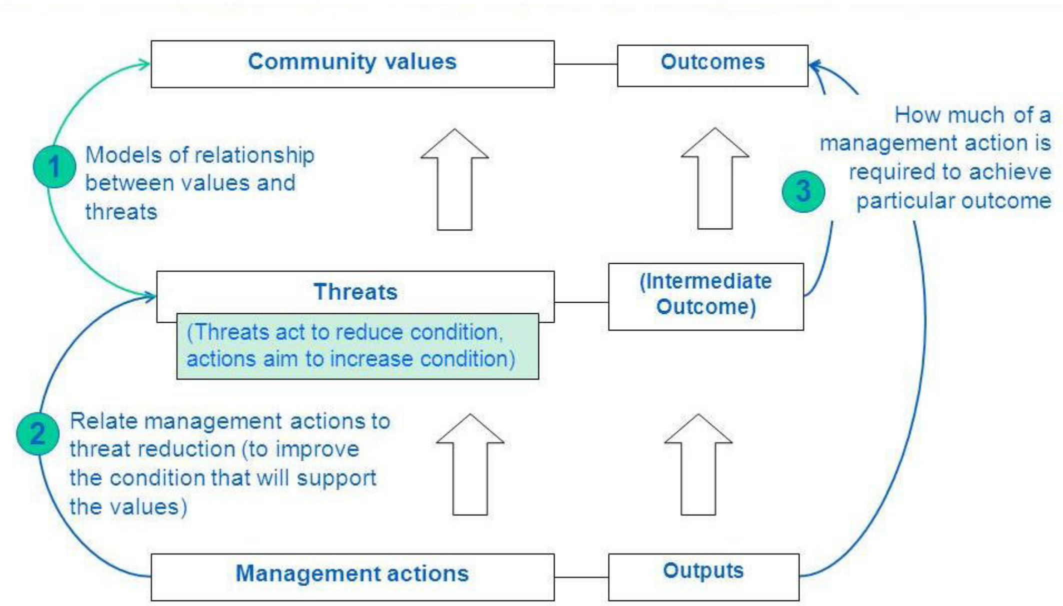


Figure 1. The steps in the Victorian Waterway Health Program used to assess risks to waterway values and prioritise management interventions to deliver improved outcomes for community values.

Objectives

This report provides information to support Step 1 and Step 2 in this process. Information to support Step 3 is beyond the scope of this project. This report informs the following components of Step 1 and Step 2.

Step 1: Wetland Value-Threat Associations

- assesses the strength of association between a particular value and a particular threat
- provides confidence ratings for each value-threat association.

Step 2: Management Intervention - Threat Associations

- identifies management strategies and activities to reduce threats to wetland values
- assesses the effectiveness of particular management activities in addressing particular threats
- assigns expected time frame(s) over which a management activity is expected to reduce or eliminate a particular threat, and thus improve the condition of a particular value
- provides models that describe the management strategies and activities to reduce specific threats.

This report is the first account of this process. Model interrogation and evaluation should be ongoing and the models should be refined and updated as new information and knowledge is sourced and incorporated.

2 Wetland value –threat associations

The strength of the association between wetland values and threats was assessed for 35 wetland values and nine wetland threats described in AVIRA (Tables 1 and 2; Peters 2009). In AVIRA *reduced wetland connectivity* is listed as a threatening process but has been excluded in this report because metrics to assess connectivity have not been developed. To align with AVIRA this report has used the term *disturbance of acid sulfate soils* in referring to threat-value associations but in the wetland management models this has been changed to *formation and activation of acid sulfate* *soils* as this captures more fully the scope of the threat. The threat *degraded wetland vegetation* is not included in AVIRA but impacts on many wetland values. To address this, a management intervention model is provided for degraded wetland vegetation.

Table 1. Wetland values listed in AVIRA (Peters 2009).

Broad Value	Value Category	Value
Environmental	Rare or threatened species/communities	Significant fauna: amphibians
		Significant fauna: birds
		Significant fauna: fish
		Significant fauna: invertebrates
		Significant fauna: mammals
		Significant fauna: aquatic reptiles
		Significant fauna: riparian reptiles
		Significant flora
		Significant wetland EVCs
	Naturalness	Wetland vegetation condition
	Special Features	Drought refuges
		Important bird habitats
Social	Activity	Recreational fishing
		Non-motor boating
		Motor boating
		Camping
		Swimming
		Beside water activities (picnics & BBQs)
		Beside water activities (sightseeing)
		Beside water activities (tracks)
		Game hunting
	Place	Heritage (post-European)
		Heritage (pre-European/indigenous)
	People	Community Groups
		Use of flagship species (wetland)
		Landscape
Economic	Water	Urban or rural domestic water sources
		Rural water sources for production
		Water storages
		Water carriers
		Wastewater discharges
	Power generation	Hydroelectricity
	Other resources	Commercial fishing
		Extractive industries
		Timber harvesting and firewood collection

Table 2. List of wetland threats considered in this report. All threats are listed in AVIRA with the exception of degraded wetland vegetation. Degraded wetland vegetation has only been used in this report to develop threat-management intervention models.

Threat Category	Threat
Altered Water Regime	Changed water regime
Altered Physical Form	Reduced wetland area Altered wetland form
Poor water quality	Degraded water quality Disturbance of acid sulfate soils
Degraded Habitats	Soil disturbance Degraded wetland vegetation
Invasive flora and fauna	Invasive flora (wetland) Invasive fauna (aquatic) Invasive fauna (terrestrial)

2.1 Method

Associations

The association rating is a key component of the risk assessment processes within AVIRA and represents the influence that a particular threat can have on a particular value (Doeg 2009). The strength of the association between values and threats has been determined by assessing the degree to which the level of a value will change in response to changes in the level of a threat. Associations are ranked as high, medium, low or none according to the definitions described in Table 3. For values such as significant flora which represent many species with different sensitivities to threats, the assigned association rating was based on the strongest reported association between a given species and a threat. This avoided under estimating the impact of a threat agent.

Table 3. Description of association ratings (taken from Peters et al. 2009)

Rating	Description
High	The threat always or often impacts the value
Medium	The threat may impact the value
Low	The threat does not impact the value but it is remotely possible
None	The threat does not impact the value

Confidence ratings

Confidence ratings represent the level of evidence that is available to support each threat-value association and are ranked as low, medium or high according to the definitions described in Table 4 (Doeg 2009). For environmental values, confidence ratings for threat-value associations have been based on the scientific literature and government and consultant reports obtained through on-line searches (e.g. Google Scholar, ProQuest, Google, government websites). For social and economic values, confidence ratings for threat-value associations were not investigated due to time constraints and are based on limited expert opinion. To reflect this, the level of confidence in the threat-value associations for these values is generally rated as low.

Table 4. Description of Confidence Rating (based on Doeg 2009)

Rating	Description
High	Where multiple peer reviewed research publications support the association assessment
Moderate	Where at least one peer reviewed research publications supports the association assessment
Low	Where the association is based only on expert opinion

2.2 Results

In total, 315 individual value-threat associations were assessed and are detailed in Appendix 1; 38% of threat-value associations were assessed as high, 28% as medium, 20% as low and 13% as having no association. Figures 2a and 2b summarise wetland threat-value associations that were ranked as high and medium, respectively. Table 5 provides a summary of the number of wetland values with a high or medium association with each threat.

Association ratings: Disturbance of ASS, reduced wetland area, and changed water regime may be considered the most significant threats to wetland values as they have high or medium associations with more than 85% of wetland values, encompassing environmental, social and economic values. The threat, soil disturbance affected the fewest number of wetland values, having a high or medium association with 37% of wetland values but affected all twelve environmental values.

Table 5. Number of wetland values with a high or medium association with each threat, as well as the total number of values with either a high or medium association with each threat. HA, High Association; MA, Medium Association.

	Number of values with:		
Threat	HA	MA	HA+MA
Disturbance of ASS	34	1	35
Reduced wetland area	23	11	34
Changed water regime	21	9	30
Degraded water quality	11	14	25
Altered wetland form	8	16	24
Introduced flora (wetland)	9	8	17
Introduced fauna (terrestrial)	7	9	16
Introduced fauna (wetland)	2	13	15
Soil disturbance	6	7	13
TOTALS	*121*	*88*	*209*

Confidence ratings: Associations that are ranked as high or medium but have low confidence (i.e. little evidence to support the association) represent significant knowledge gaps and warrant further research. A summary of the association-confidence assessment for environmental values are provided in Table 6. Although literature searches were not exhaustive, the association-confidence assessments reported provide an indication of where further research is most needed. Threats were found to have a high or medium association with at least eight (67%) of the 12 environmental values assessed - the majority of associations were ranked as high (Table 6). Threat-value associations that scored high also had stronger support (i.e. high confidence scores) compared with associations that were scored medium, which mostly had a low confidence rating. The pattern indicates that research effort has focused on threats that have the highest perceived impacts on wetland values. Even so, many high associations are inadequately supported by empirical data.

Table 6. Number of wetland environmental values (*n*=12) with a high or medium association (HA and MA, respectively) with each threat, and the number of values with a high and medium association with each threat that have a high, medium or low confidence rating. HA-HC, High Association and High Confidence; HA-MC, High Association and Moderate Confidence; High Association and Low Confidence; MA-HC, Medium Association and High Confidence; MA-MC, Medium Association and Medium Confidence; Medium Association and Low Confidence.

	Number of values with:								
Threat	**HA**	HA-HC	HA-MC	HA-LC	**MA**	MA-HC	MA-MC	MA-LC	**HA+MA**
Disturbance of ASS	**12**	8	3	1	**0**	0	0	0	**12**
Reduced wetland area	**11**	4	0	7	**1**	0	0	1	**12**
Changed water regime	**11**	7	2	2	**1**	0	0	1	**12**
Degraded water quality	**7**	6	0	1	**3**	0	0	3	**10**
Introduced fauna (terrestrial)	**7**	2	2	3	**3**	0	0	3	**10**
Introduced fauna (wetland)	**2**	2	0	0	**8**	0	4	4	**10**
Soil disturbance	**6**	0	1	5	**3**	0	0	3	**9**
Altered wetland form	**7**	1	1	5	**3**	0	0	3	**10**
Introduced flora (wetland)	**5**	1	1	3	**3**	1	0	2	**8**
TOTALS	**68**	31	10	27	**25**	1	4	20	**93**

Limitations: Assigning associations between broad wetland values and threats can be problematic as species associated with an environmental value (e.g. significant flora) exhibit a range of sensitivities to a particular threat. In this report the association was assigned based on the strongest reported association found between a species and the threat. As such, the variability in association ratings across significant species is not apparent. Similarly, some threats encompass a broad range of threat agents that are likely to exert different impacts on wetland values. For example, the threat of invasive terrestrial fauna will vary depending on the invasive species considered while the impact of degraded water quality will vary depending on the specific water quality variable considered (e.g. turbidity, nutrients, salinity, pH). The sensitivity of wetland values to threats also varies with wetland type, landscape context and the presence of other threatening processes; these are not considered in the current assessment. Confidence rating are also somewhat problematic as high confidence is assigned when several peer reviewed publications support the assigned association, but evidence may only be based on responses of a few species. As such, a high confidence rating should not be used to infer that there has been adequate research of the impacts of a threat on a specific wetland value.

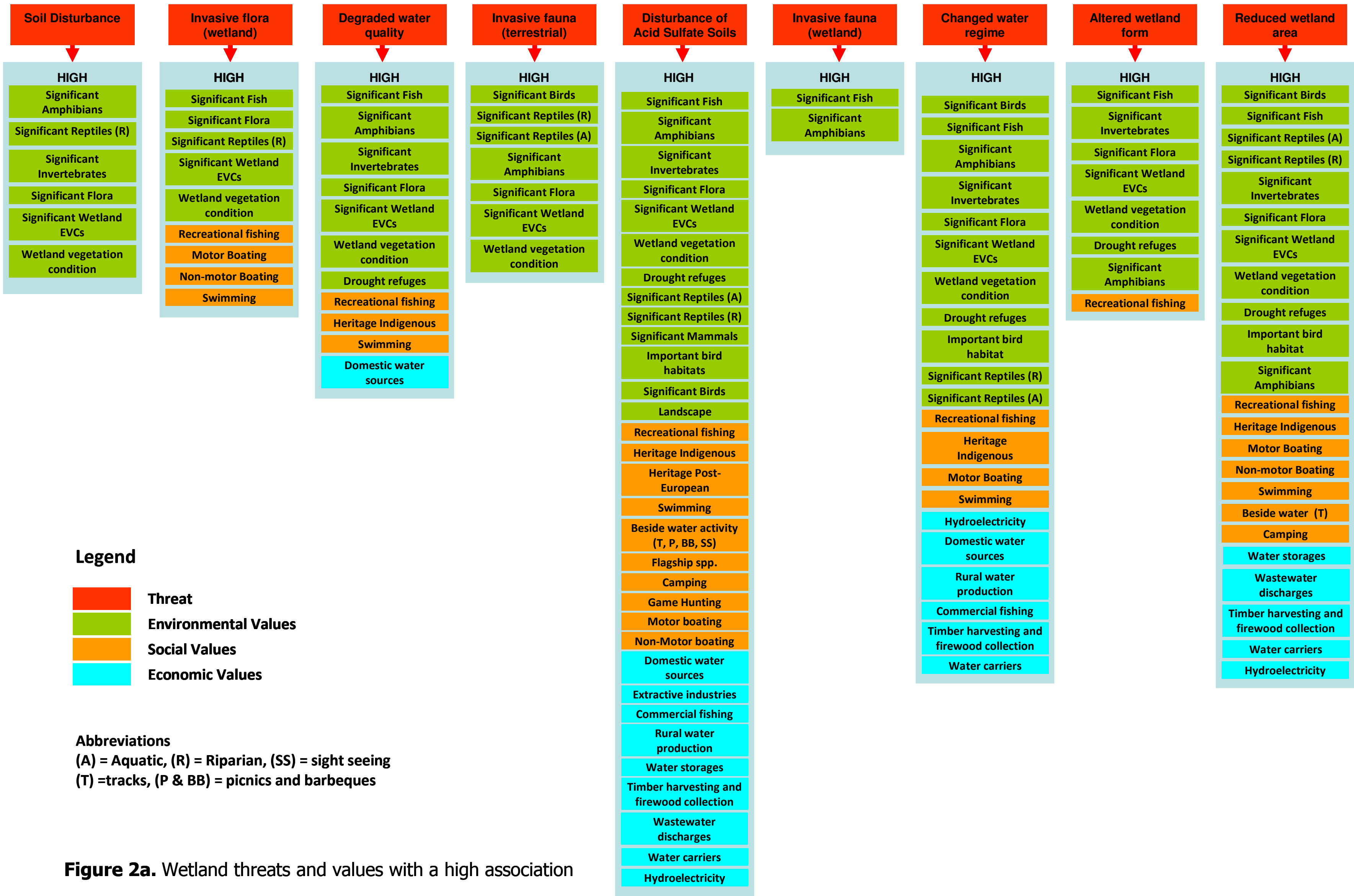
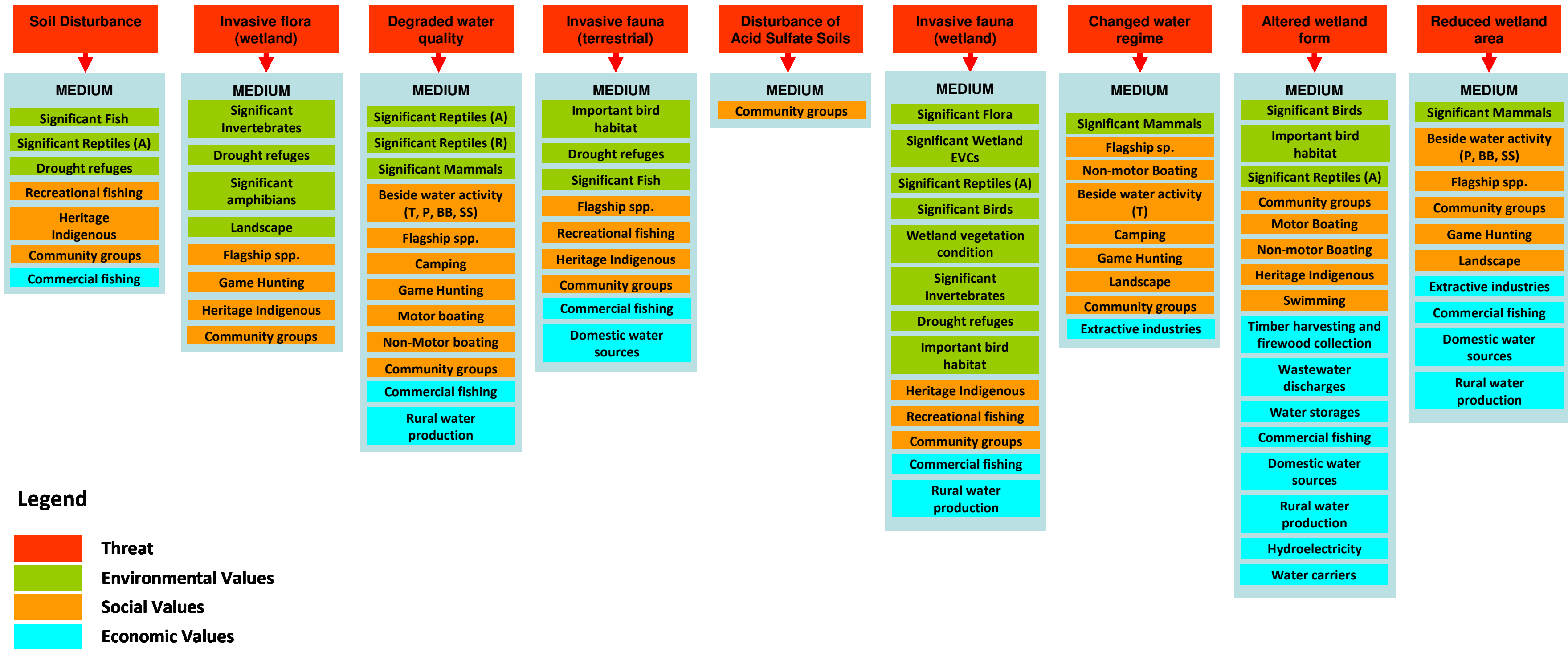


Figure 2a. Wetland threats and values with a high association



Abbreviations
(A) = Aquatic, (R) = Riparian, (SS) = sight seeing
(T) =tracks, (P & BB) = picnics and barbeques

Figure 2b. Wetland threats and values with a medium association.

3 Threat-management intervention models and associations

Threat-management intervention models identify the management strategies and activities that may be undertaken to reduce the threats to wetlands listed in AVIRA. Management strategies and activities to mitigate threats to wetlands were identified based on a range of resources including: the Victorian Investment Framework (VIF) standard management outputs, expert opinion, the scientific literature and government and consultant reports. Due to time constraints investigation of the scientific literature and government and consultant reports was not exhaustive. The effectiveness of each management activity in reducing the level of a particular threat was also assessed. Where the effectiveness of a management activity was rated as moderate or high the expected response time for the management activity to reduce the level of the threat was also assessed.

3.1 Method

Model structure

Threat-management intervention models are presented as a hierarchical box and arrow type model with four key components identified:

1. key threat
2. management strategies to address the threat
3. threat sources
4. management activities associated with each strategy for which targets can be set.

For some models *management approaches* form an additional component in the model and are included to help guide the choice of management activities.

Each threat-management intervention model includes a general description of the threat and an explanatory table that describes the management activity and the rationale for implementing it. The table also provides an assessment of the effectiveness and the expected response time for the management activity to reduce the level of the threat.

When using threat-management intervention models the source(s) of the threat impacting the wetland must be known in order to select appropriate and effective management activities to reduce the threat level. For example, selecting appropriate management activities to reduce the threat of degraded water quality (nutrients) requires that the main source(s) of excess nutrient inputs to the wetland are known. In some cases additional information and/or monitoring may be needed to identify key sources of the threat. Prior to implementing any management activity a thorough assessment of potential risks must be undertaken. Key areas of risk that should be considered are outlined in the section on assessing risks.

Where a number of management activities could be implemented to reduce the level of a threat, selection should be based on careful consideration of the likely effectiveness, response time, costs, feasibility and risks associated with implementing the activity, as well as the level of community support. In some cases management activities will be complementary and implementing a suite of activities may prove the most effective approach to reduce the threat level.

Effectiveness

The effectiveness of a particular management activity to reduce the level of a threat was scored as high, medium, low or none according to the definitions described in Table 7. In most instances effectiveness ratings were assigned based on limited expert opinion due to time constraints. In some cases a key publication was available that provided guidelines for the management of specific threats and was used to inform the models.

Table. 7. Description of effectiveness ratings of management interventions to reduce threats to wetlands.

Effectiveness	Description
High	The management intervention will result in a significant and consistent reduction in the level of the threat
Moderate	The management intervention will result in a moderate reduction in the level of the threat but this will not always be consistent
Low	The management intervention will result in a small reduction in the level of the threat

Response times

Response times represent the period of time before a management activity is expected to eliminate or reduce the level of a threat. Response times do not represent the time frame over which the condition of a particular value will improve following the elimination or reduction of a threat. Management response times were scored as immediate, medium-term or long-term according to the criteria described in Table 8.

Table 8. Description of response time frames for management interventions

Rating	Description
Immediate	Less than one year
Medium-term	More than one year but less than six years
Long-term	More than six years

For some threat-management activities a range of response times were assigned to reflect variation that may occur depending on the type and amount of a management action that is carried out. For some management actions, such as those that enhance public awareness of invasive species, the effectiveness of the management action in reducing the threat will increase over time. In addition, differences in the magnitude and specific type of threat present will produce variation in response times to management activities. For example, the threat of invasive aquatic fauna encompasses a range of species that are likely to respond over different time frames to a management activity.

Confidence ratings

Due to time constraints, the management intervention-threat associations and response times have been based on expert opinion only and therefore have a low confidence rating. A robust search of the scientific and grey literature will be needed in the future to inform confidence in the assigned associations.

Assessing risks of implementing management activities

In assessing the risks of implementing a management activity three types of risk should be assessed, as described below. It should also be noted that approvals may be required for some management activities in certain circumstances and a risk assessment may be required as part of the approval process.

1. Will the management activity reduce the condition of any non-target wetland values?
In some cases implementing a management activity to reduce the level of a threat may not be beneficial to all values. For example, drying the wetland to restore the natural water regime may reduce the level of threat to some species but increase it for others; it may also impact on social values such as swimming and boating. Where the intervention will reduce the threat level to one or more values, but raise the level of a threat to other values, a consultation process should be

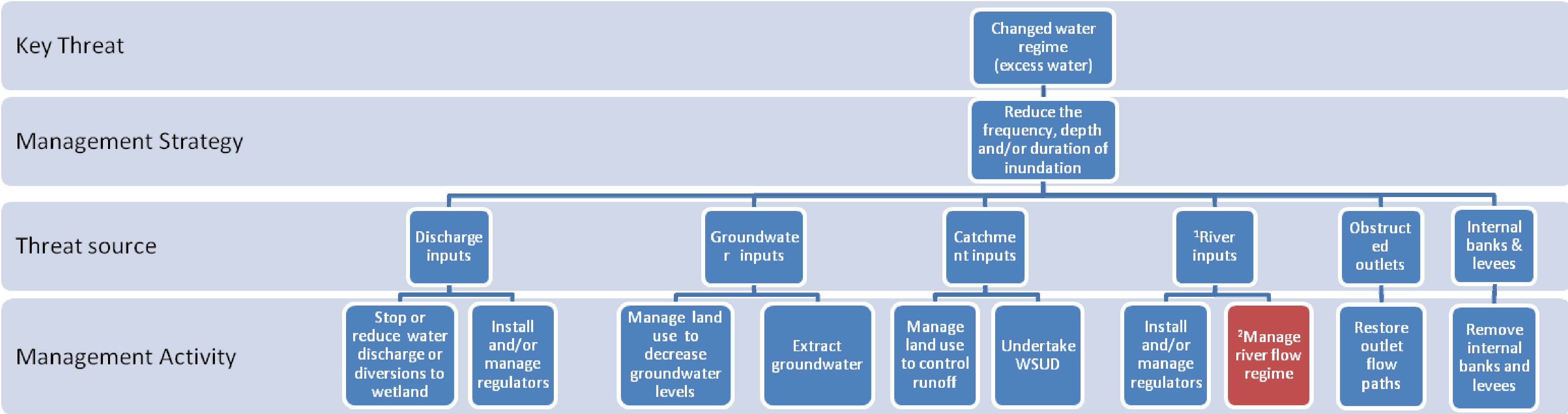
undertaken involving community representatives to determine which values should be prioritised for management.

2. Will the management activity increase the level of other threats in the wetland?
A management activity that is carried out to reduce one threat may increase the level of another threat. For example, removing excess water to restore the natural water regime may be problematic where acid sulfate soils are present, as drying will result in the oxidation of the soil and in the production of acids. Where a management activity increases the level of another threat, the benefits of undertaking the management activity will need to be weighed up against the potential impacts of increasing the level of other threats.

3. Does the management intervention present risks to public health and safety, domestic animals or livestock?
Where management activities are hazardous to the public, domestic animals or livestock they may be unsuitable, or specific precautions may be needed before they can be implemented. Some activities (e.g. baiting programs) require approval from regulatory agencies.

3.2 Models and descriptions

Management strategies and activities to reduce the threat of changed water regime (water excess)



Text boxes coloured red indicate that the management strategies and activities are described in another model as indicated by the superscript.

[1]Applies to floodplain wetlands only
[2]Refer to management strategies and activities to reduce the threat of altered flow regimes (river reaches)

Abbreviations:
WSUD= water-sensitive urban design

Description: changed water regime (water excess)

Wetland water regime describes the depth, duration, frequency, timing, rate and variability of wetting and drying cycles (Bunn et al. 1997). Changes to the water regime exert profound effects of wetland ecosystems and have the potential to alter the assemblage of plants and animals present as well as ecological processes such as dispersal, nutrient cycling and decomposition. The threat of changed water regimes due to excess water refers to changes in the natural water regime caused by an artificial increase in the frequency, duration and/or depth of wetland inundation.

KEY: Effectiveness is the expected level of threat reduction that will be achieved by a management intervention and is scored as: Low, a small reduction in the level of the threat; Med, a moderate reduction in the level of the threat which will not always be consistent; and high, a significant and consistent reduction in the level of the threat. Response times represent the period of time before a management activity is expected to eliminate or reduce the level of a threat and are scored as: 1, less than 1 year; 2, 1 -6 years; and 3, > 6 years.

Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Reduce the frequency, depth and/or duration of inundation	Stop or reduce water discharge or diversion to wetland	High	1	Water may be discharged or diverted to wetlands for flood mitigation, water storage or for water disposal. Water disposal can include: drainage water, stormwater, industrial, agricultural or domestic effluent, sewage treatment water, runoff from crop irrigation or the disposal of water from groundwater interception schemes. Stopping or reducing these inputs to the wetland will help to restore the water regime.
	Install and/or manage regulators	Med-High	1	Where too much water is delivered to wetlands regulators can be installed and/or managed to control water levels and prevent excess water inputs.
	Manage land use to decrease groundwater levels	Med	2-3	Changed land use practices such as irrigated agriculture and clearing of deep rooted native vegetation can cause groundwater tables to rise. This can cause excess groundwater recharge to wetlands with a connection to groundwater and a more permanent water regime. Facilitating efficient agricultural irrigation practices and revegetating areas with trees or other perennial deep rooted plants can help lower groundwater tables.
	Extract groundwater	Med-High	1	Changed land use practices such as irrigated agriculture and clearing of deep rooted native vegetation can cause groundwater tables to rise. This can cause excess groundwater recharge to wetlands with a connection to groundwater and a more permanent water regime. Pumping or draining groundwater to lower the groundwater table helps to restore natural drying cycles.
	Manage land use to control runoff	Med-	1-3	Reduced vegetation cover in the catchment increases surface water runoff to surface-fed wetlands. Revegetating cleared catchments can increase the retention of water in the catchment and reduce the amount and rate of water inflows to wetlands.
	Undertake water sensitive urban design (WSUD)	Med	1-2	Impervious surfaces in urban catchments increase surface runoff to surface-fed wetlands. Runoff can be reduced through water-sensitive urban design.
	Install and/or manage regulators (floodplain wetlands)	Med-High	1	In regulated rivers, high flows during irrigation releases or high water levels in instream storages can result in prolonged flooding in highly connected wetlands. Installing and managing regulators between regulated rivers and floodplain wetlands can prevent excess inundation.

(Continued on next page)

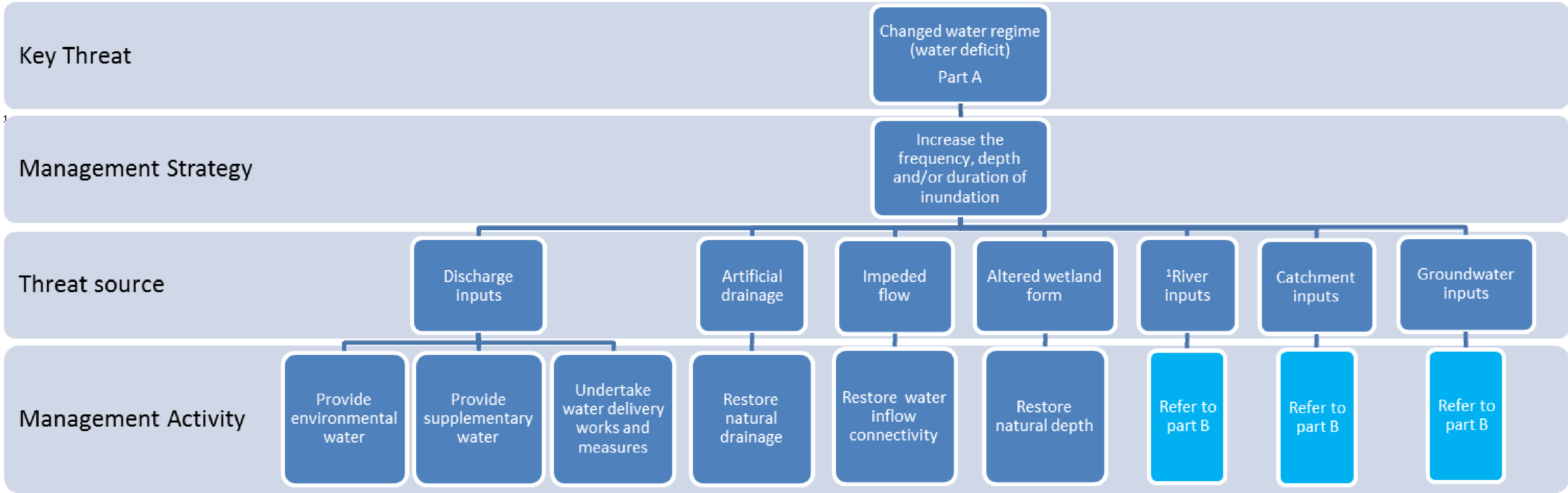
Description: changed water regime (water excess) (continued)

Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Reduce the frequency, depth and/or duration of inundation	Manage river flow regime (floodplain wetlands)	Med-High	1	The flow regime of a regulated river which is the source of water to the wetland may be altered in such a way that artificially high river levels are maintained which lead to constant or more frequent wetland inundation. *Refer to management strategies and activities to reduce the threat of altered river flow regimes (rivers) (GHD 2012).*
	Restore outlet flow paths	High	1	In some wetlands natural outlets have been blocked to increase water storage capacity. These changes can increase the depth and duration of wetland inundation. Restoring outlet pathways can help to restore the nature water regime.
	Remove internal banks and levees	High	1	In some wetlands artificial levees may have been installed to prevent areas of the wetland becoming inundated. These changes can increase the depth and duration of water in areas of the wetland that continue to receive water. Removing internal barriers to water movement can help to restore the natural water regime.

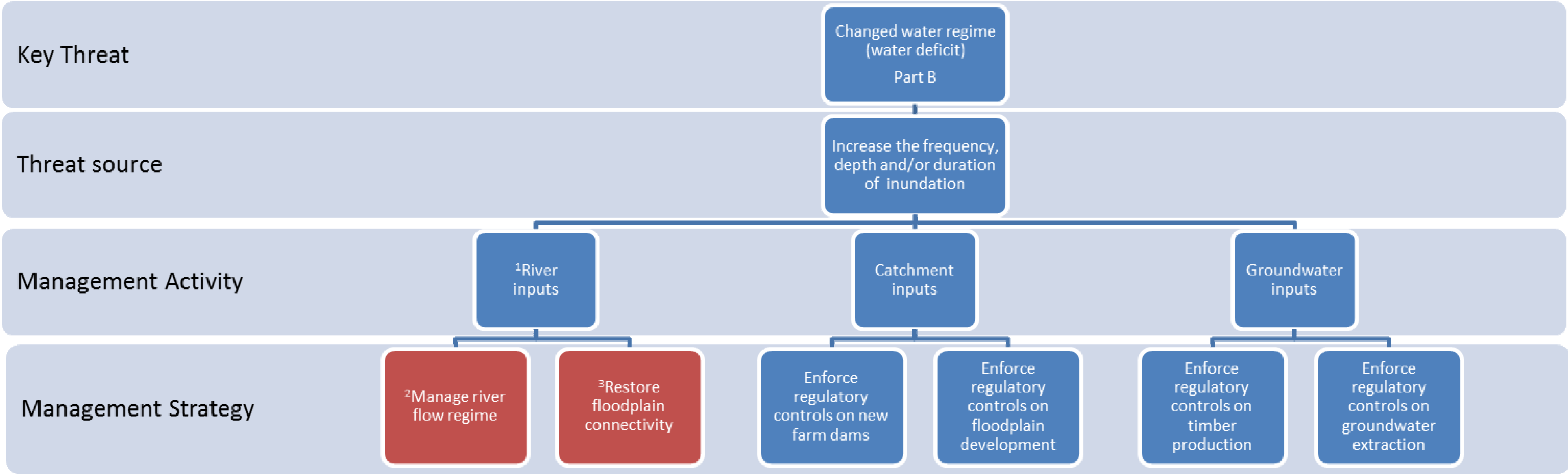
Potential risks associated with management interventions

When assessing the suitability of a management activity to reduce the level of a threat to wetland values a thorough assessment of all potential risks associated with the management activity must be carried out. The types of risks that should be considered are described in the methods (see pages 10-11).

Management strategies and activities to reduce the threat of changed water regime (water deficit): Part A



Management strategies and activities to reduce the threat of changed water regime (water deficit): Part B



Text boxes coloured red indicate that the management activities are described in another model as indicated by the superscript.

[1]Applies to floodplain wetlands only
[2]Refer to management strategies and activities to reduce the threat of altered flow regimes (river reaches)
[3]Refer to management strategies and activities to reduce the threat of altered floodplain connectivity (river reaches)

Description: changed water regime (water deficit)

Wetland water regime describes the depth, duration, frequency, timing, rate and variability of wetting and drying cycles (Bunn et al. 1997). Changes to the water regime exert profound effects of wetland ecosystems and may potentially alter the assemblage of plant and animals present as well as ecologic processes such as dispersal, nutrient cycling and decomposition. The threat of changed water regimes due to water deficit refers to changes in the natural water regime caused by a reduction in the frequency and/or duration of wetland inundation.

KEY: Effectiveness is the expected level of threat reduction that will be achieved by a management intervention and is scored as: Low, a small reduction in the level of the threat; Med, a moderate reduction in the level of the threat which will not always be consistent; and high, a significant and consistent reduction in the level of the threat. Response times represent the period of time before a management activity is expected to eliminate or reduce the level of a threat and are scored as: 1, less than 1 year; 2, 1 -6 years; and 3, > 6 years.

Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Increase the frequency, depth and/or duration of inundation	Provide environmental water	High	1	Diminished inflows reduce the frequency and duration of inundation. Providing environmental water will improve or restore the water regime.
	Provide supplementary water (not environmental water)	High	1	Diminished inflows reduce the frequency and duration of inundation. Providing supplementary water from high quality wastewater from a source such as stormwater, agriculture or industry can improve or restore the water regime.
	Undertake water delivery works and measures	High	1	Where the natural water sources are insufficient to maintain the required wetland water regime, environmental watering may be feasible if certain works (e.g. regulators and/or channels) and measures (e.g. pumping) are put in place. Undertaking required works and measures would enable supplementary water to be provided to improve or restore the water regime.
	Restore natural drainage	High	1	Drainage of wetlands leads to reduced frequency and duration of inundation. Blocking outlet drains and restoring natural outlet levels can improve or restore the natural water regime.
	Restore water inflow connectivity	Med-High	1	Inflows to the wetland can be blocked or impeded by infrastructure such as roads, levees, regulators, irrigation or floodplain development or by-pass channels. Removing the obstruction can restore inflow connectivity and improve or restore the water regime.
	Restore natural depth	High	1	Deepening a wetland (e.g. by constructing a farm dam within the wetland) directs inflows to the deepened area and away from the rest of the wetland which will reduce the inundation duration for most of the wetland. *See management strategies and activities to reduce the threat of altered wetland form.*
	Manage river flow regime (floodplain wetlands)	Med-High	1	The flow regime of a regulated river which is the source of water to the wetland may be altered in such a way that flood frequency is reduced and restoring the river flow regime can also restore the natural water regime of the wetland. *Refer to management strategies and activities to reduce the threat of altered river flow regimes (river reaches) (GHD 2012).*

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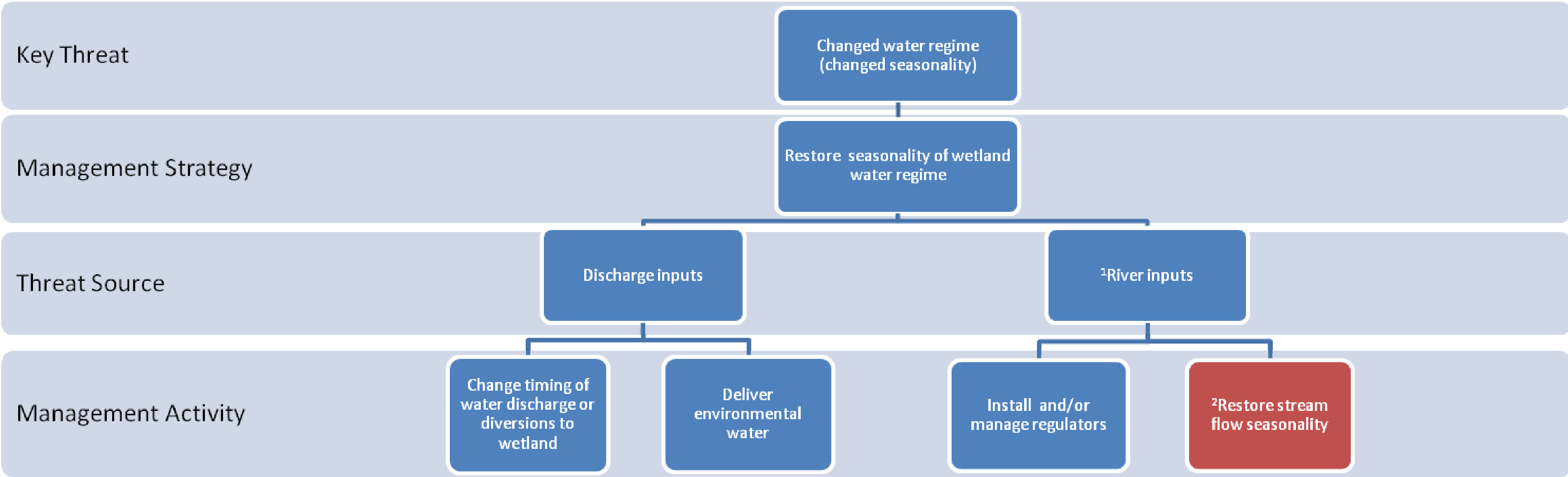
Description: changed water regime (water deficit) continued

Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Increase the frequency, depth and/or duration of inundation	Restore floodplain connectivity (floodplain wetlands)	Med-High	1	The flow of water from a regulated river which is the source of water to the wetland may be altered in such a way that the frequency, duration or depth of flooding is reduced. Restoring connectivity between the floodplain wetland and its source river can restore the natural water regime of the wetland. *Refer to management strategies and activities to reduce the threat of altered floodplain connectivity (river reaches) (GHD 2012).*
	Enforce regulatory controls on new farm dams	High	1	Farm dams in the wetland catchment capture surface runoff that would otherwise flow to wetlands, reducing the frequency and duration of inundation. Enforcing existing regulatory controls on new farm dams can limit the amount of water diverted to farm dams.
	Apply and enforce regulatory controls on floodplain development	High	1	Floodplain development has the potential to obstruct flow paths to wetlands. Applying and enforcing planning controls such as the Rural Flood Overlay, Land Subject to Inundation Overlay or Environmental Significance Overlay can ensure that flow paths are not obstructed by floodplain development.
	Enforce regulatory controls on timber production	Med	1-2	Groundwater levels can be lowered in the vicinity of the wetland by certain land uses (e.g. plantation forestry). Enforcing existing regulatory controls on land use practices (e.g. Code of Practice for timber production) can reduce the threat of lowered groundwater tables.
	Enforce regulatory controls on groundwater extraction	Med	1-2	The over extraction of groundwater resources for agriculture and human use can lead to lowering of the water table and the drying of groundwater dependent wetlands. Enforcing existing regulatory controls on groundwater extraction will help to restore groundwater tables to natural levels and improve or restore the water regime.

Potential risks associated with management interventions

When assessing the suitability of a management activity to reduce the level of a threat to wetland values a thorough assessment of all potential risks associated with the management activity must be carried out. The types of risks that should be considered are described in the methods (see pages 10-11).

Management strategies and activities to reduce the threat of changed water regime (changed seasonality)



[1]Applies to floodplain wetlands only
[2]Refer to management strategies and activities to reduce the threat of altered flow regimes (river reaches) (GHD 2012).

Description: changed water regime (changed seasonality)

Wetland water regime describes the depth, duration, frequency, timing, rate and variability of wetting and drying cycles (Bunn et al. 1997). The threat of changed water regime (altered seasonality) refers to unseasonal wetting and drying patterns. Changes to the seasonality of the water regime can alter the assemblage of plant and animals present as well as ecological processes such as breeding, dispersal, nutrient cycling and decomposition.

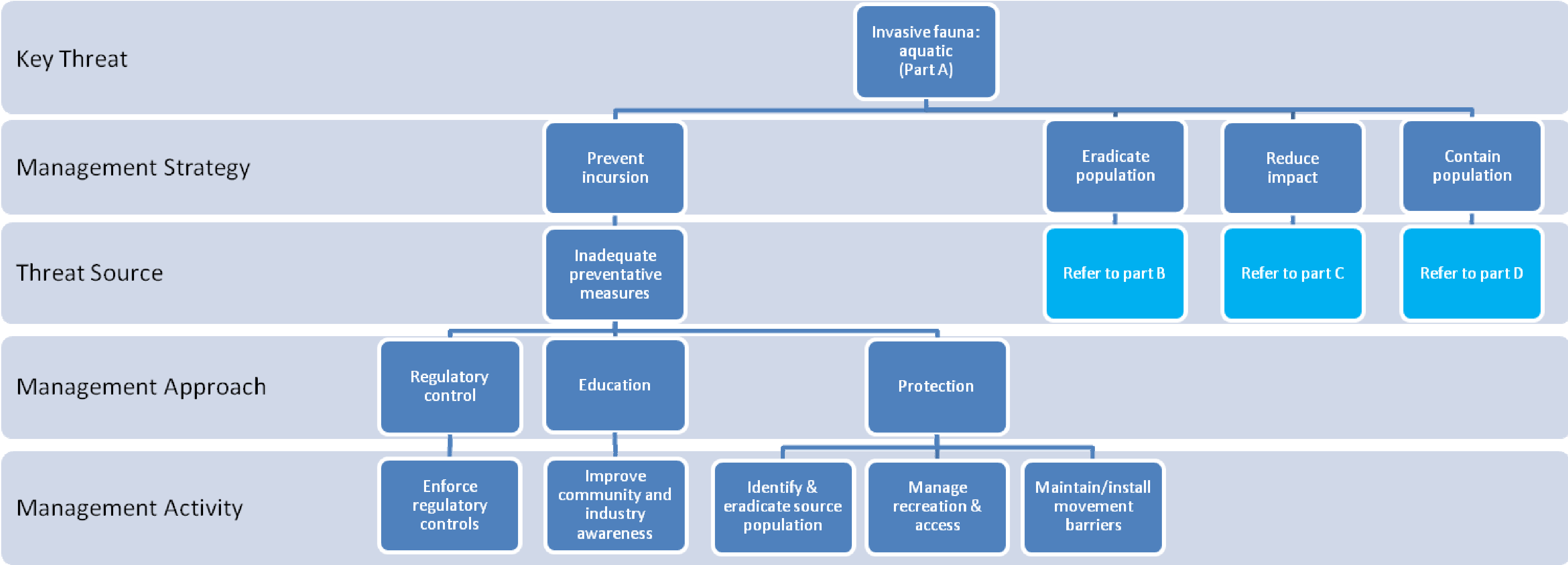
KEY: Effectiveness is the expected level of threat reduction that will be achieved by a management intervention and is scored as: Low, a small reduction in the level of the threat; Med, a moderate reduction in the level of the threat which will not always be consistent; and high, a significant and consistent reduction in the level of the threat. Response times represent the period of time before a management activity is expected to eliminate or reduce the level of a threat and are scored as: 1, less than 1 year; 2, 1 -6 years; and 3, > 6 years.

Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Restore the natural seasonality of inundation	Change the timing of water discharge or diversion to wetland	High	1	Where water is discharged or diverted to a wetland, the timing of water inputs may not be in accord with the natural seasonal cycle of wetland inundation. Changing the timing of inputs to the wetland will help to restore the natural seasonality of the water regime.
	Deliver environmental water	High	1	Where drought or the over extraction of water for human use results in the premature drying of the wetland the delivery of environmental water can restore the natural seasonal pattern of wetland inundation.
	Install and/or manage regulators (floodplain wetlands)	Med-High	1	In regulated rivers the natural flow pattern may be reversed causing unseasonal summer/autumn flooding and a lack of the normal winter/spring flooding in connected wetlands. The installation and/or management of water regulators between the river and the wetland can prevent water entering the wetland in summer and autumn or enable flows to be delivered in winter and spring.
	Restore stream flow seasonality	Med-High	1	In regulated rivers the natural flow patterns may be reversed causing unseasonal summer/autumn flooding and a lack of the normal winter/spring flooding in connected wetlands. Re-instating more natural seasonal flow patterns in regulated rivers can help to restore the natural seasonal pattern of inundation in floodplain wetlands. *Refer to management strategies and activities to reduce the threat of altered streamflow seasonality (river reaches*) (GHD 2012).

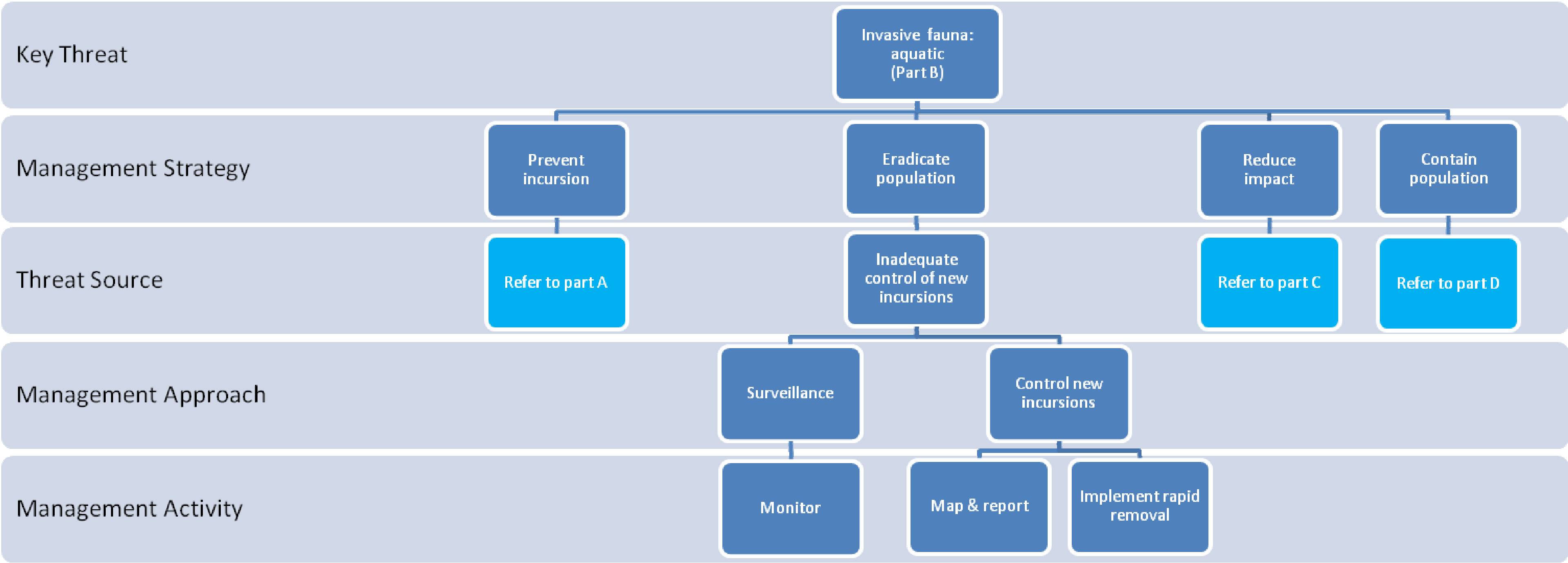
Potential risks associated with management interventions

When assessing the suitability of a management activity to reduce the level of a threat to wetland values a thorough assessment of all potential risks associated with the management activity must be carried out. The types of risks that should be considered are described in the methods (see pages 10-11).

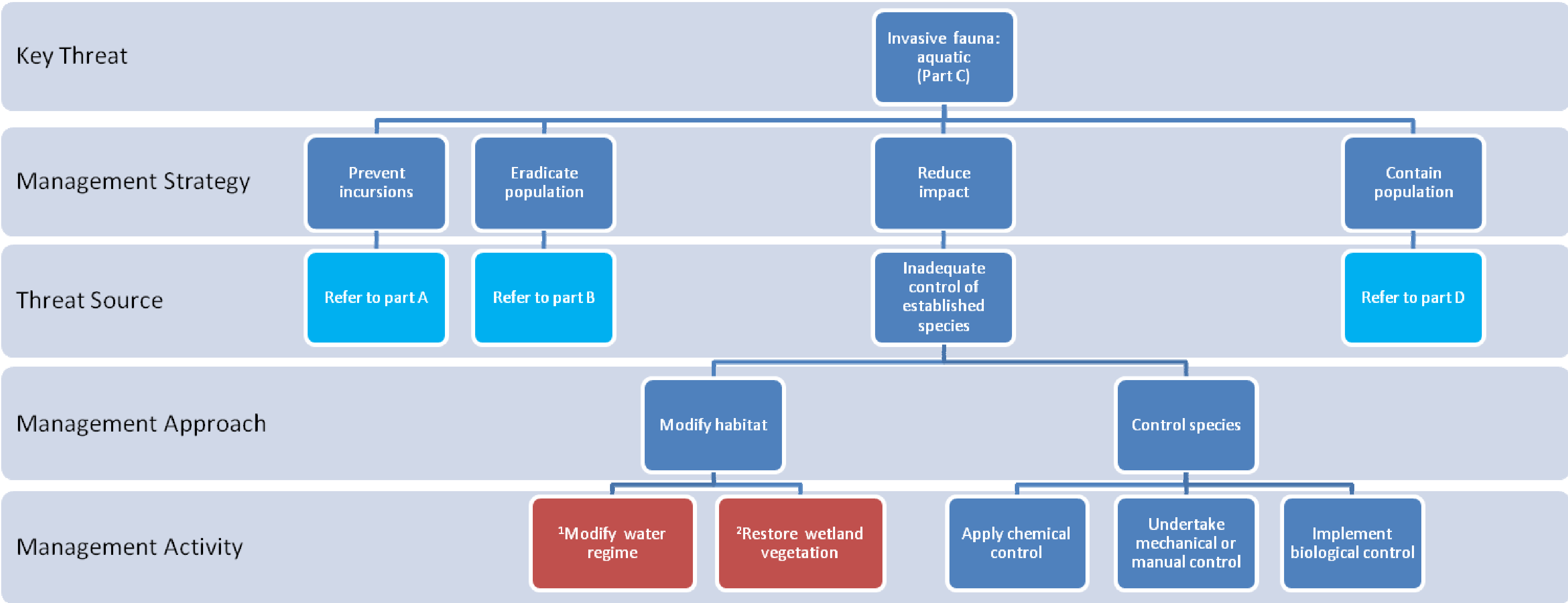
Management strategies and activities to reduce the threat of invasive fauna: aquatic (Part A)



Management strategies and activities to reduce the threat of invasive fauna: aquatic (Part B)



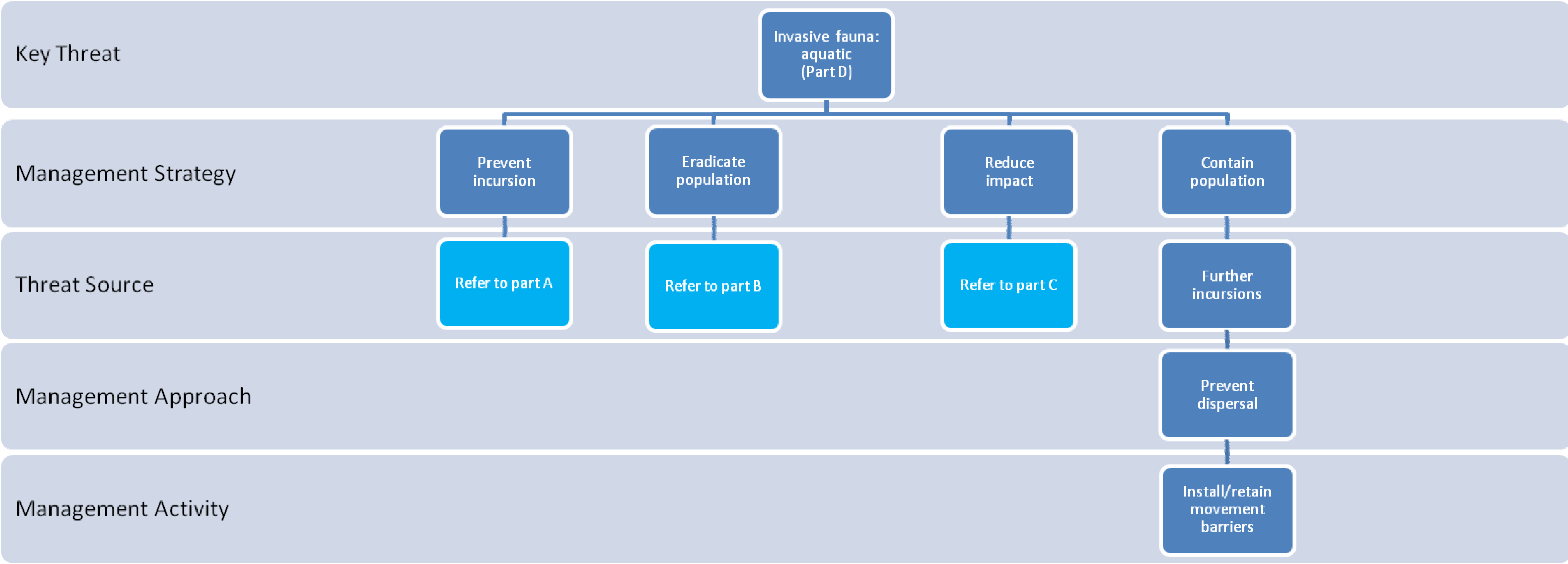
Management strategies and activities to reduce the threat of invasive fauna: aquatic (Part C)



Text boxes coloured red indicate that the management activities are described in another model as indicated by the superscript.

[1]Refer to management strategies and actions to reduce the threat of changed water regimes
[2]Refer to management strategies and actions for degraded wetland vegetation

Management strategies and activities to reduce the threat of invasive fauna: aquatic (Part D)



Description: invasive fauna (aquatic)

A range of invasive aquatic fauna impact on wetland values. Invasive fauna may predate on native species, compete for resources, modify habitat structure, degrade water quality and/or introduce disease or parasites (Crowl et al. 1992, Rowe et al. 2008). In Victoria, a number of invasive fish species utilise wetland habitats, including Common Carp (*Cyprinus carpio*), Goldfish (*Carassius auratus*), Weather Loach (*Misgurnus angullicaudatus*), Mosquitofish (*Gambusia holbrooki*), Redfin Perch (*Perca fluviatilis*) and Tench (*Inca tinca*). Brown Trout (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*) are introduced species that mainly occur in lakes and farm dams. Other aquatic fauna that are invasive in Victoria include two species of freshwater crayfish: Marron, *Cherax cainii* (Austin 2002) endemic to the south-west of Western Australia and Redclaw, *Cherax quadricarinatus*, native to tropical Queensland and the Northern Territory, both species are declared noxious in Victoria. Several freshwater introduced snails have establish populations in Victorian waterways including the American ribbed fluke snail (*Pseudosuccinea columella*) and European physa, *Physa acuta* (Ponder et al. 2000; Zukowski and Walker 2009). The Asian freshwater leech *Barbronia weberi* and the freshwater jellyfish *Craspedacusta sowebyi*, are also known to occur in Victoria (Govedich et al. 2002, Williams 1980).

KEY: Effectiveness is the expected level of threat reduction that will be achieved by a management intervention and is scored as: Low, a small reduction in the level of the threat; Med, a moderate reduction in the level of the threat which will not always be consistent; and high, a significant and consistent reduction in the level of the threat. Response times represent the period of time before a management activity is expected to eliminate or reduce the level of a threat and are scored as: 1, less than 1 year; 2, 1 -6 years; and 3, > 6 years.

Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Prevent incursion	Enforce regulatory controls	Med	1	Lack of compliance with existing regulatory requirements to control invasive species can increase the risk of invasive species establishing in a wetland. In Victoria the Catchment and Land Protection Act 1994 (CaLP Act) covers the classification and control of pest animals and regulates their importation, possession, sale or release. The Fisheries Act 1995 provides for the declaration of noxious aquatic species. Species listed as noxious under the Section 75 of the Fisheries Act 1995 must be reported and are subject to regulations that restrict their use and spread. The translocation (or stocking) of fish for recreational fishing or conservation purposes is regulated to reduce the risk of feral populations establishing, the introduction of parasites and disease, and genetic shifts in wild populations (DPI 2005a). Protocols for the translocation of fish are available through DPI.
	Improve community and industry awareness	Med	1-2	Lack of awareness by the community or industry (e.g. recreational anglers, commercial fisheries, aquaculture industry, aquarium industry) can lead to the unintentional introduction of invasive aquatic fauna such as the release of aquarium species or pets into waterways. Improving community and industry awareness of the risks presented by invasive species, how to identify and report them, and how to prevent their dispersal to new sites will reduce new incursions, facilitate the early detection and eradication of new incursions, and reduce the risk of human mediated dispersal.
	Identify and eradicate source population	Med-High	1	If source populations of invasive aquatic fauna species are not eradicated, a wetland will be subject to ongoing incursions. Eradicating source populations of invasive species from which individuals are able to disperse and colonise the wetland will prevent new incursions and re-introductions.

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Description: invasive fauna (aquatic) (continued)

Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Prevent incursion	Manage recreation and access	Med	1	Introduced aquatic fauna can be spread unintentionally by people who access the wetland for recreation or other activities. In some instances it may be necessary to close access to sites to minimise the risk of introducing or spreading high impact invasive species.
	Maintain/install movement barriers	Med-High	1	Invasive aquatic fauna species that are established outside the wetland may reach the wetland by dispersing along permeable routes in the landscape. Installing barriers to movement along these routes can prevent invasive species reaching the wetland. The exclusion of invasive fish from wetlands can be achieved by creating vertical drops that the species is unable to negotiate or by installing physical or behavioural barriers. Physical barriers are mesh screens that are placed across channels or culverts that exclude fish of a particular size class. Behavioural barriers generate noise, electricity or flows that deter movement in a particular direction.
Eradicate population	Monitor	Med	1	Unless new incursions of invasive species are detected and controlled at an early stage they are likely to quickly establish and become much more difficult to control. Establishing monitoring programs to detect the occurrence of invasive species will enable the early detection of new incursions. Populations that are detected early are likely to be small and this enhances the likelihood of successful eradication and reduces the risk of dispersal to other sites. The effectiveness of monitoring programs is dependent on their frequency, areal extent and rigour.
	Map and report	Med	1	When new incursions have been detected they should be reported and their location and extent mapped so the effectiveness of eradication or control measures can be assessed.
	Implement rapid removal	Med-High	1	Unless new incursions of invasive species are eradicated at an early stage they are likely to quickly establish and become much more difficult to control. Eradication success is more likely while the population is small. Eradication techniques include physical control, chemical control or habitat manipulation. The most suitable approach will depend on the traits of the species, the nature of the site and the risks associated with each control technique.
Reduce impact	Modify water regime	Med	1	There is a high likelihood that the invasive aquatic fauna species could be controlled by manipulating the water regime of the wetland. Partially or completely drying the wetland can be effective in reducing populations of invasive aquatic fauna that are intolerant of drying. However non-target organisms will also be affected. Partially drying the wetland coupled with chemical control can be effective in some instances (Ayres and Clunie 2010). *Refer to management strategies and activities to reduce the threat of changed water regimes.*
	Restore wetland vegetation	High	1-2	Wetland vegetation can provide important food and habitat for native aquatic fauna and degradation of wetland vegetation can therefore impact on native aquatic fauna populations and increases the likelihood of invasions occurring. Restoring wetland vegetation can increase the resilience of native aquatic fauna communities and decrease the likelihood of invasive species becoming established. *Refer to management strategies and activities to reduce the threat of degraded wetland vegetation* and *invasive flora (wetlands).*

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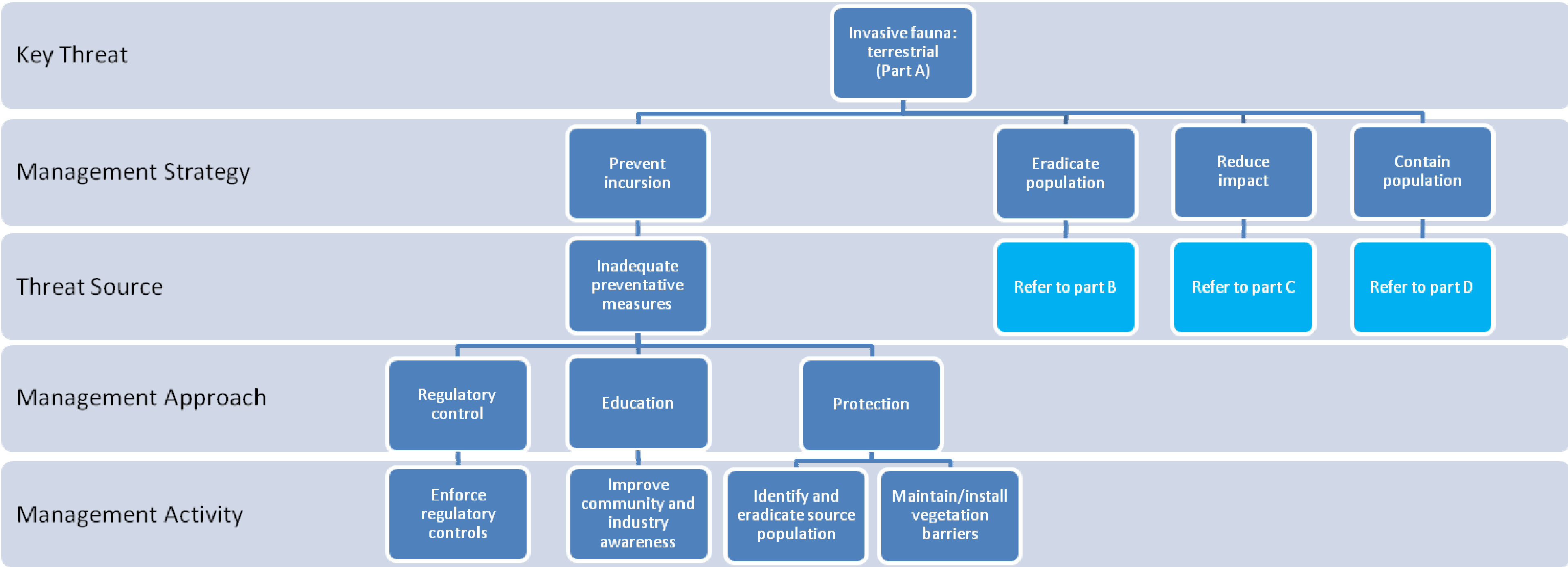
Description: invasive fauna (aquatic) (continued)

Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Reduce impact	Apply chemical control	Med-High	1	Chemicals such as lime, chlorine or a piscicide can be effective in reducing numbers of an invasive aquatic fauna species in certain situations. Chemicals used to control invasive fauna must be registered for use in Australia and permits for their use must be acquired. Chemical treatment can achieve eradication of invasive species in some cases but is generally only suitable in small shallow wetlands. Partially drying the wetland coupled with chemical control can be effective in some instances (Ayres and Clunie 2010). Chemical control techniques will impact on non-target species and result in the temporary loss of the water body for recreation and as a water supply.
	Undertake mechanical or manual control	Low-Med	1	There is a high likelihood that capturing the invasive aquatic fauna species would be effective in reducing numbers. Capture techniques for invasive fish include electro-fishing, netting, traps, cages and angling. Angling is probably the least effective technique but also raises public awareness (for a review of these techniques see Ayres and Clunie 2010).
	Implement biological control	Med-High	1-2	The principle of biological control is to use one organism to control another by restoring an ecological process (e.g. herbivory or disease) that limits the competitive ability of the invasive species. For example, stocking wetlands with native species that are known predators of the target invasive species may reduce or eliminate populations within the wetland. Thorough testing is needed to ensure that native species are not impacted. Biological control should only be carried out as part of an approved, co-ordinated biological control program.
Contain population	Install or maintain dispersal barriers	High	1	An invasive species that is established in the wetland may disperse to other wetlands resulting in new incursions. Installing barriers to movement along dispersal routes can prevent the invasive species reaching new wetlands. Restricting the movement of invasive fish to new sites can be achieved by creating vertical drops that the species is unable to negotiate or by installing physical or behavioural barriers. Physical barriers are mesh screens that are placed across channels or culverts that exclude fish of a particular size class. Behavioural barriers generate noise, electricity or flows that deter movement in a particular direction.

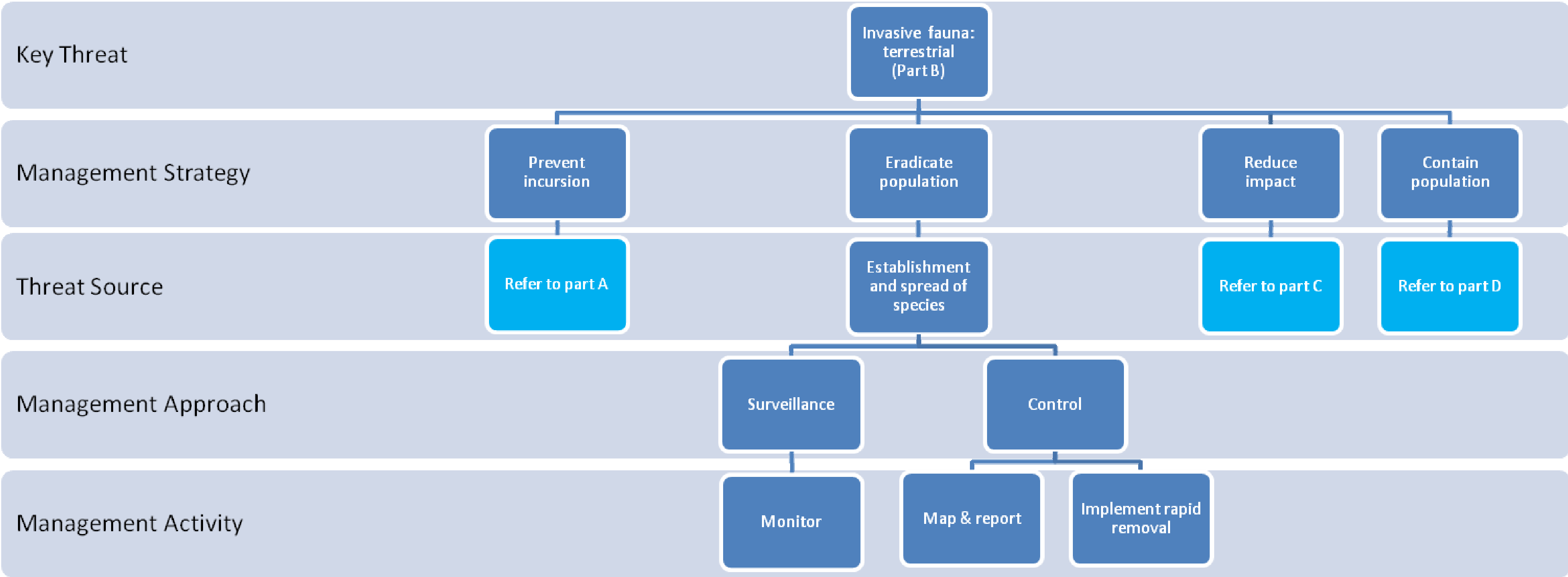
Potential risks associated with management interventions

When assessing the suitability of a management activity to reduce the level of a threat to wetland values a thorough assessment of all potential risks associated with the management activity must be carried out. The types of risks that should be considered are described in the methods (see pages 10-11).

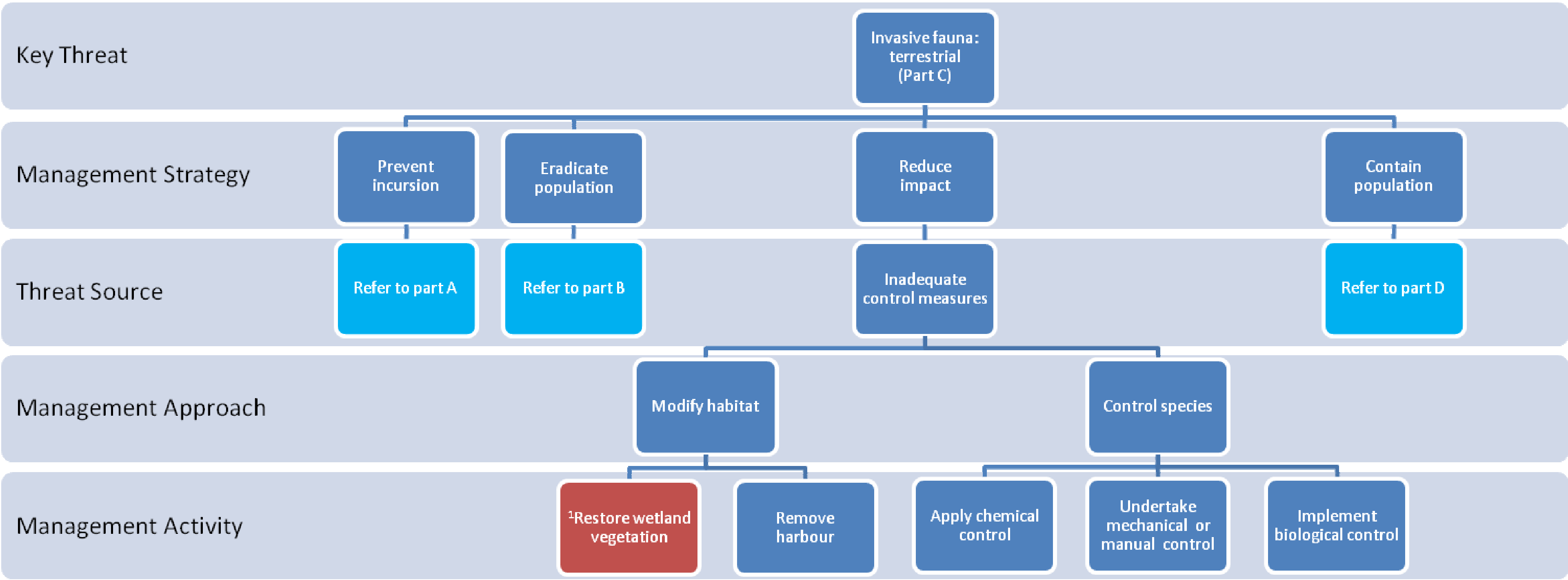
Management strategies and activities to reduce the threat of invasive fauna: terrestrial (Part A)



Management strategies and activities to reduce the threat of invasive fauna: terrestrial (Part B)



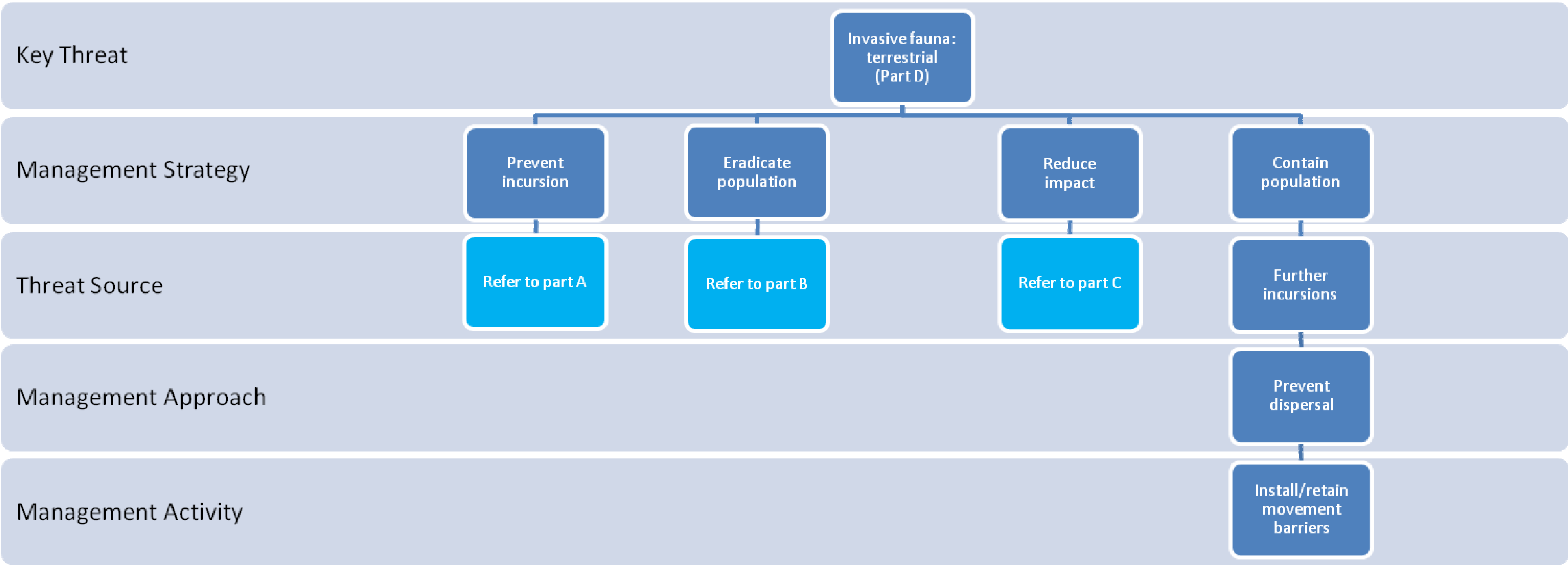
Management strategies and activities to reduce the threat of invasive fauna: terrestrial (Part C)



Text boxes coloured red indicate that the management strategies and activities are described in another model as indicated by the superscript.

[1]Refer to management strategies and activities for degraded wetland vegetation

Management strategies and activities to reduce the threat of invasive fauna: terrestrial (Part D)



Description: invasive fauna (terrestrial)

Invasive animals are non-native species that are, or have the potential to become, established in the wild. Wild populations establish when species escape from captivity and domestication, are deliberately or accidentally released, or are accidentally or illegally imported. A range of invasive terrestrial fauna impact on wetland values by predating on native aquatic fauna, competing for resources, destroying or damaging vegetation, transporting invasive plants, modifying habitat structure, degrading water quality and/or introducing disease or parasites (Crowl et al. 1992, Rowe et al. 2008). Invasive terrestrial fauna that can occur in Victorian wetlands include: *Capra hirus* (Feral goat), *Equus caballus* (Feral horse), *Felis catus* (Feral cat), *Oryctolagus cuniculus* (European wild rabbit), *Sus scrofa* (Feral pig), *Vulpes vulpes* (European red fox) and Cervidae (Feral deer).

KEY: Effectiveness is the expected level of threat reduction that will be achieved by a management intervention and is scored as: Low, a small reduction in the level of the threat; Med, a moderate reduction in the level of the threat which will not always be consistent; and high, a significant and consistent reduction in the level of the threat. Response times represent the period of time before a management activity is expected to eliminate or reduce the level of a threat and are scored as: 1, less than 1 year; 2, 1 -6 years; and 3, > 6 years.

Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Prevent incursions	Enforce regulatory controls for invasive species	Med	1	Lack of compliance with existing regulatory requirements to control invasive species can increase the risk of invasive species establishing in a wetland. In Victoria the Catchment and Land Protection Act 1994 (CaLP Act) covers the classification and control of pest animals and regulates their importation, possession, sale or release.
	Improve community and industry awareness	Med	1-2	Lack of awareness by the community or industry can lead to the unintentional introduction of invasive terrestrial fauna. Improving community and industry awareness of the risks presented by invasive species, how to identify and report them and how to prevent their dispersal to new sites will reduce new incursions, facilitate the early detection and eradication of new incursions and reduce the risk of human mediated dispersal.
	Identify and eradicate source population	Med-High	1	The wetland can be protected from new incursions of invasive terrestrial fauna by identifying and eradicating populations that lie outside the wetland but have the potential to reach and establish in the wetland. The most suitable eradication technique will depend on the traits of the species and the nature of the site.
	Maintain or install vegetation barriers	Low-Med	1-3	A dense band of vegetation around the perimeter of the wetland may help to limit some invasive terrestrial fauna accessing the wetland.
Eradicate population	Monitor	High		Unless new incursions of invasive species are detected at an early stage they are likely to establish and become much more difficult to control. Establishing surveillance and reporting programs to detect the occurrence of invasive species will enable the early detection of new incursions. Populations that are detected early are likely to be small and this enhances the likelihood of successful eradication and reduces the risk of dispersal to other sites. Surveillance and reporting programs can also be implemented to assess the success of management activities to control established populations. The effectiveness of surveillance programs is dependant on their frequency, areal extent and rigour.
	Map and report	High	1	When new incursions have been detected they should be reported and their location and extent mapped so the effectiveness of eradication or control measures can be assessed.
	Implement rapid removal	High	1	Unless new incursions of invasive species are controlled at an early stage, they are likely to establish and become much more difficult to control. New incursions require rapid eradication as success is more likely while the population is small. The most suitable eradication technique will depend on the traits of the species and the nature of the site.

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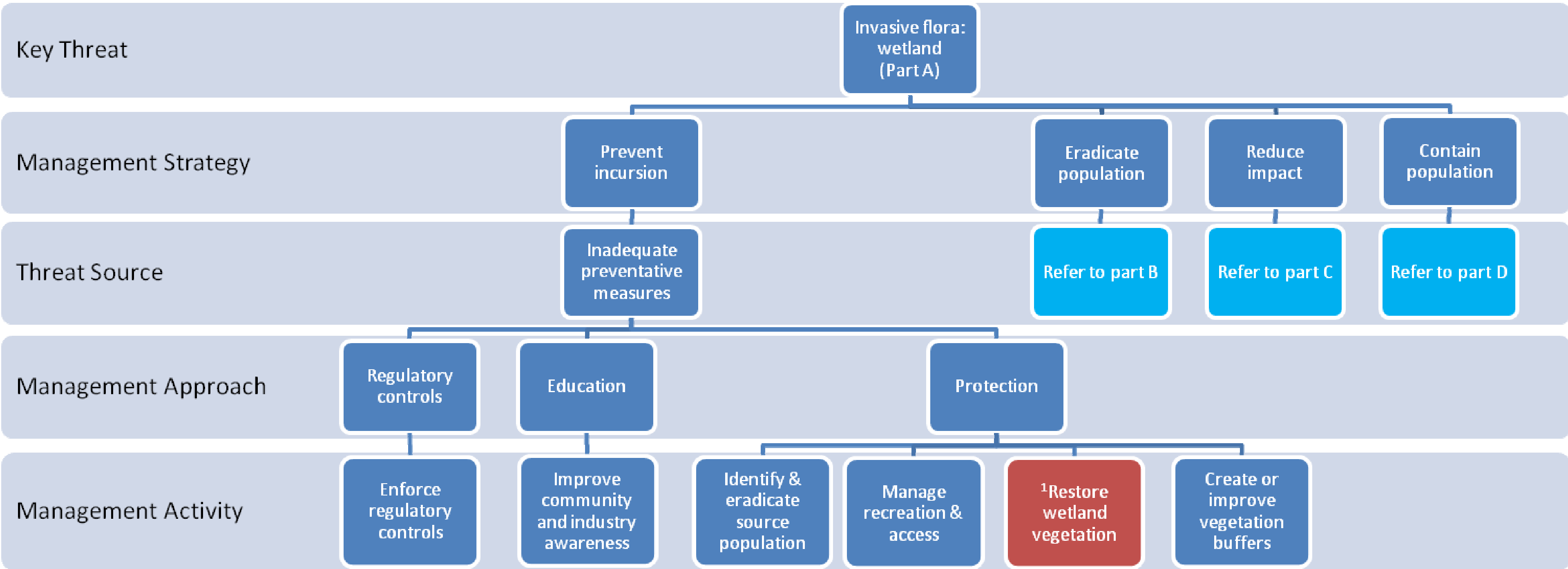
Description: invasive fauna (terrestrial) (continued)

Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Reduce impact	Restore wetland vegetation	High	1-3	Although reducing the threat of invasive terrestrial fauna will prevent further loss or damage to native wetland vegetation, where significant degradation has already occurred additional management activities will be needed to restore wetland vegetation. *Refer to management actions and strategies to reduce the threat of degraded wetland vegetation condition*.
	Remove harbour	Med	1-2	In newly colonised areas rabbits will temporarily use above-ground harbours for protection until warrens are completed. These harbours include dense thickets of blackberry or lantana. Removing these harbours may help to prevent colonisation. Once rabbits have established warrens in or near the wetland they are likely to breed, increasing the level of threat. Warren-ripping is used to destroy warrens (and rabbits). Without the protection of warrens breeding success is reduced.
	Apply chemical control	Med-High	1	For some terrestrial fauna species such as European red fox there is a high likelihood that baiting will be effective in reducing population size. The pesticide 1080 is used extensively in Australia to reduce fox populations. Fumigation of rabbit warrens uses poisons which kill rabbits in their burrows. Chemical control programs usually require permits and strict measures must be in place to protect the community and non-target organisms. These measures may include public notices and bait exclusion zones to protect the public, waterways, livestock and domestic animals.
	Undertake mechanical or manual control	Med-High	1	There is a high likelihood that capturing the invasive terrestrial fauna species would be effective in reducing numbers. Capture programs include trapping, hunting and mustering. Bounty programs offer a monetary reward to eligible hunters for contributing to the control of invasive animals. In Victoria bounty programs are used in conjunction with baiting programs to control foxes and wild dogs.
	Implement biological control	Med	2-3	In certain cases an invasive terrestrial species may be effectively controlled by implementing a biological control program. The principle of biological control is to use one organism to control another by restoring an ecological processes (e.g. herbivory or disease) that limits the competitive ability of the invasive species. Thorough testing is needed to ensure that the control agent does not impact non-target species. Biological control should only be carried out as part of an approved, co-ordinated biological control program.
Contain population	Install or maintain dispersal barriers	High	1	An invasive terrestrial fauna species could reach the wetland by moving through the landscape. Erecting barrier fencing can prevent invasive terrestrial species accessing the wetland but can also exclude native species. Cost will usually limit the application of this approach to high value assets that are at high risk or to smaller wetlands.

Potential risks associated with management interventions

When assessing the suitability of a management activity to reduce the level of a threat to wetland values a thorough assessment of all potential risks associated with the management activity must be carried out. The types of risks that should be considered are described in the methods (see pages 10-11).

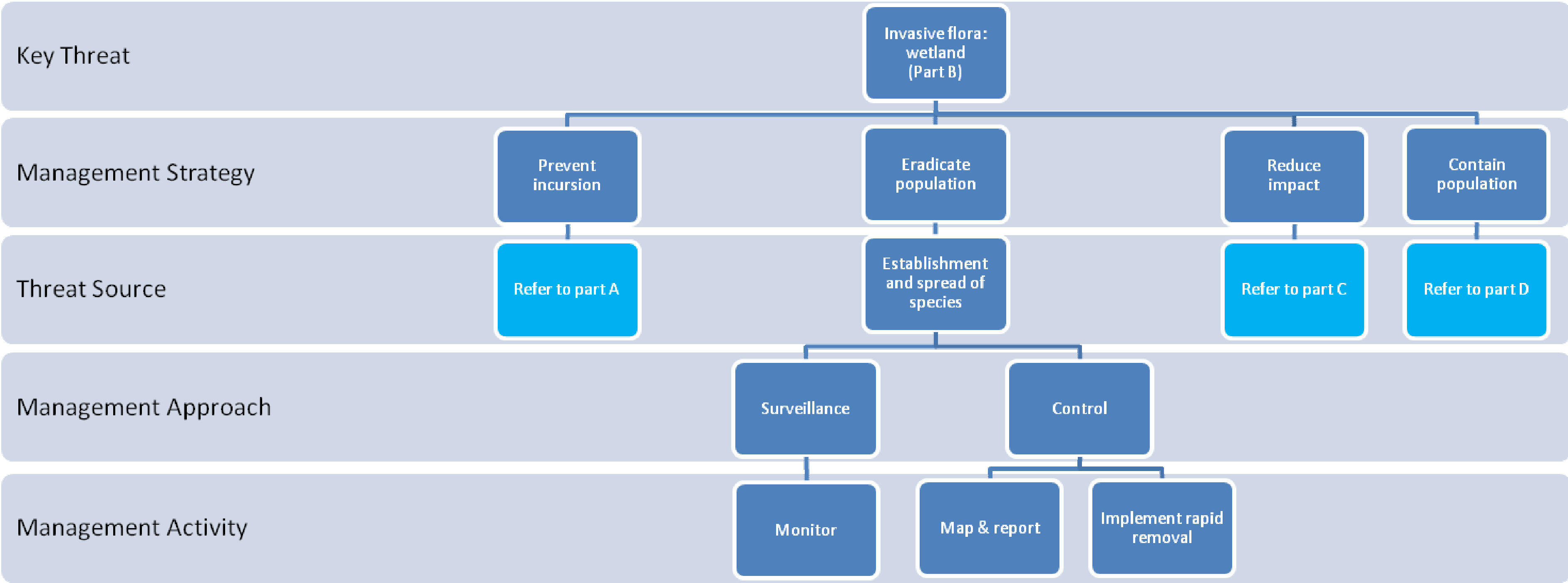
Management strategies and activities to reduce the threat of invasive flora: wetland (Part A)



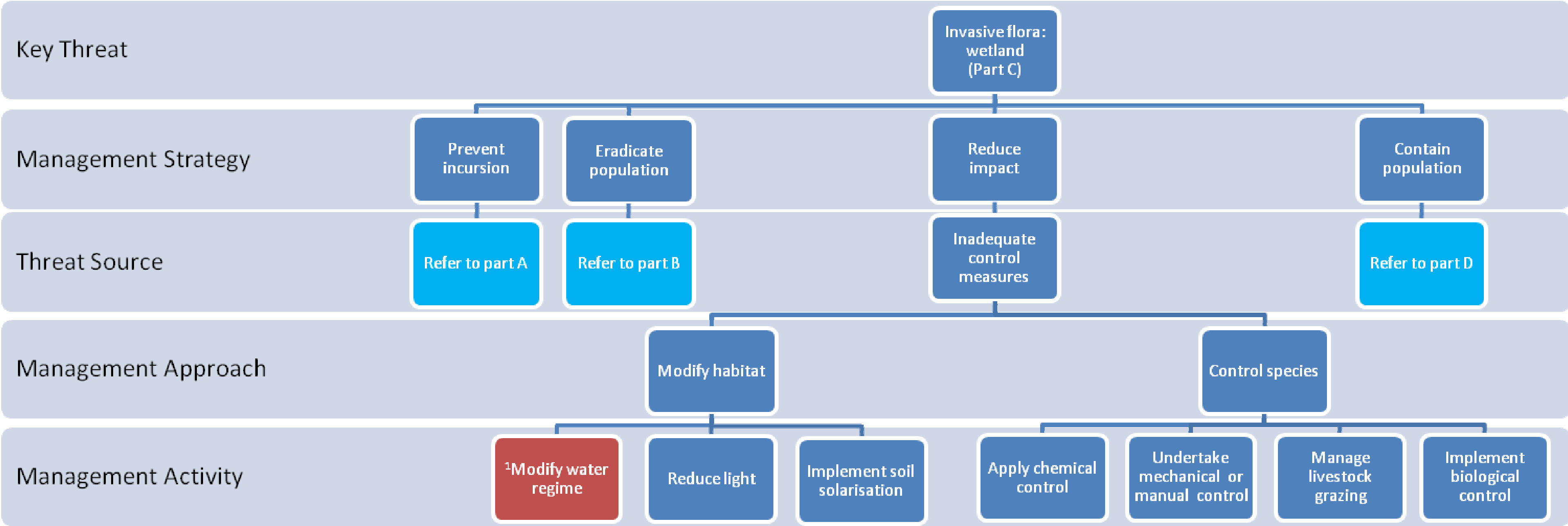
Text boxes coloured red indicate that the management strategies and activities are described in another model as indicated by the superscript.

[1]Refer to management strategies and activities for degraded wetland vegetation

Management strategies and activities to reduce the threat of invasive flora: wetland (Part B)



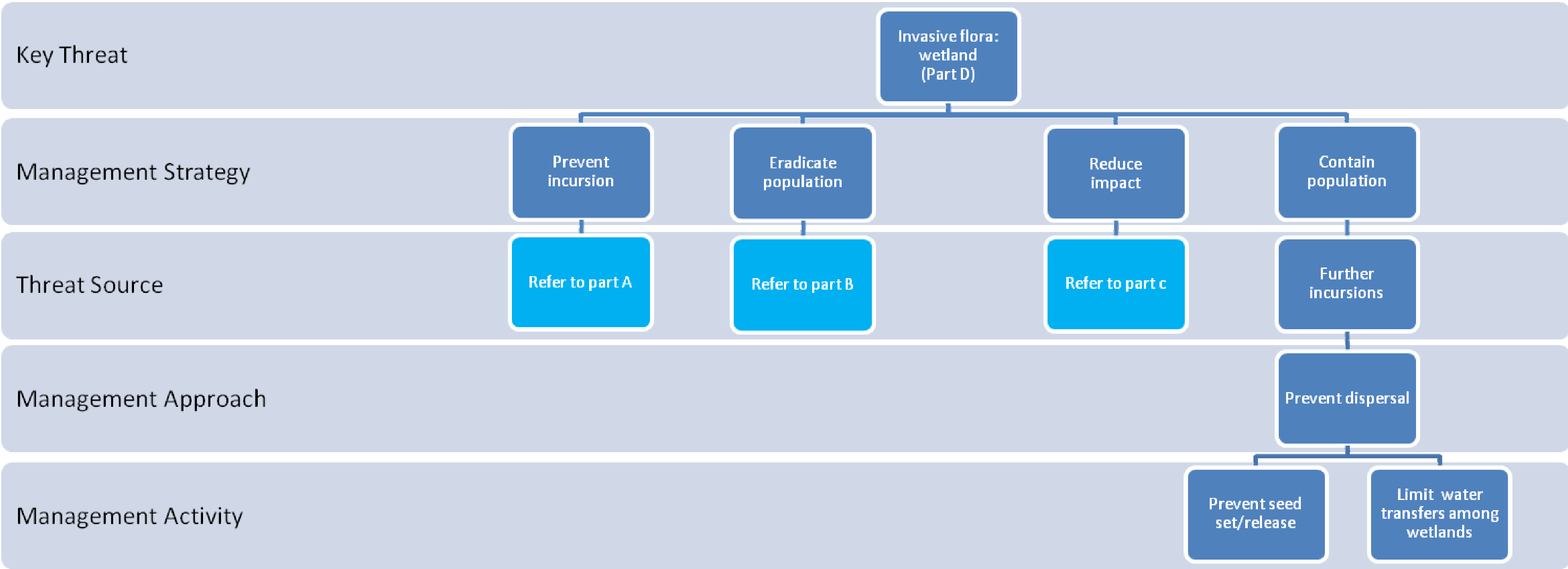
Management strategies and activities to reduce the threat of invasive flora: wetland (Part C)



Text boxes coloured red indicate that the management strategies and activities are described in another model as indicated by the superscript.

[1]Refer to management strategies and activities to reduce the threat of changed water regime

Management strategies and activities to reduce the threat of invasive flora: wetland (Part D)



Description: invasive flora (wetlands)

Globally invasive plants are considered the second most important threat to biodiversity (DSE 2009). Invasive plants exert significant impacts on biodiversity as they can displace native flora that provide food resources and/or habitat for native fauna. Invasive plants usually have fast growth rates and outcompete native plants for water, nutrients, light and/or space. Certain types of invasive plants can choke waterways and reduce water quality, flow velocities and flow paths. The threat of invasive plants in Victorian wetlands is measured in the Index of Wetland Condition (IWC) through assessing the percentage cover of environmental weeds, and the proportion that are classified as high threat weeds (DSE 2006). High threat weeds are those that are have a comparatively high potential to outcompete native species. They may include native species outside their normal range. High threat species are specific to different EVC types and are identified in wetland EVC benchmarks (DSE 2006).

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Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Prevent incursions	Enforce regulatory controls	Med	1	The Quarantine Act 1908 and the Environment Protection and Biodiversity Conservation Act 1999 are national legislation that serve to prevent the entry and spread of invasive species and the protection of the environment once they are present. Species listed as Noxious Weeds, Weeds of National Significance or on the National Alert List are subject to regulations that control there use and spread (Petroeschevsky et al 2006). Legislation and policy related to the management of invasive flora in Victoria can be found in EWWG (2007).
	Improve community and industry awareness	Med	1-2	Lack of awareness by the community or industry can lead to the unintentional introduction of invasive wetland flora. Improving community and industry awareness of the risks presented by invasive species, how to identify and report them and how to prevent their dispersal to new sites will reduce new incursions, facilitate the early detection and eradication of new incursions and reduce the risk of human mediated dispersal (EWWG 2007, NRMMC 2007). The WeedStop Vehicle Hygiene program offered by DPI is a example of an education program that improves awareness of landowners, contractors and the community of practical ways to reduce the spread of invasive species (see http://www.dpi.vic.gov.au/agriculture/pests-diseases-and-weeds/weeds/weedstop).
	Identify and eradicate source population	High	1-2	Invasive plant species may arrive in the wetland when their seeds or vegetative fragments are carried from populations outside the wetland by wind, water or animals. Eradicating these source populations will reduce the likelihood of invasive species arriving in the wetland.
	Manage recreation and access	High	1	Providing walking tracks, board walks, boating ramps, parking bays and vehicle tracks help to reduce the introduction of invasive species carried on shoes, clothing, boats and vehicles. Where there is a high risk of introducing or spreading a highly invasive species site access may be restricted.

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Description: invasive flora: wetland (continued)

Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Prevent incursions (cont.)	Restore wetland vegetation	High	2-3	There is an increased risk of incursions of invasive flora species where the wetland vegetation has been removed or highly degraded. Re-establishing native vegetation can assist in minimising the impact of invasive flora by out-competing the invasive species and changing the habitat to make it less suitable for the establishment or growth of the invasive species (e.g. by creating a more shaded environment). *Refer to management strategies and activities to restore wetland vegetation.*
	Create or improve vegetation buffer	Med	1-3	Native vegetation around the perimeter of the wetland can stop seeds carried in surface water flows reaching the wetland, and can act as a barrier for the dispersal of wind dispersed seed. Intact native vegetation around the perimeter of the wetland will reduce opportunities for invasive species to establish and enhances competitive exclusions by native species.
Eradicate population	Monitor	High	1	Establishing surveillance and reporting programs to detect the occurrence of invasive species will enable the early detection of new incursions (EWWG 2007). Populations that are detected early are likely to be small which increases the chances of successful eradication and reduces the risk of dispersal to other sites. The effectiveness of surveillance programs is dependant on their frequency, areal extent and rigour.
	Map and report	High	1	When new incursions have been detected they must be reported and their location and extent mapped so the effectiveness of eradication or control measures can be assessed.
	Implement rapid removal	Med-High	1	New incursions require rapid eradication as success is more likely while the population is small and before seeds are produced. The most suitable eradication technique will depend on the traits of the species (e.g. woody or herbaceous, seedling or adult, submerged or emergent), whether the area is inundated or not, and whether other threats are present as this may preclude some control measures (e.g. hoeing is problematic where there are acid sulfate soils (ASS).
Reduce impact	Modify water regime	Med- High	1	Where growth and/or reproduction of an invasive wetland plant species is reduced by a specific water regime, modifying the water regime can help to eliminate or reduce the size of populations of invasive species. For example, long periods of complete submergence will reduce the growth of emergent invasive species that may have established under drier conditions. *Refer to management strategies and activities to reduce the threat of changed water regime.*
	Reduce light	Med-High	1	Covering low growing invasive plants or seedlings with mulch, plastic sheeting or shade cloth can be used to suppress their growth by reducing light required for photosynthesis. Death will only be achieved if enough light is excluded for a sufficient period of time. Plants with underground storage structures can prove difficult to eliminate with this method. Shading plants with plastic sheeting or shade cloth can not easily be applied to large incursions or tall vegetation.
	Implement soil solarisation	Med- High	1	Soil solarisation involves covering damp soil with plastic to raise the soil temperature sufficient to kill the plants present. This can not be applied easily to large incursions or tall vegetation.

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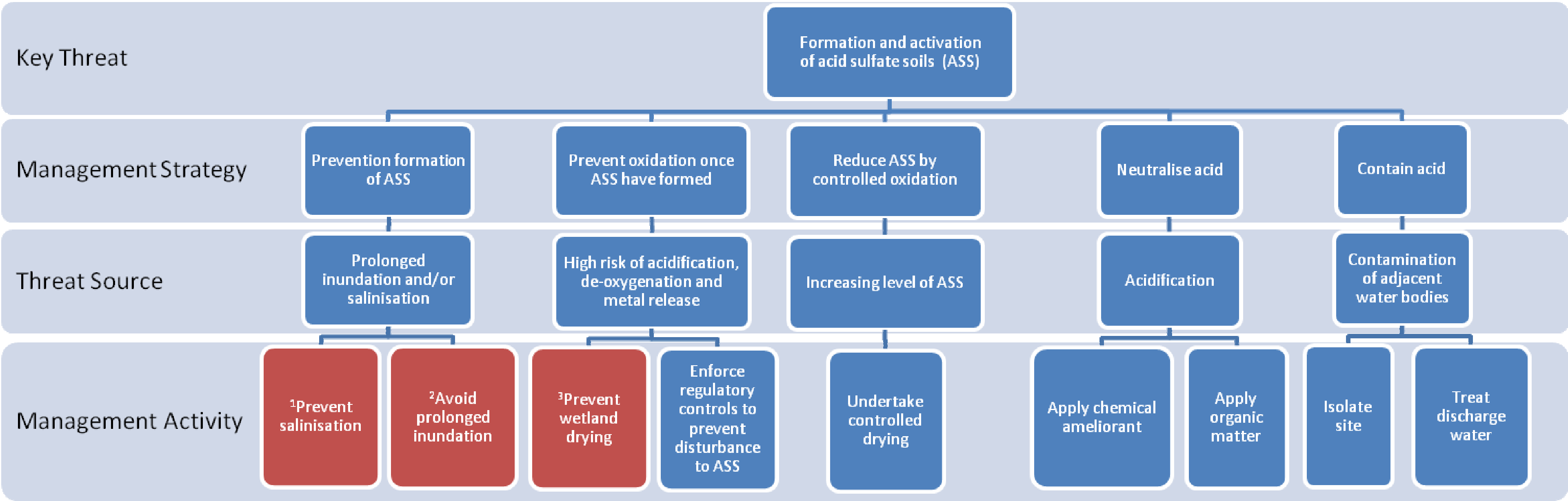
Description: invasive flora: wetland (continued)

Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Reduce impact	Apply chemical control	Med-High	1	Only a few herbicides are registered for use in aquatic areas in Australia and include several glyphosphate-based products that *do not* contain surfactants (surfactants are known to be harmful to aquatic organisms). The use of herbicides in Victorian waters is tightly regulated and permits must be obtained prior to their application near a waterway. Guidance should be obtained in selecting the best herbicide, application technique and appropriate timing of application to best manage a particular invasive species. All herbicides must be used with care and measures taken to minimise adverse effects on non-target organism and risks to public health and safety.
	Undertake mechanical or manual control	Med- High	1	Mechanical measures include hoeing, harvesting machines and bulldozing. These measures may be problematic in sites with ASS or potential ASS, or when there is a risk of penetrating a saline groundwater table. Manual control measures include hand removal, slashing and ring barking and are suited to managing small populations.
	Manage livestock grazing	Med	1-2	Livestock consume some invasive species and can help to suppress the growth and spread of invasive flora. The timing and intensity of grazing is used to optimise invasive plant control and minimise adverse effects associated with livestock grazing (includes impacts on water quality, soils and native vegetation).
	Implement biological control	High	1-3	The principle of biological control is to use one organism to control another by restoring an ecological processes (e.g. herbivory or disease) that limits the competitive ability of the invasive species. Thorough testing is needed to ensure that the control agent does not attack native species or valuable plants (CRC for Weed Management 2003). Biological controls are usually developed for large chronic infestations. Blackberry leaf rust fungus is a biological control agent used to control blackberries in Australia. Biological control should only be carried out as part of an approved, co-ordinated biological control program. Control agents for invasive plants are actively being researched and guidance on biological control approaches for particular invasive species should be obtained from DPI.
Contain population	Prevent seed set/release	High	1	Seeds and vegetative fragments of invasive wetland flora that have established in a wetland may disperse to other wetlands via wind, water or animal vectors. Measures to limit dispersal will help contain the spread of invasive species. Harvesting invasive plants prior to seed set or release can help limit both the expansion of the population within the wetland and dispersal to new sites.
	Limit water transfers among wetlands	High	1	Seeds and vegetative fragments of invasive wetland flora that have established in a wetland may disperse to other wetlands via wind, water or animal vectors. The transfer of water among wetlands where invasive species are present has the potential to disperse buoyant seeds and vegetative fragments to new sites. Avoiding the transfer of water from a wetland where invasive species are present to other sites will help to contain the incursion.

Potential risks associated with management interventions

When assessing the suitability of a management activity to reduce the level of a threat to wetland values a thorough assessment of all potential risks associated with the management activity must be carried out. The types of risks that should be considered are described in the methods (see pages 10-11).

Management strategies and activities to reduce the threat of formation and activation of acid sulfate soils (ASS)



Text boxes coloured red indicate that the management activities are described in another model as indicated by the superscript.

[1]Refer to management strategies and activities to reduce the threat of degraded water quality (salinity)
[2]Refer to management strategies and activities to reduce the threat of changed water regime (water excess)
[3]Refer to management strategies and activities to reduce the threat of changed water regime (water deficit)

Description: acid sulfate soils

Acid sulfate soils (ASS) refers to soils or sediment that contains reduced inorganic sulfur. Exposure of ASS to the air will result in a chemical reaction that produces sulfuric acid (H_2SO_4). Acid sulfate soils were previously only recognised as a threat in coastal regions but are now considered an emerging issue of inland aquatic ecosystems (EPHC and NRMMC 2011). The activation of ASS is detrimental to aquatic ecosystems as it can result in: acidification, de-oxygenation and/or metal mobilisation in the soil/sediment and water column. The management activities described in this model are based on the recommendations described in the Environmental Protection and Heritage Council and the Natural Resource Management Ministerial Council report (EPHC and NRMMC 2011).

KEY: Effectiveness is the expected level of threat reduction that will be achieved by a management intervention and is scored as: Low, a small reduction in the level of the threat; Med, a moderate reduction in the level of the threat which will not always be consistent; and high, a significant and consistent reduction in the level of the threat. Response times represent the period of time before a management activity is expected to eliminate or reduce the level of a threat and are scored as: 1, less than 1 year; 2, 1 -6 years; and 3, > 6 years.

Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Prevention formation	Prevent salinisation	Med	1-3	Secondary salinisation contributes to the formation of ASS at susceptible sites as it provides a source of sulfate needed for their formation. Reducing the risk of secondary salinisation can minimise the threat of ASS forming or worsening. *Refer to management strategies and activities to reduce the threat of degraded water quality (salinity).*
	Avoid prolonged inundation	Med	1	In sites susceptible to the formation of ASS sediment, anoxia produced by prolonged periods of inundation can contribute to the formation of ASS. Changing the water regime to include regular periods of drying can reduce the risk of ASS forming or worsening. *Refer to management strategies and activities to reduce the threat of change water regime (water excess).*
Prevent oxidation	Prevent wetland from drying	High	1	Where ASS are present, there is a risk of oxidation if they are exposed to the air which can result in acidification, de-oxygenation and/or metal mobilisation in the soil and water column. Maintaining a layer of water over the sediments will reduce this threat. *Refer to management strategies and activities to reduce the threat of change water regime (water deficit).*
	Enforce regulatory controls to prevent disturbance to ASS	High	1	Soil disturbances such as excavation or drainage increase the risk of exposure of ASS to the air which causes oxidation and can result in acidification, de-oxygenation and/or metal mobilisation in the soil and water column. The risk of the disturbance of ASS can be reduced by enforcing any existing regulatory controls.
Reduce ASS by controlled oxidation	Undertake controlled drying	Med-High	1	Where ASS have formed in the wetland, they may be reduced by controlled oxidation, i.e. by drying the sediments and allowing oxidation to occur in a controlled manner. However, there is a risk that this could cause excessive acid production and this risk needs to be assessed prior to undertaking controlled oxidation. Controlled oxidation is only possible if the system is found to have a high capacity to neutralise the acid that will be produced during oxidation. To manage the risk of acidification during controlled oxidation a carefully planned contingency strategy is needed and close monitoring of the level of acid production is required during drying. Contingency strategies may include the addition of chemical ameliorants and/or re-flooding.

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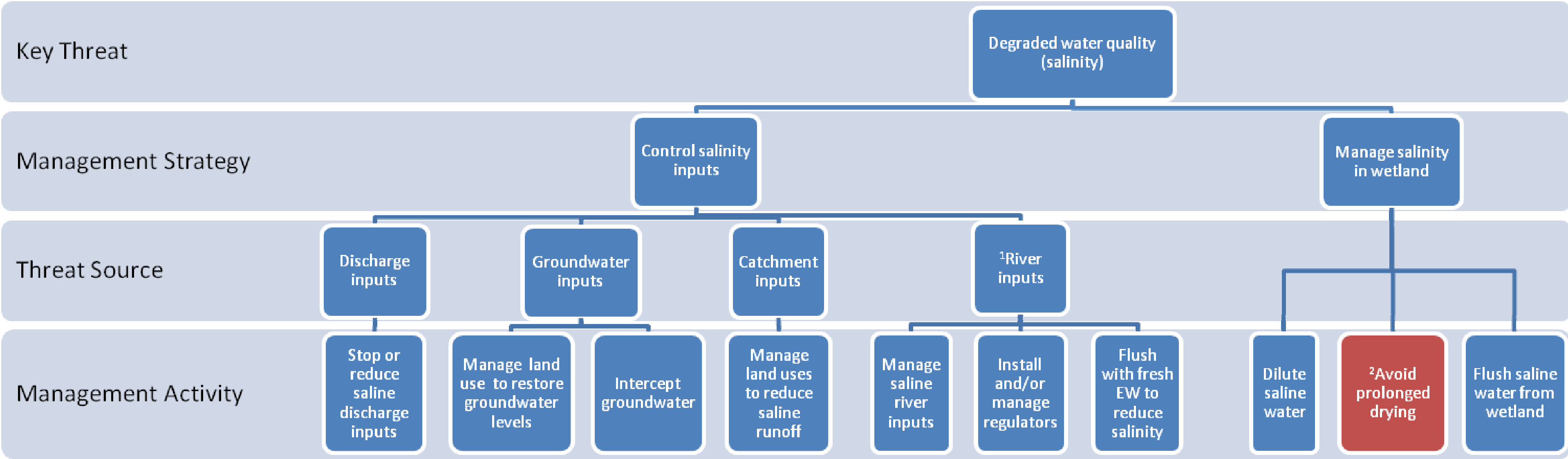
Description: acid sulfate soils (continued)

Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Neutralise acid	Apply chemical ameliorant	Med-High	1	There is a high likelihood that applying a chemical ameliorant would be effective in neutralising acid in a wetland where ASS have been activated. A comprehensive list of suitable ameliorants is provided in EPHC & NRMMC (2011).
	Apply organic matter	Med-	1	The addition of organic matter (such as a thick layer of mulch) increases microbial activity which produces anoxic condition (through microbial respiration) and this prevents further oxidation and acid production. Under anoxic conditions organic matter also fuels the reduction of iron and sulfur by micro-organisms which generates alkalinity, and this helps to neutralise acids already present (EPHC & NRMMC 2011). Although organic matter may help manage acidity in the short term, it also generates sulphide and therefore the potential for future acid production. Applying organic matter can be effective in treating the wetland where ASS have been activated, but success is variable and it is only recommended as a stop-gap measure until other measures can be implemented (EPHC & NRMMC 2011).
Contain acid	Isolate wetland	Med-High	1	Wetlands in which ASS have been activated and the resulting acidification can not be ameliorated present a risk to aquatic systems downstream if acid water is discharged. When this occurs the wetland should be isolated and downstream discharges prevented.
	Treat discharge water	Med-High	1	Wetlands in which ASS have been activated and the resulting acidification can not be ameliorated present a risk to aquatic systems downstream if acid water is discharged. If discharges from the wetland cannot be prevented the water discharged from the wetland should be treated to reduce impacts on receiving areas. Treatment of water discharges can include chemical or biological amelioration and dilution.

Potential risks associated with management interventions

When assessing the suitability of a management activity to reduce the level of a threat to wetland values a thorough assessment of all potential risks associated with the management activity must be carried out. The types of risks that should be considered are described in the methods (see pages 10-11).

Management strategies and activities to reduce the threat of degraded water quality (salinity)



Text boxes coloured red indicate that the management strategies and activities are described in another model as indicated by the superscript.

[1] River inputs only apply to floodplain wetlands
[2] Refer to management strategies and activities to reduce the threat of changed water regimes (water deficit).

Abbreviations:
EW= environmental water

Description: degraded water quality (salinity)

Salinisation is a major threat to aquatic habitats throughout Australia (Hart et al. 1991). Salinisation due to human disturbance (secondary salinisation) results mainly from landscape changes that cause saline groundwater tables to rise. These include the clearing of deep rooted native vegetation (dryland salinity) and irrigated agriculture in poorly drained land, which both increase groundwater recharge. Increased groundwater recharge promotes the seepage of saline groundwater directly into watercourses and wetlands. Elevated groundwater tables also increase the surface expression of salts resulting in land salinisation. Surface runoff from salinised land then carries salts to watercourse and wetlands (Peck et al. 1983). Salinity exerts multiple impacts on aquatic systems including direct effects of aquatic fauna and flora and altered chemical processes, as well as the degradation of habitat and damage to infrastructure.

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Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Control salinity inputs	Stop or reduce saline discharge inputs	High	1	Water may be discharged to wetlands to dispose of drainage water, industrial, agricultural or sewage treatment water, irrigation tailwater, or the water from groundwater interception schemes. Where these discharges are saline they should be stopped, reduced or diverted to other storages to prevent further increases in wetland salinity.
	Manage land use to restore groundwater levels	Low-Med	2-3	Land use changes can cause saline groundwater tables to rise and increase the salinity of wetlands that have a connection to the groundwater. Groundwater levels can be reduced by: (1) revegetating groundwater recharge and transmission zones with trees and other salt-tolerant perennial, high water use vegetation; (2) ensuring efficient water irrigation practices are in place and (3) preventing water seepage from water supply channels.
	Intercept groundwater	Med-High	1-2	Where high saline groundwater tables cannot be lowered by managing land use, groundwater interception works may be necessary to protect wetlands. Groundwater should be disposed in purpose-built disposal basins.
	Manage land uses to reduce saline runoff	Low-Med	2-3	Salts can enter wetlands from diffuse sources through salt wash-off from salinised land or when low quality irrigation water is used in the local catchment. Reducing salt wash–off from salinised land involves revegetating bare areas to reduce erosion and lowering the groundwater table to reduce the expression of salts at the soil surface.
	Miminise impacts from saline river inputs	High	1	Saline water inputs to freshwater wetlands from rivers can be avoided by ensuring off-takes are placed above stratified saline layers or impacts reduced by ensuring adequate fresh flows to dilute/flush salts.

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Description: degraded water quality (salinity) (continued)

Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Control salinity inputs	Install and /or manage regulators (floodplain wetlands)	High	1	For lower river reaches affect by salt water intrusions the installations and/or management of regulators can help to prevent water entry into naturally freshwater wetlands during periods of high river salinity. Bottom-gated regulators should be avoided as they limit the capacity to deliver freshwater to wetlands (salt water is denser than freshwater and the most saline water sits at the bottom of the water column).
	Flush with fresh environmental water to reduce intrusion	Med-High	1	When river flows are substantially reduced by river regulation, a saline intrusion in the lower river reaches can move further upstream, this increases the salinity of water supplied to floodplain wetlands. The release of water from storages can reduce the upstream extent of saline intrusion and freshen the top layers of the water column improving the quality of river inputs to floodplain wetlands.
Manage salinity in wetland	Dilute saline water	Med-High	1	The concentration of salts present in the wetland can be diluted by the addition of fresh water. However, dilution may exert negative impacts if the depth or duration of inundation is increased for long periods. Other measures to address salinity will also be needed in the long-term.
	Flush saline water from wetland	Med-High	1	During periods of high water availability, draining saline water from the wetland and replacing it with fresh water can reduce the salt load in the wetland.
	Avoid prolonged drying	Med	1	When wetlands with a shallow saline groundwater table are dry capillary action will deliver saline groundwater to the soil surface where it evaporates and deposits salt. This process can result in a persistent increase in salinity unless salts are adequately flushed from the wetland. Unnaturally long periods of drying should therefore be avoided in wetlands where the main source of salinity is due to a shallow saline groundwater.

Potential risks associated with management interventions

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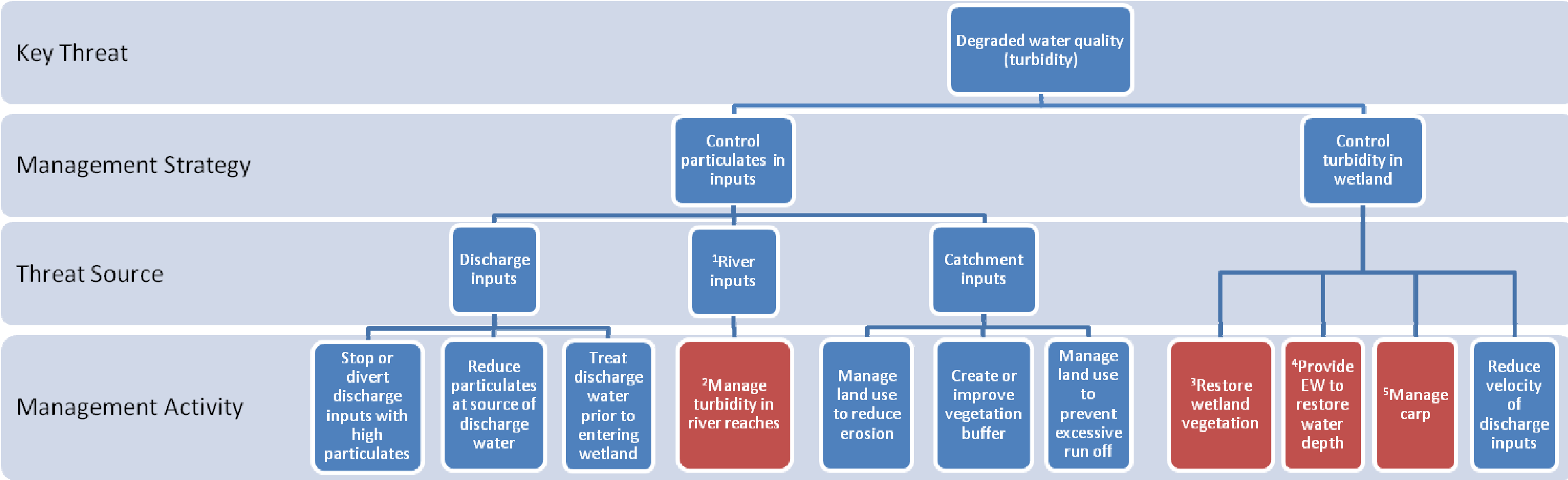
Management strategies and activities to reduce the threat of degraded water quality (turbidity)



Text boxes coloured red indicate that the management activities are described in another model as indicated by the superscript.

[1]River inputs only apply to floodplain wetlands
[2]Refer to management strategies and activities to reduce the threat of degraded water quality: turbidity (river reaches) (GHD 2012).
[3]Refer to management strategies and activities to reduce the threat of degraded wetland vegetation
[4]Refer to management strategies and activities to reduce the threat of changed water regime
[5]Refer to management strategies and activities to reduce the threat of invasive aquatic fauna

Abbreviations: EW= environmental water

Description: degraded water quality (turbidity)

Turbidity refers to the suspension of particles in the water column that reduce its clarity. Turbidity can be caused either by the suspension of soil particles in the water column or by the growth of phytoplankton. This threat-management intervention model only examines the threat of turbidity that results from increasing levels of suspended soil particles in the water column. High levels of soil particulates in the water column can result from soil erosion or construction activity in the catchment, discharge inputs to the wetland that are high in particulates, or by soil disturbance within the wetland created by livestock or invasive fauna (e.g. Common Carp, feral pigs). High levels of turbidity in wetlands exert negative impacts on submerged aquatic plants by reducing light needed for growth. Turbidity due to suspended sediments also impacts on fish and invertebrates by clogging gills, reducing feeding efficiency of visual feeders and through loss of habitat.

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Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Control particulate inputs	Stop or divert discharge inputs with high particulates	High	1	Where discharge inputs are high in suspended soil particles, this can cause high levels of turbidity in the wetland. Stopping or reducing discharge inputs high in suspended soil particles will reduce the threat level in the wetland.
	Reduce particulates at source of discharge inputs	High	1	Where discharge inputs are high in suspended soil particles, this can cause high levels of turbidity in the wetland. Reducing the amount of suspended soil particles in the source water can reduce the threat level in the wetland.
	Treat discharge inputs prior to entering wetland	High	1	Where the turbidity of the discharge inputs cannot be reduced at the source, the water could be treated en route to the wetland. Artificial wetlands reduce particulate loads by slowing the flow of water and using vegetation filters to trap particulates.
	Manage degraded water quality (turbidity) in river reach	Med-High	1-2	Turbidity levels in floodplain wetlands can be increased when turbidity levels of their source rivers are high. Addressing high levels of turbidity in river reaches can therefore help to reduce the threat level in floodplain wetlands. *Refer to management strategies and activities to reduce the threat of degraded water quality turbidity (river reaches) (GHD 2012).*
	Manage land use to reduce erosion	Low-Med	2-3	Runoff from eroded areas carries high levels of suspended soil particles. Agricultural and construction activities require sediment and erosion controls to minimise particulates in stormwater runoff.
	Create or improve vegetation buffer	Med	1-2	Vegetation around the perimeter of the wetland acts as a filter and lowers particulate inputs from catchment sources. Creating riparian buffers along the lower reaches of streams and along drainage lines that flow into wetlands, as well as the wetland itself, can reduce particulates carried in water inflows.

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Description: degraded water quality (turbidity) continued

Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Control particulate inputs (continued)	Manage land use to prevent excessive runoff	Low-Med	2-3	Surface water runoff from eroded areas or in catchment where soil disturbance has occurred carries particulates to wetlands. The greater the volume of surface water runoff reaching the wetland the greater the total amount of sediment that reaches the wetland. Reducing excessive surface water runoff will therefore reduce the particulate load to wetlands
Control turbidity in wetland	Restore wetland vegetation	Med	1-3	Aquatic plants reduce sediment re-suspension as they stabilise the sediment and reduce flow velocity. Restoring wetland vegetation can therefore reduce the threat level. *Refer to management strategies and activities to reduce the threat of degraded wetland vegetation.*
	Deliver environmental water to restore/maintain water depth	Med	1	Wind action on the surface of open water can create turbulent mixing of the water column and the re-suspension of soil particles. Sediments are less likely to be re-suspended by this process in deeper water and restoring or maintaining the natural filling depth can help reduce sediment re-suspension. *Refer to management strategies and activities to reduce the threat of changed water regime.*
	Manage carp	Med	1-2	The invasive freshwater fish, Common Carp (*Cyprinus carpio*) are sediment feeders. These disturb the sediments, uproot plants and destabilise banks. Managing carp populations can help reduce turbidity. *Refer to management strategies and activities to reduce the threat of invasive aquatic fauna.*
	Reduce velocity of discharge inputs	High	1-2	Reducing the velocity of water flowing into the wetland reduces sediment re-suspension and allows particles carried in the water to settle out. Reducing flow velocity may be achieved by creating a vegetation filter at the point of water entry.

Potential risks associated with management interventions

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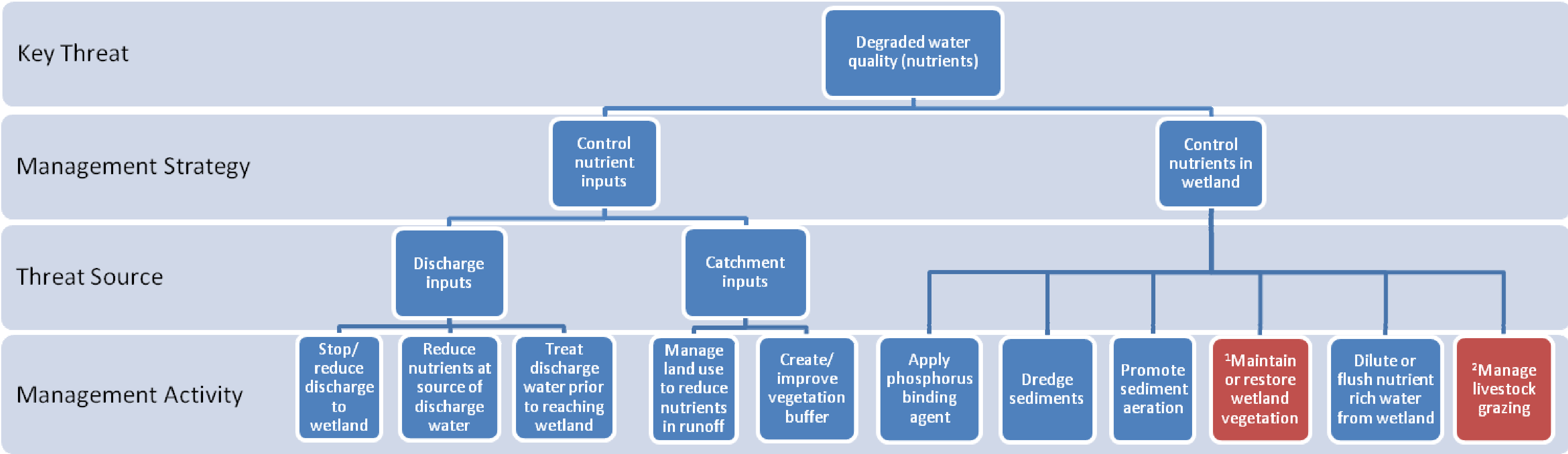
Management strategies and activities to reduce the threat of degraded water quality (nutrients)



Text boxes coloured red indicate that the management activities are described in another model as indicated by the superscript.

[1]Refer to management strategies and activities to reduce the threat of degraded wetland vegetation.
[2]Refer to management strategies and activities to reduce the threat of soil disturbance.

Description: degraded water quality (nutrients)

The nutrient content of natural wetlands is highly variable from bogs that are naturally very low in nutrients to marshes that are fed by surface or groundwater inputs and have naturally higher levels of nutrients (Sorrell 2010). Excessive levels of nutrients cause adverse effects of wetland values. Signs of excessive nutrients in a wetland can include high levels of primary productivity and litter accumulation, proliferation of plant species with high growth rates, increased algal abundance, and low levels of oxygen. These changes ultimately can result in algal blooms, fish deaths and impact on a wide range of wetland values.

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Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Control nutrient inputs	Stop or reduce discharge inputs with high nutrient levels	High	1	Discharge inputs such as agricultural and domestic wastewater can contain high levels of nutrients and should be stopped, reduced or diverted to a treatment wetland to prevent further increases of nutrients in the wetland.
	Reduce nutrients at source of discharge water	High	1-2	The nutrient level of water discharges can be reduced by treating agricultural or industrial wastewater at their source..
	Treat discharge water prior to reaching wetland	High	1-2	Diverting wastewater into artificial wetlands designed to reduce nutrients can reduce the level of nutrients reaching natural wetlands.
	Manage land use to reduce nutrients in runoff	Med-high	1-3	Diffuse nutrient runoff from agricultural land can be reduced by managing the use of fertilisers, controlling wastewater discharge, trapping sediment in streams that flow into wetland, vegetating drainage networks on farms to act as filters and by excluding livestock and establishing riparian vegetation along streams that run into wetlands (Sorrell 2010).
	Create or improve vegetation buffer	Low-Med	1-3	A wetland is more susceptible to nutrient inputs where there is no vegetation around the perimeter of the wetland to act as a filter and lower nutrient inputs from catchment sources. Creating riparian buffers along the lower reaches of streams and drainage lines that flow into wetlands and around the wetland itself can reduce nutrients in inflow. Fencing vegetation buffers may be needed to reduce disturbance and nutrient inputs from livestock.
Control nutrients in wetland	Apply phosphorus (P) binding agent	Med	1	Phosphorus inactivation aims to lower the P content of the water and retard the release of P from the sediment. It involves the addition of compounds that bind P (e.g. aluminium salts, clay material) (Cooke et al. 2005). This management activity is more common in lakes and reservoirs that provide water for human consumption or are used for recreation (e.g. swimming) because it helps to control toxic blue green algae by limiting the availability of P.
	Dredge sediments	Med	1	Nutrients, particularly P, are stored in wetland sediments. Where high concentrations have been reached sediment removal may be appropriate. However, dredging the sediments will have adverse effects on other wetland values and these should be weighed up against the benefits. Dredging is also costly and dredge material needs appropriate disposal (Cooke et al. 2005).

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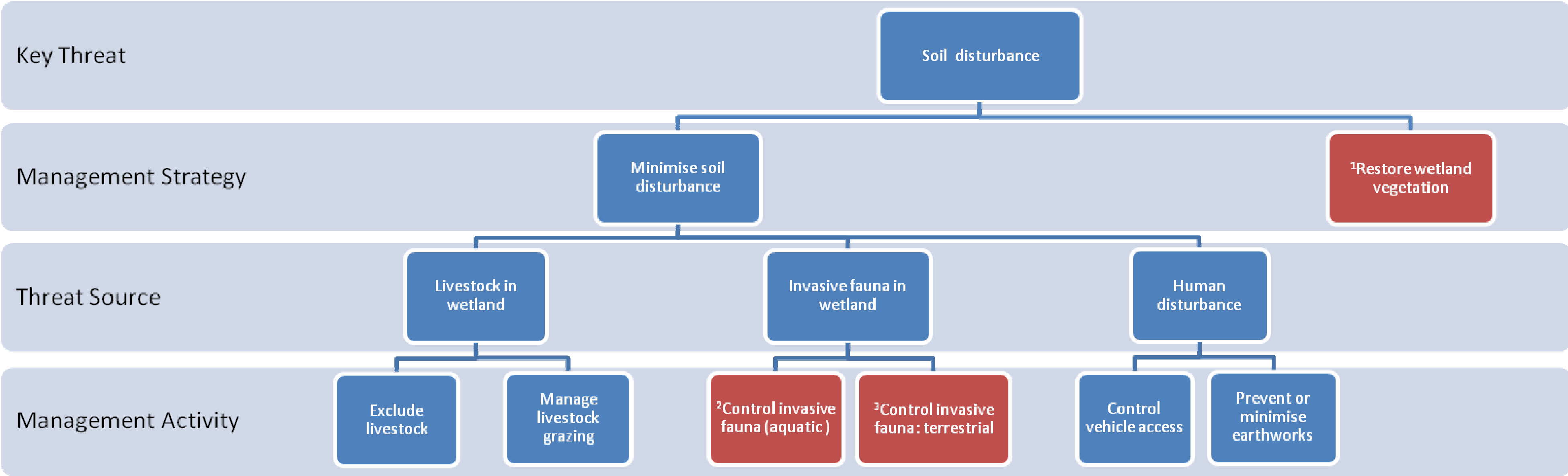
Description: degraded water quality (nutrients) (continued)

Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Control nutrients in wetland (cont.)	Promote sediment aeration	Med	1	De-oxygenation of the sediments can result in the release of sediment bound P into the water column which may cause blue-green algal blooms. Stands of some emergent plants such as *Phragmites* and *Typha* can aerate the root zone through a process called convective gas flow. Aeration of the root zone contributes to nutrient reduction by: i) promoting the binding of P to the sediments and ii) creating aerated zones adjacent to anaerobic zones that favour nitrification-denitrification by soil bacteria. In deep water bodies such as lakes and reservoirs that have a high levels of P bound in the sediments, mechanical aeration may be needed to limit P availability and control algal blooms (Cooke et al. 2005). Mechanical aeration is usually only applied to deep lakes, as these water bodies can become thermally stratified producing anoxic sediments. Aeration is usually achieved by pumps that deliver air/oxygen to the bottom of the lake through perforated tubes. Aeration techniques that result in the mixing of the water column are often not suitable because mixing delivers nutrient rich water from the lake bottom to surface waters where they can promote algal growth.
	Maintain or restore wetland vegetation	Med	1-3	Aquatic vegetation is important in controlling nutrients in wetlands through uptake, facilitating nitrification-denitrification and promoting the binding of P to sediments (see row above). Aquatic plants help control algal blooms by competing with algae for light and nutrients and in some cases producing chemicals that inhibit algal growth. At high nutrient levels submerged plants can be lost with a shift to phytoplankton dominance. When this occurs it can be very difficult to re-establish submerged aquatic plants. *Refer to management strategies and activities to reduce the threat of degraded wetland vegetation.*
	Dilute/ flush nutrients in water column	Med	1	Diluting nutrients with low nutrient water can help reduce nutrient concentrations and limit phytoplankton abundance. During periods of high water availability, draining nutrient rich water from the wetland and replacing it with low nutrient water can help remove nutrients from the system. Where there is a large store of nutrients in the sediment this may only produce a short-term reduction in the level of nutrients in the water column.
	Manage livestock grazing	High	1	Livestock increase nutrients in the wetland through faecal inputs and when carcasses are left to decompose in the wetland. *Refer to management strategies and activities to reduce the threat of soil disturbance.*

Potential risks associated with management interventions

When assessing the suitability of a management activity to reduce the level of a threat to wetland values a thorough assessment of all potential risks associated with the management activity must be carried out. The types of risks that should be considered are described in the methods (see pages 10-11).

Management strategies and activities to reduce the threat of soil disturbance



Text boxes coloured red indicate that the management activities are described in another model as indicated by the superscript.

[1]Refer to management strategies and activities to reduce the threat of degraded wetland vegetation
[2]Refer to management strategies and activities to reduce the threat of invasive fauna: aquatic
[3]Refer to management strategies and activities to reduce the threat of invasive fauna: terrestrial

Description: soil disturbance

Soil disturbance can alter the structural complexity of vegetation, disrupt soil based eggs and seed banks, increase turbidity and change the form of the wetland. Soil disturbance may be caused by earthworks, vehicle access, invasive terrestrial or aquatic fauna, and/or livestock.

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Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Prevent soil disturbance	Exclude livestock access	High	1	Livestock cause soil disturbance which reduces the abundance, diversity and structure of wetland vegetation. It also disrupts soil based egg and seed banks, creates gaps in native vegetation cover in which invasive species may establish and changes the microtopography of the wetland. Excluding livestock will prevent these impacts. However, where significant soil disturbance has already occurred, the exclusion of livestock may not be sufficient to restore wetland vegetation and additional management interventions may be required.
	Manage livestock grazing	Med	1	Livestock cause soil disturbance which reduces the abundance, diversity and structure of wetland vegetation. It also disrupts soil based egg and seed banks, creates opportunities for invasive species to establish and changes the microtopography of the wetland. Managing livestock by restricting the area, timing, frequency and/or intensity of grazing can minimise adverse effects on the wetland. As soil disturbance is greatest when the soil is wet livestock access to the wetland should be avoided during these periods. To promote the regeneration of native aquatic flora, livestock access should be avoided when species are flowering and setting seed. Soil disturbance by livestock can also be limited by restricting access to specific watering points in the wetland. This can be achieved by installing fencing, or by placing watering troughs on higher ground. Reducing the number of livestock in the wetland will reduce the level of soil disturbance. Stocking rates can be manipulated by varying the number, duration and frequency that livestock access the wetland.
	Manage carp	Med-High	1-2	The invasive freshwater fish, Common Carp (*Cyprinus carpio*) are sediment feeders. They disturb sediments, uproot plants and destabilise banks. Managing carp populations can reduce the threat of soil disturbance. *Refer to management strategies and actions to reduce the threat of invasive fauna (aquatic).*
	Control invasive fauna (terrestrial)	Med-High	1-3	Several invasive terrestrial species can create significant soil disturbance. Eradicating or reducing populations of invasive terrestrial fauna will help prevent soil disturbance in the wetland. *Refer to management strategies and activities to reduce the threat of invasive fauna (terrestrial).*
	Control human access	High	1	Driving vehicles or walking in the wetland, particularly when the soil is wet can cause significant soil disturbance. Providing board walks, boat ramps, vehicle tracks, and access paths can limit soil disturbance created by human access for recreational purposes.
	Prevent or minimise earthworks	High	1	Earthworks create significant soil disturbance in the wetland. Where earthworks must be carried out in the wetland the impacted area should be minimised as much as practical and where ever possible the work should be undertaken when the sediments are dry.

(continued next page)

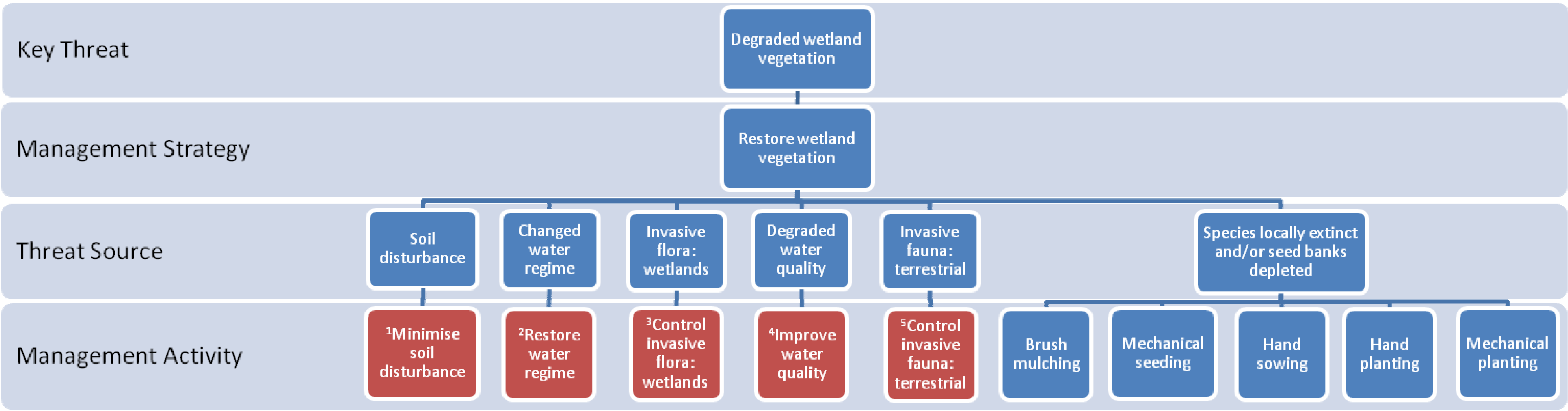
Description: soil disturbance (continued)

Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Restore wetland vegetation	Restore wetland vegetation	Low-High	1-3	Where soil disturbance has significantly degraded wetland vegetation, then revegetation may be required. Further disturbance to the soil should be prevented or minimised, other processes that degrade wetland vegetation managed, and/or direct seeding or planting undertaken. *Refer to management strategies and activities to reduce the threat of degraded wetland vegetation.*

Potential risks associated with management interventions

When assessing the suitability of a management activity to reduce the level of a threat to wetland values a thorough assessment of all potential risks associated with the management activity must be carried out. The types of risks that should be considered are described in the methods (see pages 10-11).

Management strategies and activities to reduce the threat of degraded wetland vegetation



Text boxes coloured red indicate that the management activities are described in another model as indicated by the superscript.

[1]Refer to management strategies and activities to reduce the threat of soil disturbance
[2]Refer to management strategies and activities to reduce the threat of changed water regime
[3]Refer to management strategies and activities to reduce the threat of invasive flora: wetlands
[4]Refer to management strategies and activities to reduce the threat of degraded water quality: salinity, nutrients, turbidity, acid sulfate soils
[5]Refer to management strategies and activities to reduce the threat of invasive faunal: terrestrial

Description: degraded wetland vegetation

Degraded wetland vegetation refers to a reduction in the condition of vegetation compared with an undisturbed system of the same vegetation type (IWC 2010). The condition of vegetation is described in terms of critical life form grouping, weeds, indicators of altered processes and vegetation structure and health. Changes in these attributes may be caused by changed water regime, degraded water quality, soil disturbance and invasive species. Reducing these threats can enable wetland vegetation to recover, but where species have become local extinct, or the seed bank is depleted revegetation will be needed.

KEY: Effectiveness is the expected level of threat reduction that will be achieved by a management intervention and is scored as: Low, a small reduction in the level of the threat; Med, a moderate reduction in the level of the threat which will not always be consistent; and high, a significant and consistent reduction in the level of the threat. Response times represent the period of time before a management activity is expected to eliminate or reduce the level of a threat and are scored as: 1, less than 1 year; 2, 1 -6 years; and 3, > 6 years.

Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Restore wetland vegetation	Minimise soil disturbance	Med-High	1-2	Natural regeneration is likely to be impaired when soil disturbance occurs. *Refer to management strategies and actions to reduce the threat of soil disturbance.*
	Manage livestock grazing	Med	1	Livestock can potentially degrade native wetland vegetation by: (1) consuming and trampling native plants; (2) creating soil disturbance which disrupts soil seed banks and alters the microtopography of the wetland; (3) increasing nutrient levels in the wetland (through inputs of dung and urine) which can alter competitive interactions among species and lead to compositional change; (4) transporting seeds and vegetative fragments of invasive species into the wetland and creating gaps in vegetation cover which increase the likelihood that invasive species will establish in the wetland. Managing livestock grazing by restricting the area, timing, frequency and/or intensity of livestock can minimise adverse effects on the wetland vegetation. As soil disturbance is greatest when the soil is wet livestock access to the wetland should be avoided during these periods. To promote the regeneration of native aquatic flora, livestock access should be avoided when native species are flowering and setting seed. Soil disturbance by livestock can also be limited by restricting access to specific watering points in the wetland. This can be achieved by installing fencing, or by placing watering troughs on higher ground. Reducing the number of livestock in the wetland will reduce the level of soil disturbance. Stocking rates can be manipulated by varying the number, duration and frequency that livestock access the wetland.
	Restore water regime	Med-High	1-3	Natural regeneration is likely to be impaired when the natural water regime is not maintained. *Refer to management strategies and actions to reduce the threat of changed water regime.*
	Control invasive flora: wetland	Med-High	1-2	Natural regeneration is likely to be impaired when invasive flora are not controlled. *Refer to management strategies and actions to reduce the threat of invasive flora (wetland).*
	Improve water quality	Med-High	1-2	Natural regeneration of is likely to be impaired by poor water quality such as high levels of salinity, nutrient, turbidity and/or acidification. *Refer to management strategies and activities to reduce the threat of degraded water quality (salinity, nutrients, turbidity) and to formation and activation of acid sulfate soils.*
	Control invasive fauna: terrestrial	Med-High	1-3	Natural regeneration will be impaired when invasive terrestrial fauna are not controlled. *Refer to management strategies and activities to reduce the threat of invasive fauna (terrestrial).*

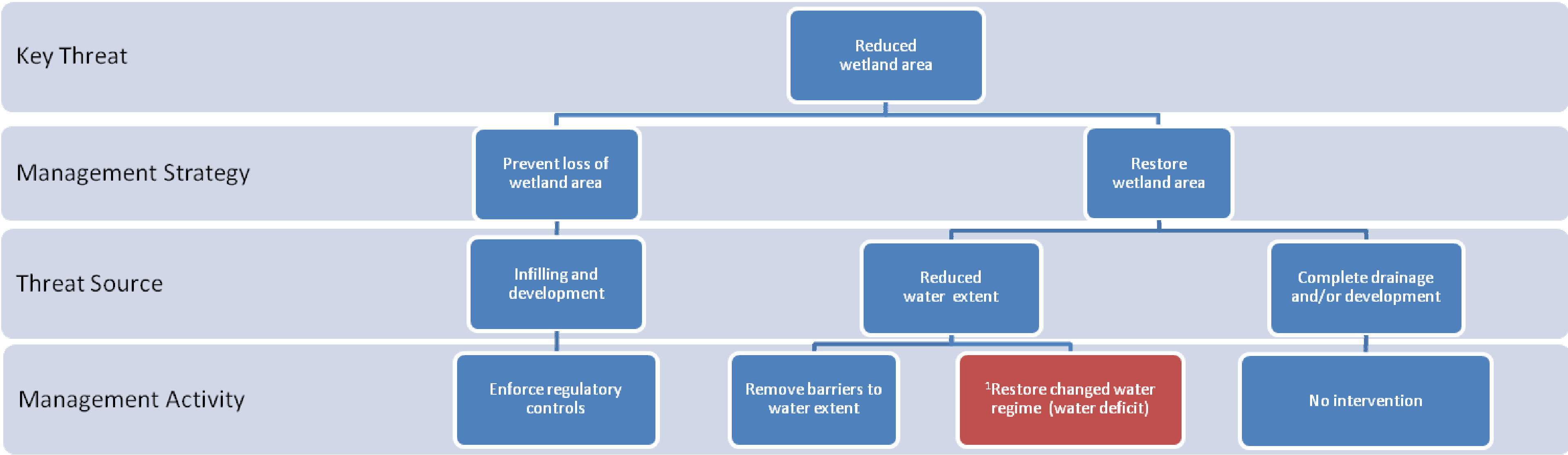
Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Restore wetland vegetation	Brush mulching	Med	1	Brush mulching involves placing cut branches of trees and shrubs with ripe fruit on the revegetation site. Cut branches and shrubs improve establishment success as they help to reduce erosion and trap sediment, litter and seed. The approach is best suited to revegetating small patches within a site.
	Hand sowing	Low-Med	1	Two hand sowing approaches are used: (i) broadcast seeding and (ii) niche seeding. Broadcast seeding is used to distribute seeds over large areas and involves throwing seeds over prepared soil. Niche seeding is used to seed small areas under existing vegetation and involves placing seeds on prepared soil[1].
	Mechanical seeding	Low-Med	1	Mechanical seeders are used for sowing seed over large areas. A variety of seeding machines are available. Mechanical seeders scrape the soil to remove weed seeds in the soil before cutting a slot in the soil in which seeds are deposited. Some mechanical seeders also deliver water and fertilisers[1].
	Hydro mulching	Med-High	1	Hydro-mulching is where seeds are mixed with mulch, water and fertiliser to form slurry which is sprayed on the area[1].
	Hand planting	Med-High	1	Hand planting is where tube stock is planted by hand or with simple instruments (e.g. mattock, hamilton planter)[1]
	Mechanical planting	Med-High	1	Mechanical planters are used for planting tube stock over large areas[1]

[1]A comprehensive account of planting methods can be found at http://www.florabank.org.au/

Potential risks associated with management interventions

When assessing the suitability of a management activity to reduce the level of a threat to wetland values a thorough assessment of all potential risks associated with the management activity must be carried out. The types of risks that should be considered are described in the methods (see pages 10-11).

Management strategies and activities to reduce the threat of reduced wetland area



Text boxes coloured red indicate that the management activities are described in another model as indicated by the superscript.

[1]Refer to management strategies and activities to reduce the threat of changed water regime (water deficit)

Description: reduced wetland area

Wetland area can be reduced when it is completely or partially converted to dry land through infilling or drainage, or when levee banks or water diversions prevent water reaching areas of the wetland that would normally experience inundation. A reduction in the area of a wetland reduces the availability of habitat for aquatic organisms and can lead to a reduction in population size or in the local extinction of species. Reduced wetland area can also alter the water regime (unless there is a comparable reduction in water inputs) and this can drive changes in wetland biota and alter ecological processes such as nutrient cycling and decomposition.

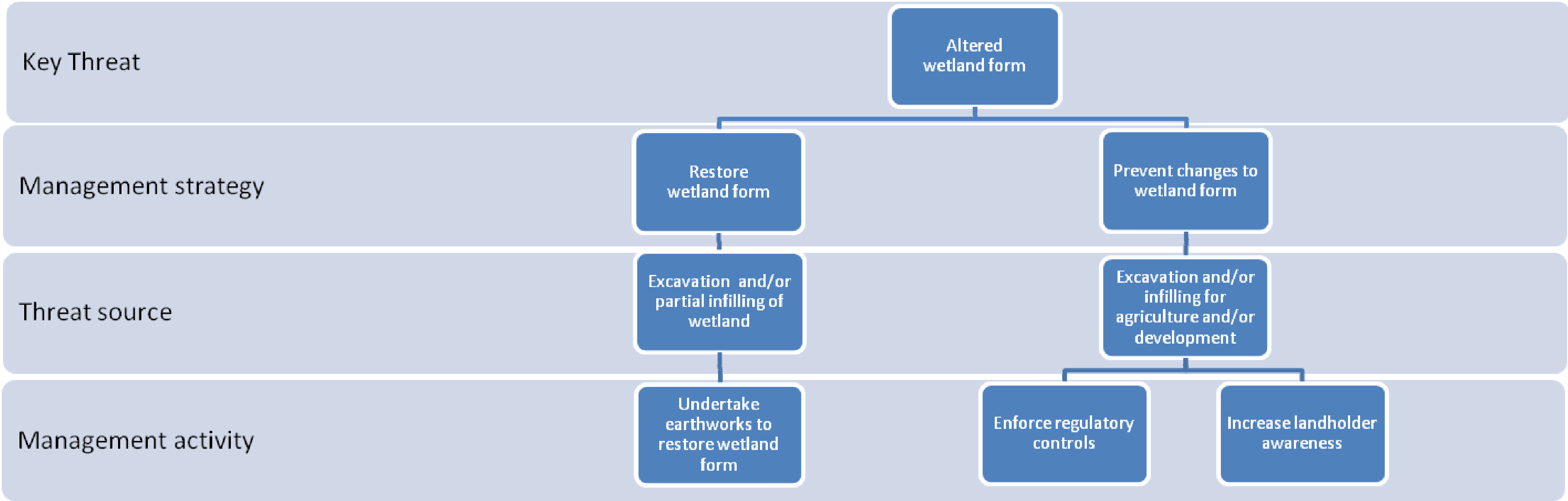
KEY: Effectiveness is the expected level of threat reduction that will be achieved by a management intervention and is scored as: Low, a small reduction in the level of the threat; Med, a moderate reduction in the level of the threat which will not always be consistent; and high, a significant and consistent reduction in the level of the threat. Response times represent the period of time before a management activity is expected to eliminate or reduce the level of a threat and are scored as: 1, less than 1 year; 2, 1 -6 years; and 3, > 6 years.

Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Prevent loss of wetland area	Apply and enforce regulatory controls	High	1	Wetland area can be lost by infilling and/or drainage for development or agriculture production. Preventing a reduction in wetland area can be achieved by applying planning controls such as new schedules to the Environmental Significance Overlay (ES0) and by enforcing existing regulatory controls (e.g. existing schedules to the ESO or the *Ministerial guidelines for assessment of environmental effects under the Environmental Effects Act 1978*).
Restore wetland area	Remove barriers to water extent	High	1	Remove channels, drains or levees that prevent water reaching areas of the wetland that would normally be inundated. Controlling invasive plants that obstruct and/alter the natural flow of water into and within the wetland.
	Restore changed water regime (water deficit)	Med-High	1-2	A change in the water regime caused by a reduction in water inputs can reduce the functional area of the wetlands when water no longer reaches areas of the wetland that would normally be inundated. *Refer to management strategies and action to reduce the threat of changed water regime (water deficit).*
	No intervention	None	Not applicable	In cases where the wetland has been permanently drained and the land developed it may not be possible to restore the natural wetland area.

Potential risks associated with management interventions

When assessing the suitability of a management activity to reduce the level of a threat to wetland values a thorough assessment of all potential risks associated with the management activity must be carried out. The types of risks that should be considered are described in the methods (see pages 10-11).

Management strategies and activities to reduce the threat of altered wetland form



Description: altered wetland form

Altered wetland form is where the natural bathymetry (underwater topography), depth, shape and/or size of the wetland is altered (DSE 2006). These physical attributes of the wetland influence the depth and duration of inundation which in turn influence the flora and fauna communities present and biological processes (e.g. nutrient cycling and decomposition).

KEY: Effectiveness is the expected level of threat reduction that will be achieved by a management intervention and is scored as: Low, a small reduction in the level of the threat; Med, a moderate reduction in the level of the threat which will not always be consistent; and high, a significant and consistent reduction in the level of the threat. Response times represent the period of time before a management activity is expected to eliminate or reduce the level of a threat and are scored as: 1, less than 1 year; 2, 1 -6 years; and 3, > 6 years.

Management Strategy	Management Activity	Effectiveness	Response Time	Rationale
Restore wetland form	Undertake earthworks to restore natural bathymetry	High	1	Where wetlands have been deepened for water storage, earthworks may be needed to restore the natural bathymetry of the wetland.
Prevent further changes to wetland form	Enforce regulatory controls	High	1	Wetland form may be altered to permit agriculture. Preventing changes to the natural form of the wetland can be achieved by applying planning controls such as new schedules to the Environmental Significance Overlay (ES0) and by enforcing existing regulatory controls (e.g. existing schedules to the ESO or the *Ministerial guidelines for assessment of environmental effects under the Environmental Effects Act 1978*).
	Increase landholder awareness	Med-High	1-2	Landowners may deepen the wetland to improve water storage or they may divert water from areas of the wetland to permit grazing or agricultural production. Landowners that understand the value of wetlands and the impact of altered wetland form on wetland value may be less likely to change the form of the wetland.

Potential risks associated with management interventions

When assessing the suitability of a management activity to reduce the level of a threat to wetland values a thorough assessment of all potential risks associated with the management activity must be carried out. The types of risks that should be considered are described in the methods (see pages 10-11).

3.3 Discussion

All management activities to reduce wetland threats that are identified in the models are also listed in Appendix 2. Management activities were developed to address individual threats, and as such few are applicable across multiple threats. The effectiveness of most management activities were scored as moderate to high (Appendix 2). The least effective included activities to control invasive species or restore vegetation. Management activities that were considered most effective generally had short response times. Activities with long response times (> 6 yrs) included catchment scale initiatives, managing groundwater and activities to raise public awareness.

Limitations: Assessments of the effectiveness of management interventions to reduce the level of a threat, and response times, have been based on limited expert opinion. A robust examination of the scientific literature and government and consultant reports, as well as a more comprehensive evaluation by natural resource managers is need to increase confidence in the current assessments. Assessing the effectiveness of management interventions and response times proved difficult, and in many cases a range of values were assigned. This was necessary to reflect either the spectrum of threat agents represented by a threat category (e.g. invasive flora encompasses a large number of species with differing responses to management activities) or variation in the level of the threat. Although it is expected that management activities directed at mitigating a threat will improve wetland values (based on threat-value associations), this may not be sufficient in systems where the threat has already caused significant impacts. At these sites active restoration of the site may be needed in addition to threat mitigation to improve wetland values.

4 Recommendations

This report represents the first attempt to document the strength of association between wetland threats and values and to provide a framework for identifying management activities to reduce threats. While this report provides a valuable resource to managers, there are a number of limitations to the current approach and it is anticipated that they will be addressed in future revisions to this document. Current limitations include the following.

- Confidence in the association between threats and social and economic values were not evaluated; this work will need to be undertaken in the future.
- Confidence in the effectiveness of management activities to mitigate threats has not been assessed and this should be prioritised in subsequent revisions.
- The threats and values indentified in AVIRA may warrant revision in the future to address the following points.
    - Some threats and values are too broad to provide meaningful association and confidence ratings. For example, significant flora and fauna, and invasive flora and fauna encompass a diverse range of taxa. Similarly, degraded water quality represents a range of water quality variables (nutrients, salinity, turbidity, pH, phytoplankton, dissolved oxygen, heavy metals, pesticides, herbicides and other contaminants). In future revisions, threat-value associations for the values, significant flora and fauna, and for the threats, invasive fauna (aquatic, and terrestrial) and flora (wetland) should be assessed using key species and species groupings (based on similar habitat requirements and water regimes). Similarly, threat-value assessments should be made for each water quality variable.
    - Wetland vegetation condition is not appropriate terminology for a wetland value. The value of naturalness should represent all aspects of wetland condition not just vegetation.

  - The threat *disturbance of acid sulfate soils* is an inappropriate term as there are two threats association with ASS: formation and activation. A more appropriate term would be formation and activation of ASS as adopted in the threat-management intervention models.

- The potential risks associated with implementing management activities to reduce the level of a threat are not described and will need to be developed in the future.
- Selecting effective management activities using the threat-management intervention models rely on the accurate identification of the source(s) of a particular threat. There is currently no guidance on how to identify the source(s) of a particular threat and this should be addressed in subsequent revisions.
- The AVIRA process is based on the premise that a reduction in the level of a threat will improve wetland values impacted by the threat. Although this is true, there may be cases where the condition of the wetland component is improved (threat level reduced) by the management activity but this does not result in the improvement in the value. For example, management activities may improve degraded wetland vegetation but significant fauna species that depend on this improved vegetation may have become locally extinct and fail to re-colonise the wetland. Where this occurs additional management activities may need to be directed at restoring the values rather than reducing the threat. These have not been covered in the threat-management intervention models and should be considered in future work.

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Appendix 1. Threat-value associations for wetlands

KEY: The association represents the influence that a threat has on a value and is scored as follows: Low, the threat does not impact the value but it is remotely possible; Medium, the threat may impact the value; High, the threat always or often impacts the value. Confidence represents the level of evidence that is available to support the association rating and is scored as follows: Low, the association is based only on expert opinion; Moderate, at least one peer reviewed research publications supports the association assessment; High, multiple peer reviewed research publications support the association assessment.

Attribute	Threat	Association	Confidence	Explanation
Significant fauna (fish)	Changed water regime	High	High	The frequency of drying influences the probability of fish being present (Baber et al. 2002). Fish require a minimum water depth 1.5 times their body depth to swim and therefore water depth will influence the suitability of a wetland for large fish (Lucus and Baras 2001). Water regime can influence spawning in some fish species (Drew 2008). Beesley et al. 2011 "Environmental watering increases the abundance of the total fish community (all species considered together) within wetlands, by increasing the abundance of fish in their first year of life (larval and recruit fish)." The greatest threat to Murray Hardyhead (*Craterocephalus fluviatilis*) population are reduced water levels (Backhouse et al. 2008)
	Reduced wetland area	High	High	Direct effects through loss of habitat (Drew 2008). The key threat to Murray Hardyhead (*Craterocephalus fluviatilis*) is habitat loss due to lack of water (Backhouse et al. 2008). Snodgrass et al. (1996) found no correlation between wetland size and fish in coastal plains wetlands and attributed this to the system being subject to frequent disturbances. When the level of disturbance is high, rates of colonisation are the dominant influence on fish community assemblages. In contrast, in more stable systems biotic interaction shape community assemblages and habitat complexity and hence size is more strongly correlated with community assemblages. Lakes are hydrologically more stable and size is correlated with species richness (Barbour and Brown 1974). A reduction in total wetland area across the landscape will likely have an effect on fish.
	Altered wetland form	High	High	Assessment based on the impact of altered wetland form on water regime. The association rating is therefore the same as reported for altered water regime.
	Degraded water quality	High	High	Numerous reports on the impact of water quality on individual species, including some significant species (see reviews by Koehn and O'Connor, 1990; Drew 2008). "Reduced abundance of large-bodied native species, such as Murray Cod, Trout Cod, Silver Perch and Golden Perch at sites affected by blackwater compared to unaffected sites." (King et al. 2011).

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Significant fauna (fish)	Disturbance of acid sulfate soils	High	High	"Acidified waters injure or kill aquatic organisms by causing lesions in gills and skin, disrupting gas exchange as well as acid-base and osmoregulatory mechanisms" (Kingsford et al. 2011, Callinan et al. 2005, Sammut et al. 1995). Low-pH waters and metals can also disrupt calcium mineralisation (Kingsford et al. 2011). High concentrations of monomeric aluminium produced by acidification is a major cause of fish injury or death (Driscoll et al. 1980, Sammut et al. 1995). Multiple reports of fish kills due to stream acidification resulting from drainage from oxidised sulfidic sediment (Sammut et al. 1996 and references within). Acidification, high metal concentration and salinity were associated with a large carp kill (*Cyprinus carpio*) and a pronounced reduction in fish diversity in Bottle Bend Lagoon (McCarthy et al. 2006).
	Soil disturbance	Medium	Low	Soil disturbance can affect fish populations when it suspends sediment particles or when sediments settle and coat benthic organisms and surfaces. While there is little evidence of direct effects of increased sediments on fish populations, negative effects are likely to occur by: i) clogging gills and limiting oxygen uptake; ii) loss of suitable habitat for spawning in fish that need silt free surfaces to attach adhesive eggs , iii) coating of fish eggs may reduce oxygen exchange and affect viability or development; iii) reduced feeding efficiency in visual feeders; iii) limiting diet by impact of sediments on algae, macrophytes and benthic invertebrate (Metzeling et al. 1995, Clunie and Koehn 2001). Soil disturbance in wetlands during the drying phase may destroy desiccation resistant eggs.
	Invasive flora (wetland)	High	High	Arthington et al. (1983) found native fish species with a preferences for open water and aquatic macrophyte beds declined in creeks overgrown by floating plants and para grass (*Urochloamutica* (Forssk.), an exotic perennial grass. Species affected included *Melanotaenia fluviatis* and *Craterocephalus stercusmuscarum*. Drew (2008) identifies aquatic weeds as a threat to the quality of fish habitats. High algal biomass and/or thick mats of floating plants (native and exotic) that cover a high proportion of the water surface can lower dissolved oxygen levels in the water column, particularly in productive systems (Janes et al. 1996, Morris et al. 2003) with potential impacts on fish populations. The abundance, diversity and size of fish were found to be reduced in a hypoxic wetland reach with high cover of floating plants compared with a more oxygenated wetland reach with lower vegetation cover (Killgore and Hoover 2000).
	Invasive fauna (terrestrial)	Medium	Low	Association rating based on impact of threat on water quality and habitat through physical disturbance and faecal inputs.

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Significant fauna (fish) (cont.)	Invasive fauna (aquatic)	High	High	Multiple reports and reviews demonstrate that exotic fish impact on native fish populations (including significant species) through predation or competition for food and space (Arthington and McKenzie 1997, Rowe et al. 2008; Closs et al. 2006, Drew 2008). Negative impacts of exotic redfin perch and tench in billabongs of Murray Darling Basin (Cadwallader 1977) and carp and goldfish in permanent billabongs (Closs et al. 2006 and refs within).
Significant fauna (birds)	Changed water regime	High	High	Floods trigger breeding in many species and wetland systems that are flooded after a dry period support high numbers of waterbirds compared to permanently flooded sites (Kingsford and Norman 2002, Kingsford and Auld 2005, Scott 1997). A review by Scott (1997) reports that Ciconiiformes and Pelecaniformes require spring-summer floods of 5-7 months for successful breeding. Colonial nesting waterbirds including Egrets and Ibis abandon nest sites in response to sudden falls in water level (Scott 1997). Significant species occur in each of these groups.
	Reduced wetland area	High	High	Direct effects through habitat loss. Negative effects will also occur through reduction in size of individual wetlands as there is good evidence of a positive relationship between wetland or lake area and waterbird species richness (Brown and Dinsmore 1986, Hoyer and Canfield 1990, Celada and Bogliani 1993, Baldassarre and Bolen 1994, Hoyer and Canfield 1994). A reduction in total wetland area across the landscape will likely have an effect on birds.
	Altered wetland form	Medium	Low	Association rating based on the impact of the threat on food resources
	Degraded water quality	Low	Medium	Avian botulism can kill thousands of birds, Rocke (1999) found that the risk of botulism outbreaks in North American wetlands declined when redox potential increased (>100), water temperature decreased (10-15°C), pH was <7.5 or >9.0, or salinity was low (<2.0 ppt). Poor water quality may impact on waterbirds indirectly by affecting their food resources.
	Disturbance of acid sulfate soils	High	High	Association rating based on the expected impact of the threat on food resources and the quality of water for consumption. Confidence ratings are based on evidence for the effect of the threat on food resources (fish, vegetation) and water quality. Increases in salinity associated with the development of acid sulfate soils reduced populations of waterbirds (Kingsford et al. 2011)
	Soil disturbance	Low	Low	Association rating based on the impact of the threat on food resources.
	Invasive flora (wetland)	Low	Low	Association rating based on the impact of the threat on food resources and habitat

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Significant fauna (birds)	Invasive fauna (terrestrial)	High	Medium	Several waterbird species may be adversely affected by European red fox (*Vulpes vulpes*) some of which are listed at threatened in Victoria including: Australasian bittern (*Botaurus poiciloptilus*), Lesser sand plover (*Charadrius mongolus*), Lathan's snipe (*Gallinago hardwickii*), White-bellied sea eagle (*Haliaeetus leucogaster*), Black faced cormorant (*Phalacrocorax fuscescens*), Hooded plover (*Thinornis rubricollis*) (DEWHA 2008a). Predation of Brolga (*Grus rubicundus*) eggs and chicks by European red fox (*Vulpes vulpes*) also been reported (DSE 2003a FFG Action Statement 119). Feral cats are known to adversely affect a large number of birds and although there are no threatened Victorian waterbirds currently listed as threatened by feral cats the list is not considered comprehensive (DEWHA 2008b). Bird species most susceptible to predation by feral cats are those that are: < 200 g body weight, utilise habitats with open vegetation, aggregate in large groups for feeding or reproduction and produce <1 young per female per year (Dickman 1996).
	Invasive fauna (aquatic)	Medium	Low	Association rating based on the effect exotic wetland fauna may have on food resources. Braithwaite et al. (1989) reports that weed invasion in northern Australian sedgelands had a negative impact on birds.
Significant fauna (amphibians)	Changed water regime	High	High	Snodgrass et al. (2000) found a significant positive relationship between amphibian diversity and duration of inundation. The relationship between duration of inundation and diversity was not linear as several wetlands with long hydro-period also contained fish populations and had lower amphibian species richness. Species showed preferences for different hydro-periods indicating the importance of preserving wetlands representing the entire spectrum of the hydroperiods.
	Reduced wetland area	High	High	Hecnar and M'Closky (1997) found no relationship between pond size and amphibian species richness among 97 Canadian ponds. Similarly Snodgrass et al. (2000) found no relationship found between wetland size and amphibian species richness in 22 U.S. coastal plains wetlands. Although the size of individual wetlands has minimal effect of amphibian species richness a reduction in wetland area is likely to reduce abundance with implications for population persistence. A reduction in total wetland area across the landscape is likely to have a strong negative effect on amphibian diversity, abundance and regional population persistence.

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Significant fauna (amphibians)	Altered wetland form	High	Low	Amphibians utilise a range of microhabitats, from deep water areas to shallow vegetated zones (Watson et al. 2003). Areas of deep water enable frogs to avoid avian predators, and shallow vegetated areas provide foraging sites and refuge from predatory fish. Changes to wetland form that results in a loss in these microhabitats will impact on amphibian populations.
	Degraded water quality	High	High	Numerous studies and reviews show impacts of degraded water quality on a range of frog species (see review by Boyer and Grue 1995) and responses are likely to extend to significant frog species. Surveys conducted in north-west Victoria indicate low probability of frogs in wetland where salinities are >2400 mg/L (Smith et al. 2009). Low concentration of insecticides and pesticides can impact on amphibians (Relyea 2005 2009).
	Disturbance of acid sulfate soils	High	Medium	Direct impacts expected due to effects of low pH, increased metal concentration, salinity and depletion of dissolved oxygen in the water column. Indirect effect due to impact on food resources and vegetation structure.
	Soil disturbance	High	Medium	Jansen and Healey (2003) report a decline in species richness and populations of some species with increasing grazing intensity, probably mediated through reduced condition of wetland vegetation. Vegetation influences the abundance of prey species and help amphibians to maintain thermal regulation and avoid predation. A high proportion of vegetation cover has been associated with high amphibian species diversity (Ficetola and Bernardi 2004, Hazell et al. 2004, Hazell et al. 2001). Growling Grass Frogs favour sites with a high proportion of emergent vegetation (Clemann and Gillespie 2010). Green and Golden Bell Frogs prefer sites with certain plant species that are used for basking and foraging (e.g. *Juncus krasussi*) (Goldingay 2008). These studies suggest that soil disturbance that results in changes in the cover of aquatic and/or adjacent terrestrial vegetation cover will exert negative impacts on amphibian populations.
	Invasive flora (wetland)	Medium	Low	Exotic wetland flora will exert adverse effect when invasions reduce habitat complexity or the abundance of key native species. Habitat complexity can assist amphibians to thermoregulate by providing basking spots and shaded area as well as cover from predators. Green and Golden Bell Frogs prefer sites with certain plant species that are used for basking and foraging (e.g. *Juncus kraussii*) (Goldingay 2008).

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Significant fauna (amphibians)	Invasive fauna (terrestrial)	High	Medium	Feral cats (*Felis catus*) and European red fox (*Vulpes vulpes*) adversely affect several significant amphibian species. Feral cats adversely affect: Giant Burrowing Frog (*Heleioporus australiacus*), Green and Golden Bell Frog (*Litoria aurea*) and Baw Baw Frog (*Philoria frosti*) (DEWHA 2008b). European red fox adversely affects Giant Burrowing Frog (*Heleioporus australiacus*) and Green and Golden Bell Frog (*Litoria aurea*) (DEWHA 2008a). Deer and pigs impact on fringing vegetation which provide shelter and over winter sites for amphibians.
	Invasive fauna (aquatic)	High	High	Both Australian native and invasive fish species predate amphibian larvae and tadpoles (Gillespie 2001). Susceptibility to predation by Gambusia (*Gambusia holbrooki*) has been reported for a range of amphibians (Harris 1995, Morgan and Buttemer 1996, Komak and Crossland 2000, and reviewed by Rowe et al. 2008). In Australia, Trout (Gillespie 2001) and Gambusia (Webb and Joss 1997, Healey 1998) are documented to predate tadpoles. Predation by Gambusia can be selective with tadpoles of *Limnodynastes ornatus* preferred over those of the introduced *Bufo-marinus*. Regression analysis showed a negative relationship between the density of Gambusia and frogs abundance (Webb and Joss 1997). A US study found numbers of the amphibian *Rana muscosa* to increase significantly following removal of non-native fish compared with populations in fishless lakes (Knapp et al. 2007). It is unclear if predation by invasive fish species is greater than by native fish.
Significant fauna (invertebrates)	Changed water regime	High	Medium	Western swamp crayfish (*Gramastacus insolitus*) is confined to permanent freshwater swamps and will be impacted by changes to the permanency of water bodies (DSE 2003b, FFG Action Statement). Hemiphlebia damselfly (*Hemiphlebia mirabilis*) are thought to insert their eggs inside aquatic vegetation (DSE 2003c, FFG Action Statement 46) and changes in the water regime that reduce the prevalence of vegetation may impact on this species.
	Reduced wetland area	High	Low	Direct effects through habitat loss.
	Altered wetland form	High	Medium	Assessment based on the impact of altered wetland form on water regime, and the association rating is therefore the same as reported for altered water regime.

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Significant fauna (invertebrates)	Degraded water quality	High	High	Low concentrations of insecticides and pesticides can impact on invertebrates (Relyea 2009). Decapod crustaceans are very sensitivity to certain pesticides (Davies et al. 1994) and it is expected that the Western Swamp Crayfish (*Gramastacus insolitus*) which doesn't burrow would be very vulnerable to exposure to pesticides (Doran and Richards 1996, DSE 2003b Action Statement). Invertebrates are among the most sensitive biota to increasing salinity and adverse effects are expected when salinities reach around 1000 mg/L (Hart et al. 1991). Sub-lethal and indirect effects however may occur at lower levels of salinity (Hart et al. 1991). Emergence from the water and death of some crustaceans has been reported in response to extremely low dissolved oxygen levels in the water column (King et al. 2011, McKinnon 1995). Field based studies demonstrate that high levels of suspended sediments (SS) reduce the density of sensitive taxa such as mayflies and caddisflies (Suren et al. 2005). High levels of SS can reduce invertebrate populations by: abrading gill structures, reducing feeding efficiency, smothering food sources and reducing habitat availability by filling in interstitial spaces (see references in Suren et al. 2005). Short-term experimental exposure to SS did not alter mortality of five New Zealand invertebrate species and one crayfish species suggesting that the key effects of SS on invertebrates may be indirect through modification of habitat and effects of food resources (Suren et al. 2005).
	Disturbance of acid sulfate soils	High	High	"Acidified waters kill aquatic organisms by damaging their gills and disrupting gas exchange and osmoregulatory processes. Low pH waters and higher metal levels also disrupt calcium mineralisation (Kingsford et al. 2011). Oxygen depletion and increased salinity associated with acid sulfate soils will also exert negative impact on invertebrates. Confidence ratings based on reports of the effect of acid sulfate soils on habitat and food resources, other aquatic organisms and water quality.
	Soil disturbance	High	Low	Trampling by grazing animals may damage or disturb soil based propagule banks.

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Significant fauna (invertebrates)	Invasive flora (wetland)	Medium	Medium	The invasive ponded pasture grass Olive Hymenachne (*Hymenachne amplexicaulis*) was found to reduce the abundance of Ephemeroptera (mayflies), Hemiptera (true bugs) and Odonata (dragonflies and damselflies) but to increase the abundance of Coleoptera (beetles and weevils) (Houston and Duivenvoorden, 2002). Reed sweet-grass *Glyceria maxima*), also a ponded pasture grass, was found to reduce macroinvertebrate diversity and functional feeding groups (Clarke et al. 2004). A U.S study by Toft et al. (2003) found invertebrate community assemblages to differ between Water Hyacinth (*Echhornia crassapes*) an introduced floating plant, and the native pennywort (*Hydrocotyle umbellata*) which occupy similar niches. A native amphipod prevalent in the diet of native fish was abundant on the native pennywort, whereas a non-indigenous amphipod which was not preyed upon by native fish was abundant on Water Hyacinth. These studies demonstrate the weed invasion can exert effect on invertebrate assemblages that have implications for food web dynamics. Some studies have failed to identify differences in invertebrate abundance or diversity between native and exotic macrophytes (Papas 2007).
	Invasive fauna (terrestrial)	Low	Low	Feral pigs, deer and rabbits are likely to impact on water quality and/or create habitat disturbance with secondary impacts on invertebrates.
	Invasive fauna (aquatic)	Medium	Medium	Aquatic invertebrates are the principal food source for Gambusia (Rowe et al. 2008). Carp impacts will be associated with habitat disturbance (disturbance of soil and removal of aquatic vegetation) with secondary impacts on invertebrates.
Significant aquatic fauna (reptiles)	Changed water regime	High	Low	Altered water regimes may adversely affect population of Broad-shelled turtles by reducing the abundance of key prey species (fish and amphibians).
	Reduced wetland area	High	Low	Direct effects through habitat loss. A reduction in total wetland area across the landscape will likely have an effect on aquatic reptile populations.
	Altered wetland form	Medium	Low	Rating based on the impact of the threat on their prey.
	Degraded water quality	Medium	Low	High level of suspended-sediments may reduce the ability of Broad-shelled turtles (*Chelodina expansa*) to visually detect prey. Reduced water quality may also alter food web structure and limit the abundance of preferred prey species.
	Disturbance of acid sulfate soils	High	High	Direct impacts expected through exposure to hazardous substances (low pH, metals, salinity, hydrogen sulfide gas) depleted dissolved oxygen levels and hydrogen sulfide gas. Indirect effects through impact on food resources (invertebrates, amphibians) and changes in habitat structure through loss of vegetation.

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Significant aquatic fauna (reptiles) (cont.)	Soil disturbance	Medium	Low	Soil disturbance may affect the Broad-shelled turtle (*Chelodina expansa*) when it suspends sediment particles which can reduce water clarity and lower predation success. Soil disturbance by livestock may damage buried eggs or compact the soil making it difficult for hatchlings to emerge.
	Invasive flora (wetland)	Low	Low	Exotic wetland flora will exert adverse effect when it displaces a significant amount of native wetland flora which is important for the persistence of prey species (e.g. amphibians, fish, insects).
	Invasive fauna (terrestrial)	High	High	Significant levels of nest predation on Australian freshwater turtles by the introduced European red fox (*Vulpes vulpes*) have been experimentally demonstrated through fox exclusion studies (Spencer 2002, Spencer and Thompson 2004). Predation on Broad-shelled turtle (*Chelodina expansa*) nests varied from 50-70% in sites with foxes but fell to 18-38% after foxes were removed (Spencer and Thompson 2004).
	Invasive fauna (aquatic)	Medium	Low	Carp suspend sediment which may affect the ability of Broad-shelled turtles to visually detect prey. Increases in the population of introduced fish which results in the decline of preferred prey species may also affect populations.
Significant riparian fauna (reptiles)	Changed water regime	High	Medium	Negative impacts may be mediated through effects of altered water regime on habitat availability and food resources. River Red Gum forests provide key habitat for the threatened Inland Carpet Python (*Morelia spilota metcalfei*) (DSE 203d, FFG Action Statement 175).
	Reduced wetland area	High	Low	Direct effects through loss of habitat.
	Altered wetland form	Low	Low	Assessment rating based on impact of threat on food resources (invertebrates, amphibians). See associations for invertebrates and amphibians.
	Degraded water quality	Medium	Low	Assessment rating based on impact of threat on food resources (invertebrates, amphibians). See associations for invertebrates and amphibians.
	Disturbance of acid sulfate soils	High	Medium	Assessment rating based on impact of threat on food resources (invertebrates, amphibians), changes in habitat structure through loss of vegetation, and direct effects through exposure to hazardous substances (low pH , metals, hydrogen sulfide gas), increases in salinity or depleted levels of dissolved oxygen.
	Soil disturbance	High	Low	Soil disturbance created by pigs and deer can exert strong effects when it results in a significant loss of vegetation and or habitat complexity which reptiles rely on for thermoregulation and prey avoidance. Where the capacity to thermoregulate is compromised, breeding, foraging and prey avoidance capacity will be impacted.

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Significant riparian fauna (reptiles) (cont.)	Invasive flora (wetland)	High	Medium	Braithwaite et al. (1989) reports that weed invasion of northern Australian sedgelands exert negative effects on lizards. Exotic flora may exert adverse effects when it displaces wetland flora that provide habitat for prey species (e.g. amphibians and insects). Where exotic flora reduces habitat heterogeneity it will impact on the capacity of reptiles to thermoregulate with consequences for breeding, foraging and prey avoidance.
	Invasive fauna (terrestrial)	High	High	European red fox (*Vulpes vulpes*) and feral cats (*Felis catus*) prey on the threatened Inland Carpet Python (*Morelia spilota metcalfei*) as they are slow moving and non-venomous (DSE 2003d, FFG Action Statement 175) as well as the Corangamite water skink (*Eulamprus tympanum marnieae*) (DEWHA 2008a,b) In contrast, rabbits are an important prey item for the Inland Carpet Python, comprising 50-80 % of their diet in Victoria (DSE 2003d, FFG Action Statement 175).
	Invasive fauna (aquatic)	None	Low	
Significant fauna (mammals)	Changed water regime	Medium	Low	Association rating based on impact of threat on food resources (fish and invertebrates) and roosting habitat (e.g. tree hollows).
	Reduced wetland area	Medium	Low	Association rating based on impact of threat on food resources (fish and invertebrates) and roosting habitat (e.g. tree hollows).
	Altered wetland form	Low	Low	Association rating based on impact of threat on food resources (fish and invertebrates) and roosting habitat (e.g. tree hollows).
	Degraded water quality	Medium	Low	Association rating based on impact of threat on food resources (fish and invertebrates) and roosting habitat (e.g. tree hollows).
	Disturbance of acid sulfate soils	High	Low	Association rating based on impact of threat on food resources (fish and invertebrates) and roosting habitat (e.g. tree hollows) and direct effects through exposure to low pH and metals.
	Soil disturbance	Low	Low	Association rating based on impact of threat on food resources (fish and invertebrates) and roosting habitat (e.g. tree hollows).
	Invasive flora (wetland)	Low	Low	Association rating based on impact of threat on food resources (fish and invertebrates) and roosting habitat (e.g. tree hollows).
	Invasive fauna (terrestrial)	Low	Low	Association rating based on impact of threat on food resources (fish and invertebrates) and roosting habitat (e.g. tree hollows).
	Invasive fauna (aquatic)	Low	Low	Association rating based on impact of threat on food resources (fish and invertebrates) and roosting habitat (e.g. tree hollows).

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Significant flora (wetland) (cont.)	Changed water regime	High	High	Water regime is a key driver of wetland vegetation community structure influencing: i) germination from the soil seed bank; ii) oxygen levels in the soil which inturn influence the concentration of nutrients and toxins; iii) light available to submerged plants for photosynthesis; iv) desiccation of aquatic plants and iv) inundation of emergent or terrestrial plants which limits gas exchange and photosynthesis (Brock and Casanova 1997, Casanova and Brock 2000). Effects on community assemblage have been reported by Mayence et al. 2010, Raulings et al. 2010, Raulings et al. 2011).
	Reduced wetland area	High	Low	Direct effects on significant flora through habitat destruction.
Significant flora (wetland)	Altered wetland form	High	Low	Altered wetland form is likely to alter water regime and exert strong effects on flora (see effects of altered water regime).
	Degraded water quality	High	High	Multiple studies demonstrating effects of salinity. Many freshwater plants absent when salinities are > 4000 mg/L and at 10000 mg/L only halophytic species are likely to occur (Brock 1981, Brock and Shiel 1983, Brock and Lane 1983). The emergence and survival of plants from soil seed banks show similar sensitivities to salinity (Nielsen et al. 2003, Nielsen et al. 2008, Brock et al. 2005). In Victoria, Smith et al. (2009) report a 40-50% decline in species number in wetlands at salinities of 1000 mg/L and a 60-70% decline at 4000 mg/L. Multiple studies demonstrate the impact of nutrient enrichment, including shifts from plant to phytoplankton dominance in shallow lakes (Scheffer et al. 2001, Morris et al. 2003) and dominance by competitive species is favoured by enrichment (Wetzel and van der Valk 1998, Macek and Rejmánková 2007).
	Disturbance of acid sulfate soils	High	High	Several studies report chronic exclusion of vegetation due to acid sulfate soils (Rosicky et al. 2006 and references within) As soil pH falls (i.e. more acidic) the solubility of a several toxic metal ions (Al, Mn and Fe) increase with potentially adverse effects on plants. Low pH can also inhibit the uptake of Ca and N leading to nutrient deficiencies (Bloomfield and Coulter 1973). Very low soil pH can also damage soil structure (DPI 2005b). Acid sulfate soils are also associated with oxygen depletion and increased salinity; both have adverse affects on plants.
	Soil disturbance	High	Low	Negative impacts via dislodgement or trampling of plants and increased turbidity.
	Invasive flora (wetland)	High	Low	Invasive species can outcompete native species and result in major changes in vegetation structure. Infestations can choke waterways (Sainty and Jacobs 2003). Wetland invasion by the ponded pasture grass *Hymenachne. amplexicaulis* displaces floating-attached/submerged native aquatic plants beds and reduces plant species richness (Houston and Duivenvoorden 2002).

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Significant flora (wetland) (cont.)	Invasive fauna (terrestrial)	High	Low	Grazing by invasive terrestrial fauna can directly impact on plants through trampling and consumption. Trampling by invasive terrestrial fauna can also damage/disturb soils based regenerative structures such as rhizomes, tubers and seed bank.
	Invasive fauna (aquatic)	Medium	Medium	Carp reported to uproot plants and increase turbidity (Roberts et al. 1995, Roberts and Tilzey 1997) but evidence is equivocal (see Arthington and Mackenzie 1997). Britton et al. (2007) found that macrophyte regeneration in littoral areas occurred despite increasing carp abundance.
Significant EVCs	Changed water regime	High	High	Water regime is a key driver of wetland vegetation community structure influencing: i) germination from the soil seed bank; ii) oxygen levels in the soil which inturn influence the concentration of nutrients and toxins; iii) light available to submerged plants for photosynthesis; iv) desiccation of aquatic plants and iv) inundation of emergent or terrestrial plants which limits gas exchange and photosynthesis (Brock and Casanova 1997, Casanova and Brock 2000). Effects on community assemblage have been reported by Mayence et al. 2010, Raulings et al. 2010, Raulings et al. 2011).
	Reduced wetland area	High	Low	Direct effects on significant flora through habitat destruction.
	Altered wetland form	High	Low	Altered wetland form is likely to alter water regime and exert strong effects of flora (see effects of altered water regime).
	Degraded water quality	High	High	Multiple studies demonstrating effects of salinity. Many freshwater plants absent when salinities >4000 mg/L and at 10000 mg/L only halophytic species are likely to occur (Brock 1981; Brock and Shiel 1983; Brock and Lane 1983). The emergence and survival of plants from soil seed banks show similar sensitivities to salinity (Nielsen et al. 2003; Nielsen et al. 2008; Brock et al. 2005). In Victoria, Smith et al. (2009) report a 40-50% decline in species number in wetlands at salinities of 1000 mg/L and 60-70% at 4000 mg/L. Multiple studies demonstrate the impact of nutrient enrichment, including shifts from plant to phytoplankton dominance in shallow lakes (Scheffer et al. 2001, Morris et al. 2003) and dominance by competitive species is favoured by enrichment (Wetzel and van der Valk 1998, Macek and Rejmánková 2007).
	Disturbance of acid sulfate soils	High	High	Several studies report chronic exclusion of vegetation due to acid sulfate soils (Rosicky et al. 2006 and references within) As soil pH falls (i.e. more acidic) the solubility of a several toxic metal ions (Al, Mn and Fe) increase with potentially adverse effects on plants. Low pH can also inhibit the uptake of Ca and N leading to nutrient deficiencies (Bloomfield and Coulter 1973). Very low soil pH can also damage soil structure (DPI 2005b). Acid sulfate soils are also associated with oxygen depletion and increased salinity; both have adverse affects on plants.

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Significant EVCs (cont.)	Soil disturbance	High	Low	Negative impacts via dislodgement or trampling of plants and increases in suspended-sediments.
	Invasive flora (wetland)	High	Low	Invasive species can outcompete native species. Infestations can choke waterways.
	Invasive fauna (terrestrial)	High	Low	Grazing by invasive terrestrial fauna can directly impact on plants through trampling and consumption. Trampling by invasive terrestrial fauna can also damage/disturb soils based regenerative structures such as rhizomes, tubers and seed bank.
	Invasive fauna (aquatic)	Medium	Medium	Carp reported to uproot plants and increase turbidity (Roberts and Tilzey 1997) but evidence is equivocal (see Arthington and Mackenzie 1997). Britton et al. 2007 macrophyte regeneration in littoral areas occurred despite increasing carp abundance.
Wetland vegetation condition	Changed water regime	High	High	Water regime is a key driver of wetland vegetation community structure influencing: i) germination from the soil seed bank; ii) oxygen levels in the soil which inturn influence the concentration of nutrients and toxins; iii) light available to submerged plants for photosynthesis; iv) desiccation of aquatic plants and iv) inundation of emergent or terrestrial plants which limits gas exchange and photosynthesis (Brock and Casanova 1997, Casanova and Brock 2000). Effects on community assemblage have been reported by Mayence et al. 2010, Raulings et al. 2010, Raulings et al. 2011).
	Reduced wetland area	High	Low	Direct effects on significant flora through habitat destruction.
	Altered wetland form	High	Low	Altered wetland form is likely to alter water regime and exert strong effects of flora (see effects of altered water regime).
	Degraded water quality	High	High	Multiple studies demonstrating effects of salinity. Many freshwater plants absent when salinities > 4000 mg/L and at 10000 mg/L only halophytic species are likely to occur (Brock 1981, Brock and Shiel 1983, Brock and Lane 1983). The emergence and survival of plants from soil seed banks show similar sensitivities to salinity (Nielsen et al. 2003, Nielsen et al. 2008, Brock et al. 2005). In Victoria, Smith et al. (2009) report a 40-50% decline in species number in wetlands at salinities of 1000 mg/L and 60-70% at 4000 mg/L. Multiple studies demonstrate the impact of nutrient enrichment, including shifts from plant to phytoplankton dominance in shallow lakes (Scheffer et al. 2001, Morris et al. 2003) and dominance by competitive species is favoured by enrichment (Wetzel and van der Valk 1998, Macek and Rejmánková 2007).

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Wetland vegetation condition (cont.)	Disturbance of acid sulfate soils	High	High	Several studies report chronic exclusion of vegetation due to acid sulftate soils (Rosicky et al. 2006 and references within) As soil pH falls (i.e. more acidic) the solubility of a several toxic metal ions (Al, Mn and Fe) increase with potentially adverse effects on plants. Low pH can also inhibit the uptake of Ca and Nitrogen leading to nutrient deficiencies (Bloomfield and Coulter 1973). Very low soil pH can also damage soil structure (DPI 2005b). Acid sulfate soils are also associated with oxygen depletion and increased salinity; both have adverse affects on plants.
	Soil disturbance	High	Low	Negative impacts via dislodgement of plants and increases in suspended-sediments.
	Invasive flora (wetland)	High	Low	Invasive species can outcompete native species and result in major changes in vegetation structure. Infestation can choke waterways (Sainty and Jacobs 2003). Invasion of wetlands by the ponded pasture grass Olive Hymenachne (*Hymenachne amplexicaulis*) displaces floating-attached/submerged native aquatic plants beds and reduces plant species richness (Houston and Duivenvoorden 2002).
	Invasive fauna (terrestrial)	High	Low	Grazing can directly impact on plants through trampling and consumption. Trampling can also damage/disturb soils based regenerative structures such as rhizomes and tubers and seed bank.
	Invasive fauna (aquatic)	Medium	Medium	Carp reported to uproot plants and increase turbidity (Roberts and Tilzey 1997) but evidence is equivocal (see Arthington and Mackenzie 1997). Britton et al. 2007 macrophyte regeneration in littoral areas occurred despite increasing carp abundance.
Drought refuges	Changed water regime	High	Low	Association based on the impact of the threat on persistence of water in refuge wetland.
	Reduced wetland area	High	Low	Association based on the impact of the threat on persistence of water in refuge wetland.
	Altered wetland form	High	Low	May increase or decrease persistence of water in refuge wetland.
	Degraded water quality	High	Low	Persistence of wetland species in drought refuges will depend on suitable water quality within refuge wetlands.
	Disturbance of acid sulfate soils	High	High	Based on the effect of the threat on habitat and on the suitability of water for consumption. Confidence rating based on evidence of the effect of the threat on vegetation, aquatic fauna and water quality.
	Soil disturbance	Medium	Low	Association rating based on the impact of the threat on water quality of wetland refuge.
	Invasive flora (wetland)	Medium	Low	Association rating based on impact of threat on habitat quality and food resources for wetland taxa.

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Drought refuges (cont.)	Invasive fauna (terrestrial)	Medium	Low	Association rating based on impact of threat on habitat quality and food resources for wetland taxa.
	Invasive fauna (aquatic)	Medium	Low	Association rating based on impact of threat on habitat quality and food resources for wetland taxa.
Important bird habitats	Changed water regime	High	High	Floods trigger breeding in many species and wetland systems that are flooded after a dry period support high numbers of waterbirds compared to permanently flooded sites (Kingsford and Norman, 2002; Kingsford and Auld 2005). A review by Scott (1997) reports that *Cicconiformes* and *Pelecaniformes* require spring-summer floods of 5-7 months for successful breeding. Colonial nesting waterbirds including Egrets and Ibis abandon nest sites in response to sudden falls in water level (Scott 1997). Significant species occur in each of these groups.
	Reduced wetland area	High	High	Direct effects through habitat loss. Negative effects will also occur through reduction in size of individual wetland as there is good evidence of a positive relationship between wetland or lake area and waterbird species richness (Brown and Dinsmore 1986, Hoyer and Canfield 1990, Celada and Bogliani 1993, Baldassarre and Bolen 1994, Hoyer and Canfield 1994).
	Altered wetland form	Medium	Low	Association rating based on the impact of the threat on food resources.
	Degraded water quality	Low	Medium	High waterbird abundance and diversity can occur in saline wetlands but many species will require a nearby source of freshwater. Avian botulism can kill thousands of birds; Rocke (1999) found that the risk of botulism outbreaks in North American wetlands declined when redox potential increased (>100), water temperature decreased (10-15°C), pH was <7.5 or >9.0, or salinity was low (<2.0 ppt). Poor water quality may impact on waterbirds indirectly by affecting their food resources.
	Disturbance of acid sulfate soils	High	Medium	Association rating based on the impact of the threat on food resources and water quality. Expect direct negative effects on birds through exposure to low pH, high metal concentrations or hydrogen sulfide gas. Confidence ratings are based on evidence for the effect of the threat on food resources (fish, vegetation) and water quality. Increases in salinity associated with the development of acid sulfate soils reduced populations of waterbirds (Kingsford et al. 2011).
	Soil disturbance	Low	Low	Association rating based on the impact of the threat on food resources.

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Important bird habitats (cont.)	Invasive flora (wetland)	Low	Low	Association rating based on the impact of the threat on food resources and habitat. Studies of weed impacts in aquatic systems have found that the composition of a wide range of faunal groups can be altered, with negative effects on some species and positive effects on others (Houston and Duivenvoorden 2002, Keast 1984, Howard-Williams and Davies 1988, Braithwaite et al. 1989, Arthington et al.1983). Howard-Williams and Davies (1988) demonstrated that the invasion of New Zealand lakes by the submerged macrophyte *Lagarosiphon major* favoured herbivorous waterbirds.
	Invasive fauna (terrestrial)	Medium	Low	Association rating based on the effect exotic wetland fauna may have on food resources.
	Invasive fauna (aquatic)	Medium	Low	Association rating based on the impact of the threat on food resources and habitat.
Recreational fishing	Changed water regime	High	High	Association based on impact of threat on fish stocks. Confidence of associated based on evidence cited for significant fish which is likely to hold for recreational fish (particularly native species).
	Reduced wetland area	High	High	Association based on impact of threat on fish stocks. Confidence of associated based on evidence cited for significant fish which is likely to hold for recreational fish (particularly native species).
	Altered wetland form	High	High	Association based on impact of threat on fish stocks. Confidence of associated based on evidence cited for significant fish which is likely to hold for recreational fish (particularly native species).
	Degraded water quality	High	High	Association based on impact of threat on fish stocks. Confidence of associated based on evidence cited for significant fish which is likely to hold for recreational fish (particularly native species).
	Disturbance of Acid Sulfate Soils	High	High	Multiple reports of fish kills due to stream acidification resulting from drainage from oxidised sulfidic sediment (Sammut et al. 1996). For more information see association for significant fish.
	Soil disturbance	Medium	Low	Association based on impact of threat on fish stocks. Confidence of associated based on evidence cited for significant fish which is likely to hold for recreational fish (particularly native species).
	Invasive flora (wetland)	High	High	Association based on impact of threat on fish stocks. Confidence of associated based on evidence cited for significant fish which is likely to hold for recreational fish (particularly native species).

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Recreational fishing (cont.)	Invasive fauna (terrestrial)	Medium	Low	Association based on impact of threat on fish stocks. Confidence of associated based on evidence cited for significant fish which is likely to hold for recreational fish (particularly native species).
	Invasive fauna (aquatic)	Medium	Low	Association based on impact of threat on fish stocks. Confidence of associated based on evidence cited for significant fish which is likely to hold for recreational fish (particularly native species).
Non-motor boating	Changed water regime	Medium	Low	Association rating based on impact of threat on likelihood of non-motor boating.
	Reduced wetland area	High	Low	Association rating based on impact of threat on likelihood of non-motor boating.
	Altered wetland form	Medium	Low	Association rating based on impact of threat on likelihood of non-motor boating.
	Degraded water quality	Medium	Low	Association rating based on impact of threat on likelihood of non-motor boating.
	Disturbance of Acid Sulfate Soils	High	High	Association based on public health risks of water with low pH and high metal concentrations (EPHC & NRMMC 2011).
	Soil disturbance	None	Low	
	Invasive flora (wetland)	High	Low	Association rating based on impact of threat on likelihood of non-motor boating.
	Invasive fauna (terrestrial)	None	Low	
	Invasive fauna (aquatic)	None	Low	
Motor boating	Changed water regime	High	Low	Association rating based on impact of threat on likelihood of motor boating.
	Reduced wetland area	High	Low	Association rating based on impact of threat on likelihood of motor boating.
	Altered wetland form	Medium	Low	Association rating based on impact of threat on likelihood of motor boating.
	Degraded water quality	Medium	Low	Association rating based on impact of threat on likelihood of motor boating.
	Disturbance of Acid Sulfate Soils	High	High	Association based on public health risks of water with low pH and high metal concentrations (EPHC & NRMMC 2011).
	Soil disturbance	None	Low	
	Invasive flora (wetland)	High	Low	Association rating based on impact of threat on likelihood of motor boating.
	Invasive fauna (terrestrial)	None	Low	
	Invasive fauna (aquatic)	Low	Low	Association rating based on impact of threat on likelihood of motor boating.

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Camping	Changed water regime	Medium	Low	Association rating based on impact of threat on likelihood of camping.
	Reduced wetland area	High	Low	Association rating based on impact of threat on likelihood of camping.
	Altered wetland form	None	Low	
	Degraded water quality	Medium	Low	Association rating based on impact of threat on likelihood of camping.
	Disturbance of Acid Sulfate Soils	High	High	Association based on public health risks of coming into contact with hazardous materials (low pH and high metal concentrations and hydrogen sulfide gas). When the wetland dries contaminated wind borne dusts also present health risk (EPHC & NRMMC 2011).
	Soil disturbance	Low	Low	Association rating based on impact of threat on likelihood of camping.
	Invasive flora (wetland)	Low	Low	Association rating based on impact of threat on likelihood of camping.
	Invasive fauna (terrestrial)	Low	Low	Association rating based on impact of threat on likelihood of camping.
	Invasive fauna (aquatic)	Low	Low	Association rating based on impact of threat on likelihood of camping.
Swimming	Changed water regime	High	Low	Association rating based on impact of threat on likelihood of swimming.
	Reduced wetland area	High	Low	Association rating based on impact of threat on likelihood of swimming.
	Altered wetland form	Medium	Low	Association rating based on impact of threat on likelihood of swimming.
	Degraded water quality	High	Low	Association rating based on impact of threat on likelihood of swimming.
	Disturbance of Acid Sulfate Soils	High	High	Association based on public health risks of coming into contact with hazardous materials (low pH, high metal concentrations and hydrogen sulfide gas (EPHC & NRMMC 2011).
	Soil disturbance	Low	Low	Association rating based on impact of threat on likelihood of swimming.
	Invasive flora (wetland)	High	Low	Association rating based on impact of threat on likelihood of swimming.
	Invasive fauna (terrestrial)	None	Low	
	Invasive fauna (aquatic)	Low	Low	Association rating based on impact of threat on likelihood of swimming.
Beside Water Activities (Tracks)	Changed water regime	Medium	Low	Association rating based on impact of threat on walking tracks.
	Reduced wetland area	High	Low	Association rating based on impact of threat on walking tracks.
	Altered wetland form	None	Low	
	Degraded water quality	Medium	Low	Association rating based on impact of threat on walking tracks.

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Beside Water Activities (Tracks) (cont.)	Disturbance of acid sulfate soils	High	High	Association based on public health risks of coming into contact with hazardous materials (low pH and high metal concentrations and hydrogen sulfide gas). When the wetland dries contaminated wind borne dusts also present health risk (EPHC & NRMMC 2011).
	Soil disturbance	Low	Low	Association rating based on impact of threat on walking tracks.
	Exotic flora (wetland)	Low	Low	Association rating based on impact of threat on walking tracks.
	Exotic fauna (terrestrial)	Low	Low	Association rating based on impact of threat on walking tracks.
	Exotic fauna (aquatic)	None	Low	
Beside Water Activities (Sightseeing)	Changed water regime	Low	Low	Association rating based on impact of threat on quality of sightseeing.
	Reduced wetland area	Medium	Low	Association rating based on impact of threat on quality of sightseeing.
	Altered wetland form	None	Low	
	Degraded water quality	Medium	Low	Association rating based on impact of threat on quality of sightseeing.
	Disturbance of acid sulfate soils	High	High	Association based on public health risks of coming into contact with hazardous materials (low pH and high metal concentrations and hydrogen sulfide gas). When the wetland dries contaminated wind borne dusts also present health risk (EPHC & NRMMC 2011).
	Soil disturbance	Low	Low	Association rating based on impact of threat on quality of sightseeing.
	Invasive flora (wetland)	Low	Low	Association rating based on impact of threat on quality of sightseeing.
	Invasive fauna (terrestrial)	Low	Low	Association rating based on impact of threat on quality of sightseeing.
	Invasive fauna (aquatic)	None	Low	
Beside Water Activities (Picnics and Barbecues)	Changed water regime	None	Low	
	Reduced wetland area	Medium	Low	Association rating based on impact of threat on decision to picnic and BBQs at the site.
	Altered wetland form	None	Low	
	Degraded water quality	Medium	Low	Association rating based on impact of threat on decision to picnic and BBQs at the site.
	Disturbance of acid sulfate soils	High	High	Association based on public health risks of coming into contact with hazardous materials (low pH and high metal concentrations and hydrogen sulfide gas. When the wetland dries contaminated wind borne dusts also present health risk (EPHC & NRMMC 2011).
	Soil disturbance	Low	Low	Association rating based on impact of threat on decision to picnic and BBQs at the site.
	Exotic flora (wetland)	Low	Low	Association rating based on impact of threat on decision to picnic and BBQs at the site.

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Beside Water Activities (cont.)	Exotic fauna (terrestrial)	Low	Low	Association rating based on impact of threat on decision to picnic and BBQs at the site.
	Exotic fauna (aquatic)	None	Low	
Game hunting	Changed water regime	Medium	Low	Association assessment based on impact of threat on hunting experience.
	Reduced wetland area	Medium	Low	Association assessment based on impact of threat on hunting experience.
	Altered wetland form	Low	Low	Association assessment based on impact of threat on hunting experience.
	Degraded water quality	Medium	Low	Association assessment based on impact of threat on hunting experience.
	Disturbance of acid sulfate soils	High	High	Association based on public health risks of coming into contact with hazardous substances (low pH and high metal concentrations and hydrogen sulfide gas). When the wetland dries contaminated wind borne dusts also present health risk (EPHC & NRMMC 2011).
	Soil disturbance	Low	Low	Association assessment based on impact of threat on hunting experience
	Invasive flora (wetland)	Medium	Low	Association assessment based on impact of threat on hunting experience
	Invasive fauna (terrestrial)	Low	Low	Association assessment based on impact of threat on hunting experience
	Invasive fauna (aquatic)	Low	Low	Association assessment based on impact of threat on hunting experience
Pre-European Heritage	Changed water regime	High	Low	Association assessment rating based on impact of threat on cultural and spiritual values (e.g. dreamtime stories, artefacts and resources).
	Reduced wetland area	High	Low	Association assessment rating based on impact of threat on cultural and spiritual values (e.g. dreamtime stories, artefacts and resources).
	Altered wetland form	Medium	Low	Association assessment rating based on impact of threat on cultural and spiritual values (e.g. dreamtime stories, artefacts and resources).
	Degraded water quality	High	Low	Association assessment rating based on impact of threat on cultural and spiritual values (e.g. dreamtime stories, artefacts and resources).
	Disturbance of acid sulfate soils	High	Low	Association assessment rating based on impact of threat on cultural and spiritual values (e.g. dreamtime stories, artefacts and resources).
	Soil disturbance	Medium	Low	Association assessment rating based on impact of threat on cultural and spiritual values (e.g. dreamtime stories, artefacts and resources).
	Invasive flora (wetland)	Medium	Medium	Association assessment rating based on impact of threat on cultural and spiritual values (e.g. dreamtime stories, artefacts and resources).
	Invasive fauna (terrestrial)	Medium	Medium	Association assessment rating based on impact of threat on cultural and spiritual values (e.g. dreamtime stories, artefacts and resources).
	Invasive fauna (aquatic)	Medium	Low	Association assessment rating based on impact of threat on cultural and spiritual values (e.g. dreamtime stories, artefacts and resources).

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Post-European Heritage (cont.)	Changed water regime	Low	Low	Association assessment rating based on impact of threat on aesthetic, historic, scientific or social significance, or other significance, for current and future generations.
	Reduced wetland area	Low	Low	Association assessment rating based on impact of threat on aesthetic, historic, scientific or social significance, or other significance, for current and future generations.
	Altered wetland form	Low	Low	Association assessment rating based on impact of threat on aesthetic, historic, scientific or social significance, or other significance, for current and future generations.
	Degraded water quality	Low	Low	Association assessment rating based on impact of threat on aesthetic, historic, scientific or social significance, or other significance, for current and future generations.
	Disturbance of acid sulfate soils	High	Low	Association assessment rating based on impact of threat on aesthetic, historic, scientific or social significance, or other significance, for current and future generations.
	Soil disturbance	Low	Low	Association assessment rating based on impact of threat on aesthetic, historic, scientific or social significance, or other significance, for current and future generations.
	Invasive flora (wetland)	Low	Low	Association assessment rating based on impact of threat on aesthetic, historic, scientific or social significance, or other significance, for current and future generations.
	Invasive fauna (terrestrial)	Low	Low	Association assessment rating based on impact of threat on aesthetic, historic, scientific or social significance, or other significance, for current and future generations.
	Invasive fauna (aquatic)	Low	Low	Association assessment rating based on impact of threat on aesthetic, historic, scientific or social significance, or other significance, for current and future generations.
Landscape	Changed water regime	Medium	Low	Association assessment rating based on impact of threat on scenic values.
	Reduced wetland area	Medium	Low	Association assessment rating based on impact of threat on scenic values.
	Altered wetland form	Low	Low	Association assessment rating based on impact of threat on scenic values.
	Degraded water quality	None	Low	

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Landscape (cont.)	Disturbance of Acid Sulfate Soils	High	Medium	Association assessment rating based on impact of threat on scenic values (EPHC & NRMMC 2011).
	Soil disturbance	None	Low	
	Invasive flora (wetland)	Medium	Low	Association assessment rating based on impact of threat on scenic values (e.g. willows).
	Invasive fauna (terrestrial)	Low	Low	Association assessment rating based on impact of threat on scenic values.
	Invasive fauna (aquatic)	None	Low	
Use of flagship species	Changed water regime	Medium	Low	Association assessment rating based on impact of threat on waterbirds especially brolgas, swans, egrets, ducks.
	Reduced wetland area	Medium	Low	Association assessment rating based on impact of threat on waterbirds especially brolgas, swans, egrets, ducks.
	Altered wetland form	Low	Low	Association assessment rating based on impact of threat on waterbirds especially brolgas, swans, egrets, ducks.
	Degraded water quality	Medium	Low	Association assessment rating based on impact of threat on waterbirds especially brolgas, swans, egrets, ducks.
	Disturbance of acid sulfate soils	High	High	Association rating based on the expected impact of the threat on food resources and the quality of water for consumption for waterbirds, specially brolgas, swans, egrets, ducks. Confidence ratings are based on evidence for the effect of the threat on food resources (fish, vegetation) and water quality. Increases in salinity associated with the development of acid sulfate soils reduced populations of waterbirds (Kingsford et al. 2011).
	Soil disturbance	Low	Low	Association assessment rating based on impact of threat on waterbirds especially brolgas, swans, egrets, ducks.
	Invasive flora (wetland)	Medium	Low	Association assessment rating based on impact of threat on waterbirds especially brolgas, swans, egrets, ducks.
	Invasive fauna (terrestrial)	Medium	Low	Association assessment rating based on impact of threat on waterbirds especially brolgas, swans, egrets, ducks.
	Invasive fauna (aquatic)	Low	Low	Association assessment rating based on impact of threat on waterbirds especially brolgas, swans, egrets, ducks.

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Urban/rural township water sources	Changed water regime	High	Low	Association rating based on the impact of the threat on the quality and quantity of the water for domestic use.
	Reduced wetland area	Medium	Low	Association rating based on the impact of the threat on the quality and quantity of the water for domestic use.
	Altered wetland form	Medium	Low	Association rating based on the impact of the threat on the quality and quantity of the water for domestic use.
	Degraded water quality	High	Low	Association rating based on the impact of the threat on the quality and quantity of the water for domestic use.
	Disturbance of acid sulfate soils	High	Low	Association rating based on the impact of the threat on the quality and quantity of the water for domestic use. Association also based on public health risks of coming into contact with hazardous materials (low pH, high metal concentrations and hydrogen sulfide gas) . When the wetland dries contaminated wind borne dusts also present health risk (EPHC & NRMMC 2011).
	Soil disturbance	Low	Low	Association rating based on the impact of the threat on the quality and quantity of the water for domestic use.
	Invasive flora (wetland)	Low	Low	Association rating based on the impact of the threat on the quality and quantity of the water for domestic use.
	Invasive fauna (terrestrial)	Medium	Low	Association rating based on the impact of the threat on the quality and quantity of the water for domestic use.
	Invasive fauna (aquatic)	Low	Low	Association rating based on the impact of the threat on the quality and quantity of the water for domestic use.
Rural water sources for production	Changed water regime	High	Low	Association rating based on the impact of the threat on the quality and quantity of the water for production.
	Reduced wetland area	Medium	Low	Association rating based on the impact of the threat on the quality and quantity of the water for production.
	Altered wetland form	Medium	Low	Association rating based on the impact of the threat on the quality and quantity of the water for production.
	Degraded water quality	Medium	Low	Association rating based on the impact of the threat on the quality and quantity of the water for production.

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Rural water sources for production	Disturbance of acid sulfate soils	High	Low	Association rating based on the impact of the threat on the quality and quantity of the water for production. Association also based on public health risks of coming into contact with hazardous substances (low pH, high metal concentrations and hydrogen sulfide gas). When the wetland dries contaminated wind borne dusts also present health risk (EPHC & NRMMC 2011).
	Soil disturbance	Low	Low	Association rating based on the impact of the threat on the quality and quantity of the water for production.
	Invasive flora (wetland)	Low	Low	Association rating based on the impact of the threat on the quality and quantity of the water for production.
	Invasive fauna (terrestrial)	None	Low	
	Invasive fauna (aquatic)	Medium	Medium	The introduced aquatic gastropod *Lymnaea columella* is an intermediate host of the mammalian liver fluke (*Faxiola heptica*) which can parasite sheep and cattle with significant economic impact in many countries (Arthington and McKenzie 1997).
Water storages	Changed water regime	Low	Low	Associations based on the value of the physical structure and not the resource.
	Reduced wetland area	High	Low	Associations based on the value of the physical structure and not the resource.
	Altered wetland form	Medium	Low	Associations based on the value of the physical structure and not the resource.
	Degraded water quality	Low	Low	Associations based on the value of the physical structure and not the resource.
	Disturbance of acid sulfate soils	High	High	Association based on public health risks of coming into contact with hazardous substances (low pH, high metal concentrations and hydrogen sulfide gas). When the wetland dries contaminated wind borne dusts also present health risk (EPHC & NRMMC 2011). Concrete and other irrigation infrastructure can be damaged by acid sulfate soils (van Holst and Westerveld 1973).
	Soil disturbance	Low	Low	Associations based on the value of the physical structure and not the resource.
	Invasive flora (wetland)	Low	Low	Associations based on the value of the physical structure and not the resource.
	Invasive fauna (terrestrial)	None	Low	
	Invasive fauna (aquatic)	Low	Low	Associations based on the value of the physical structure and not the resource.

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Wastewater discharges	Changed water regime	Low	Low	Association rating based on the impact of threat on the capacity to hold waste water.
	Reduced wetland area	High	Low	Association rating based on the impact of threat on the capacity to hold waste water.
	Altered wetland form	Medium	Low	Association rating based on the impact of threat on the capacity to hold waste water.
	Degraded water quality	Low	Low	Association rating based on the impact of threat on the capacity to hold waste water.
	Disturbance of acid sulfate soils	High	High	Association based on public health risks of coming into contact with hazardous substances (low pH, high metal concentrations and hydrogen sulfide gas). When the wetland dries contaminated wind borne dusts also present health risk (EPHC & NRMMC 2011).
	Soil disturbance	None	Low	
	Invasive flora (wetland)	None	Low	
	Invasive fauna (terrestrial)	None	Low	
	Invasive fauna (aquatic)	None	Low	
Commercial fishing	Changed water regime	High	Low	
	Reduced wetland area	Medium	Low	Association rating based on impact of threat on commercial fishing viability. Fishery includes eels and yabbies.
	Altered wetland form	Medium	Low	Association rating based on impact of threat on commercial fishing viability. Fishery includes eels and yabbies.
	Degraded water quality	Medium	Low	Association rating based on impact of threat on commercial fishing viability. Fishery includes eels and yabbies.
	Disturbance of acid sulfate soils	High	High	Multiple reports of fish kills due to stream acidification resulting from drainage from oxidised sulfidic sediment (Sammut et al. 1996 and references within). Acidification, high metal concentration and salinity were associated with a large carp kill (*Cyprinus carpio*) and a pronounced reduction in fish diversity (McCarthy et al. 2006). See association for significant fish for more information. Association also based on health risks of coming into contact with hazardous substances (low pH, metals and hydrogen sulfide gas) (EPHC & NRMMC 2011).
	Soil disturbance	Medium	Low	Association rating based on impact of threat on commercial fishing viability. Fishery includes eels and yabbies.

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Commercial fishing (cont.)	Invasive flora (wetland)	Low	Low	Association rating based on impact of threat on commercial fishing viability. Fishery includes eels and yabbies.
	Invasive fauna (terrestrial)	Medium	Low	Association rating based on impact of threat on commercial fishing viability. Fishery includes eels and yabbies.
	Invasive fauna (aquatic)	Medium	Low	Association rating based on impact of threat on commercial fishing viability. Fishery includes eels and yabbies.
Extractive industries	Changed water regime	Medium	Low	Association rating based on impact of threat on viability of extractive industry.
	Reduced wetland area	Medium	Low	Association rating based on impact of threat on viability of extractive industry.
	Altered wetland form	Low	Low	Association rating based on impact of threat on viability of extractive industry.
	Degraded water quality	Low	Low	Association rating based on impact of threat on viability of extractive industry.
	Disturbance of acid sulfate soils	High	Low	Association rating based on impact of threat on viability of extractive industry and health risks of coming into contact with hazardous substances (low pH, metals and hydrogen sulfide gas) (EPHC & NRMMC 2011).
	Soil disturbance	Low	Low	Association rating based on impact of threat on viability of extractive industry.
	Invasive flora (wetland)	None	Low	
	Invasive fauna (terrestrial)	None	Low	
	Invasive fauna (aquatic)	None	Low	
Timber harvesting and firewood collection	Changed water regime	High	Low	Association based on impact of threat on quality and quantity of timber for timber harvesting and firewood collection.
	Reduced wetland area	High	Low	Association based on impact of threat on quality and quantity of timber for timber harvesting and firewood collection.
	Altered wetland form	Medium	Low	Association based on impact of threat on quality and quantity of timber for timber harvesting and firewood collection.
	Degraded water quality	None	Low	Association based on impact of threat on quality and quantity of timber for timber harvesting and firewood collection.
	Disturbance of acid sulfate soils	High	Low	Association based on impact of threat on quality and quantity of timber for timber harvesting and firewood collection and health risks of coming into contact with hazardous substances (low pH, metals and hydrogen sulfide gas) (EPHC & NRMMC 2011).

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Timber harvesting and firewood collection (cont.)	Soil disturbance	None	Low	
	Invasive flora (wetland)	None	Low	
	Invasive fauna (terrestrial)	None	Low	
	Invasive fauna (aquatic)	None	Low	
Community groups	Changed water regime	Medium	Low	Association could be positive or negative.
	Reduced wetland area	Medium	Low	Association could be positive or negative.
	Altered wetland form	Medium	Low	Association could be positive or negative.
	Degraded water quality	Medium	Low	Association could be positive or negative
	Disturbance of acid sulfate soils	Medium	Low	Association could be positive or negative.
	Soil disturbance	Medium	Low	Association could be positive or negative.
	Invasive flora (wetland)	Medium	Low	Association could be positive or negative.
	Invasive fauna (terrestrial)	Medium	Low	Association could be positive or negative.
	Invasive fauna (aquatic)	Medium	Low	Association could be positive or negative.
Water carriers	Changed water regime	High	Low	
	Reduced wetland area	High	Low	
	Altered wetland form	Medium	Low	
	Degraded water quality	None	Low	
	Disturbance of acid sulfate soils	High	High	Association rating based on the effect of the threat on water quality and the health risks of coming into contact with hazardous substances (low pH, metals and hydrogen sulfide gas) (EPHC & NRMMC 2011) as well as the corrosive effects of acid sulfate soils on concrete and other irrigation infrastructure (van Holst and Westerveld 1973).
	Soil disturbance	None	Low	
	Invasive flora (wetland)	None	Low	
	Invasive fauna (terrestrial)	None	Low	
	Invasive fauna (aquatic)	None	Low	

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Appendix 1 (continued)

Attribute	Threat	Association	Confidence	Explanation
Hydro-electricity	Changed water regime	High	Low	Changes to the depth, duration, frequency or seasonality of wetland inundation may impact on the capacity of the wetland to hold water discharges associated with hydroelectricity generation.
	Reduced wetland area	High	Low	Changes to the areas of wetland may impact on capacity of the wetland to hold water discharges associated with hydroelectricity generation.
	Altered wetland form	Medium	Low	Changes to the bathymetry of the wetland may impact on capacity of the wetland to hold water discharges associated with hydroelectricity generation.
	Degraded water quality	None	Low	
	Disturbance of acid sulfate soils	High	High	Association rating based on the effect of the threat on water quality and the health risks of coming into contact with hazardous substances (low pH, metals and hydrogen sulfide gas) (EPHC & NRMMC 2011)as well as the corrosive effects of acid sulfate soils on concrete and other irrigation infrastructure (van Holst and Westerveld 1973).
	Soil disturbance	None	Low	
	Invasive flora (wetland)	None	Low	
	Invasive fauna (terrestrial)	None	Low	
	Invasive fauna (aquatic)	None	Low	

Appendix 2. List of management activities to reduce the level of wetland threats listed in AVIRA.

KEY: Effectiveness is the expected level of threat reduction that will be achieved by a management intervention and is scored as: Low, a small reduction in the level of the threat; Med, a moderate reduction in the level of the threat which will not always be consistent; and high, a significant and consistent reduction in the level of the threat. Response times represent the period of time before a management activity is expected to eliminate or reduce the level of a threat and are scored as: 1, less than 1 year; 2, 1 -6 years; and 3, > 6 years.

Management Activity	Effectiveness	Response Time
Changed water regime (water excess)		
Stop or reduce water discharge or diversion to wetland	High	1
Install and/or manage regulators	Med-High	1
Manage land use to decrease groundwater levels	Med	2-3
Extract groundwater	Med-High	1
Manage land use to control runoff	Med-	1-3
Undertake water-sensitive urban design (WSUD)	Med	1-2
Install and/or manage regulators (floodplain wetlands)	Med-High	1
Manage river flow regime (floodplain wetlands)	Med-High	1
Restore outlet flow paths	High	1
Remove internal banks and levees	High	1
Changed water regime (water deficit)		
Provide environmental water	High	1
Provide supplementary water (not environmental water)	High	1
Undertake water delivery works and measures	High	1
Restore natural drainage	High	1
Restore water inflow connectivity	Med-High	1
Restore natural depth	High	1
Manage river flow regime (floodplain wetlands)	Med-High	1
Restore floodplain connectivity (floodplain wetlands)	Med-High	1
Enforce regulatory controls on new farm dams	High	1
Apply and enforce regulatory controls on floodplain development	High	1
Enforce regulatory controls on timber production	Med	1-2
Enforce regulatory controls on groundwater extraction	Med	1-2
Changed water regime (seasonality)		
Change the timing of water discharge or diversion to wetland	High	1
Deliver environmental water	High	1
Install and/or manage regulators (floodplain wetlands)	Med-High	1
Restore stream flow seasonality	Med-High	1
Invasive fauna (aquatic)		
Enforce regulatory controls	Med	1
Improve community and industry awareness	Med	1-2
Identify and eradicate source population	Med-High	1
Manage recreation and access	Med	1
Maintain/install movement barriers	Med-High	1
Monitor	Med	1
Map and report	Med	1
Implement rapid removal	Med-High	1
Modify water regime	Med	1
Restore wetland vegetation	High	1-2
Apply chemical control	Med-High	1
Undertake mechanical or manual control	Low-Med	1
Implement biological control	Med-High	1-2
Install or maintain dispersal barriers	High	1

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Appendix 2 (continued)

Management Activity	Effectiveness	Response Time
Invasive fauna (terrestrial)		
Enforce regulatory controls for invasive species	Med	1
Improve community and industry awareness	Med	1-2
Identify and eradicate source population	Med-High	1
Maintain or install vegetation barriers	Low-Med	1-3
Monitor	High	
Map and report	High	1
Implement rapid removal	High	1
Restore wetland vegetation	High	1-3
Remove harbour	Med	1-2
Apply chemical control	Med-High	1
Undertake mechanical or manual control	Med-High	1
Implement biological control	Med	2-3
Install or maintain dispersal barriers	High	1
Invasive flora (wetlands)		
Enforce regulatory controls	Med	1
Improve community and industry awareness	Med	1-2
Identify and eradicate source population	High	1-2
Manage recreation and access	High	1
Restore wetland vegetation	High	2-3
Create or improve vegetation buffer	Med	1-3
Monitor	High	1
Map and report	High	1
Implement rapid removal	Med-High	1
Modify water regime	Med- High	1
Reduce light	Med-High	1
Implement soil solarisation	Med- High	1
Apply chemical control	Med-High	1
Undertake mechanical or manual control	Med- High	1
Manage livestock grazing	Med	1-2
Implement biological control	High	1-3
Prevent seed set/release	High	1
Limit water transfers among wetlands	High	1
Formation and acitivation of acid sulfate soils		
Prevent salinisation	Med	1-3
Avoid prolonged inundation	Med	1
Prevent wetland from drying	High	1
Enforce regulatory controls to prevent disturbance to ASS	High	1
Undertake controlled drying	Med-High	1
Apply chemical ameliorant	Med-High	1
Apply organic matter	Med-	1
Isolate wetland	Med-High	1
Treat discharge water	Med-High	1
Degraded water quality (salinity)		
Stop or reduce saline discharge inputs	High	1
Manage land use to restore groundwater levels	Low-Med	2-3
Intercept groundwater	Med-High	1-2
Manage land uses to reduce saline runoff	Low-Med	2-3
Minimise impacts from saline river inputs	High	1
Install and /or manage regulators (floodplain wetlands)	High	1
Flush with fresh environmental water to reduce intrusion	Med-High	1
Dilute saline water	Med-High	1
Flush saline water from wetland	Med-High	1
Avoid prolonged drying	Med	1

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Appendix 2 (continued)

Management Activity	Effectiveness	Response Time
Degraded water quality (turbidity)		
Stop or divert discharge inputs with high particulates	High	1
Reduce particulates at source of discharge inputs	High	1
Treat discharge inputs prior to entering wetland	High	1
Manage degraded water quality (turbidity) in river reach	Med-High	1-2
Manage land use to reduce erosion	Low-Med	2-3
Create or improve vegetation buffer	Med	1-2
Manage land use to prevent excessive runoff	Low-Med	2-3
Restore wetland vegetation	Med	1-3
Deliver environmental water to restore/maintain water depth	Med	1
Manage carp	Med	1-2
Reduce velocity of discharge inputs	High	1-2
Degraded water quality (nutrients)		
Stop or reduce discharge inputs with high nutrient levels	High	1
Reduce nutrients at source of discharge water	High	1-2
Treat discharge water prior to reaching wetland	High	1-2
Manage land use to reduce nutrients in runoff	Med-high	1-3
Create or improve vegetation buffer	Low-Med	1-3
Apply phosphorus (P) binding agent	Med	1
Dredge sediments	Med	1
Promote sediment aeration	Med	1
Maintain or restore wetland vegetation	Med	1-3
Dilute or flush nutrients in water column	Med	1
Manage livestock grazing	High	1
Soil disturbance		
Exclude livestock access	High	1
Manage livestock grazing	Med	1
Manage carp	Med-High	1-2
Control invasive fauna (terrestrial)	Med-High	1-3
Control human access	High	1
Prevent or minimise earthworks	High	1
Degraded wetland vegetation		
Minimise soil disturbance	Med-High	1-2
Manage livestock grazing	Med	1
Restore water regime	Med-High	1-3
Control invasive flora: wetland	Med-High	1-2
Improve water quality	Med-High	1-2
Control invasive fauna: terrestrial	Med-High	1-3
Brush mulching	Med	1
Hand sowing	Low-Med	1
Mechanical seeding	Low-Med	1
Hydro mulching	Med-High	1
Hand planting	Med-High	1
Mechanical planting	Med-High	1
Reduced wetland area		
Apply and enforce regulatory controls	High	1
Remove barriers to water extent	High	1
Restore changed water regime (water deficit)	Med-High	1-2
No intervention	None	
Altered wetland form		
Undertake earthworks to restore natural bathymetry	High	1
Enforce regulatory controls	High	1
Increase landholder awareness	Med-High	1-2

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