National Land & Water Resources Audit
An Initiative of the Natural Heritage Trust

Reporting on the environmental condition of Victorian estuaries – a discussion paper

April 2008

H Arundel, J Barton, A Becker and G Quinn

Natural Heritage Trust
Helping Communities Helping Australia
An Australian Government Initiative

This report has been produced in partnership with:

Published by: National Land & Water Resources Audit

Postal address: GPO Box 2182 Canberra ACT 2601

Office location: 86 Northbourne Ave Braddon ACT 2612

Telephone: 02 6263 6035

Facsimile: 02 6257 9518

Email: info@nlwra.gov.au

Internet: http://www.nlwra.gov.au

The National Land & Water Resources Audit provides data, information and nationwide assessments of Australia's land, water and biological resources to support sustainable development.

Publication data: Arundel H, Barton J, Becker A and Quinn G (2008) *Reporting on the environmental condition of Victorian estuaries – a discussion paper*, Deakin University, prepared for the National Land & Water Resources Audit, Canberra.

Table of contents

1. Introduction

Deakin University was contracted by the National Land & Water Resources Audit (the Audit) to:

1. Develop a draft resource condition report card for estuarine natural resources that is flexible enough to report on estuarine ecological condition

    - with differing levels of available information, and

    - at regional, state and national levels.

2. Communicate the findings and learnings to the Audit and at a national estuarine forum.

The lack of data on and knowledge about estuaries along the Victorian coast pose considerable hurdles for identifying and assessing the state's estuarine health. Basic descriptors of individual systems such as size, bathymetry, sediments and habitats, water residence time, salinity regimes, freshwater hydrology, and mouth closure frequency and duration are lacking for most estuaries.

This report describes a general approach for reporting on estuarine condition that aligns with both the current Victorian approach to reporting on freshwater reaches and the proposed national estuarine framework. It highlights the types of reports possible and presents examples of information that could potentially be included in inventory, risk, condition and estuary status reports.

It should be noted that the details of the reports are likely to be revised following the development, later this year, of an Index of Estuarine Condition in Victoria to complement the Index of Stream Condition (ISC). The ISC is used in Victoria for the assessment of the ecological condition of freshwater reaches. Studies are also underway, which will support incorporating estuaries into the River Values and Environmental Risk System (RiVERS) program. The RiVERS program currently supports prioritising management investment in rivers within each Catchment Management Authority region.

2. Relevant programs and reports

It was appropriate to align the pilot Victorian report card with both the current State approach to reporting on river condition (the ISC and RiVERS) and the national approach including the proposed national assessment framework for estuaries (the NEECAF), and the draft Framework for the Assessment of River and Wetland Health (FARWH). Further details of these programs are presented below.

Reports currently being used or developed in Western Australia (V. Forbes pers comm), New South Wales (T. Roper pers comm) and Queensland (e.g. VPSIRR & SEQWMP) were also reviewed and their relevance to reporting on the condition of Victorian estuaries assessed and incorporated into the approach and content where applicable.

2.1. Victorian programs

Victorian government strategies support an asset-based approach for natural resource management. This approach was formally recognised with the release of a draft paper 'Land Asset-Based Approach Framework' (Department of Sustainability and Environment. 2007). An asset-based approach allows management priorities to be directed towards protecting the environmental, social, economic and cultural assets most highly valued by the community. This approach has four key steps (Figure 1) namely: identifying the assets of a particular environment (or land management unit); determining the value of these assets; identifying threats to the assets and using this information to assess the risks to the assets.

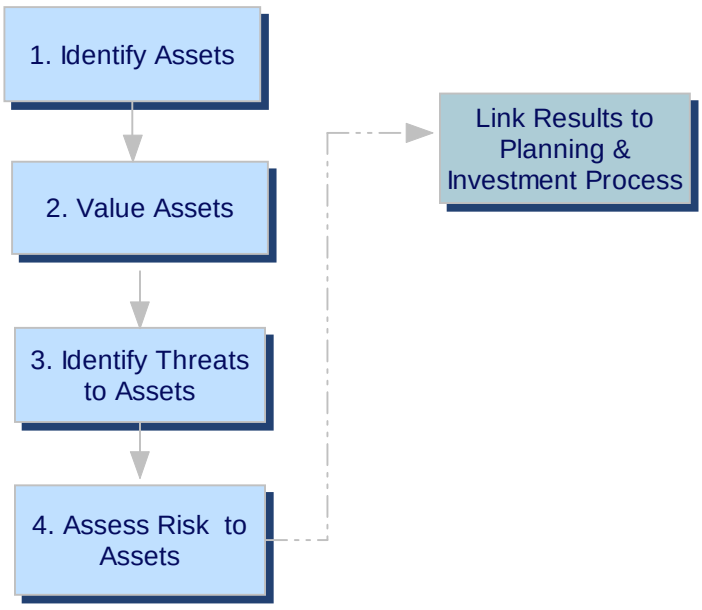


Figure 1. An assets-based approached for NRM investment Source: DSE (2007)

The Index of Stream Condition (ISC)

The Index of Stream Condition (ISC) was developed for assessing the condition of rural rivers and streams in Victoria (Department of Sustainability and Environment 2006). It provides a consistent state-wide assessment of river condition. This information is used in a River Values and Environmental Risk System (RiVERS) to assist with setting priorities and assessing the effectiveness of management programs. The ISC provides a measure of river health for Victorian freshwater river reaches. The Index comprises five components (sub-indices): Hydrology; Physical form; Streamside zone; Water quality; and Aquatic life (Table 1). Each component is scored between 0 and 10 based on an assessment of indicators. A report card provides scores for each sub-indice (1 to 10) as well as an overall environmental condition score for individual river reaches, rivers and basins (see examples Appendix 1 & Appendix 2).

The Department of Sustainability and Environment (DSE) is currently investigating the development of an Index of Estuarine Condition. This will provide sub-indices and indicators for reporting on the environmental condition of the estuarine reach of Victorian Rivers.

Table 1. ISC (2004) sub-indices (in bold) and indicators

Hydrology: Low Flows: High Flows; Zero Flows; Seasonality; Variability	**Physical Form:** Large Wood; Fish Barriers
Water Quality: Phosphorus; Turbidity; Salinity; pH;	**Aquatic Life:** AUSRIVAS; SIGNAL
Streamside Zone: Width; Longitudinal Continuity; Understorey; Recruitment; Large Trees; Tree Canopy cover; Litter; Logs; Weeds	

The Victorian River Health Strategy (VRHS) identified the environmental, social and economic assets of rivers; these were subsequently incorporated into each regional River Health Strategy (RHS). RiVERS is a risk based program which supports each regional RHS. STREAMs is a similar program used to assess urban rivers and streams in the region around Melbourne and is supported by an Index of River Condition (IRC). The programs offer a consistent method for prioritising river reaches by providing a set of rules for valuing each asset and the threats to those assets. These scores generate a risk assessment for individual river reaches and entire river systems. This information is used to guide investment in river health in each Catchment Management Authority region. Scores from ISC assessments support the environmental risk assessments for RiVERS and STREAMS, by providing scores for both assets (e.g. aquatic life) and threats (e.g. water quality & hydrology)

The DSE and Melbourne Water have recently investigated modifying RiVERS and STREAMS respectively, to include estuarine assessments. This involved identification of ‘estuarine assets’ (Arundel 2007) and potential threats to those assets.

Further details of the approach used in the RiVERS and STREAMs programs is provided in Section 3.5. To avoid repetition only RiVERS and the ISC is referred to in subsequent sections of this report but comments are also applicable to STREAMS and IRC programs.

2.2. National programs

National Estuarine Environmental Condition Assessment Framework

The National Land & Water Resources Audit is currently developing a scoping report to guide the next national Estuarine Coastal and Marine Assessment. As part of this program, a National Estuarine Environmental Condition Assessment Framework (NEECAF) (Arundel and Mount 2007) was developed to provide direction for reporting on the broad ecological integrity of estuaries at a national level. The NEECAF is based on a generic Environmental Condition Assessment Framework (ECAF) (see Appendix 3), which is designed be used in other thematic areas including the marine environment.

Although the NEECAF is still under development, there was strong support for the general approach and key components of the Framework by researchers and regional, state and national managers who participated in a series of round table discussions. These discussions aimed to assess and provide feedback on the feasibility of developing a national environmental assessment framework (Arundel and Mount 2007; 2008; Mount *et al.* 2008).

The ECAF is designed to generate a range of reports to satisfy different objectives and accommodate varying levels of information. A summary list is provided in Mount *et al* (2008) and includes:

1. 1st Pass
    - Inventories and gap analyses
    - Classifications
    - Conceptual models
    - Susceptibility assessments
    - Types of pressures/threats assessments
    - Scientific research reports
2. 2nd Pass (all above plus)
    - Pressure assessments
    - Degree of modification assessments
    - Risk assessments
3. 3rd Pass (all above plus)
    - Indicator reports
4. Overall Condition Assessment e.g. Report Card
    - Based on available information drawn from all available passes

Framework for River and Wetland Health (FARWH)

The National Water Commission under the National Water Initiative (NWI) is developing the national Framework for the Assessment of River and Wetland Health (FARWH) as part of the Australian Water Resources 2005 project. The FARWH (Norris *et al.* unpub.) will guide the national assessment of river and wetland health.

A draft FARWH proposes 6 indices, or themes, for the assessment of river and wetland health by measuring human induced change in natural resource condition, as follows:

- Catchment disturbance. Land use, land cover change and infrastructure.
- Hydrological change. Deviation from mean annual flow, Change to the flow duration curve, Change to seasonal amplitude and periodicity; Changes to water regime timing, frequency, extent & depth and variability, including groundwater contribution
- Physical form and processes. Bedload condition, (compared with pre-1750 condition, and connectivity (comparison with no dam, levee diversion or pumping regime)
- Water (and sediment) quality. Basin scale - four indices; SS, TP, TN and salinity. Reach scale- three indices; SS, TN and TP. Data for toxicants and salinity considered too sparse
- Fringing zone (i.e. Includes 100m beyond riparian). Includes riparian biota condition and riparian vegetation condition
- Biota. Comparison with biota in near pristine environments. Ideally several would be used e.g. invertebrates, but also fish water plants algae and riparian vegetation

Two extra themes were recommended for inclusion if the framework was applied to estuarine systems (Arundel & Mount 2007).

- Waterway activities. Commercial and recreational fishing boating etc
- Marine Connectivity. Changes to connectivity e.g. dredging groynes artificial opening.

3. Process for development of report cards

The approach used for reporting on the condition of, and risk to, ecological condition of estuaries for this project builds on programs currently used at a state and national levels.

The steps undertaken to develop the pilot report cards for Victorian estuaries are summarised in Figure 1 and include:

- Develop conceptual model
- Collate existing data about the estuary – this includes any existing management objectives for the estuary and biological and physicochemical information. The level of confidence in the data collated will also be noted.
- Identify and score the assets
- Identify and score the threats to the assets
- Score the level of association of each threat to each asset
- Score or note the vulnerability of an estuary to a particular threat.
- Calculate the risk to the assets from the threat
- Describe the condition of the estuary

The information collected at each step supports the production of a range of reports. Each step is discussed in more detail below. This report focuses on the process of development and the content of four reports; an inventory report, a risk assessment report, a condition and an estuary status report. Time constraints precluded the design and development of the actual report cards.

3.1. Develop conceptual model

A conceptual model depicts our understanding of the structure and function of a particular estuary, or estuary type. It provides a pictorial or schematic representation of the key physical features and processes (assets) within a system, the pressures on those assets and any interactions between pressures. Developing a conceptual model is therefore an important first step for identifying and selecting key assets and threats for reporting on estuarine condition.

Conceptual models for intermittently open estuaries are still at an early stage of development. They will be developed for Victorian estuaries as part of the ‘Index of Estuarine Condition’ (IEC) project being undertaken by the DSE in 2008. The project will be informed by conceptual models developed for estuaries with some common characteristics in other states, in particular ICOLLs in New South Wales and estuaries in Western Australia and South Africa.

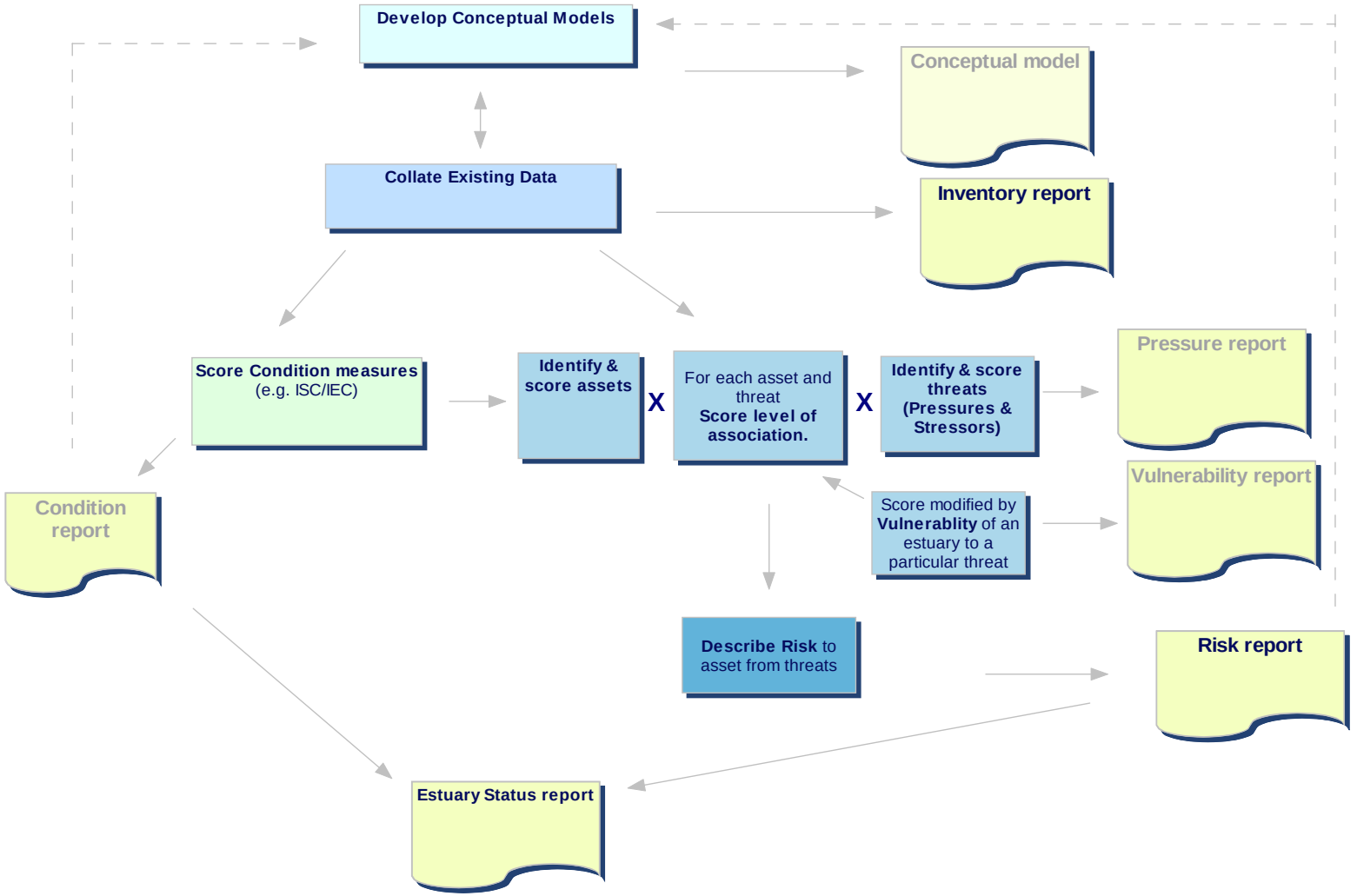


Figure 2. Steps for developing pilot report cards for Victorian estuaries. All potential report cards are shown, those in bold are presented in this report

3.2. Collate existing data

An inventory template was developed for this project to guide collection of all data potentially relevant to the assessment of Victorian estuarine condition (Appendix 4). How the information is presented was largely dictated by how it is to be used in subsequent reports. The template includes a section for physicochemical parameters, which provides a context for understanding and interpreting the ecological data. Further information was grouped under broad categories provided by the FARWH. Allocation of measures to particular categories is often ambiguous, however, these categories accommodated both measures used in the ISC and RiVERS and are generally consistent with other state and national programs (Table 3)

The information under these categories closely followed the format of an inventory being compiled in Western Australia (V. Forbes pers. comm.). Further measures, relevant to Victorian estuaries, were identified from research conducted on Victoria's estuarine systems (Barton 2006; Arundel 2007; Barton *et al* 2008). However, it should be noted that these will be reviewed and revised this year as part of the IEC project.

Data for the inventory report was sourced from a number of outlets and included EPA monitoring programs, 'snap-shot' data collected by the EPA from selected estuaries, PhD, MSc. and honours studies. In addition, management plans, technical reports and other short term studies were also obtained and relevant data and information extracted.

3.2.1 Management objectives

Establishing management objectives enables estuarine values to be identified and targets to be set to protect or enhance those values. It is important that ecological assessment reports are set against realistic benchmarks. For example, comparing and scoring a highly modified urban estuary against a pristine estuary would set an unattainable standard and would not be useful for directing management resources. Inclusion of objectives in reports also provides a context for interpreting information about an estuary's ecological condition.

For some estuaries, estuary management plans may establish clear objectives specific to an estuary. These plans often identify the values of the estuary and the pressures on those values. They may also specify the level at which they should be maintained or targets for improvement.

In the absence of objectives for specific estuaries, broad objectives for water quality are provided by State Environment Protection Policy (SEPP) (Waters of Victoria). This policy is consistent with the categories in the National Water Quality Guidelines.

The SEPP recognises three categories of aquatic ecosystem protection based on the degree of modification to the system. These are:

Largely unmodified ecosystem: means an aquatic ecosystem where human activity has had a minimal impact and consequently the system is largely undisturbed

Slightly to moderately modified ecosystem: means an aquatic ecosystem where human activity has caused a measurable disturbance

Highly modified ecosystem means an aquatic ecosystem which has been significantly disturbed as a result of human activity

Rivers recognised as Heritage Rivers under the Heritage Rivers Act 1992 have significant nature conservation, recreation, scenic or cultural heritage attributes. The objectives for these rivers should include protection of the particular values nominated in their listing as a Heritage River.

3.2.2. Data quality

The quality of data used to support each measure will vary between estuaries as well as between the variables themselves. Some measures may be collected using recognised sampling protocols, supported by strong quality control measures. Others may be collected as part of a single-time study with little spatial replication. Assigning levels of confidence to the data allows the report writer to include all available data but also provides the reader with the information necessary to interpret and weight the information supplied. It also highlights estuaries or particular measures where investment in data collection is required

Ideally, for each measure, best-practice protocols should be developed to guide data collection. However, for the purpose of this report, data quality scores were assigned using categories described in the draft Stream and Estuary Assessment Program (SEAP) (pers comm. D.Scheltinga Qld EPA) (Table 2).

Table 2. Data Quality Source: D. Scheltinga pers comm.)

Confidence in Data	Scoring category	Definition
Very high	1	High quality data collected according to international, national or state recommended protocols, good temporal and spatial replication. Strict quality assurance and quality control measures in place. Data ‘current’.
High	2	Good quality data collected according to recognised protocols but poor temporal and spatial replication. Quality assurance and quality control measures in place.
Moderate	3	Data quality and replication questionable. Little quality assurance or control.
Low	4	One-off data used (no replication) or data of dubious quality. Low accuracy equipment used. Poor methodologies used with no quality assurance or control. Data ‘old’.

Table 3. Categories used in state and national programs for grouping measures relevant to ecological condition reporting.

ISC	Estuarine threats (Barton *et al* 2007)	Streams & Estuaries Assessment Program (VIPSIRR)	Nationally agreed estuarine, coastal & marine (ECM) Indicators	Framework for assessment of river and wetland health (FARWH)
Physical form				**Physical form and processes.**
Large Wood; Fish Barriers			Sedimentation/erosion rates, Shoreline position	Bedload condition, (compared with pre-1750 condition, and connectivity (comparison with no dam, levee diversion or pumping regime)
	Entrance modification			**Marine connectivity**
Water quality		**Nutrients**		**Water (and sediment) quality**
Phosphorus; Turbidity; Salinity; pH;		Total P load Total N load	Turbidity, Salinity, pH, Nutrients, Toxicants, Dissolved oxygen, Temperature	Basin scale - four indices; SS, TP, TN and salinity. Reach scale- three indices; SS, TN and TP.
Hydrology	**Hydrological change**	**Hydrodynamics**		**Hydrological change**
Low Flows: High Flows; Zero Flows; Seasonality; Variability		% of estuary modified (channels, walls etc); Presence of structures/behaviours that modify flow		Deviation from mean annual flow, Change to the flow duration curve, Change to seasonal amplitude and periodicity; Changes to water regime timing, frequency, extent & depth and variability, including groundwater contribution
Aquatic life		**Habitat removal**		**Biota**
AUSRIVAS; SIGNAL		% habitat modified (includes intertidal, subtidal and floodplain)	Chlorophyll a Animal or plant species abundance Coral bleaching Pest species Algal blooms Targeted pathogen counts Vertebrates impacted by human activities Mass mortality events	Comparison with biota in near pristine environments. Ideally several would be used e.g. invertebrates, but also fish water plants algae and riparian vegetation
Streamside zone				**Fringing zone**
Width; Longitudinal Continuity; Understorey; Recruitment; Large Trees; Tree Canopy cover; leaf litter; Logs; Weeds			Extent/presence litter	(i.e. Includes 100m beyond riparian). Includes riparian biota condition and riparian vegetation condition
	Catchment land-use			**Catchment disturbance**
	Fluvial catchment land use			Land use, land cover change and infrastructure.
	Coastal development			
	Built infra structure; estuarine catchment land use			
	Recreational & commercial use			**Waterway activities**
	Fishing, ports; boating			

3.2.3. Inventory report

Data from a Victorian estuary was used to populate the template to create an inventory report (Appendix 5.). Information supplied by the inventory report enables:

- development and refinement of conceptual models;
- population of the ISC/IEC;
- population of the RiVERS program;
- identification of information gaps; and
- a focus for data collection and monitoring programs.

The inventory templates should be modified in future to better support the information requirements of both the IEC and the revised RiVERS when developed.

3.3. Identification of estuarine assets

The Victorian River Health Strategy (VRHS) defines assets as 'The attributes of the river which hold value for the community and about which the community would be concerned if they were lost or degraded' (DNRE 2002). Riverine assets selected for inclusion in the VRHS, and hence RiVERS, also need to meet the criteria of naturalness, rarity, diversity, and/or significance at a landscape scale.

A recent project (Arundel 2007) evaluated the environmental, social and economic assets currently used in RiVERS for their applicability to assessments of estuarine reaches and suggested the inclusion of some specific estuarine assets. The recommendations from this project provided direction for the pilot report cards regarding the asset categories (rarity, representativeness and naturalness) and the approximate number of assets selected. Representativeness has not been included as there are no estuaries identified as 'representative' of an 'ecologically healthy state' in each region. The rationale for inclusion of each asset is presented in Arundel (2007).

Table 4. Recommended environmental estuarine assets

Asset	Description
Rarity	
Ecological Vegetation Classes	Bioregional conservation status
Rare and threatened species - Flora	No. of rare and threatened species
Rarity & depletion of Wetland Type	Percent of type remaining or status in the bioregion
Wetland/Estuary significance	Recognised as significant at a state, national or international level
Naturalness	
Riparian 1	Width of riparian area
Riparian 2	Longitudinal continuity
Riparian 3	Structural intactness & % indigenous
Rare and threatened species - Fauna	Presence of rare and threatened species
Native fish 1	Observed to expected species (diversity measure)

Native fish 2	Migration (use of reach by facultative and obligate estuarine species)
Birds	Observed to expected (diversity) Abundance (% of population)

For some assets, attributes used to score the importance of the asset previously developed for freshwater reaches were considered applicable to estuaries, e.g. Bioregional Conservation Status of Ecological Vegetation Classes (Table 5). For other assets, attribute descriptions were suggested in Arundel (2007), but these have not been tested to determine whether the attribute descriptions and scores reflect the range of conditions of the assets in Victorian estuaries. In particular, descriptions and scores associated with assets as measures of 'Naturalness' (i.e. fish, birds, riparian vegetation) need further development. For the purpose of developing the report cards 'expert opinion' was used to provide a score for relevant assets if detailed attribute descriptions were not available.

Table 5. Example: Bioregional Conservation Status of EVCs (s)

Score	Attribute descriptions
1	Least concern- >50% of pre-European extent exists and subject to little to no degradation over a majority of this area
3	Rare-(as defined by geographic occurrence) but neither depleted, degraded nor currently threatened to an extent that would qualify as endangered, vulnerable or depleted, or Depleted- >30%-50% of pre-European extent remains (or a combination of depletion, loss of quality, current threats and rarity that gives a comparable status)
4	Vulnerable-10-30% of pre-European extent remains (or a combination of depletion, loss of quality, current threats and rarity that gives a comparable status)
5	Endangered- <10% of pre-European extent remains (or a combination of depletion, loss of quality, current threats and rarity that gives a comparable status), or Presumed Extinct probably no longer present in the bioregion (or, if present, below the resolution of available mapping)

3.4. Identification of potential threats

Victoria has tried to assess the impact or threat of human activities to estuaries under five broad logical management categories: catchment land use; freshwater alteration; coastal development; mouth manipulation; and recreational and commercial use. These five categories are used to group more specific threats based on our current understanding of their impact on estuary assets.

Water quality measures in Victorian estuaries do not provide a clear indication of estuary condition (Barton 2006). She found that water quality measures (dissolved oxygen, turbidity, nutrients) in surface and bottom waters did not distinguish estuaries of different condition (minimally, intermediately or highly modified -based on degree of alteration and land use). High nutrients and low dissolved oxygen were found in minimally as well as highly modified estuaries. The nutrient concentrations she found were higher than those found in the same estuaries in Mondon et al (2003), and for comparable estuaries in NSW (Scanes et al. 1997) and Tasmania (Murphy et al. 2003). The median NOx was higher than the Victorian specific guidelines for all estuaries (Leonard & Steven 2001). The ISC Total Score of the immediate upstream

freshwater reach provided a good indication of the freshwater catchment condition and the water quality entering the estuary.

Water algal or chlorophyll *a* measures are commonly used for estuary water quality monitoring but with the exception of some estuaries in western Victoria, are not routinely collected from Victorian estuaries. These measures warrant further investigation and are included as a potential threat in this report. However, the algal blooms, associated with high nutrient in NSW and WA estuaries, are not often observed in Victorian estuaries.

The ISC Hydrology score of the immediate upstream reach provides a measure of the hydrologic deviation of freshwater entering the estuary from the natural flow regime and incorporates high flow, low flow, zero flow variability and seasonality. A methodology to specifically determine the environmental flow requirement (eFLOWS) of Victorian estuaries is currently being developed. The methodology will help determine the level of threat to estuaries associated with altering the flow regime.

Barton (2006) found that estuarine catchment land use and population density were significantly correlated with sediment quality measures, but not water quality measures. The physical characteristics and degree of alteration in the estuary and its immediate catchment distinguished between estuaries of different types and conditions. This relationship was not found for the estuaries freshwater catchment, nor its coastal characteristics or its water quality. The percentage of the estuarine catchment under dry land agricultural or urban use was the major significant difference between estuary conditions. She found that land-use intensity was high in Victorian estuaries especially the degree of urbanisation in their estuarine catchment compared to Tasmanian or southern Western Australian estuaries (Edgar & Barrett 2000, Radke et al. 2004). Coastal development in the estuary catchment is also associated with modification of the estuaries physical attributes through channelisation, dredging, marinas, jetties, levee banks, bank armouring (built edges) that can alter connectivity of the estuary to its flood plain.

Estuary mouth manipulation occurs in many Victorian estuaries. The building of infrastructure such as groynes and walls at the estuary entrance can alter currents entering and leaving the estuary and hence patterns of sand deposition. Many intermittently closed estuaries are artificially opened, thereby altering the inundation regime of riparian areas and causing the potential loss of fish eggs and larvae and a reduction in available breeding and foraging habitat for fish and birds. Artificial entrance openings have also been associated with mass ‘Fish Kills’, particularly in stratified estuaries.

The majority of Victorian estuaries are too small to support commercial fishing except for the major bays and inlets (Port Phillip Bay, Western Port Bay, Corner Inlet, and Gippsland Lakes). Several of the smaller estuaries do support eel fisheries, which in a recent review were considered to be managed sustainably (McKinnon 2002).

3.5. Assess risk

Risk is conventionally defined as a combination of the likelihood of a risk and the consequence of the risk occurring (AS/NZS 1999)

In RiVERS, and this report, likelihood is a combination of the strength of the threat (scored from 1 to 5) and the strength of the association of that threat to a particular asset. The association score recognises that not all threats will impact equally on all

assets. For example, the threat ‘Barriers’ will strongly impact on the asset, ‘Fish migration’ but will not influence the ‘Riparian’ assets.

An influence matrix is used in RiVERS to score the strength of various threats on each asset, that is, the level of association. Scores are assigned from 1 (‘practically impossible’) to 5 (‘almost certain’)

Consequence corresponds to the value of the asset, scored from 1 to 5. The higher the value of the asset, the greater the consequence to the estuary function or management objectives (in the case of some ‘rarity’ assets) if it is lost or degraded.

Risk =	**Likelihood of the risk**	X	**Consequence of the risk occurring**
	(Threat score x Association score)	X	(Asset score)

3.5.1. Levels of association and vulnerability

This report also recognises that some aspects of the physical structure or function of estuaries are likely to increase their susceptibility or vulnerability to change from particular pressures. The level of vulnerability will therefore modify the assigned association score. Classification of estuaries into groups of similar physical form or function can provide a structure for evaluating vulnerability (Moverley & Hirst 1999, Heap et al. 2001, Barton 2003, Ryan et al. 2003, Barton 2006, Kurtz et al. 2006). Barton (2006) found a simple classification (open coast West- or East-facing or embayment.) that captured variation in estuary and catchment physical characteristics, freshwater hydrology, coastal energy and climate along the Victorian coast and allowed the identification of correlations between threats and estuary condition within groups. That is, different groups of estuaries may have differing vulnerabilities to some specific threats.

Some characteristics of estuaries would intuitively be expected to indicate vulnerability to a particular threat. For example, estuaries with a history of fish kills would suggest an increased vulnerability to artificially opening entrances; and algal blooms a vulnerability to nutrient loads. Further study is required to establish the importance of certain estuarine characteristics for indicating vulnerability to given threats. Vulnerability scores are not available at this stage, but where applicable, characteristics considered to be potential indicators of vulnerability should be included on inventory reports.

3.5.2. Risk reports

The Risk report assists Victorian regional managers assign investment priorities. It provides information about the level of risk to each asset selected for assessment (Appendix 6). The Risk report includes assets that measure the ecological condition of the estuary and also those that are measures of rarity e.g. important wetlands, rare and threatened species. These assets may not necessarily contribute to the function of the system but reflect human values and in some instances legislative responsibilities. The inclusion of economic and social assets in Risk reports explicitly acknowledges the importance of estuaries to the community for recreation and commercial investment.

The risk level supports the direction of management priorities to estuaries or reaches within estuaries considered most at risk. Providing information about the key assets and threats, which combine to create the risk, allows investment to be allocated to

appropriate management responses. That is, initiatives may focus on reducing the threat or protecting the asset in some other way.

Summary information from the report can be presented for state and national audiences. Reports could include the location and number of estuaries at various levels of risk and highlight key threats. This information allows trends in estuaries at risk to be monitored and agencies to respond to different threats at an appropriate spatial scale.

Managers can also use Risk reports to inform and focus monitoring and data collection programs. These could include:

- further data collection to refine asset and threat scoring i.e. assess both the score level and the associated attribute descriptions.

- data collection to increase the level of confidence in the data;

- programs to measure the success of management initiatives designed to mitigate threats or increase value of assets;

- further research to address uncertainties in assigning association scores i.e to better understand the link between threats and assets.

3.6. Condition and condition reports

The Index of Stream Condition is currently used in Victoria to report on the condition of freshwater streams (Victorian Water Resources Data Warehouse.). In 2008 the Department of Sustainability and Environment propose to develop an Index of Estuarine Condition (IEC). The IEC will probably be consistent with the general approach of the ISC. That is, it will comprise five sub-indices and associated indicators, which are considered likely to reflect or influence the ecological integrity of Victoria's estuaries. To enable compatibility with the freshwater reaches, where possible the same broad categories will be used to group indicators: streamside zone; hydrology; water quality; physical form and aquatic life. Unlike the ISC, the causal link between many potential measures and the ecological function of estuaries has not been established. However, potential links will be identified during the development of both conceptual models and the IEC. It is acknowledged that selected measures will require testing in subsequent trials.

The applicability of the freshwater sub-indices to estuarine condition assessments is discussed below. Section 3.4. also includes a discussion of water quality, hydrology and algal blooms (aquatic life).

There is some evidence the sub-index 'water quality' should be modified to include sediment measures. Barton (2006) found that these sediment measures (microbial community function, organic content, phaeophytin concentration, grain size, redox and nutrient levels) distinguished estuaries of different condition. Some physical measures also described condition (e.g. water depth, temperature and redox potential, and habitat occurrence). However, both physical and sediment measures had different abilities to distinguish estuary condition within the three different estuary types. This suggests different processes or responses to processes were occurring in the different estuary types. The inclusion of estuary type (*sensu* Barton 2006) is recommended on estuary status reports.

Several recent studies have not supported the use of macroinvertebrate communities for assessing estuarine condition in Victorian estuaries. Factors found to limit the

usefulness of these communities in predictive models included spatial and temporal patchiness (Barton 2003), assemblages that are characterised by low species richness and many rare taxa and hence a more variable observed to expected ratio than for freshwater systems (Moverley & Hirst 1999) and no clear links between community structure and estuarine condition (Mondon et al. 2003).

Other measures of aquatic life, including submerged aquatic vegetation, algal blooms, fish and birds require further investigation to assess their value as estuarine condition measures. Fish diversity indices (e.g. Cooper *et al*. 1995), as used in South Africa, need to be tested in Victorian estuaries and possibly modified to include measures of abundance and recruitment. A bird index should also be considered. Species utilising estuaries may provide an integrated measure of habitat condition including vegetation types, range of water depths and prey species

Streamside zone is applicable to estuarine assessment but the indicators may need to be modified to ensure assessments reflect the naturalness of the entire floodplain and the particular vegetation structure found in the estuarine environment.

The IEC will generate condition reports that include scores assigned to the selected sub-indices and indicators. The format of these reports will probably be similar to the current ISC reports (see appendices 1 & 2). That is, they will provide a score for each sub-index and an integrated condition measure for each estuary.

It is envisaged that, as for the ISC, IEC sub-indices scores will also be used to populate some asset and threat scores in the RiVERS .

The Condition report will inform future data collection and monitoring programs. These could include:

- programs designed to test predicted connections between subindices and estuary condition;
- continuous monitoring programs required for some indicators (e.g. hydrology); and
- Field assessments to support assessments (e.g. streamside/riparian).

Information from both the risk and condition reports, and associated monitoring and data collection programs, increases our conceptual understanding of how estuarine systems function and enables refinement of conceptual models.

3.7. Estuary status report

It is recommended that a summary report that combines elements of inventory, condition and risk reports be produced for a wider audience including national reporting (Appendix 7). Estuary status reports could provide a summary of physical information about the estuary and provide context for other elements of the report which could include:

- integrated IEC scores as a summary of the ecological condition and condition targets;
- key assets and threats including environmental, social and economic values;
- critical and high risks for the estuary.

The broad categories used for reporting critical and high risk still needs to be considered. It is important for national reporting that these groupings are comparable

with other states. Other categories e.g. stressors used in the SEAP, require further investigation, however, as discussed in the Section 3.2, use of the FARWH categories is consistent with other Victorian assessment programs.

The status report could include references to any management objectives and indicate, where applicable, the vulnerability of the estuary to particular threats.

It is acknowledged that much of the information recommended for inclusion on the status reports is not currently available for Victorian estuaries. However, some sections of the report could be completed for all estuaries.

5. Glossary

DSE – Department of Sustainability and Environment

ECAF – Environmental Condition Assessment Framework

EPA – Environmental Protection Authority

EVC – Ecological Vegetation Classes

FARWH – Framework for River and Wetland Health

ICOLL – Intermittently Closed or Open Lake and Lagoon

IEC – Index of Estuarine Condition

IRC – Index of River Condition- for assessment of urban rivers and streams

ISC – Index of Stream Condition –for assessment of rural rivers and streams

NEECAF – National Estuarine Environmental Condition Assessment Framework

NLWRA – National Land and Water Resources Audit

NWI – National Water Initiative

RHS – River Health Strategy

RiVERS – River Values and Environmental Risk System. Database for prioritising management of rural rivers and streams

SEAP – Stream and Estuary Assessment Program

SEPP – State Environment Protection Policy

SEQWMP – South East Queensland Water Monitoring Program

STREAMs – database for prioritising management of urban rivers and streams

VRHS – Victorian River Health Strategy

VPSIRR- VPSIRR is a software package based on the Vulnerability-Pressure-State-Impact-Risk and Response model

6. References

Arundel H (2007) 'An asset based framework for Victoria's estuaries: Identification of assets.' Department of Sustainability and Environment, Melbourne.

Arundel H, Mount R (2008) 'National Marine Environmental Condition Assessment Framework (ECAF). Round Table Report.' National Land & Water Resources Audit.

AS/NZS (1999) 'Australian Standards/ New Zealand Standards- Risk Management 4360.' Australian Standards.

Barton JL (2006) Indicators of estuarine health in south-east Australian estuaries. PhD thesis, Flinders University, Adelaide

Barton J, Quinn G, Sherwood J (2007) 'Development of a methodology for assessing estuary pressures: relationships with catchment conditions.Stage 2 Linking catchments to the sea - understanding how human activities impact on Victorian estuaries.' Department of Sustainability and Environment, Melbourne.

Cooper, J. A. G., A. E. L. Ramm and T. D. Harrison (1994). "The Estuarine Health Index - a New Approach to Scientific-Information Transfer." Ocean & Coastal Management 25(2): 103-141.

Department of Sustainability and Environment. (2007) 'Land Asset-Based Approach Framework. Consultation draft, March 2007.' Department of Sustainability and Environment., Melbourne.

DNRE (2002) 'Healthy Rivers, Healthy communities and Regional Growth: Victorian River Health Strategy.' The State of Victoria, Department of Natural Resources and Environment, 2002.

Edgar GJ, Barrett NS (2000) Effects of catchment activities on macrofaunal assemblages in Tasmanian estuaries. *Estuarine, Coastal and Shelf Science* **50**, 639-654.

Leonard A, Steven A (2001) 'Water quality objectives for marine and estuarine waters - Ecosystem protection.' Environment Protection Authority, Melbourne.

McKinnon L (2002) 'Victorian Eel Fishery Management Plan.' Department of Natural Resources and Environment, Melbourne.

Mondon J, Sherwood J, Chandler F (2003) 'Western Victorian Estuaries Classification Project.' Prepared for the Western Coastal Board, Warrnambool, Victoria.

Mount R, Arundel H, Auricht C (2008) 'National NRM ECM Report Carding Best Practice Framework (BPF) Workshop. Background briefing paper.' National Land and Water Resources Audit, Canberra.

Murphy RJ, Crawford CM, Barmuta LA (2003) 'Estuarine health in Tasmania, status and indicators: Water quality.' Tasmanian Aquaculture and Fisheries Institute, 16, Hobart, Tasmania.

NLWRA (2002) 'Australian Catchment, River and Estuary Assessment.' prepared by National Land & Water Resources Audit.

Norris R, Dyer F, *et al.* (unpub.) 'A Framework For Comparable Assessment of the Ecological Condition of Australian Rivers and Wetlands. Draft report for the Australian Water Resources.'

Radke LC, Prosser IP, Robb M, Brooke B, Fredericks D, Douglas GB, Skemstad J (2004) The relationship between sediment and water quality, and riverine sediment loads in the wave-dominated estuaries of south-west Western Australia. *Marine and Freshwater Research* **55**, 581-596.

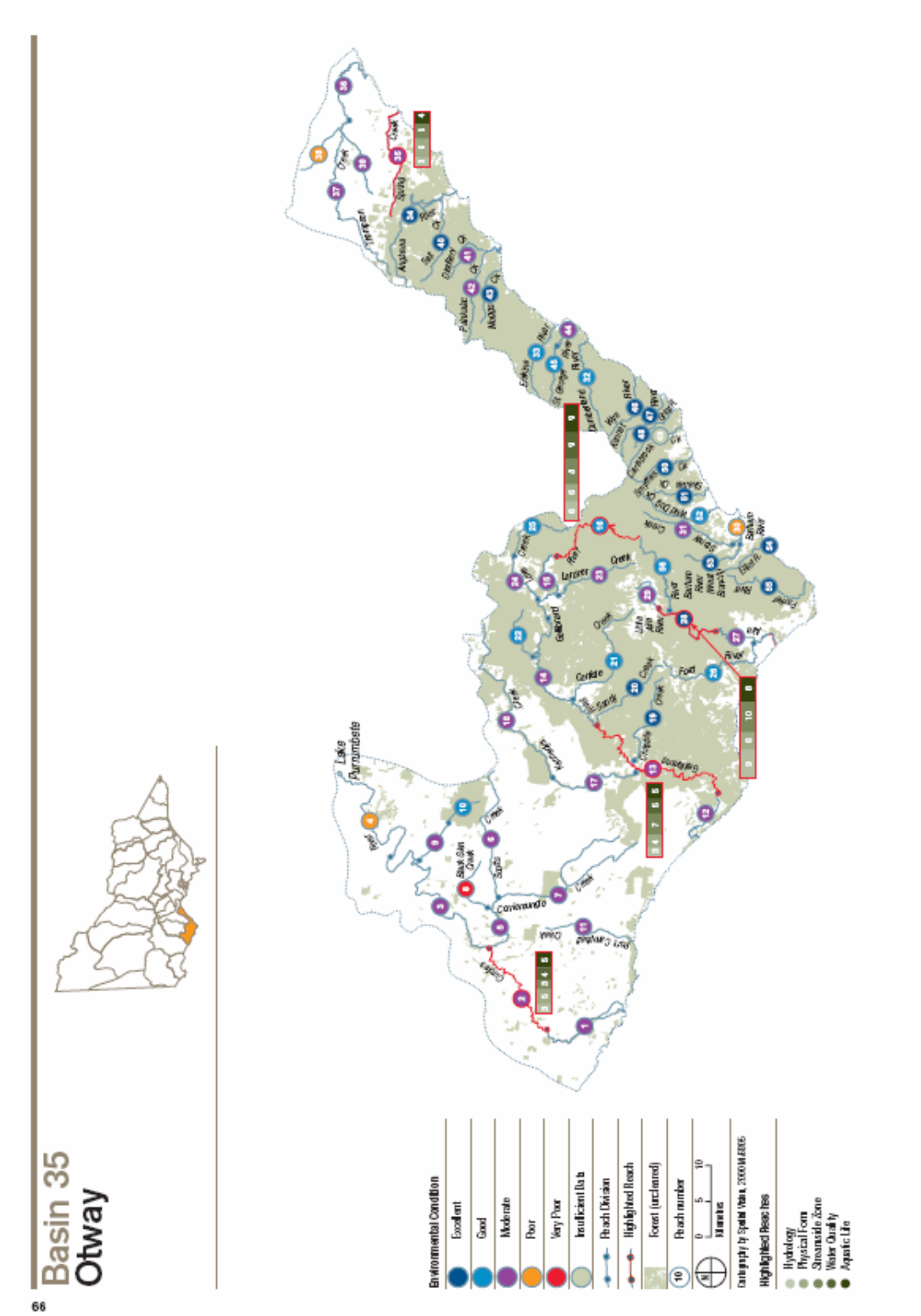
Scanes P, Coade G, Large D, Roach T (1997) Developing criteria for acceptable loads of nutrients from catchments. In 'Coastal nutrients workshop'. (Ed. K Koop) pp. 89 - 99. (Australian Water and Wastewater Association Incorporated: Sydney)

VCMC (2007) 'Catchment Condition Report 2007.' Victorian Catchment Management Council.

Victorian Water Resources Data Warehouse. Index of Stream Condition 4/4/08 http://www.vicwaterdata.net/vicwaterdata/home.aspx

7. Appendices

Appendix 1. Report of environmental condition of reaches and streams in the Otway Basin. Source (DSE 2008)



Extensive native hardwood forests cover more than 60% of the catchment. Towards the west, forests have been logged to make way for agriculture, mainly dairying and cattle grazing. There are no major water storages.

Almost half of the stream length was in good or excellent condition (16% and 24% respectively). This was attributed to the largely undisturbed environment. Just over half the stream length was in moderate condition (53%), mainly in the cleared western section of the basin. Four reaches, representing 6% of total stream length, were in poor or very poor condition.

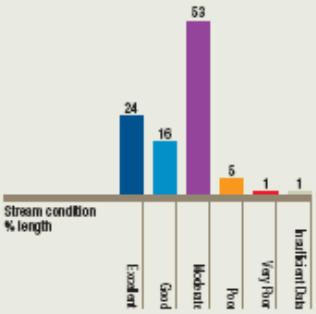
Of the 56 reaches, 17 had flow regimes at or near natural conditions. These reaches included many tributaries of the Gellibrand and Aire Rivers and small mountain streams, including Wye, Kennet and Parker Rivers and Carlsbrook and Smythes Creeks. The Curdies River, the lower Gellibrand River, Kennedys Creek and Barham River, demonstrated periods of low flow and summer stress. Lower scores were attributed to water diversions for small coastal towns.

Water quality data was collected for nine reaches. Water quality at reaches 16 and 21 was near reference condition. The two poorest quality sites were on reaches 17 and 24. Both recorded elevated levels for total phosphorus, salinity and turbidity. High levels of total phosphorus were recorded in nearly all tested reaches. This was attributed to stock access, dairy effluent and agricultural run-off.

The heavily vegetated catchment meant that nearly 60% of reaches scored well for streamside zone parameters. Reaches 25, 28, 32, 40, 51 and 55 – all in the forested mountains – were in reference condition. Reaches with highly modified streamside zones, are on the Upper Curdies River and Black Glen Creek (reaches 4 and 8). Both have been degraded by grazing.

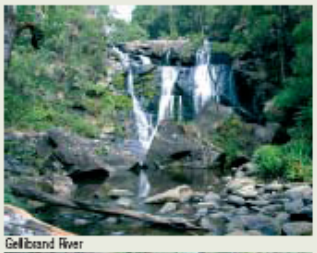
Like streamside zone results, scores for physical form were generally moderate to good. Reaches 34, 51 and 55 were in near pristine condition. In contrast, reach 15 (upper Gellibrand River) scored poorly for all physical form parameters, indicating a highly modified environment. For most reaches banks were generally stable. Typically, forested reaches had higher levels of instream wood.

Seventeen reaches were assessed for aquatic life and of these, two-thirds had above average macroinvertebrate populations. Reach 15, on the upper Gellibrand River, was in reference condition. Other high quality reaches included reaches 14, 16, 28 and 29, all located in forested sections. The two lowest scoring reaches, 27 and 35, were in cleared areas.



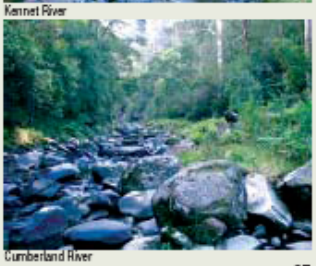
Otway

"Just under one-half of the basin's stream length is in good or excellent condition attributed to the largely undisturbed environment."


Gellibrand River

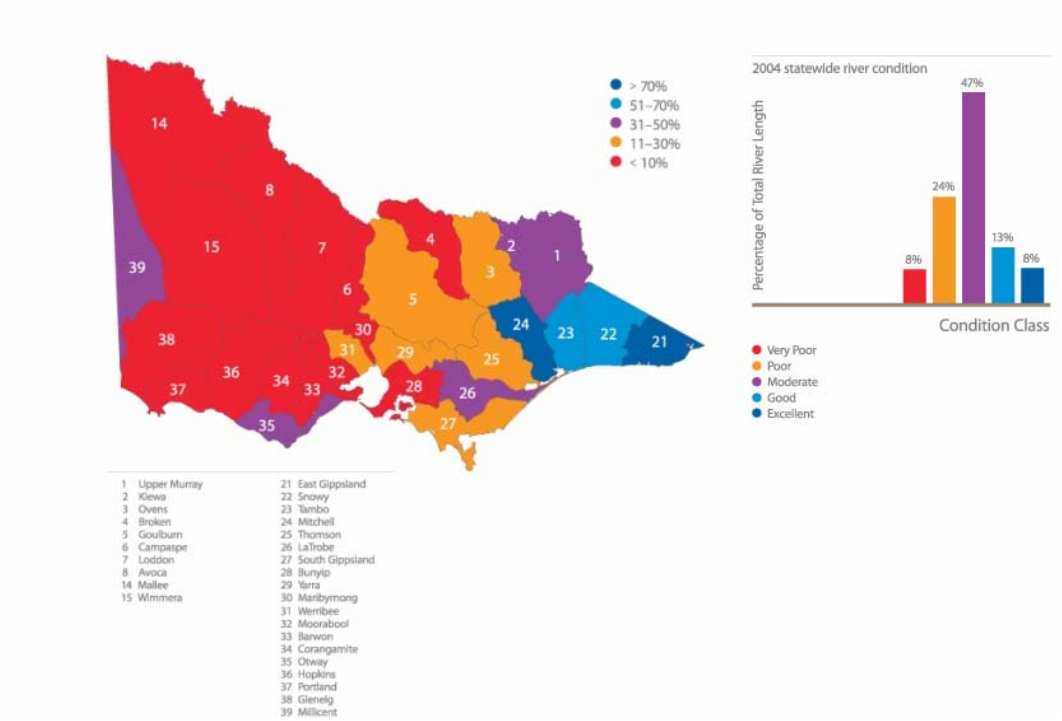

Kennet River


Gellibrand River

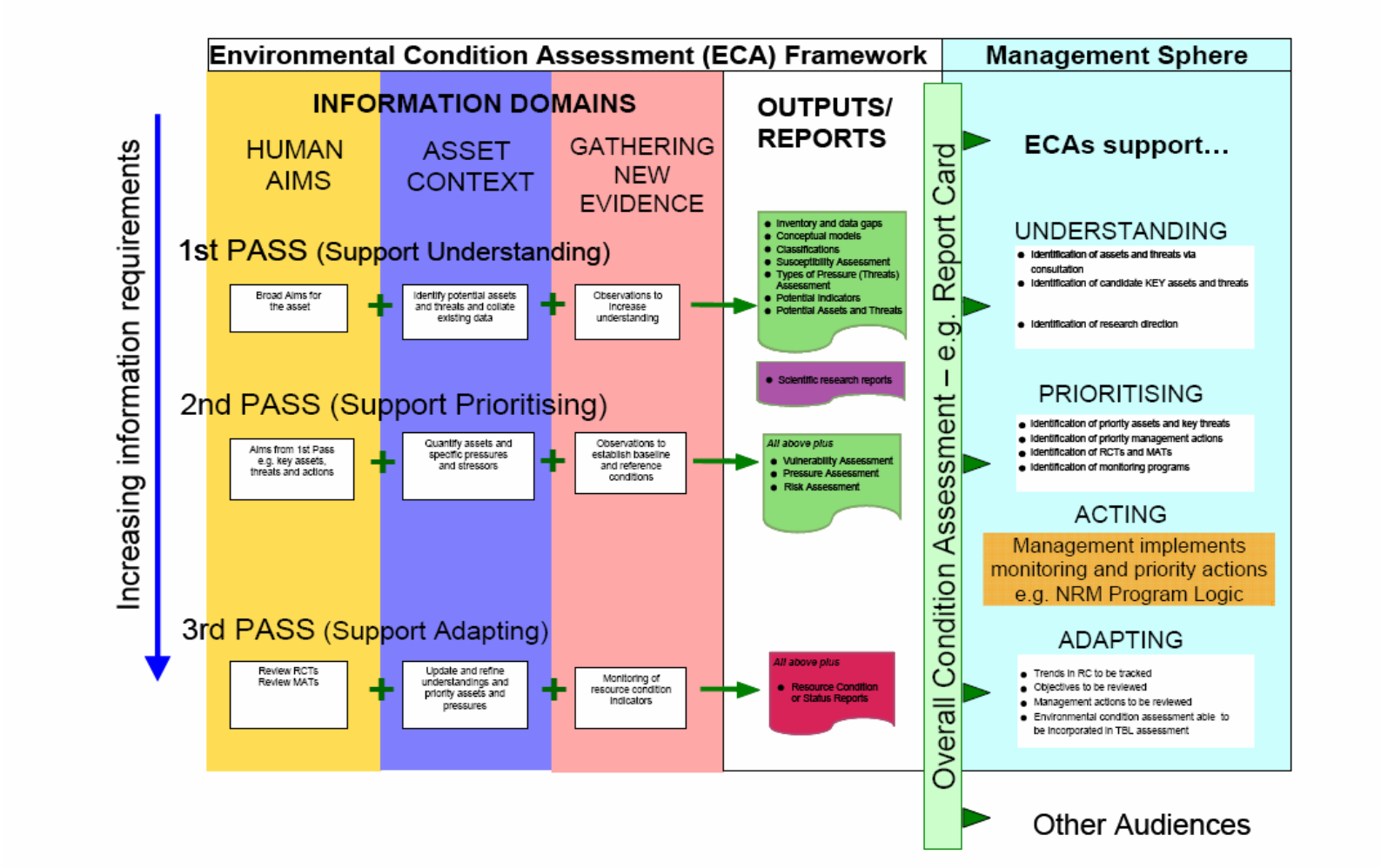

Cumberland River

67

Appendix 2. Report of environmental condition of basins. Source DSE (2008)



Appendix 3. The proposed National Environmental Condition Assessment Framework. Source (Mount *et al.* 2008)



Appendix 4. Inventory template

Physical Description	**Description**				
Size	ha/km2				
Catchment : Inlet	x:y				
Salinity profile	Long.	Horiz.			
Frequency of stratification	Freq.	Infreq.	Never		
Saline extent	km				
Estuary surface area	km^2				
Volume	m^3				
Residence time	Hours	Days	Weeks	Months	
Geomorphic type					
Victorian classification					
Water & Sediment Quality	**Description**				**Data Quality**
Water quality					
Nutrients	**TN**				
	Median	**Min**	**Max**		
	TP				
	Median	**Min**	**Max**		
	NH3				
	Median	**Min**	**Max**		
	FRP				
	Median	**Min**	**Max**		
Dissolved oxygen	Anoxic	Oxic			
Anoxia	Never	Infreq.	Freq.		
Hypoxia	Never	Infreq.	Freq.		
Clarity (secchi depth m)	**Median**	**Min**	**Max**		
ISC (immediately upstream)					
Sedimentation	**Description**				**Data Quality**
Sediment transport (mean TSS)	TSS				
Sediment load	mm/yr				
Sediment	**Description**				
Organic matter	% Loss				
	Median	**Min**	**Max**		
Nutrient sink or source	Sink	Source			
P binding	Yes	No			
Denitrification efficiency					
MPB (Chl a)	**Median**	**Min**	**Max**		
Redox mV	**Median**	**Min**	**Max**		
Oxic Depth (cm)	**Median**	**Min**	**Max**		
Sediment oxygen demand					
Size distribution	coarse	sand	mud	clay	
Marine connectivity	**Description**				
Opening type	Perm	Natural	Assisted		
Bar opening frequency	Always	Freq.	Infreq.	Never	
Bar opening duration	Days	Weeks	Months	Always	
Waterway Biota	**Description**				
Microbial community function (MCF)	assemblage				
SAV					
Present	Yes	No			
Coverage	Area				
Type	Perrenial	Annual			

Epiphyte coverage	Yes	No			
Epiphyte type	Micro	Filamentous			
Macrophyte coverage	Yes	No			
Macrophyte type	Seagrass	Charophyte	Other		
Macroalgal blooms	Freq.	Infreq.	Never		
Microalgae	Description				
Phytoplankton dominance	Yes	No			
Activity	cells/ml				
Microalgal blooms	Freq.	Infreq.	Never		
Harmful algal blooms	Freq.	Infreq.	Never		
chlorophyll (mg/L)	**Mean**	**Min**	**Max**		
Birds					
species	species names				
Fish	**Description**				**Data Quality**
Fish Stocks	number				
Target species	species names				
Dominant type	fresh	estuarine	marine		
Introduced species	**Description**				**Data Quality**
Introduced fauna	Species /abundance				
Introduced flora					
Streamside Zone					
Riparian vegetation	Description				
Dominant type	Samphire	Melaleuca	Mangrove	Cleared	
Flood plain connectivity	Yes	Partial	No		
Weed dominated					
ISC					
Physical form & Processes					
Built structures	Levees/ groynes/ channels	Number and length if applicable			
Waterway activities	**Description**				
Commercial fishing	Yes	No			
Recreational fishing	Yes	No	popularity: high med low		
Port					
Boating	Motor/non motor popularity high med low				
Catchment use					
Estuary Catchment					
	Forestry	Dryland Agriculture	Irrigated Agriculture	Urban	Conservation
	%	%	%	%	%
Stormwater & licensed discharge	Number & pipe size: description of discharge				
Fluvial Catchment					
	Forestry	Dryland Agriculture	Irrigated Agriculture	Urban	Conservation
‘	%	%	%	%	%
Other					
‘Fish Kill’	frequency				

Appendix 5. Inventory Estuary A

Physical Description	Description				
Size	12 363 km2				
Catchment : Inlet	x:y				
Salinity profile		Horizontal.			
Frequency of stratification	Freq.		Never		
Saline extent	70 km				
Estuary surface area	5.11km^2				
Volume	22 000 M^3				
Residence time	Hours	Days	Weeks	Months	
Geomorphic type	2b				
Victorian classification	Open west				
Water & Sediment Quality	**Description**				**Data Quality**
Water quality					
Nutrients					
TN	**Median**	**Min**	**Max**		
	1.2	0.1	5.1		**1**
TP	**Median**	**Min**	**Max**		
	0.04	0.02	0.27		**1**
NH3	**Median**	**Min**	**Max**		
	NA				
FRP	**Median**	**Min**	**Max**		
	NA				
Dissolved oxygen		Oxic			**2**
Anoxia		Freq.	Partic. Deeper water		**2**
Hypoxia			Freq.		**2**
Clarity (secchi depth m)	**Median** 1.25	**Min** 1.1	**Max** 1.75		
ISC (immediately upstream)					
Sedimentation	**Description**				**Data Quality**
Sediment transport (mean TSS)	TSS				
Sediment load	mm/yr				
Sediment	**Description**				
Organic matter	% Loss				
	Median 3.8	**Min** 3.175	**Max** 4.319		
Nutrient sink or source					
P binding					
Denitrification efficiency					
MPB (Chla)	**Median** 8.4	**Min** 0	**Max** 13.64		
Redox mV	**Median** 60.5	**Min** -188	**Max** 320		
Oxic Depth (cm)	**Median** 2	**Min** 0	**Max** 5		
Sediment oxygen demand					
Size distribution					
Marine connectivity	**Description**				
Opening type		Natural	Assisted	both	
Bar opening frequency		Freq.			
Bar opening duration		Weeks to Months			
Waterway Biota	**Description**				
Microbial community function					
SAV					

Present	Yes	No			
Coverage	Area				
Type	Perrenial	Annual			
Epiphyte coverage	Yes	No			
Epiphyte type	Micro	Filamentous			
Macrophyte coverage	Yes	No			
Macrophyte type	Seagrass	Charophyte	Other		
Macroalgal blooms	Freq.	Infreq.	Never		
Microalgae	Description				
Phytoplankton dominance					
Activity					
Microalgal blooms		I			
Harmful algal blooms					
chlorophyll (mg/L)					
Birds					
species					
Fish	**Description**				**Data Quality**
Fish Stocks					
Target species	Black bream; mulloway; yellow eye mullet; estuary perch				
Dominant type		Estuarine & Marine			
Introduced species	**Description**				**Data Quality**
Introduced fauna					
Introduced flora					
Streamside Zone					
Riparian vegetation	Description				
Dominant type					
Flood plain connectivity	Yes	Partial	No		
Weed dominated					
ISC					
Physical form & Processes					
Built structures	none				
Waterway activities	**Description**				
Commercial fishing		No			
Recreational fishing	Yes		high		
Port	no				
Boating	Motor & non motor popularity moderate				
Catchment use					
Estuary Catchment					
	Forestry	Dryland Agriculture	Irrigated Agriculture	Urban	Conservation
	2%	49%	2%	2%	46%
Stormwater & licensed discharge					
Fluvial Catchment					
	Forestry	Dryland Agriculture	Irrigated Agriculture	Urban	Conservation
	6%	68%	1%	3%	22%
Other					
'Fish Kill'	Yes one event in last 5 years				

Appendix 6. Risk report- example estuary A . Association and risk scores for threats 'artificial entrance openings' and 'flow deviation' provided as examples. Source: Modified from GHCMA RHS

Critical Risk High Risk Low Risk			Coastal development					Catchment land use				Hydrology		Entrance modification		Recreational & Commercial
		Asset Score ⟵	Connectivity (incl Channel modification)	Licensed & stormwater discharge	Estuarine land use Sediment	Degraded riparian	Loss of Instream habitat	Barriers (to upstream)	Nutrient Load	Land Use (Fluvial)	Algal Blooms	Flow deviation		Entrance modification		Introduced Predators
	Threat Score ⟶		0	2	4	3	3	3	2		1	3		5		5
Rarity	EVC's (Bioregional conservation status)	5										4		4		
	Rare and threatended species (flora)	5										4		4		
	Presence of rare and threatened fauna	5										4		5		
	Rarity and depletion of wetland type	1										4		4		
	Wetland/Estuary significance	5										4		5		
Naturalness	Width of riparian area	5										3		2		
	Longitudinal continuity of riparan zone	5										2		2		
	Riparian structural intactness & % indigenous	2										2		2		
	Native Fish - Observed to expected	2										5		5		
	Fish migration (use of reach by facultative and obligate species)	4										5		5		

Appendix 7 Estuary status report

Estuary name:

General physical description: estuary location, type, size

Management objective: general aims and legislative protection if applicable

Condition

	Current IEC ***(Compared with pristine*****)**	**Target condition score** ***Takes into account level of modification)***
Hydrology		
Streamside Zone		
Physical form		
Aquatic Life		
Water & Sediment Quality		
Catchment disturbance		
Marine connectivity		
Waterway activities		

Key Features

	Description
Key assets	
Environmental	
Social - recreation	
Social - cultural	
Economic	
Key threats	

High and Critical Risks:

Summary: Factors that contribute to vulnerability; and possible management responses to high and critical risks