



# DRAFT GUIDELINES FOR RISK ASSESSMENT OF WASTEWATER DISCHARGES TO WATERWAYS

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## EXECUTIVE SUMMARY

Water businesses and others discharging wastewater to waterways (including freshwater and marine environments) need to know the nature and extent of impacts associated with wastewater discharges. This allows better decision making on the acceptability of current discharges, the need for upgrades and actions to reduce mixing zones. Our drying climate has increased the need to consider these issues, including the potential discharge of appropriately treated and managed wastewater to a waterway to provide water for the environment.

The rigour and transparency of a risk assessment process produces information that is more targeted and defensible than less formal processes. This information is particularly useful to decision makers and managers who must evaluate alternatives, compare or prioritise risks, evaluate the most cost-effective actions to maximise environmental gains or determine the extent to which stressors must be reduced to achieve a given outcome.

These guidelines are intended to provide practitioners conducting wastewater discharge risk assessments with guidance on what EPA expects from them.

The guidelines provide the risk assessment framework and guidance on its implementation. It is based on current, nationally and internationally accepted risk assessment approaches. The framework ensures all potential risks can be clearly identified and appropriately assessed. It also enables the required interactions between technical experts, risk managers and interested stakeholders.

There are three main phases in the risk assessment process: problem formulation, risk analysis and risk characterisation.

**Problem formulation** determines the focus and scope of the risk assessment and the management information it needs to provide. This includes identification of the scope of the risk assessment, beneficial uses and values requiring protection, potential threats to these values, factors influencing the likelihood of the risk(s) occurring and the impacts from these. The problem formulation phase also includes development of a conceptual model of the

system, the wastewater discharge and the interactions between them.

**Risk analysis** determines the probability and magnitude of an adverse effect with specific consequences occurring to beneficial uses and values.

**Risk characterisation** is the evaluation and reporting of the problem formulation and risk analysis results for decision-making and risk management purposes.

A number of risk assessment pilot applications will be conducted in the year following release of these draft guidelines. The pilots will provide practical examples of the implementation of the risk assessment process for wastewater discharges. The practical information gained from these pilots will be used to refine and update the draft guidelines.

## 1. INTRODUCTION

The impact of wastewater discharges to inland and marine water bodies is attracting greater interest, particularly given predictions for a drier climate in the future. Impacts are often exacerbated by drought conditions, with low flows reducing the dilution of discharges. In other cases, the flow from some wastewater discharges can be an important contribution to waterway health, if they are of the right environmental quality and managed well.

These issues are driving the need for a more detailed assessment of the impact of wastewater discharges to support decision making.

### 1.1 What is risk assessment?

Risk is the likelihood of an undesirable event. We often assess risk when we need to make decisions between alternative courses of action. Risk assessment is used by a wide range of industries and organisations in areas such as engineering, economics, public health, medicine, natural resource management, irrigation and biosecurity.

Environmental risk assessment evaluates the interactions between environmental values, the stressors to these and management actions for protecting the values. This is used to assess the potential impacts of stressors to the environmental values. This is done in a consistent, clear and structured way using the risk assessment framework

(Figure 1). This framework is based on nationally and internationally accepted risk assessment frameworks (Suter, 1993; USEPA, 1998; ANZECC and ARMCANZ, 2000; USEPA, 2001; Hart *et al.*, 2005; Burgman, 2005).

The framework ensures that all potential risks can be clearly identified and appropriately assessed. It also facilitates the required interactions between technical experts, risk managers and interested stakeholders.

The outcomes of a risk assessment are:

- an estimation of the likelihood that values may be impacted, and how the impact changes given alternative scenarios
- detailed information and tools that help in better understanding how systems work
- targeted management actions and monitoring programs.

### 1.2 Why use risk assessment for wastewater discharges to waterways?

Managers and regulators of wastewater discharges need to make management decisions to protect natural systems impacted by varied stressors, where information and data may be scarce and uncertain. Risk assessment is an effective and transparent way of assessing wastewater discharges. It will clearly provide information needed for managing these discharges for the protection of beneficial uses.

EPA has already developed guidance on how to undertake risk assessments in ambient waters in EPA publication 961 (EPA Victoria, 2004). The purpose of these guidelines is to provide specific guidance on how to undertake risk assessments for wastewater discharges to waterways.

### 1.3 What is the scope of these guidelines?

Risk assessment and risk management are different processes; the outcomes of the former are used to inform the latter. Risk assessment is the formal process of understanding and evaluating the magnitude and probability of risks posed to values from stressors. Risk management combines these risk characterisations with statutory, legal, social, economic and political factors in assessing options to manage risk (USEPA, 2001).

The focus of these guidelines is on the risk assessment process, including the assessment of risk to beneficial uses in the *State Environment Protection Policy Waters of Victoria* (SEPP (WoV)).

This document provides a risk assessment framework and guidance on its implementation. It allows flexibility for businesses to use the appropriate method for each situation, and to implement new and improved approaches when available.

The intended users of these guidelines are the businesses discharging to surface waters that are

required to conduct a risk assessment (section 2) and the risk assessors/consultants (Box 2) conducting risk assessments on their behalf.

### 1.4 Roles and responsibilities

#### EPA Victoria (EPA)

Under the *Environment Protection Act 1970* and *State Environment Protection Policy Waters of Victoria* (SEPP (WoV)) EPA is responsible for developing environmental guidelines within the regulatory framework that encourages best practice. In particular, it produces guidance on recycling and discharges to waterways to ensure that schemes are both safe and sustainable.

SEPP (WoV) has a risk-based approach to the protection of beneficial uses. The SEPP identifies that, where an environmental quality objective is not met, further investigation is needed to assess the risk to beneficial uses. SEPP (WoV) indicates that EPA will provide guidance on the implementation of this risk-based approach to the protection and assessment of beneficial uses in Victoria's waterbodies.

EPA will ensure that this guideline is effectively implemented. EPA is responsible for:

- requiring, where necessary, a risk assessment for a discharge to a waterway
- the review and approval of risk assessments conducted under these guidelines.

#### Water authorities and other businesses

Water authorities and businesses discharging to waterways are expected to manage the risks associated with these schemes (Box 1). Where a risk assessment is required, it is their responsibility to obtain suitably qualified risk assessors to conduct the risk assessment (Box 2). Water authorities and other businesses will also be responsible for supplying information required by EPA to make informed decisions about conducting risk assessments and subsequent risk management.

#### Box 1: Risk managers

Risk managers are the individuals or organisations that have the responsibility or authority to take or require action to mitigate identified risk. This may be one individual, an organisation (e.g., water authority, industry, catchment management authority) or there may be several groups that have responsibility and authority for risk mitigation, forming a risk management team (e.g., state and local government organisations, industry and a catchment management authority).

**Box 2: Risk assessors**

Risk assessors are professionals with experience in undertaking the risk assessment process. For relatively narrowly scoped and well defined risk assessments only one trained individual may be needed to do a risk assessment. For more complex risk assessments one individual can rarely provide the necessary breadth or expertise needed, and a risk assessment team is required. A risk assessment team should include at least one professional who is knowledgeable and experienced in using the risk assessment process. Other team members bring specific expertise on the local area, stressors, values (such as ecosystem and human health issues), scientific issues, facilitation for community consultations and any other type of expertise required for the assessment.

## 2. WHEN SHOULD A RISK ASSESSMENT BE CONDUCTED?

EPA will make the final decision on whether a risk assessment should be conducted, and the level of assessment required. This is to allow for case-by-case circumstances that cannot be covered by general guidance.

In making decisions on whether a risk assessment should be conducted, and the level of assessment required, consideration will be given to the following:

- The SEPP (WoV) beneficial uses and regional values (Box 3) of a water body that may be impacted, and the importance of these values. Local water body values and their importance (e.g., high values) can be identified through state, national and international designations such as aquatic reserves, RAMSAR wetlands, heritage rivers; regional processes such as regional river health strategies and coastal plans; and local community processes.
- The vulnerability of a water-body to impacts. For example, estuaries, lakes and wetlands are particularly vulnerable systems.
- The potential level of impact to beneficial uses, including consideration of:
  - the discharge constituents, including their concentrations, level of toxicity and persistence in the environment
  - the dilution capacity of the water body under low-flow conditions. This is particularly important if low-flow conditions are predicted to increase from climate change impacts
  - the size of the mixing zone.
- Whether the potential impacts from a discharge are well understood. If the impacts to beneficial uses and values are not well understood, a risk assessment may be required to provide the information needed to make decisions and manage these. If the impacts are well understood, then a risk assessment may not be required.

Scenarios for when a risk assessment may be required and the appropriate level of risk assessment (qualitative or semi-quantitative/quantitative) are presented in Table 1.

As a risk assessment is being conducted, the findings might indicate a need for a more detailed level of assessment. As more is learnt about the potential risks, this may lead to a re-evaluation of previous assumptions. For example, if the impact is found to be greater than previously assumed, a more quantitative and detailed risk assessment may be required.

**Box 3: Beneficial uses and values of waterbodies**

Beneficial uses are described in SEPP (WoV) as current or future environmental values or uses of surface waters that communities want to protect. The beneficial uses that are protected in Victoria's waterbodies are identified in SEPP (WoV) and include: aquatic ecosystems; primary and secondary contact recreation; aesthetic enjoyment; indigenous and non-indigenous cultural and spiritual values; agriculture and irrigation; aquaculture; industrial and commercial use; human consumption after appropriate treatment; and fish, crustacea and molluscs for human consumption.

Specific local values within these beneficial uses are identified through regional planning processes such as regional river health strategies (RRHS) and coastal planning processes, and state, national and international designations such as aquatic reserves, RAMSAR wetlands and heritage rivers.

For example, for SEPP (WoV)'s aquatic ecosystems beneficial use, local values may be identified for specific river reaches in RRHSs such as: Golden perch populations, migratory fish populations, macroinvertebrate community diversity and growling grass frogs.

Table 1: Guidance on deciding whether a risk assessment should be conducted and the level of assessment required

Water body values <sup>a</sup> and/or vulnerability	Potential impacts <sup>b</sup> to water body values from discharge	Knowledge and understanding <sup>c</sup> of water body values and risks	Is a risk assessment required?	What level of assessment should be conducted?
High	Moderate to high	Substantial	If the values and risks are well understood a risk assessment may not initially be required. Instead the impacts can be directly managed using the available information. Monitoring should be conducted to assess the effectiveness of management actions and whether the prior assumptions of risk are correct.	If monitoring shows that management actions are not effective or the prior assumptions of risk are incorrect, then a semi-quantitative or quantitative risk assessment should be conducted.
High	Moderate to high	Minimal	A risk assessment should be conducted.	A semi-quantitative or quantitative risk assessment should be conducted.
High	Minor	Substantial	If the values and risks are well understood a risk assessment may not initially be required. Monitoring should be conducted to assess whether the impact to values remains minor.	If monitoring shows that the prior assumption of a low impact is incorrect (i.e., there is the potential for a moderate to high impact to values), then a semi-quantitative to quantitative risk assessment should be conducted.
High	Minor	Minimal	A risk assessment should be conducted.	Initially a qualitative risk assessment may be conducted to assess the prior assumption of a low impact to values. If the qualitative risk assessment indicates the prior assumption of minor impact to values is correct, then monitoring should be conducted to assess whether the impact to values remains minor. If the qualitative risk assessment, or monitoring, indicates the potential for a moderate to high impact, then a further semi-quantitative to quantitative risk assessment should be conducted.
Low	Moderate to high	Substantial	If the values and risks are well understood a risk assessment may not initially be required. Instead the impacts can be directly managed using the available information. Monitoring should be conducted to assess the effectiveness of management actions and whether the prior assumptions of risk are correct.	If monitoring shows that management actions are not effective or the prior assumptions of risk are incorrect, then a qualitative risk assessment may be conducted initially. If this level of assessment is insufficient to fully understand the risks for management, then a further, semi-quantitative risk assessment may be required.
Low	Moderate to high	Minimal	A risk assessment should be conducted.	A qualitative risk assessment may be conducted initially. If this level of assessment is insufficient to fully understand the risks for management, then a further semi-quantitative to quantitative risk assessment may be required.

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Water body values <sup>a</sup> and/or vulnerability	Potential impacts <sup>b</sup> to water body values from discharge	Knowledge and understanding <sup>c</sup> of water body values and risks	Is a risk assessment required?	What level of assessment should be conducted?
Low	Minor	Substantial	A risk assessment may not initially be required. Monitoring should be conducted to assess whether the impact to values remains minor	If monitoring shows that the prior assumption of a low impact is incorrect (i.e., there is the potential for a moderate to high impact to values), then a qualitative risk assessment should be conducted initially. If this level of assessment is insufficient to fully understand the risks for management, then a further semi-quantitative risk assessment may be required.
Low	Minor	Minimal	A preliminary qualitative desktop risk assessment should be conducted to better understand the potential risks.	If the desktop risk assessment indicates the potential for moderate to high impacts to values, then a further, more detailed qualitative assessment or semi-quantitative risk assessment should be conducted. If the desktop risk assessment indicates the prior assumption of minor impact to values is correct, then monitoring should be conducted to assess that the impact to values remains minor. If monitoring shows that there is potential for moderate to high impact to values in the future, then a qualitative risk assessment should be conducted initially. If this level of assessment is insufficient to fully understand the risks for management, then a further, semi-quantitative risk assessment may be required.

<sup>a</sup> Values: These include environmental, social and economic aspects of the beneficial uses and values of a water body (Box 3). High-value waterbodies can be identified through state, national and international designations such as aquatic reserves, RAMSAR wetlands, heritage rivers; regional processes such as regional river health strategies and coastal plans; and local community processes.

<sup>b</sup> Impacts: Examples of scenarios that might be considered to have a high impact are: an impact that may alter the ecosystem (i.e., from which there isn't recovery but results in a change in the system); an impact from which recovery would be very slow; a continuous downward trend in biota health; an impact that prohibits any identified beneficial use (such as primary or secondary recreational activities ) from being protected in the water body. . Examples of scenarios that might be considered a minor impact are: occasional small impact from which biota can recover quickly back to previous levels; where all beneficial uses are still protected continuously (i.e., all SEPP (WoV) objectives still met).

<sup>c</sup> Knowledge and understanding: Substantial knowledge and understanding would be considered as having:

- clearly and objectively identified all the key values of the water body
- characterised the discharge effluent and identified key threats to water body values
- conducted extensive monitoring and assessment of the biota and water quality to evaluate potential impacts to values
- determined a mixing zone and assessed the level of impact to beneficial uses within the mixing zone .

Minimal knowledge and understanding (i.e., as in table) would be considered as having not undertaken the above evaluations.

### 3. CONDUCTING A RISK ASSESSMENT OF WASTEWATER DISCHARGES

Environmental risk assessment is a formal process to understand and evaluate the magnitude and probability of risks posed to ecosystems and human health from environmental stressors (USEPA, 2001). It provides a structured and transparent way to deal with the difficulty of assessing multiple stressors and interactions in naturally variable and complex aquatic systems.

The risk assessment process systematically organises and evaluates data, information, assumptions and uncertainties to assess risks. It also identifies key knowledge gaps and can be used to assess the effectiveness of various management actions in reducing risks.

Risk assessments can be conducted to predict the likelihood of future adverse effects or evaluate the likelihood that effects are caused by current or past events or activities. Where water bodies have a history of previous impacts and the potential for future impacts from multiple chemical, physical or biological stressors, there may be a need to address both future and past risks (USEPA, 1998).

Figure 1 provides the framework for conducting a risk assessment of wastewater discharges to waterways, and how this links to decision making and risk management. This framework is based on current nationally and internationally accepted risk

assessment frameworks (Suter, 1993; USEPA, 1998; ANZECC and ARMCANZ, 2000; USEPA, 2001; Hart *et al.*, 2005; Burgman, 2005). It is intended to provide general guidance that can be tailored to meet the needs of varied and often complex assessments.

There are three main phases in the risk assessment process (Figure 1):

- problem formulation (Section 3.1)
- risk analysis (Section 3.2)
- risk characterisation (Section 3.3).

While these are shown in a linear fashion, risk assessments are often interactive and iterative processes and the framework should be interpreted in this way. For example, as more is learnt about the potential risks, this may lead to a re-evaluation of previous assumptions and problem formulation, and/or collection of new data and other analyses being conducted.

As more than one risk may be of concern at a site, and in many cases these do not operate independently, an integrated assessment approach needs to be taken. This will include all factors that may affect the beneficial uses and values being assessed. For example, assessment of aquatic ecosystems needs to include factors such as water quality and quantity, physical habitat requirements and seasonal and physical biotic cues (e.g., for migration or reproduction).

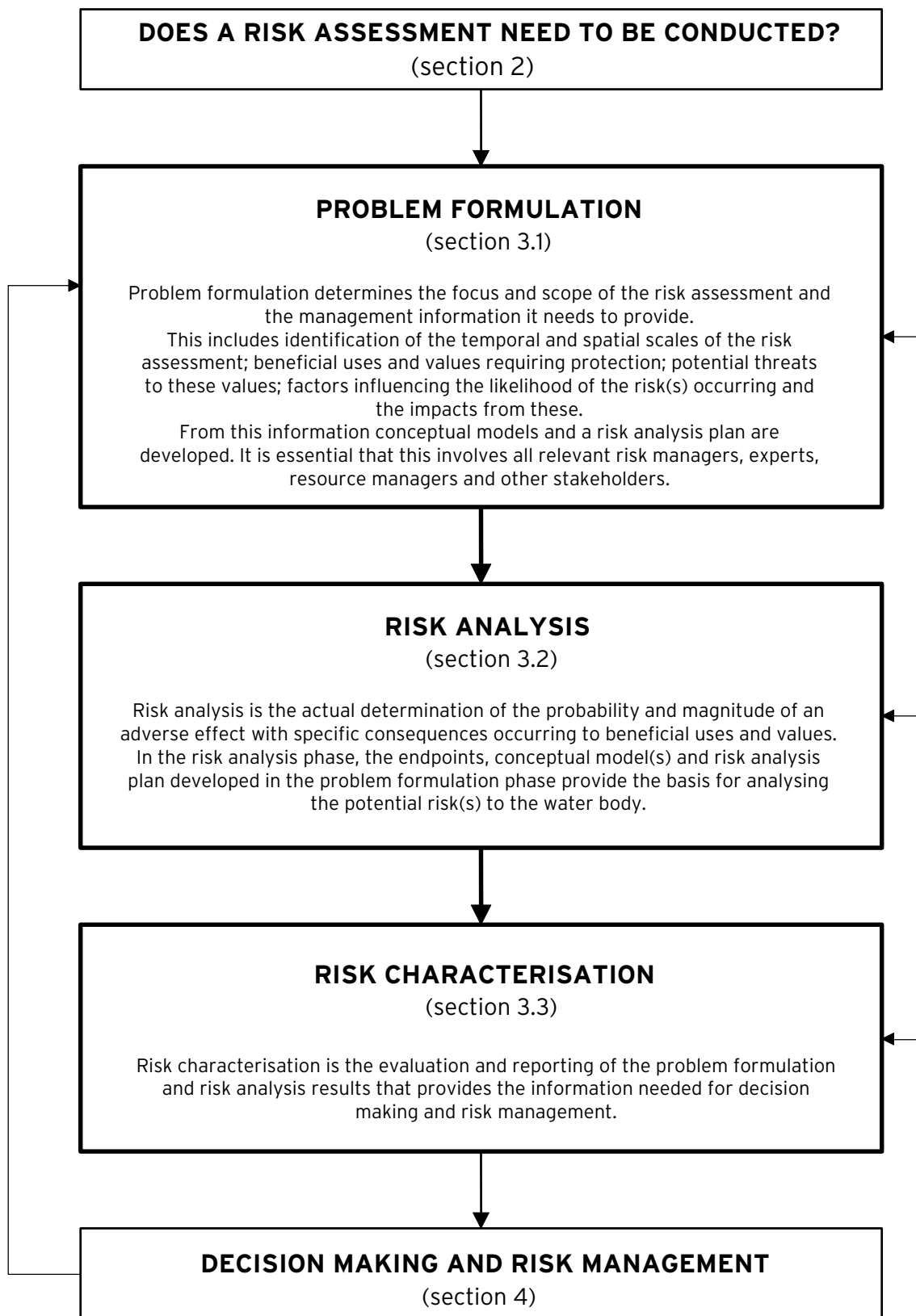


Figure 1: Risk assessment framework for wastewater discharges to waterways

### 3.1 Problem formulation

The problem formulation phase determines the focus and scope of the risk assessment and the type of management information required.

It is essential that the risk assessors involve risk managers, technical and scientific experts, resource managers and other relevant stakeholders in the problem formulation phase. This will ensure that the scope of the investigation is appropriate, all potential risks are identified and clearly defined, and the investigation outcomes are practical for risk management. Stakeholders may include industry representatives, regulators/decision-makers, relevant state agencies and natural resource managers, local government, scientific and technical experts, adjacent landholders, downstream users, local communities and NGOs. Section 5 provides more guidance on stakeholder participation.

Problem formulation involves:

- clearly defining management goals
- collation and integration of available information and data
- defining the potential risks, including identification of the –
  - beneficial uses and values (Box 3) requiring protection
  - potential stressors (or threats) to these key values
  - factors influencing the likelihood of the risk(s) occurring and the magnitude of the impacts
  - temporal and spatial scales of the risk assessment
- development of conceptual models that visually describe the relationships between key values, threats and factors influencing the likelihood of the risk(s) occurring and the magnitude of the impacts to values
- identification of endpoints that effectively assess the risks to key values
- a risk analysis plan.

The steps outlined above may initially be performed sequentially, but the process of problem formulation is often iterative as more information becomes available.

#### 3.1.1 Management goals

Management goals provide direction for the focus of the assessment. They are statements that embody broad objectives. For example, management goals could be: a river/stream to be free of toxicants and pathogens, ensuring that primary recreation in the water body (e.g., swimming) can occur; or maintaining a healthy aquatic ecosystem.

Natural resource management goals are often already determined in local strategies (for example, regional river health strategies and regional catchment

strategies). A particular management goal can consist of a series of management objectives that help in interpreting the goal and aid in the selection of appropriate endpoints for assessment (Section 3.1.5).

For example, the management goal 'maintaining a healthy aquatic ecosystem' could be defined by these management objectives:

- prevention of algal blooms in water bodies
- reduction in the concentrations of toxic metals in the water column and sediments to levels that are not harmful to biota
- maintaining healthy fish populations and their habitat
- maintaining healthy macroinvertebrate communities.

#### 3.1.2 Collation of available data and information

All available data and information needs to be gathered and integrated on a water body's beneficial uses and values and the potential stressors and impacts to these. This may include monitoring data, data and information from models, previous research, literature reviews and local plans and strategies. This information should provide a sound basis on which to identify and define potential risks.

If key information and data is missing or unavailable, this may need to be identified for collection as part of the risk analysis phase.

#### 3.1.3 Defining the potential risks

Potential risks from wastewater discharges need to be identified and clearly defined. It is important that this process involve all relevant risk managers, technical and scientific experts, resource managers and other local stakeholders.

Identification of the beneficial uses and values to be protected occurs through consultation with all relevant stakeholders and review of local and statewide resource management and environment protection strategies and policies (such as regional river health strategies, SEPPs). From this process the beneficial uses and values – and management priorities for these – are clearly identified, providing a focus for the risk assessment.

Examples of ecological values could be:

- aquatic ecosystems
- biodiversity
- macroinvertebrate communities
- native fish populations
- threatened flora and fauna.

Examples of human values could be:

- primary recreational use of the water body
- aesthetic enjoyment.

Stressors are defined as any physical (e.g., scouring, sediment deposition), chemical (e.g., toxicants) or

biological entity (e.g., bacteria) that can induce an adverse response in a value.

Stressors and the adverse effects they may cause to water body values must be identified. Relevant experts and stakeholders work together to identify potential stressors and their impacts by considering applicable information, evidence and knowledge of biological, chemical and physical processes and mechanisms that are relevant to the aquatic system under investigation. It is important to also consider the possible interactions between multiple stressors. The source of the stressor(s) needs to be identified where possible.

Factors that influence the likelihood of the risk occurring also need to be identified. For example, if you are looking at the risk of an algal bloom occurring:

- the stressor is high nutrient concentrations
- factors that may influence a bloom occurring in the presence of high nutrient levels are light levels in the water column, flow velocity and temperature.

Box 4 provides a simple example of management goals and identification of values, stressors and factors influencing the likelihood of risks occurring for a wastewater discharge.

The spatial scale is the area appropriate for the risk assessment, which is the scale in which impacts may occur. The temporal scale is an appropriate time frame for the risk assessment, that meets management outcomes and is protective of water body values. These scales may alter for different threats and values. Temporal variability (for example, seasonality and climatic influences) should also be incorporated into the scope of the risk assessment. Box 5 provides an example of considerations in temporal and spatial scales.

**Box 4: An example of management goals, values and stressors for a discharge**

**Example**

Tertiary treated effluent from an STP is discharged into a nearby stream.

**Management goals**

- Maintaining and protecting a healthy aquatic ecosystem
- Clean water suitable for recreational purposes, e.g., swimming, fishing, boating.

**Identification of values:**

- Fish populations.
- Macroinvertebrate communities.
- Swimming and fishing.

**Identification of stressors, risks and factors influencing the likelihood of the risk occurring:**

*Fish populations and macroinvertebrate communities.*

- Nutrients are a stressor. Light, flow and temperature are the factors that interact with nutrients to generate algal blooms. The risk is algal blooms causing low dissolved oxygen.
- Organic matter is a stressor. Microbial activity is the factor influencing the breakdown of organic material, as well as consumption of dissolved oxygen. The risk is low dissolved oxygen.
- Salinity is a stressor. The risk is direct toxicity from salinity concentrations that exceed those tolerated by the aquatic organisms.
- pH is a stressor. The risk here is that low and high pH can induce toxic effects of a range of substances, as well as being directly harmful to organisms.
- Ammonia is a stressor. pH is a factor that influences the speciation and bioavailability of ammonia. The risk is direct toxicity from ammonia.
- Metals are a stressor. pH and hardness are factors that influence the speciation and bioavailability of metals. The risk is direct toxicity.

*Recreational purposes*

- Nutrients are the stressor. Light, flow and temperature are the factors that interact with nutrients to generate algal blooms. The risk is toxic algal blooms, which may cause skin and eye irritations, or more serious complications if ingested.
- Pathogens and viruses are the stressors. The risk is ingestion by humans, causing various illnesses.
- Metals are the stressor. The risk is that some metals are directly toxic to humans, causing skin irritation or illness.

**Box 5: Example of spatial and temporal scales and variability**

**Potential risk**

The potential risk of algal blooms in an inland stream from an STP discharge.

**Spatial considerations**

Spatial scale: In this case, the area included in the risk assessment would be the point of discharge, upstream of this point (background levels) and downstream to the point where nutrient concentrations have returned to background levels. The risk assessment may also encompass the entire catchment, to investigate other potential point and non-point sources of nutrients entering the waterway within the zone of influence of the discharge.

**Temporal considerations**

Temporal scale: This determines the periods of time the risk assessment needs to consider; for example, one year, five or 50. The temporal scale may be based on the timing of management plans, climatic variability or seasonality.

**Seasonal and climatic variability**

In this example, seasonal influences could be low summer flows. At such a time, nutrients in the discharge will become more concentrated in the receiving aquatic ecosystem. In addition, the climatic influence of drought would further exacerbate low flows and nutrient concentrations.

**3.1.4 Conceptual models**

A conceptual model is a diagram or picture of the relationships between:

- human activities, sources, stressors and the environment
- factors influencing the likelihood of risk(s) occurring
- impacts to the beneficial uses and values.

Conceptual models are an important initial step in the analysis of multiple stressors and provide the basis for developing hypotheses on potential cause-effect relationships (Ferenc and Foran, 2000).

The development of a conceptual model has several benefits. They:

- aid in simplifying complex processes that may not always be completely understood
- compel risk assessors to think through and clarify their assumptions about cause-effect relationships
- identify knowledge gaps and determine research/data needs
- can easily be updated as information becomes available
- provide an easily understandable communication tool for conveying the risks, assumptions and uncertainties to risk managers and stakeholders.

Development of conceptual models should involve risk managers, technical and scientific experts, resource managers and other relevant stakeholders.

Hart et al (2005) outlined the positive outcomes of stakeholder involvement in building conceptual models as:

- providing the stakeholders with some ownership of the process
- bringing out knowledge that is not formally documented
- providing a useful means for increasing participants' knowledge of the ecosystems being assessed.

Conceptual models are most commonly flow diagrams that use arrows to represent relationships between sources, stressors and values (see Appendix 2 for examples).

Conceptual models will vary in complexity, depending on the risks and systems being assessed. If there are many complex relationships, it may be more desirable and less confusing to represent the relationships and processes as a set of interrelated models. Such models could progress from a broad scale (such as the catchment level), working towards a finer scale showing more detail (for example, the relationship between wastewater pathogens and toxicants to human health issues (Appendix 2).

Depending on the complexity of the conceptual model, supplementary text is important for providing explanations of the relationships. This helps to prevent confusion. It is also important that the underlying assumptions of the model and key knowledge gaps are identified, reviewed and documented as sources of uncertainty. This avoids the inclusion of incorrect information or misrepresentation of the actual risks. Data and information can be collected to address these knowledge gaps and incorporated into the model(s) as it becomes available throughout the investigation.

**3.1.5 Identification of endpoints**

Endpoints are selected to measure/monitor the health of the beneficial uses and values being assessed. Assessment endpoints are explicit expressions of the value(s) to be protected. Measurement endpoints are the aspect of the assessment endpoint that can be measured.

For example, if the risk to aquatic ecosystem health is being investigated, the endpoints selected may be:

- assessment endpoint – macroinvertebrate community diversity
- measurement endpoint – biological indices, such as AUSRIVAS, SIGNAL, or number of families

and/or

- assessment endpoint – a native fish population (e.g., Murray cod)
- measurement endpoint – native fish (e.g., Murray cod abundance).

If the risk of an algal bloom occurring in a river is being investigated, the endpoints selected may be:

- assessment endpoint – the river phytoplankton community
- measurement endpoint – chlorophyll a and/or phytoplankton diversity and abundance.

Endpoints are distinguished from management goals by their neutrality and specificity. Endpoints do not represent a desired achievement (or goal), they are defined by specific measurable components, and provide a means of measuring stress-response relationships.

Endpoints need to be:

- susceptible to the wastewater stressor(s)
- predictable and measurable
- biologically relevant to the beneficial uses and values.

There is often a trade-off in selecting an endpoint between the costs of ambiguity if endpoints are loosely defined and a loss of generality in endpoints that are very precisely defined. In some cases more than one endpoint may be required for a risk assessment, to cover the complexity of aquatic systems and the cause-and-effect relationships within these.

The strengths and limitations of potential endpoints should be assessed to select the most appropriate endpoint(s) to analyse the risks. Selection of endpoints requires expert knowledge of aquatic processes and the assessment of these. It also requires local knowledge of the area and management concerns.

### 3.1.6 Risk analysis plan

The risk analysis plan summarises the problem formulation phase and details the design for the risk analysis phase. The plan is developed based on the conceptual model(s) and information and data collected during problem formulation. It defines the endpoints that will be used to assess risk to the ecosystem and how the risk analysis will be undertaken. Plans will vary in complexity and length, depending on the risk assessment. In any case it is important to have a sound analysis plan before entering the risk analysis phase.

For more information on conducting the problem formulation phase refer to USEPA (1998), USEPA (2001) and Hart *et al.* (2005).

## 3.2 Risk analysis

Risk analysis is the determination of the probability and magnitude of an adverse effect with specific consequences occurring to the beneficial uses and values within a certain time frame (Suter, 1993, Hart *et al.*, 2005). In the risk analysis phase, the endpoints, conceptual model(s) and risk analysis plan developed

in problem formulation are used to analyse risk(s) to the beneficial uses and values of the water body.

The analysis tools required will vary on a case-by-case basis. A tiered approach to the risk analysis can be taken, beginning with a simple analysis and increasing the effort and resources being applied as needed.

Qualitative analyses of risk are based on subjective assessments, where cultural, personal and professional experiences and values all affect the perception of risk and ultimately the risk analysis. Consequently, it should be recognised that these estimates of risk represent views or opinions to which there are likely to be many alternatives (Burgman, 1999). Issues of potential bias in qualitative estimates can be limited by wide consultation.

Semi-quantitative and quantitative risk analysis methods provide more rigour in the assessment and more detailed information for managing risks. They also provide better internal consistency and better assessment of uncertainties and assumptions in the analysis.

Table 1 provides guidance on the level of analysis (qualitative to semi-quantitative/quantitative) that may be required under different scenarios.

Examples of the types of analysis methods that can be used are given below. These range from qualitative to semi-quantitative/quantitative analysis methods. In all cases, the guidance in section 3.2.1 for assessing uncertainty needs to be incorporated into the analysis.

- Conducting a desktop study of currently available information and data for the discharge effluent and receiving water body.

This may involve data trends, patterns and correlations analysis, dilution modelling (including low-flow conditions), decay curves and comparison to available criteria and cause-effect relationships. The spatial and temporal (for example, seasonal or climatic) variability of the receiving waters and discharge effluent needs to be taken into account in these analyses.

The desktop study may also include the use of a risk matrix to conduct a preliminary prioritisation of risks. It should be noted that risk matrices are often subjective, qualitative and not transparent, so they do not replace the need to conduct a more robust analysis of risks. However, where a large number of potential risks have been identified, they can be a useful tool for identifying the key risks to prioritise for analysis (Hart *et al.*, 2005). The potential bias in risk matrices can be limited by wide consultation.

- Where the existing data does not meet all the risk assessment needs, additional data may need to be collected. Once the new data is collected, a desktop study similar to that outlined above can be conducted that specifically addresses the risk analysis needs. The type of new data required may

include flow, water quality and/or biological monitoring of the receiving waters, and chemistry screening of the effluent to better characterise both of these.

- Incorporating additional information and/or more detailed analyses from specialised technical experts (such as ecologists with expertise in the particular biota being assessed, hydrologists, ecotoxicologists, microbiologists or other human health experts).
- Analysis and interpretation of biological data, including: calculation of standard indices, expert interpretation of family or species data and multivariate analyses.
- Conducting ecotoxicity testing. This may include whole effluent toxicity testing (WET), direct toxicity assessment (DTA) of the receiving waters (Chapman & van Dam, 2001) and/or toxicity identification evaluation (TIE).
- Application of a formal 'multiple lines and levels of evidence' (MLLE) approach (an MLLE approach is described in Section 9.2 of Downes *et al.*, 2002).
- Quantitative predictive modelling, sensitivity analysis and management scenario testing (for example, Bayesian networks, Monte Carlo analyses, regression models, quantitative structure-activity relationships (QSARs), mathematical dynamic simulation models, deterministic process models). Examples of a range of these models and discussion of these are provided in Hart *et al.* (2005).

As the analysis is conducted and more information becomes available, it may also be necessary to re-evaluate how the risks will be assessed. This may include the need to update the conceptual model and analysis plan developed in the problem formulation phase, and/or to conduct further field investigations to fill key knowledge gaps identified in the risk analysis or further quantify specific cause and effect relationships.

A risk analysis may be terminated or suspended when the risk(s) and management of these are sufficiently understood.

### 3.2.1 Uncertainty analysis

The interactions within water bodies, particularly ecosystem interactions, are not always fully understood. Even when understanding is high, a degree of uncertainty exists with all data and information and their analyses, and there is a natural variability in all aquatic system processes.

There are limitations in the type and amount of data that is available or can be collected, and uncertainties associated with the accuracy and/or quality of this data. In addition, there are uncertainties and limitations associated with different methods used for analysing the data and information. For these reasons,

uncertainties in the data and information from the problem formulation and risk analysis phases should be identified, estimated and/or described. This provides transparency and credibility for the assessment and confidence that more informed and appropriate management decisions can be made. The uncertainty analysis should include:

- identification and description of any key knowledge gaps
- identification of assumptions made in the risk analysis and the rationale for these assumptions
- identification and description of data limitations. This includes limitations in both the type and amount of data available, and also uncertainties in the accuracy and/or quality of the data
- identification and description of the strengths and limitations of the analysis methods and models used
- where possible, quantitative estimates of the uncertainties in the analyses conducted.

More information on assessing uncertainties in risk assessment can be found in Warren-Hicks and Moore (1998), USEPA (1998), Hart *et al.* (2005) and Burgman (2005).

### 3.3 Risk characterisation

Risk characterisation is the evaluation and reporting of the problem formulation and risk analysis results that provides the information needed for decision making and risk management.

The main outputs from the risk characterisation phase that need to be clearly reported to risk managers and decision makers are:

- identification of what the risks are to each of the beneficial uses/values of the water body
- for each risk identified above, an evaluation of the level of change or impact to the water body value and likelihood of the risk occurring, including the conditions under which the risk is likely to occur.
- identification and evaluation of the interactions between the risks identified
- comparison and prioritisation of the risks identified
- reporting of the assumptions, uncertainties (see section 3.2.1) and strengths and limitations of the risk analyses
- a discussion of all the information gained during the assessment that is relevant to decision making and risk management. It is important that risk assessors pass on not only the information in the above five dot points, but also any other information, advice or opinions that may assist in managing the risk(s) to water body values. This includes where risk is predicted as low, advice about the potential for risk(s) to beneficial uses and values to occur under changed conditions

- a summary of the stakeholder and expert participation throughout the risk assessment
- suggested monitoring and assessment program(s) to assess risk assessment predictions and potential effectiveness of management actions.

It is important to note that the risk assessment is a relatively objective and transparent process that evaluates the risk of adverse effects to the water body values. Factors such as social and economic implications are not incorporated in the process until the decision-making and risk management stage (section 4). However, it is recognised that even when every effort is made to conduct the risk assessment in an objective manner, some value judgements are inevitable, but they should be made transparent.

#### 4. DECISION MAKING AND RISK MANAGEMENT

Risk assessments are conducted to provide information to risk managers and decision makers about the potential adverse effects of anthropogenic activities and the effectiveness of management actions for addressing these. The rigour and transparency in the risk assessment process results in information that is more targeted and defensible than less formal processes. This information is particularly useful to decision makers and managers who must evaluate trade-offs, examine different alternatives, compare or prioritise risks, evaluate the most cost-effective management actions for achieving maximum environmental gains or determine the extent to which stressors must be reduced to achieve a given outcome.

Risk management combines the information and outcomes from the risk assessment with statutory, legal, social, economic and political factors in assessing options to manage risk(s) (USEPA, 1998). Decisions must be made and clearly articulated in a management plan (such as an environment improvement plan (EIP)). Management plans include the overall management goal(s), specific management targets (with specified timeframes) that work towards achieving these goals and actions to achieve these goals.

The effectiveness of actions in meeting defined targets must be monitored, evaluated and, where necessary, updated. It is important that a monitoring program is developed with appropriate indicators to evaluate management actions. These will often include the endpoints selected in the risk assessment. Where appropriate, the collection of new monitoring data can also be used to update the risk assessment, providing increasingly more robust predictions and information for management of risks.

Risk managers also need to appropriately communicate the risk management plan to all relevant stakeholders and interested parties; in particular, the:

- results of the risk assessment (the risk characterisation reporting outlined in section 3.3 provides the basis for what is required)
- management goals and targets for addressing the risk(s) identified and management actions for achieving these
- monitoring and assessment plan (and results when available) for assessing management actions.

#### 5. STAKEHOLDER PARTICIPATION

A planned approach to stakeholder participation and ongoing dialogue with stakeholders is an important part of any risk assessment. It is beneficial to involve specialist and non-specialist people and organisations in the risk assessment process. Stakeholders may include industry representatives, regulators/decision makers, relevant state agencies and natural resource managers, scientific and technical experts, local government, adjacent landholders, downstream users, local communities and NGOs.

While the key stakeholders should be kept involved throughout the entire risk assessment process, it is particularly important that they are actively involved in the problem formulation step (Hart *et al.*, 2005). If this level of involvement is not achieved, important beneficial uses and values, threats and key local knowledge may not be considered in the risk assessment.

##### 5.1 Benefits of stakeholder participation

Stakeholder participation benefits both businesses and stakeholders. Benefits of successful participation for businesses include:

- outcomes of the risk assessment being relevant to local management needs
- access to a wider range of information and local knowledge from stakeholders
- obtaining all ideas and new information at the outset of the risk assessment, rather than partway through
- lowering the risk of negative stakeholder reactions
- a better understanding of the issues that communities face
- developing good relationships with stakeholders and identifying collaboration possibilities on issues of concern
- increasing the transparency and accountability of businesses
- Increasing business's reputation.

Benefits of successful participation for stakeholders include:

- having the opportunity to provide their expertise and local knowledge
- being aware of and involved in projects being undertaken in their region
- a sense of ownership of solutions to problems and an involvement in decision making processes
- a greater acceptance, respect and recognition of their needs
- an opportunity for a wide range of opinions to be voiced and listened to
- an increase in understanding of risks considered and the knowledge base of stakeholders
- being aware of information sources that could be useful to their own organisation
- a sense of empowerment on issues of concern to them.

## 5.2 Planning process for stakeholder participation

The process outlined below helps risk assessors think through the steps for developing a stakeholder participation plan.

### *Identify the issues/opportunities*

Why do you want to involve the public, community, stakeholders and/or technical specialists?

### *Identify the stakeholders*

Who do you need to talk to? Who's demanding to be let in? Whose input do you need? Who is legitimately part of this discussion? Whose interests are affected (positively or negatively) by the wastewater discharge? Who will be outraged later if excluded now? Whose buy-in do you need?

### *Analyse stakeholders' goals and constraints*

What do the stakeholders want from the process? What possible benefits and costs are posed to them by your activities? What possible benefits and costs are posed to them by participating in the risk assessment? How much power do they currently have to influence the outcome/decision? How much would they like to have? How would they like to be involved? What type of involvement might stakeholders be expecting?

### *Analyse your goals and constraints*

What are you hoping to get from stakeholders in order to achieve your goals? What does success look like? What does failure look like? What are you allowed to do or not to do? What is compulsory/non-negotiable? What decisions are predetermined? What is negotiable/flexible/open for debate? What are your mandate/role, budget and timelines? How would you like stakeholders to be engaged? What type of stakeholder participation is your organisation expecting?

### *Determine your purpose, process and tools*

Based on all of the above, what is your overall stakeholder participation purpose with this risk assessment? How might different people/stakeholders be engaged differently? What tools are appropriate?

The IAP2 model developed by the International Association for Public Participation provides a good approach to working with stakeholders and answering these questions. In using the IAP2 spectrum, a plan for the level of participation required for each stakeholder group can be clearly determined. A summary of the IAP2 approach is provided in Table 2.

### *Outline how participation risks will be managed*

Based on the above analysis, what are the risks if you don't engage with stakeholders? What are the risks if you do engage with stakeholders? What is the likelihood of these risks occurring? What would be the impact if they did occur? How will risks be managed?

### *Outline how success will be measured/evaluated*

What is the purpose of the evaluation? Who wants to know what from the evaluation? What evidence will be collected and how? When will this reflection occur and what resources are required for it?

### *Write up your plan and implement it*

Get buy-in internally and externally when you write up the plan. Evaluate and revise as you go along.

More information on the above stakeholder participation planning process can be found at <http://epanote2.epa.vic.gov.au/4A256593001F8336/bycat> under 'Community engagement'.

Table 2: Summary of the IAP2 Public Participation Spectrum, developed by the International Association for Public Participation

<b>INFORM</b>	<b>CONSULT</b>	<b>INVOLVE</b>	<b>COLLABORATE</b>	<b>EMPOWER</b>
<b>GOAL</b>	<b>GOAL</b>	<b>GOAL</b>	<b>GOAL</b>	<b>GOAL</b>
To provide stakeholders and the broader public with balanced and objective information to assist them in understanding the problems, alternatives and/or solutions.	To obtain feedback from stakeholders and the broader public on analysis, alternatives and/or decisions.	To work directly with stakeholders and the broader public throughout the process to ensure that their issues and concerns are consistently understood and considered.	To partner with stakeholders and the broader public in each aspect of the decision, including the development of alternatives and the identification of a preferred solution.	To place final decision making in the hands of stakeholders and the broader public.
<b>PROMISE TO THE PUBLIC</b>	<b>PROMISE TO THE PUBLIC</b>	<b>PROMISE TO THE PUBLIC</b>	<b>PROMISE TO THE PUBLIC</b>	<b>PROMISE TO THE PUBLIC</b>
We will keep you informed.	We will keep you informed, listen to and acknowledge concerns and provide feedback on how your input influenced the decision.	We will work with you to ensure that your concerns and issues are directly reflected in the alternatives developed, and provide feedback on how your input influenced the decision.	We will look to you for direct advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible.	We will implement what you decide.
<b>EXAMPLE TOOLS</b>	<b>EXAMPLE TOOLS</b>	<b>EXAMPLE TOOLS</b>	<b>EXAMPLE TOOLS</b>	<b>EXAMPLE TOOLS</b>
<ul style="list-style-type: none"> <li>• Fact sheets</li> <li>• Newsletters</li> <li>• Field trips/open days</li> <li>• Web sites</li> <li>• Stakeholder information sessions</li> </ul>	<ul style="list-style-type: none"> <li>• Surveys</li> <li>• Focus groups</li> <li>• Workshops</li> <li>• Polling</li> </ul>	<ul style="list-style-type: none"> <li>• One-on-one discussions</li> <li>• Workshops</li> <li>• Meetings</li> <li>• Development of conceptual models</li> <li>• Feedback tools on how input has been incorporated (e.g., documentation sent to stakeholders or verbal feedback sessions)</li> </ul>	<ul style="list-style-type: none"> <li>• One-on-one discussions</li> <li>• Workshops</li> <li>• Meetings</li> <li>• Development of conceptual models</li> <li>• Participatory decision making</li> <li>• Consensus-building</li> <li>• Steering committees</li> <li>• Advisory panels</li> </ul>	<ul style="list-style-type: none"> <li>• Delegated decisions</li> <li>• Ballots</li> </ul>

## **6. MIXING ZONES AND THE RISK ASSESSMENT PROCESS**

SEPP (WoV) describes a mixing zone as 'an area contiguous to a licensed waste discharge point and specified in that license, where the receiving environmental quality objectives otherwise applicable under the Policy do not apply to certain indicators as specified in the license. This means that some or all beneficial uses may not be protected in the mixing zone'.

Mixing zones are used as a tool for responsible management of the environment. They are designed to limit the impact on the environment that would otherwise occur if discharges were allowed to flow unchecked into waterways.

In issuing a license, EPA may approve a mixing zone where it is not practicable to avoid, reuse or recycle wastewater. However, the mixing zones must be kept to the smallest area possible, and the size and impact of the mixing zone on the environment needs to be decreased over time.

The temporal and spatial extents of mixing zones are determined as part of the works approval and licensing processes. Where a risk assessment is not required for a discharge, the mixing zone extent is determined by using the approach previously used as part of the works approval process. This primarily uses the SEPP (WoV) environmental quality objectives as the basis for determining the extent of a mixing zone.

Where a risk assessment is required for a wastewater discharge (section 2), the risk assessment process will instead be used to define the mixing zone extent. The risk assessment process provides more detailed information and understanding of the impacts and processes occurring in the mixing zone. This allows:

- a clear determination of the temporal and spatial extent of the mixing zone
- a better understanding of the impacts to specific beneficial uses and values, including factors that may influence the probability and level of impact
- prioritisation of the key risks to be managed within a mixing zone
- targeted information to ensure designated mixing zones are kept to the smallest area possible, and to assist in reducing the size and impact on the environment continuously over time.

## **7. PILOT STUDIES AND FINALISATION OF GUIDELINES**

Businesses and EPA will conduct a number of risk assessment pilot applications in the year following release of the draft guidelines. The pilot applications will provide practical:

- examples of the implementation of the risk assessment process for wastewater discharges
- information and learnings that will be used to refine and update the draft guidelines.

The final guidelines will include summaries of the pilot applications conducted and will be released by early 2009.

## 8. REFERENCES

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## APPENDICES

### APPENDIX 1: DEFINITIONS

*Ambient waters* are defined in the *National Water Quality Guidelines* (ANZECC and ARMCANZ, 2000) as 'all surrounding waters, generally of largely natural occurrence'.

*Assessment endpoint* is an explicit expression of the value(s) that is to be protected.

*Beneficial use*. A beneficial use is defined in the *Environment Protection Act 1970* and includes a current or future environmental value or use of surface waters that communities want to protect.

*Conceptual model* is a visual representation, with supporting text, of the relationships between key values, stressors and factors influencing the likelihood of the risk(s) occurring and the magnitude of the impacts to values.

*Indicator*. A measurement that provides information on the quality of an environment.

*Management goals* are statements that embody broad objectives; things such as clean water suitable for primary recreation or a healthy ecosystem.

*Measurement endpoint* is the aspect of an assessment endpoint that can be measured.

*Stressor*. Any physical, chemical or biological entity that can induce an adverse effect (USEPA, 1998).

*Surface waters*. For the purposes of SEPP (WoV), surface waters include any reservoir, billabong, anabranch, canal, spring, swamp, natural channel, lake, lagoon, waterway, natural dam, tidal water or coastal water. Surface waters exclude groundwaters and waters within tanks, artificial waste treatment systems, reticulated water supply distribution systems, off-stream private dams, and piped and underground drains.

APPENDIX 2: EXAMPLES OF SIMPLIFIED CONCEPTUAL MODELS ADDRESSING COMMON WASTEWATER DISCHARGE ISSUES

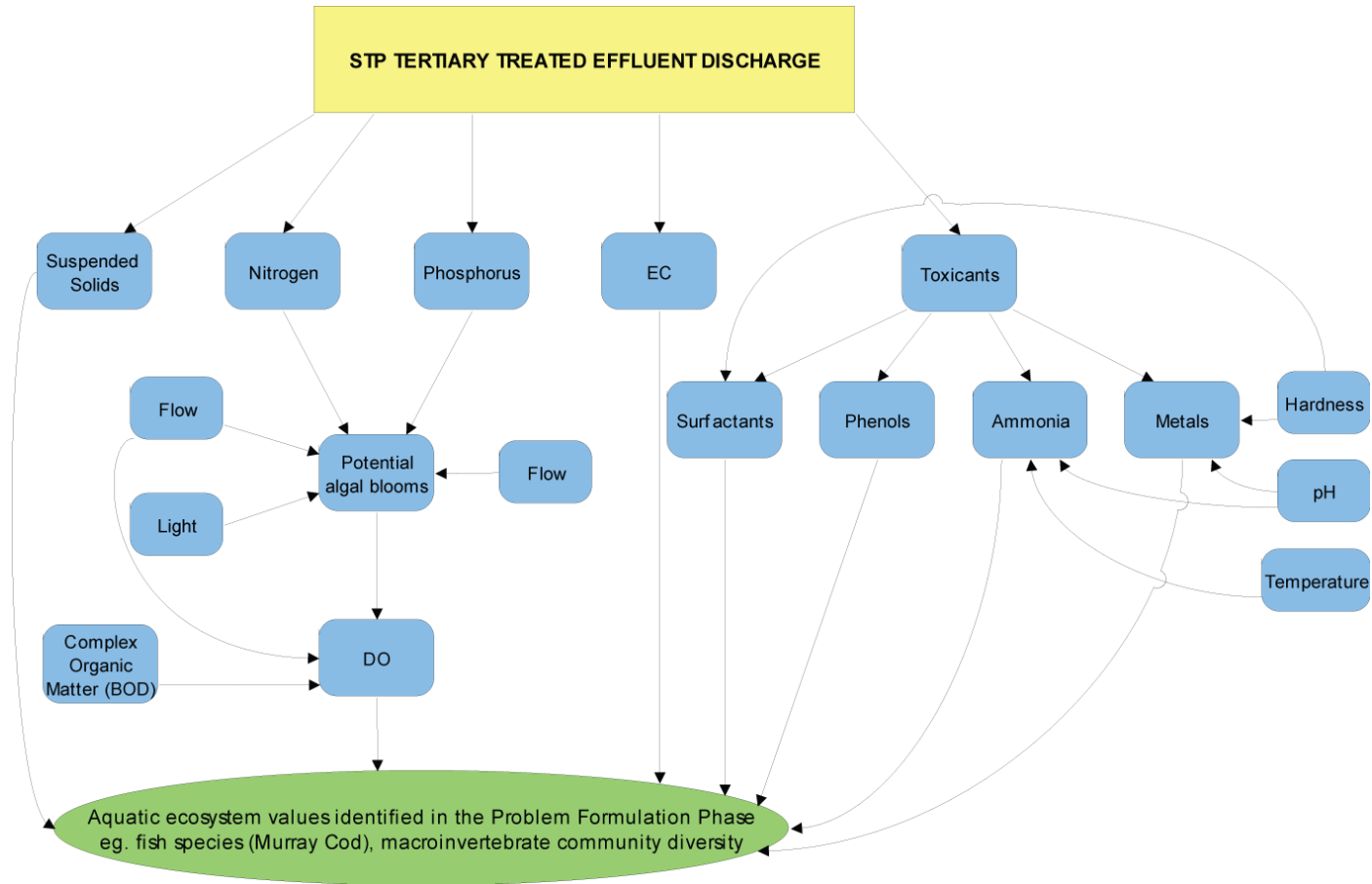


Figure 2: Simplified conceptual model of the potential risks to a river aquatic ecosystem from a tertiary treated STP effluent

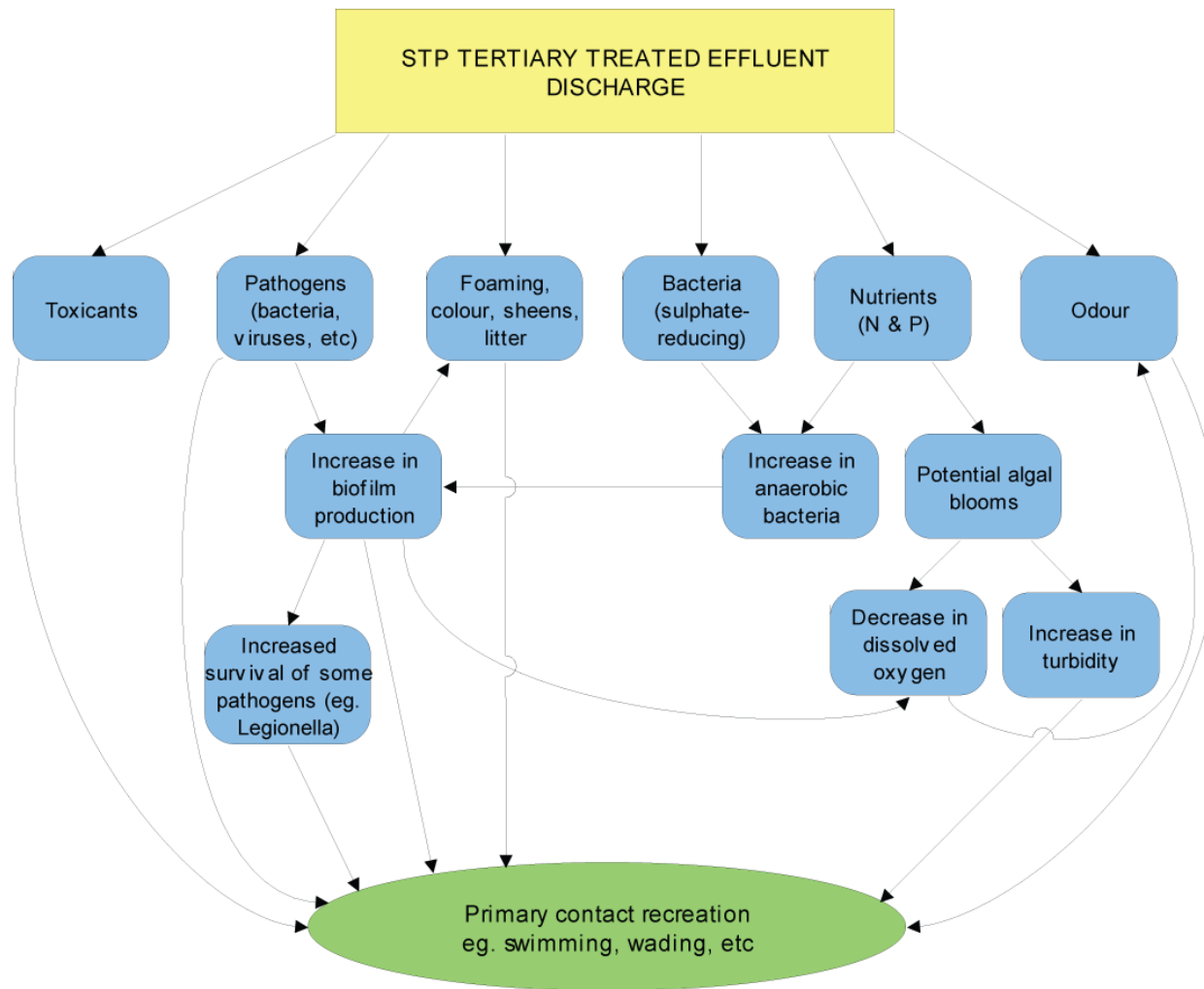


Figure 3: Simplified conceptual model of the potential risks to the beneficial use of primary contact recreation from a tertiary treated STP effluent

#### APPENDIX 4: RISK LEVELS OF SELECTED PHYSICOCHEMICAL PARAMETERS TO AQUATIC ECOSYSTEMS IN RIVERS AND STREAMS

The tables below provide ranges for water quality parameters where there is typically a *low risk* (i.e., SEPP (WoV) objectives are met), *potential risk* and *high risk* to aquatic ecosystems in rivers and streams. This has been done for physicochemical parameters for which there was enough information to derive these general risk levels; this includes phosphorus, salinity, pH and dissolved oxygen.

**Table 3: Phosphorus concentration ranges that represent a low risk, potential risk and high risk to aquatic ecosystems in rivers and streams**

SEGMENT	INDICATOR		
	Phosphorus ( $\mu\text{g/L}$ )		
	Low risk	Potential risk	High risk
Highlands	$\leq 20$	$>20$ & $<50$	$\geq 50$
Forests A	$\leq 25$	$>25$ & $<50$	$\geq 50$
Forests B	$\leq 25$	$>25$ & $<50$	$\geq 50$
<b>Cleared Hills and Coastal Plains</b> (lowlands of Barwon, Moorabool, Werribee, Maribyrnong, Curdies & Gellibrand catchments & Lowlands of Yarra, Western Port, Latrobe, Mitchell, Tambo, Snowy, Thomson & Macalister catchments)	$\leq 45$	$>45$ & $<90$	$\geq 90$
<b>Cleared Hills and Coastal Plains</b> (Uplands of Moorabool, Werribee, Maribyrnong, Campaspe, Loddon, Avoca, Wimmera, Hopkins catchments & mid-reaches of Ovens, Goulburn & Broken catchments only)	$\leq 25$	$>25$ & $<50$	$\geq 50$
<b>Murray and Western Plains</b> (lowlands of Kiewa, Ovens, Goulburn & Broken catchments & lowlands of Campaspe, Loddon & Avoca catchments)	$\leq 45$	$>45$ & $<90$	$\geq 90$
<b>Murray and Western Plains</b> (lowlands of Wimmera catchment & Mallee Basin & lowlands of Glenelg & Hopkins catchments, & Portland, Corangamite and Millicent Coast Basins)	$\leq 40$	$>40$ & $<90$	$\geq 90$

**Table 4: Salinity concentration ranges that represent a low risk, potential risk and high risk to aquatic ecosystems in rivers and streams**

SEGMENT	INDICATORS		
	Salinity (EC@25 °C – $\mu\text{s/cm}$ )		
	Low risk	Potential risk	High risk
<b>Highlands</b>	$\leq 100$	$>100$ & $<1000$	$\geq 1000$
<b>Forests A</b> (Wilson's Promontory, Strzelecki Ranges, East Gippsland & the Grampians)	$\leq 500$	$>500$ & $<1500$	$\geq 1500$
<b>Forests A</b> (Upper Murray, Kiewa, Mitta Mitta catchments and all other areas)	$\leq 100$	$>100$ & $<1500$	$\geq 1500$
<b>Forests B</b> (Otways Ranges)	$\leq 500$	$>500$ & $<1500$	$\geq 1500$
<b>Forests B</b> (all other areas)	$\leq 100$	$>100$ & $<1500$	$\geq 1500$
<b>Cleared Hills and Coastal Plains</b> (Lowlands of Barwon, Moorabool, Werribee, Maribyrnong, Curdies & Gellibrand catchments)	$\leq 1500$	$>1500$ & $<3000$	$\geq 3000$
<b>Cleared Hills and Coastal Plains</b> (Lowlands of Yarra, Western Port, Latrobe, Mitchell, Tambo, Snowy, Thomson & Macalister catchments, Uplands of Moorabool, Werribee, Maribyrnong, Campaspe, Loddon, Avoca, Wimmera, Hopkins catchments & mid-reaches of Ovens, Goulburn & Broken catchments only)	$\leq 500$	$>500$ & $<1500$	$\geq 1500$
<b>Murray and Western Plains</b> (lowlands of Kiewa, Ovens, Goulburn & Broken catchments)	$\leq 500$	$>500$ & $<1500$	$\geq 1500$
<b>Murray and Western Plains</b> (lowlands of Campaspe, Loddon & Avoca catchments, lowlands of Wimmera catchment & Mallee Basin & lowlands of Glenelg & Hopkins catchments, & Portland, Corangamite and Millicent Coast Basins)	$\leq 1500$	$>1500$ & $<3000$	$\geq 3000$

Table 5: pH ranges that represent a low risk, potential risk and high risk to aquatic ecosystems in rivers and streams

SEGMENT	INDICATORS		
	pH		
	Low risk	Potential risk	High likely risk
Highlands	6.4 – 7.7	5 – 6.3 & 7.8 – 9	<5 & >9
Forests A	6.4 – 7.7	5 – 6.3 & 7.8 – 9	<5 & >9
Forests B	6.4 – 7.7	5 – 6.3 & 7.8 – 9	<5 & >9
<b>Cleared Hills and Coastal Plains</b> (Lowlands of Barwon, Moorabool, Werribee, Maribyrnong, Curdies & Gellibrand catchments & Uplands of Moorabool, Werribee, Maribyrnong, Campaspe, Loddon, Avoca, Wimmera, Hopkins catchments)	6.5 – 8.3	5 – 6.4 & 8.4 – 9.5	<5 & >9.5
<b>Cleared Hills and Coastal Plains</b> (Lowlands of Yarra, Western Port, Latrobe, Mitchell, Tambo, Snowy, Thomson & Macalister catchments, & mid-reaches of Ovens, Goulburn & Broken catchments only)	6.4 – 7.7	5 – 6.3 & 7.8 – 9	<5 & >9
<b>Murray and Western Plains</b> (lowlands of Kiewa, Ovens, Goulburn & Broken catchments)	6.4 – 7.7	5 – 6.3 & 7.8 – 9	<5 & >9
<b>Murray and Western Plains</b> (lowlands of Campaspe, Loddon & Avoca catchments, lowlands of Wimmera catchment & Mallee Basin & lowlands of Glenelg & Hopkins catchments, & Portland, Corangamite and Millicent Coast Basins)	6.5 – 8.3	5 – 6.4 & 8.4 – 9.5	<5 & >9.5

Table 6: Dissolved oxygen concentration ranges that represent a low risk, potential risk and high risk to aquatic ecosystems in rivers and streams

SEGMENT	INDICATOR		
	DO mg/L (% sat) measured over the diurnal cycle		
	Low risk	Potential risk	High risk
Highlands	95 – 110	>60 – <95 & >110 – <140	≤60 & ≥140
Forests A	90 – 110	>40 – <90 & >110 – <140	≤40 & ≥140
Forests B	90 – 110	>40 – <90 & >110 – <140	≤40 & ≥140
Cleared Hills and Coastal Plains	85 – 110	>40 – <85 & >110 – <140	≤40 & ≥140
<b>Murray and Western Plains</b> (lowlands of Kiewa, Ovens, Goulburn & Broken catchments & lowlands of Glenelg & Hopkins catchments, & Portland, Corangamite and Millicent Coast Basins)	85 – 110	>40 – <85 & >110 – <140	≤40 & ≥140
<b>Murray and Western Plains</b> (lowlands of Campaspe, Loddon & Avoca catchments, lowlands of Wimmera catchment & Mallee Basin)	80 – 110	>40 – <80 & >110 – <140	≤40 & ≥140