Guideline

Environmental Protection (Water and Wetland Biodiversity) Policy 2019

Deciding aquatic ecosystem indicators and local water quality guideline values

March 2022

Queensland Government

Prepared by: Environmental Policy and Planning Division, Department of Environment and Science

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March 2022

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1 Introduction

1.1 This Guideline

This document informs the development of water quality guideline values to enhance or protect the 'aquatic ecosystem' environmental value, for Queensland waters, in accordance with the provisions of the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (EPP (Water and Wetland Biodiversity)). These guideline values are the scientific basis of water quality objectives (WQOs) which protect or enhance the stated environmental values (EVs) of waters and are included in Schedule 1 of the EPP (Water and Wetland Biodiversity). Although WQOs are based on guideline values in some cases the objectives may be amended from the scientifically derived guideline values due to economic and/or social considerations. This document is focussed on development of guideline values but includes limited consideration of the subsequent process of deriving water quality objectives. This document outlines protocols for comparing test site water quality against relevant water quality objectives recognised under the EPP (Water and Wetland Biodiversity), including for example, as input to regional report cards.

Guideline values developed using the methods of this document aim to protect and maintain the condition of minimally impacted waters and seek to improve those which are moderately or highly disturbed. These methods are designed for developing guideline values as input to WQOs to be scheduled under the EPP (Water and Wetland Biodiversity) and may not be suitable for application in determining Environmental Authority (EA) release limits or in environmental impact assessment of Environmentally Relevant Activities. For the purposes of deriving EA limits, refer to relevant guideline documents available on the department website.

Prior to determining the need for local WQOs, readers should firstly review whether local environmental values and water quality objectives have been, or are being, established by the department under the EPP (Water and Wetland Biodiversity) for their waters. Refer to the department website for information:
https://environment.des.qld.gov.au/water/policy/index.html.

The scope of this document is limited to guideline values for physical and chemical indicators for aquatic ecosystem protection, excluding anthropogenic toxicants. However, guideline values for metals may be derived using this document where natural background levels exceed ANZG 2018 default guideline values (DGVs, previously termed 'trigger values'). The application of the ANZG 2018 toxicant DGVs in Queensland is summarised in Appendix 2.

Guideline values for human use environmental values (e.g. drinking water, recreation, suitability for stock watering, crop irrigation etc.) are generally sourced from relevant state or national guideline documents.

1.2 Background

The purpose of the EPP (Water and Wetland Biodiversity) is to achieve the objective of the *Environmental Protection Act 1994* in relation to Queensland waters— that is, to protect Queensland's water environment whilst allowing for development that is ecologically sustainable.

Section 5 of the EPP (Water and Wetland Biodiversity) states the purpose of the EPP (Water and Wetland Biodiversity) is achieved by—

- identifying environmental values and management goals for Queensland waters
- stating water quality guidelines and water quality objectives (WQOs) to enhance or protect environmental values
- providing a framework for making consistent, equitable and informed decisions about Queensland waters, and
- monitoring and reporting on the condition of Queensland waters.

Section 11 of the EPP (Water and Wetland Biodiversity) identifies that WQOs for Queensland waters are listed in EPP (Water and Wetland Biodiversity) schedule 1, or in the absence of a listing in schedule 1, they are the set of water quality guideline values that protect all environmental values of the water. In deciding local water quality objectives for Queensland waters, Section 8 of the EPP (Water and Wetland Biodiversity) gives precedence to *site specific studies for a water* (i.e., local studies). As shown in Figure 1, water quality guidelines, such as those derived using the methods of this document, may form the technical basis for deriving WQOs under the EPP (Water and Wetland Biodiversity).

EPP (Water and Wetland Biodiversity) environmental values and water quality objectives in turn become considerations in various government decision making, ecosystem health reporting and other planning contexts. For example, the *Environmental Protection Regulation 2019* (section 35) outlines matters to be complied with for environmental management decisions, include the following links to the EPP (Water and Wetland Biodiversity)—

- the management hierarchy (EPP (Water and Wetland Biodiversity) section 14),
- environmental values (section 6),
- water quality objectives (section 11), and
- management intent (section 15).

1.3 Overview of the water quality management process

The Queensland water quality management process is outlined in Figure 1 below. This section provides an overview of each step of the process and the terms used within it. While this document is focussed on the derivation of guidelines (Sections 2-5), the complete management process is briefly described here to provide context for the guideline value derivation component of the process.

- **Define region**: This initial step is a definition of the area for which environmental values, local water quality guidelines and objectives are to be determined. This can be as large as a water basin or limited to a small sub-catchment. The aim is to ensure that all stakeholders are clear on the area of interest.

- **Consultation**: This is a process of discussion with all stakeholder groups about what uses and values of the waters they wish to maintain and/or improve. The outcome of this consultation is expressed in terms of Environmental Values (EVs) for the waters in question but may also include some more specific community aspirations and management goals.

- **Environmental Values**: Environmental values are the values and uses of waters, including for aquatic ecosystem protection, which are to be protected or enhanced. The principal EVs are the protection of aquatic ecosystems (which is the focus of this document), cultural and spiritual values, and the various human uses of waters such as crop irrigation, drinking water and aquatic recreation (EPP (Water and Wetland Biodiversity), Section 6). EVs may be further categorised with a “level of protection”. This is most relevant to aquatic ecosystems where the “level of protection” denotes the extent of modification of the aquatic system away from pristine that is acceptable (see later in the document terms such as “high ecological value” and “moderately disturbed”).

- **Definition of water types and zones**: Water quality varies naturally across different water types and different parts of a region. Thus, for the purposes of water quality management, waters within a region need to be partitioned into water types or defined zones, within which water quality is sufficiently uniform that a single set of guidelines for aquatic ecosystem protection may be applied.

- **Identify indicators**: Water quality values for each of the stated EVs is expressed against a range of relevant indicators. The task in this part of the process is to identify which indicators are to be used to express the required water quality for each EV. This is an important step. However, in practice there are a set of established or commonly used indicators for each EV and, in most cases, these are adopted, although this by no means precludes the development of new indicators. There is discussion of the scope of indicators for ecosystem protection in Section 4. ***Note, however, that this document is focussed largely on physico-chemical indicators for ecosystem protection***.

- **Identification of guideline values for indicators**: Water quality guideline values are those values of indicators that will provide comprehensive protection for a stated EV (at the defined level of protection) or for a specific management goal. Approaches for developing guideline values for aquatic ecosystems at each level of protection are discussed in Section 5. Along with guideline values for aquatic ecosystems, guideline values for each identified EV of the water are considered in this step. Guideline values for human use EVs are generally derived from state and national guideline documents and are not considered here.

- **Draft water quality objectives (WQO)**: The draft water quality objectives are the combined set of guideline values considered in the previous step which will protect or maintain all the identified EVs of the water. Importantly, note that where a guideline value for a particular indicator differs between EVs, then the stricter guideline value becomes the draft objective, thus providing for protection of all EVs.

- **Social and economic considerations**: The draft water quality objectives are designed to provide protection for the defined EVs at the specified level of protection. However, in more impacted waters, achieving these objectives may:

    - entail more expenditure than the community is either prepared or able to pay

    - be completely impractical in the foreseeable future or require social or economic disruption unacceptable to the community

    - only have a limited environmental benefit, and at a cost that is difficult to justify.

In situations where social or economic considerations prohibit achievement of the draft WQOs, it is necessary to revisit the EVs and levels of protection and derive WQOs that are a balance between what is achievable within economic and social constraints, and what is an acceptable degree of protection for the nominated EVs. This can be a difficult process due to competing economic and environmental priorities. In significantly impacted waters it may even be necessary to abandon one or more EVs in restricted reaches. Note, however, that water quality objectives must represent an improvement on existing water quality, meaning that objectives cannot allow a degradation of water quality over time.

- **Approved EVs and WQOs**: Consideration of social and economic impacts may require further consultation and subsequent revisions to the EVs and draft WQOs. These revised outcomes then become the adopted EVs and WQOs. Note that in cases where no revisions are required, the draft EVs and WQOs are approved unmodified. In Queensland, the approved EVs and WQOs are listed in Schedule 1 of the EPP (Water and Wetland Biodiversity) and are then required to be considered in various government decision processes.

1.4 Layout of this document

The remaining parts of this document do not cover the whole water quality management process as described in the previous section. Instead, it focusses on the sub-section of the process that is associated with deriving physico-chemical guideline values for aquatic ecosystem protection in Queensland waters – see highlighted section in Figure 1. However, as noted earlier, it is important to understand how this part of the process fits within the overall management process.

The highlighted sections in Figure 1 are addressed in order in this document, but the bulk of the document is contained in Section 5, the derivation of local guidelines for aquatic ecosystem protection.

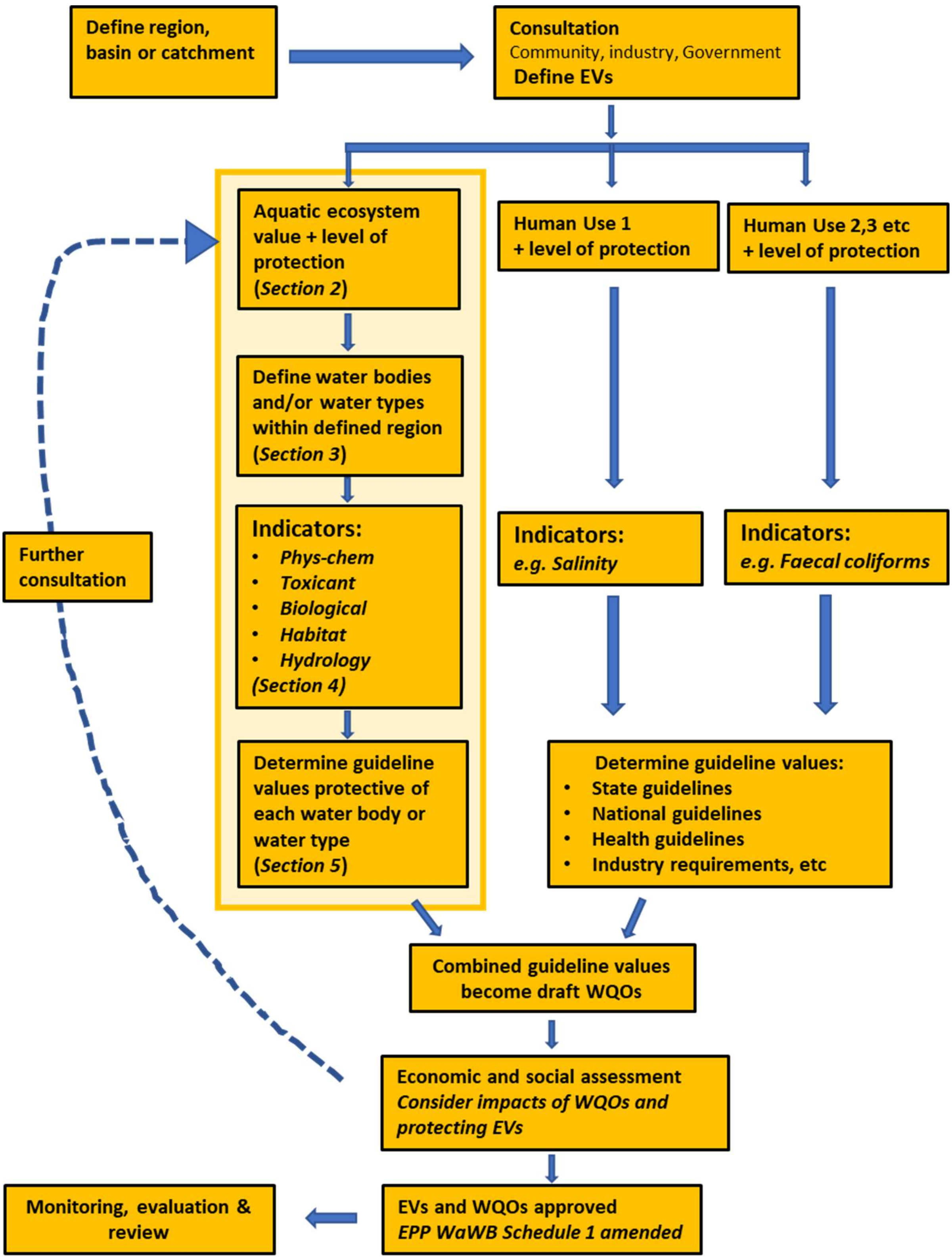

Figure 1 Queensland's water quality management framework under the EPP (Water and Wetland Biodiversity)

2 Aquatic Ecosystem Protection: levels of protection & management goals

The EPP (Water and Wetland Biodiversity) Section 15 defines four levels of protection for the aquatic ecosystem EV, as stated in Table 1 and depicted in Figure 2. The levels of protection have corresponding management intents, which determine the approach taken to managing waters of that area and also has an important bearing on the strictness of guideline values imposed and also on the methods by which these guideline values are developed. Further information on water type mapping and level of aquatic ecosystem protection for a water is provided in the *EPP (Water) 2009 Management Intent and Water Type Mapping Methodology 2018,* published on the department's website (https://environment.des.qld.gov.au/water/policy/pdf/eppw-mapping-procedure-guide.pdf).

Classification of the level of protection across the region's waterbodies is principally informed through the community consultation phase of the water quality management process. Key factors influencing classification include current water quality condition and the existence of other types of management zoning e.g., national park or fisheries habitat reserves. Where the community values a particular waterbody highly, it is also possible for waters of moderate quality to be assigned an aspirational level of protection significantly better than current condition. This would emphasise the need for significantly improved management of the area.

In addition to assigning general levels of protection and their associated management intent (Table 1), specific management goals may be developed for defined waterbodies (EPP (Water and Wetland Biodiversity), Section 10). Such goals may be developed in the community consultation phase but are also based on scientific knowledge of important habitats in the region under consideration. Protection of seagrass areas is one example of such a goal, which would then have a direct bearing on guideline values for physical factors such as turbidity and light availability. A management goal of no algal blooms would have implications for nutrient guideline values and so on.

Table 1 Level of aquatic ecosystem protection and management intent. This table summarises sections 6(2)(a)-(d) (level of protection) and 15(2) (management intent) of the EPP (Water and Wetland Biodiversity) 2019.

Level of aquatic ecosystem protection	Description (see Figure 2 below)	Management Intent
High Ecological Value waters (HEV)	Waters in which the biological integrity of the water is effectively unmodified or highly valued.	Maintain or achieve natural and/or highly valued condition
Slightly Disturbed waters (SD)	Waters that have the biological integrity of high ecological value waters, but slightly modified physical or chemical indicators.	Progressively improve to achieve WQOs for HEV condition
Moderately Disturbed waters (MD)	Waters in which the biological integrity of the water is adversely affected by human activity to a relatively small but measurable degree.	Maintain WQOs or improve towards WQOs (depending on current condition relative to WQOs)
Highly Disturbed waters (HD)	Waters that are significantly degraded by human activity and of lower ecological value than other levels of protection.	Progressively improve over time to achieve WQOs for the waters

High Ecological Value (HEV) waters **Slightly Disturbed (SD) waters**

Moderately Disturbed (MD) waters **Highly Disturbed (HD) waters**

Figure 2 Depiction of waters with different levels of aquatic ecosystem protection and management intent.

3 Definition of water types and waterbody zones

Water quality varies naturally across different water types and different parts of a region. Thus, for the purposes of water quality management, waters within a region need to be partitioned into water types or defined zones within which water quality is sufficiently uniform that a single set of guideline values for aquatic ecosystem protection may be applied.

The major water types include groundwaters, surface freshwaters (upland and lowland, lakes and wetlands), estuaries (upper, mid, and lower, and estuarine wetlands), coastal waters (enclosed coastal, open coastal), and marine waters (mid-shelf and offshore). Zones can be specific aquifers, reaches of a river or estuary, or parts of an embayment.

Use of water types allows generic guideline values to be derived for all waters of each type. Use of defined zones allows more specific guideline values to be set for each zone. Either approach or a mixture may be applied within the region under assessment.

Whilst breaking a region up into water types or zones is necessary to allow appropriate guideline values to be set, the extent to which this subdivision is undertaken requires judgement. Reducing the areal extent of zones (and thereby increasing their number) will improve internal water quality consistency. However, if this process is taken too far then the increasing number zones and objectives will make the system progressively more complex and less usable. Therefore, the subdivision of waters must be limited to a manageable scale.

Definition of water types is also an important precursor to setting indicators. Indicators suitable for marine waters may not be suitable for estuaries or freshwaters (and vice versa) and so definition of water types provides direction in the choice of appropriate indicators.

However, this document is focussed on physico-chemical indicators and, unlike biological indicators, these tend to be applied consistently across most waters.

EPP (Water and Wetland Biodiversity) Schedule 1 documents and mapping identify water quality objectives according to water types, environmental value zones, level of protection/management intent, and other characteristics. (These are available from the department's website.) The spatial definition of mapping can range from the limit of Queensland waters, to an entire basin, to a sub-catchment, or estuary, depending on the project area. Also refer to the *EPP (Water) 2009 Mapping procedural guide 2018* for more details.

An example of this mapping is shown below in Figure 3.

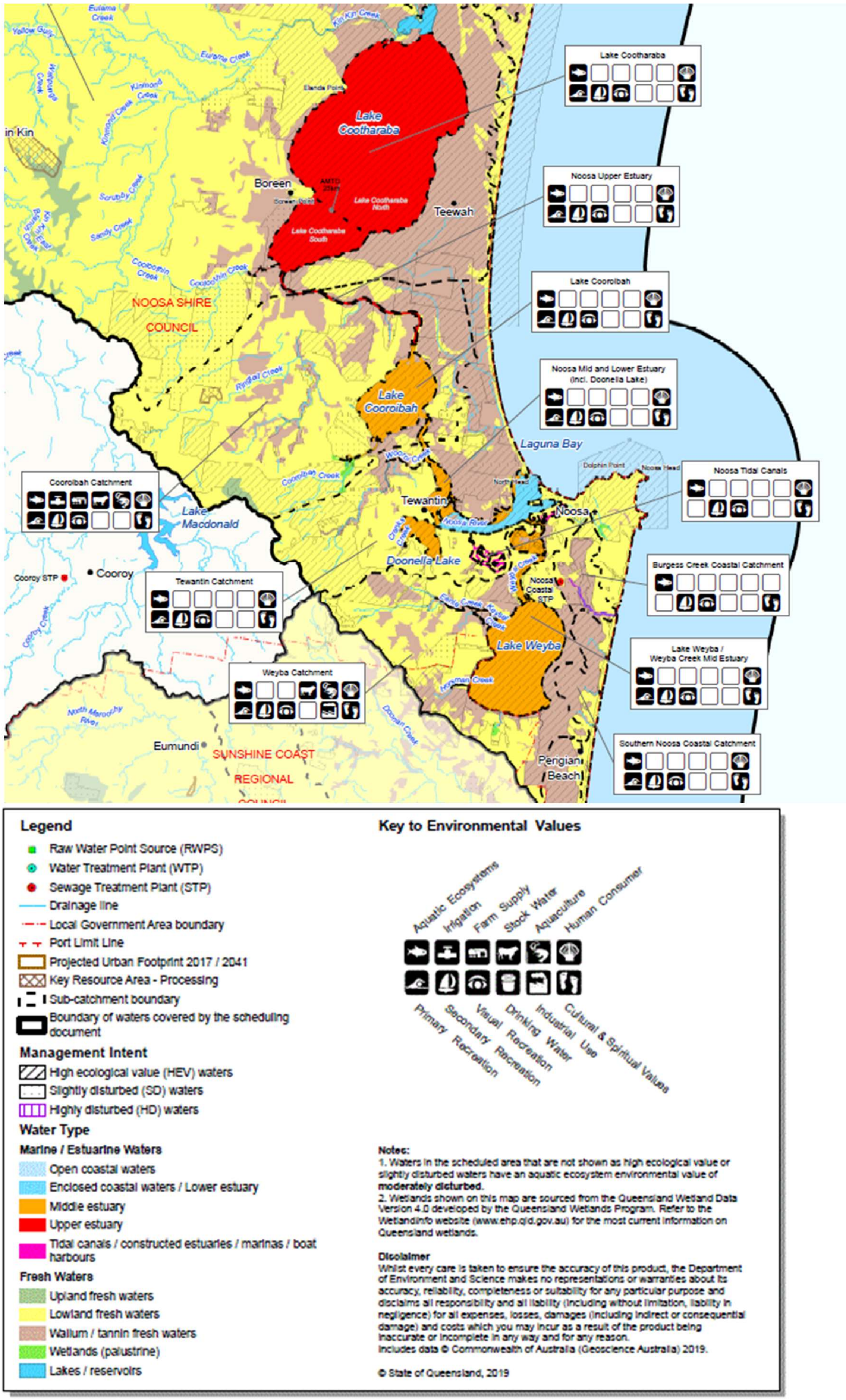

Figure 3 Example of Environmental Value zone and water type mapping. Part of Noosa River basin. Example only and not government policy.

4 Definition of indicators

Water quality guideline values for aquatic ecosystems are expressed against **indicators**. Traditionally, water quality guideline values have been understood to be limited to the physical and chemical properties of waters, and these are the focus of this document. However, it is now recognised that protection of aquatic ecosystems requires managing many more factors than just physical and chemical properties of the water. The scope of indicators that is now applied to protecting aquatic ecosystems in Queensland is extensive and includes:

- **physical and chemical indicators** (e.g. pH, nutrients, suspended solids, water clarity, salinity, dissolved oxygen). These indicators may be applied to surface or ground waters.
- **biological indicators** (e.g. in-stream biota–fish, macroinvertebrates, aquatic macrophytes—seagrass extent and distribution, coral extent and distribution, groundwater stygofauna)
- **toxicant indicators** (see Appendix 2 for further details). Toxicants and their default guideline values are stated in ANZG 2018 or derived from specific studies by a recognised entity. The guideline values for toxicants are usually determined by direct testing of the impacts (both lethal and sub-lethal) of the toxicant on target organisms.
- **physical form indicators** (e.g. beds, banks, in-stream habitat, refuge waterholes and ground cover)
- **habitat indicators** (e.g. measures of the health of the riparian zone such as width, continuity, species composition)
- **hydrology indicators and environmental flows**: (e.g. measures of alteration to flow, changes to peak or baseflow, changes in seasonality, changes to groundwater levels.) (See also *Water Act 2000* and Water (Resource) Plans).

While the above describes the scope of indicators that may be used to set water quality guideline values and objectives for Queensland waters, ***this document relates only to deriving guideline values for physical and chemical indicators*** which will protect the environmental value of aquatic ecosystems. The methodologies described are in principle applicable to most physical-chemical indicators. However, for some indicators additional information is provided in the Appendices to this document.

- Appendix 3: Freshwater salinity
- Appendix 4: Estuary and marine salinity
- Appendix 5: pH.

The derivation of guideline values for pesticides (insecticides, herbicides and fungicides) and other anthropogenic toxicants is not included in this document and Queensland guidelines refer to the ANZG default guideline values for these substances. How to apply ANZG default guideline values as water quality objectives is outlined in Appendix 2.

Metals are similarly not included here and also normally refer to ANZG default guideline values. However, where naturally occurring levels of metals exceed ANZG default guideline values a local guideline value may be determined based on the 80th percentile of the natural values.

5 Development of local physical and chemical guideline values for aquatic ecosystem protection

5.1 General approaches

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018) state that "*aquatic ecosystems are complex and heterogeneous, and it is often essential to reflect local condition in the guideline values."* Guideline values may be derived using either ecological effects or reference site data. The ANZG recognise that *"For modified ecosystems, 'best available' reference sites may provide the only choice for the reference condition"*[1]. This document is focussed on reference-based guideline values but some brief contextual information on ecological effects-based guideline values is included in this section.

It is important to note that in practice, it is necessary to consider both ecological effects (5.1.1) and reference data (5.1.2) in determining guideline values. Take the following example: a dissolved oxygen value of 70% saturation might be adequate to support a local ecosystem and could be adopted as a guideline value. However, if the reference median dissolved oxygen value for the system was 90% saturation then this would be the preferred guideline value. Thus, while ecological effects-based guideline values set a minimum to be achieved, if the system has naturally better quality, that would be the preferred target. Conversely, if a system has been degraded to the point where there is reduced ecosystem function, then ecological effects-based guideline values could be applied as a minimum target (water quality objective) for management action.

5.1.1 Guideline values for physical-chemical indicators based on ecological effects

Ecological effects-based guideline values fall into two main types. The first type are guideline values based on laboratory studies of the direct toxic effects of a substance on a range of representative organisms. Guideline values for contaminants including pesticides, organic compounds and heavy metals are nearly all derived using this approach. The ANZG contain comprehensive information regarding the derivation of these guideline values and in general Queensland guidelines default to the ANZG values. The ANZG also contain guideline values for other directly toxic water quality issues such as high levels of ammonia or extreme values of dissolved oxygen and pH.

A second group of ecological effects-based guideline values are derived from field-based studies of relationships between a physical-chemical indicator and some ecological aspect of the system. Examples include guideline values for light requirements for seagrass survival or guideline values for nutrient levels to limit algal growth. The derived water quality guideline value is defined as the level of key physical or chemical stress below which ecologically or biologically meaningful changes do not occur, i.e. the acceptable level of change.

As noted in 5.1 above, both ecological and reference-based guideline values need to be considered in setting adopted water quality objectives. However, in the absence of information on the ecological and biological effects of physical and chemical stressors, which is commonly the case, then the reference data approach becomes the default approach

[1] ANZG 2018 http://www.waterquality.gov.au/anz-guidelines/monitoring/data-analysis/derivation-assessment , accessed 6/12/18

used to derive water quality guideline values for physical and chemical indicators for all Queensland waters.

5.1.2 Guideline values for physical-chemical indicators based on reference site data

An ideal reference site for deriving guideline values is one that is minimally impacted and has limited exposure to anthropogenic drivers (ANZG 2018). However, in modified systems, minimally impacted sites may either not be available, or have insufficient data for deriving guideline values, in which case the use of ‘best available’ reference sites is warranted. ‘Best available’ reference sites would represent the least disturbed conditions within a modified system and represent an acceptable condition for other sites to achieve.

To derive guideline values using minimally impacted or ‘best available’ reference sites, an acceptable level of change from the reference condition is described by an appropriate percentile of the reference data. A percentile represents a measure that can be applied to data whether normally or non-normally distributed. The default ANZG method recommends use of the 80^{th} percentile when using minimally impacted reference sites to derive guideline values for moderately disturbed waters, but also allows for the use of alternative percentiles. When using ‘best available’ reference sites in modified systems a lower percentile of the reference distribution can be applied to limit further water quality degradation or promote water quality improvement.

This approach is suited to physical and chemical indicators, such as nutrients and turbidity, that indirectly affect the aquatic ecosystem health when levels outside the natural range occur. For some indicators, such as dissolved oxygen and pH, whilst long-term guideline values are generally derived using the reference approach, consideration also needs to be given to deriving guideline values for short-term extreme values of these indicators, which can be directly toxic.

The reference approach is not applied to man-made toxicants as these have a “nil” natural value. However, it may be applied to natural toxicants (e.g. metals) in waters where their natural background concentrations (e.g. in mineralised catchments) exceed the ANZG default guideline values that would normally be applied.

5.2 Development of local physical-chemical guidelines for aquatic ecosystem protection for Queensland waters

5.2.1 Overview

This section outlines the approach to derive aquatic ecosystem water quality guideline values in surface waters, and methods for the comparison of test site data with the derived values. This framework can be used to compare water quality condition relative to the state’s adopted WQOs, for example in catchment or regional report card processes. Where WQOs are included in schedule 1 for the region of interest, the test site data is compared against the EPP (Water and Wetland Biodiversity) WQOs. Note that further detail is provided in subsequent sections for Great Barrier Reef marine waters (Section 5.3) and groundwaters (Section 5.4).

The general principles are outlined below, followed by more detail according to level of protection/management intent (HEV, SD, MD, HD) in subsequent sections.

- Identify the EV zones for waters, water types and level of aquatic ecosystem protection for your study area
- Identify any minimally impacted reference sites or best available local sites, within each water type, where water quality data is available. If no water quality data is available, default state or national guideline values may be used whilst data is collected.
- Compile sufficient water quality monitoring data to allow reliable percentiles to be determined. The precision with which percentiles can be estimated depends on sample size — see Queensland Water Quality Guidelines (QWQG) and ANZG 2018.
- Where appropriate, segregate the data into high flow and low flow – see Appendix 1 for detail.
- From the compiled dataset, select percentiles appropriate to the level of protection and type of reference site available, as detailed in the following sections. These become preliminary guideline values.
- Water quality monitoring and sampling must be undertaken in accordance with the *EPP Water Monitoring and Sampling Manual 2018*, published on the Department's web site.

5.2.1.1 Standard information

The following guidance should be applied to the below section 5.2.2, 5.2.3 and 5.2.4.

Data: Queensland Water Quality Guidelines (QWQG) recommend a minimum of 18 data values collected over two years to derive guidelines. (See QWQG section 4.4.3.1 regarding sample data quantity and Figure 4.4.1 on the relationship between sample size and the error in estimation of percentile values.) Larger data sets give increasing reliability and ideally a data set should encompass several years and a range of climate conditions. While the QWQG permits the derivation of guidelines based on less than two years of monthly sampling, this should be considered as interim—until a full data monitoring program can be undertaken.
Sampling errors can potentially contribute significantly to the overall errors in percentile estimates. Therefore, all reference and compliance data monitoring programs must have quality assurance programs and conduct sampling in accordance with the EPP Water *Monitoring and Sampling Manual 2018*, published on the Department's website.

Flow separation and seasonality: Flow separation of reference data (i.e. into low flow and high flow) should be carried out wherever flow data exists for that sub-catchment from the relevant gauging station — refer to the Water Monitoring Information Portal for gauging station locations. In estuaries, flow separation is based on conductivity values. Flow separated data may then be used to derive flow-specific water quality guideline values. These guideline values then apply under the same flow conditions for which flows were defined. Appendix 1 provides detail on the rationale and methods for deriving separate guideline values for low and high flow conditions in both freshwaters and estuaries.

The data should also be checked for significant seasonal variations and, if warranted, objectives applicable to defined seasons may be derived.

5.2.2 High ecological value (HEV) waters

Reference sites: HEV waters are by definition unimpacted by human influence (Table 1). If water quality monitoring data from the specific HEV waters are limited, reference data from HEV waters in a comparable catchment and water type may be considered.

HEV Guideline values: Low or high flow guideline values: 20/50/80th percentiles of the relevant flow data.

Data and flow separation and seasonality: As per section 5.2.1.1 above

Comparison of test site data against HEV guideline or WQO value
Under the EPP (Water and Wetland Biodiversity), the management intent for HEV waters is that there should be 'no change' to existing water quality, i.e., no change in the natural range of values. No change is deemed to have occurred if there are no detectable changes to the 20th, 50th and 80th percentiles of the natural distribution of values.
The detailed testing regime for HEV waters is stated in the QWQG (2009), Appendix D.2.1.

5.2.3 Slightly disturbed (SD) waters

Application of SD level of protection: Under the EPP Water, the inclusion of the SD level of protection was designed to include those waters that were assessed to be only slightly impacted with a management intent to return them to natural or unmodified (HEV) condition.

Following stakeholder feedback, the use of the SD classification can now also be applied to waters that are currently impacted to a moderate degree, but which the community value highly and wish to see improved to a minimally impacted condition. Such waters would require a greater degree of improvement than waters already in an SD condition. However, as the intent is the same in either case, the guideline values would be similar, although achieving them would be a longer process with the more impacted waters.

In accordance with the EPP (Water and Wetland Biodiversity) management intent, the water quality guideline values are set on a more stringent percentile than the existing water quality — to improve towards HEV. If water quality monitoring data are limited for the SD waters in question, reference data from HEV or SD waters in the same or comparable catchment and water type may be considered.

Reference sites: Reference data should be sourced from sites in SD waters, or comparable HEV waters.

SD Guideline values for low or high flow: 20/40/70th percentiles of the existing SD water quality (30/60/80th percentiles for indicators with impact at low level or concentration). If limited data, review percentiles from comparable HEV catchment and water type (20/50/80th percentiles), or comparable SD catchment and water type (20/40/70th percentiles).

Data and flow separation and seasonality: As per section 5.2.1.1 above

Comparison of test site data against SD guideline or WQO value
Under the EPP (Water and Wetland Biodiversity), the management intent for SD waters is to progressively improve towards HEV.
The test site 20th, 50th and 80th percentiles are compared with the corresponding water quality objective distribution values for the SD waters. This protocol is designed to promote improvement in water quality compared to existing condition as required by the EPP (Water and Wetland Biodiversity) management intent for SD waters.

The testing regime is the same as for the HEV level of protection as stated in the QWQG (2009), Appendix D.2.1.

5.2.4 Moderately disturbed (MD) waters

Under the previous ANZECC Guidelines (ANZECC 2000), the default guideline values approach for MD waters based them on the 80th percentile of data from largely undisturbed reference sites. This approach will continue to be applied in Queensland in waters where this is an appropriate methodology. However, there are issues with this approach that need to be addressed:

1. Largely unimpacted reference sites are often not available for many areas, particularly lowland freshwaters and therefore some alternative approach is required.

2. Where unimpacted reference sites are available, guideline values derived from these sites may be unattainable in some MD waters within the foreseeable future without unacceptable social or economic disruption for the community, and thus may be seen as having little practical application.

The first issue can be addressed through use of a broader application of the reference site concept. Thus, while reference sites are commonly taken to be undisturbed sites, ANZG 2018 allows for the reference concept to include sites that are used to derive the quantitative values for particular physical or chemical indicators. "*For modified ecosystems 'best available' reference sites may provide the only choice for the reference condition*". Use of best available reference sites allows for reference data to be acquired in areas where there are no unimpacted sites. A method for deriving guidelines for MD waters based on best available reference sites has been designed for use in Queensland and is described in section 5.2.4.2 below.

Addressing the second issue can be more problematic. In MD waters where a guideline value based on unimpacted reference sites is clearly unattainable, then an alternative guideline value that is (i) practically achievable within economic and social constraints and (ii) still provides an appropriate level of protection for the local ecosystem and EVs is required. One example of this situation is estuaries in southeast Qld where major WWTP discharges result in relatively high nutrient levels. Even with best practice treatment, nutrient levels would remain well above unimpacted guideline values while discharges continue to occur. Another example is the elevated levels of nitrate in some intensive agricultural areas caused by high levels of fertiliser use. Reducing levels to background is impractical in the foreseeable future due to legacy groundwater contamination and continuing agricultural production even with best practice management.

Approaches to setting guideline values in this situation include assessment of what best practice can achieve (usually by modelling), assessment of the biological impacts of elevated concentrations of pollutants in question (often only one or two pollutant types are involved) and consultation with stakeholders on the extent of consequences of less stringent guideline values.

The following sections describe in more detail the alternative approaches for deriving guideline values for MD waters in Queensland. These are listed in order of priority.

- Deriving guideline values based on unimpacted reference sites (5.2.4.1)
- Deriving guideline values where no unimpacted reference sites are available and best available reference sites are used (5.2.4.2)

- Deriving guideline values in situations where certain pollutants are significantly elevated, though the biological integrity of the site is not considered ‘highly disturbed’. (5.2.4.3)

5.2.4.1 Guideline values based on unimpacted reference sites

This is the preferred approach where suitable reference sites are available and provided it is appropriate or practical.

Reference sites: The method is applied to MD waters for which data from unimpacted reference sites are available for the same water type. Criteria for unimpacted reference sites for deriving guideline values for MD waters are listed in Table 2.

Table 2 Criteria for un-impacted reference sites. From Queensland Water Quality Guidelines, Table 4.4.1

Freshwaters	
1	No intensive agriculture within 20km upstream. Intensive agriculture is that which involves irrigation, widespread soil disturbance, use of agrochemicals and pine plantations. Dry land grazing does not fall in this category.
2	No major extractive industry (current or historical) within 20km upstream. This includes mines, quarries and sand/gravel extraction.
3	No major urban area (>5000 population) within 20km upstream. If the urban area is small and the river large this criterion can be relaxed.
4	No significant point source wastewater discharge within 20km upstream. Exceptions can again be made for small discharges into large rivers.
5	Seasonal flow regime not greatly altered. This may be by abstraction or regulation further upstream than 20km. Includes either an increase or decrease in seasonal flow.
Estuaries	
1	No significant point source wastewater discharge within the estuary or within 20km upstream. Exceptions can again be made for small discharges into large rivers.
2	No major urban area (>5000 population) within 20km upstream. If the urban area is small and the river large this criterion can be relaxed.

Data and flow separation and seasonality: As per section 5.2.1.1 above

MD Guideline values:

Low flow:

- Guideline: The 80th (or 20th for indicators with impacts at low level or concentration) percentile of low flow un-impacted reference site data.

High Flow:

- Guideline: The 80th (or 20th for indicators with impacts at low level or concentration) percentile of high flow un-impacted reference site data.

Comparison of test site data against MD guideline values or WQO value

The median value of preferably five or more independent samples at test sites should not exceed the water quality objective. For DO and pH, test sample median values are compared with, and should fall within the specified percentile range.

5.2.4.2 Guideline values based on ‘best available’ local reference sites

This approach is applied where use of unimpacted reference sites is not possible or generates guideline values which are unachievable within social and economic constraints.

Best available local sites: An assessment of the complete water quality data sets within each basin/catchment /sub-catchment/EV zone and water type is undertaken to identify the best available (least disturbed) local sites.

The location of best available local sites should not be impacted by, or be immediately downstream of—

- a point source discharge, or
- intensive agricultural activities, or
- severe bank or gully erosion.

Queensland Government and stakeholder databases, land-use data, satellite imagery and/or field checks should be used to identify best available local sites before proceeding to derive water quality guideline values.

Strict data screening of 'raw' data must be adopted. Water quality at all available sites should be reviewed. Any sites with clearly anomalous or degraded water quality (e.g. from historical or current activities) should be removed from the analysis. Temporal trends in the data should also be considered. For instance, if water treatment infrastructure, land-use management or other upgrades have resulted in improved water quality, only the more recent better-quality data are used. Conversely, where development or actions have resulted in significant or acute degradation of water quality, then impacted data should not be included in the dataset used to derive water quality guidelines. Where sites are clearly different from others, the sites should be assessed to determine if this is due to natural differences (e.g. geology) between catchments. If this is the case, it may be necessary to subdivide the area and calculate separate guideline values for each.

If remaining sites have reasonably consistent water quality, then guideline value percentiles can be determined.

Data: As data is taken from the best available local sites, the data should be sourced from a range of sites so that there can be confidence that water quality in the catchment is adequately characterised. See Section 5.2.1.1

Flow separation and seasonality: see Section 5.2.1.1

MD Guidelines: Where reference data from best available local sites is employed, the approach to setting a water quality guideline value is to use a more stringent percentile than when using un-impacted reference sites, generally less than the median, aiming to both protect the aquatic ecosystem EV and encourage improvements in water quality.

The use of the 40th percentile for low flows and 30th percentile for high flows is a starting point for stakeholder consultation and consideration by the Department, in accordance with sections 11 and 12 of the EPP (Water and Wetland Biodiversity). Using the 40th and 30th percentiles as default values meets requirements of the EPP (Water and Wetland Biodiversity) that water quality objectives maintain and improve water quality in moderately disturbed waters, and also adopts the principal of continual improvement. A lower percentile (30th) is applied during high flows as these conditions transport large loads of pollutants, but also are conditions under which many landscape management and streambank stabilisation works have positive effect on water quality (Appendix 1). A site-specific investigation and/or consultation process may identify management goals that require more stringent protection, i.e. the water quality objective is set at a value lower than the 40th percentile. In the few situations where reliable modelling of the water quality attainable through best management practice is available, it may be optional to set guideline values/WQOs based on these values, in accordance with sections 11 and 12 of the EPP (Water and Wetland Biodiversity).

The Department will determine the final water quality objectives to be included in the EPP (Water and Wetland Biodiversity) in consultation with local government, industry, and the community, and in consideration of the economic and social impact of protecting the environmental values for the water.

The Department is then responsible for scheduling these values by amending the EPP (Water and Wetland Biodiversity).

Notes:

1. For DO and pH, guideline values (typically a range between 20th and 80th percentiles) are set with reference to the QWQG and review of local data.
2. Post implementation of management actions to improve water quality, should water quality monitoring and evaluation data determine the legislated WQOs are achieved for MD waters—in conjunction with stakeholders, the Department will recommend re-establishing the WQOs in accordance with EPP Water sections 11 and 12 to promote further water quality improvement with more ambitious objectives or a higher level of protection.
3. Additionally, there will be a need to confirm that regardless of which approach is employed, calculated values are not inconsistent with data from sites in comparable areas and do not represent a direct threat to the biota (i.e. meet available toxicity based guidelines such as ANZG 2018). It is also a requirement of the EPP (Water and Wetland Biodiversity) that guideline values represent an improvement from existing water quality.
4. The approach under this guideline is similar to that adopted by the NSW Government in deriving regional guideline (trigger) values for lowland rivers in ANZECC 2000[2]. The Victorian approach is also to set water quality objectives for modified ecosystem conditions—between current and desired condition—to facilitate greater management action in addressing problems. See ANZG 2018.

Default guidelines:

Low flow:

- Guideline: Based on the 40th percentile (60th percentile for indicators with impacts at low level or concentrations) of best available local reference data

High flow:

- Guideline: Based on the 30th percentile (70th percentile for indicators with impacts at low level or concentrations) of best available local reference data.

Comparison of test site data against MD guideline value or WQO value

The median value of preferably five or more independent samples at test sites should not exceed the water quality objective. (If a range of WQOs [e.g. 20th-50th-80th percentile] has been included in the EPP (Water and Wetland Biodiversity) schedule materials for MD waters, as is the case for some schedule documents, then the median of the test data is compared with the corresponding median WQO.) For DO and pH, test sample median values are compared with, and should fall within the specified percentile range.

[2] ANZECC 2000 Volume 2. Table 8.2.2.2 extract, NSW: Only sites judged fair to good condition were used. It is recommended that the 50th percentiles be used in the final table as there are no undisturbed lowland rivers and hence an 80th percentile includes values for significantly disturbed systems. This is inappropriate for trigger values."

This protocol is designed to promote improvement in water quality compared to existing condition towards achievement of the water quality objective — in accordance with the management intent and as required by the EPP (Water and Wetland Biodiversity).

5.2.4.3 Deriving guideline values for waters with significantly elevated concentrations of one or more pollutants but where the biological integrity is not considered highly disturbed

An example of this circumstance is where intensive agriculture has resulted in very high nutrient concentrations, yet mitigating circumstances (such as riparian shading) means that a diverse and functioning ecosystem still exists. This occurs in a number of Queensland waterbodies. Deriving guidelines in this situation should include consideration of the following:

- Protection and, if possible, enhancement of the existing ecosystem
- Reduction of pollutant levels as far as is economically and practically possible
- Ensuring downstream impacts of elevated pollutant concentrations are minimised.

These are considered in more detail below.

5.2.4.3.1 Protection and enhancement of existing ecosystem

Where quantitative relationships between pollutants and ecosystem condition are well understood, then these can provide a strong basis for setting a guideline value that protects and/or enhances the ecosystem. However, in many situations such relationships are often complex, poorly understood and may be complicated by synergistic effects between multiple pollutants and/or physical chemical parameters. This is particularly the case with pollutants (such as nutrients) that have no or little direct toxic effect on biota but which influence ecosystem conditions. In some cases, it may even appear that the pollutant is not having much effect on the system. Promotion of research into these relationships might at some future stage assist in understanding the system but in the present, this approach may not provide definitive guidance on setting guideline values to protect the system and it may be necessary to rely mainly on other approaches.

5.2.4.3.2 Reduction of pollutants based on best management practice and economic considerations

This approach relies on the availability of model predictions of the effect of implementing best management practice (BMP) in land uses and wastewater management on the in-stream concentrations of particular pollutants. This should ideally include BMP for both point and diffuse sources. It should also include consideration of the economic costs and benefits of different levels of BMP. If such information is available, then a guideline value can be derived based on predictions of pollutant concentrations that would be achieved under an economically realistic level of BMP. Such a guideline would always be an improvement on current condition and would, in addition, be practically achievable, albeit usually over several years.

5.2.4.3.3 Minimisation of downstream effects

While the impacts of elevated concentrations of a pollutant in the immediate receiving waterbody may be minor, it is always possible that their translation downstream to a different ecosystem may cause more significant impacts there. An example of this is the movement of elevated nutrients from turbid estuaries into clear water coastal systems. This issue is location specific, but it is important that it is always considered. Assessing the possible downstream impacts may be assessed through examination of the existing data on downstream pollutant movement/concentrations or alternatively some modelling may be required.

5.2.5 Highly Disturbed (HD) waters

For highly disturbed (HD) waters, the formulaic approaches to deriving guideline values recommended for other levels of protection are not particularly suitable. Highly disturbed waters are significantly degraded by human activities and are usually impacted by very specific pollutants, or other specific issues. These could include significant exceedances of toxicity guidelines or alternatively major disturbances to the physical habitat. These are better assessed on a case-by-case basis.

The management goal of HD waters is to bring them up to a standard roughly equivalent to moderately disturbed but this may be a long-term process, only achieved in stages. Guideline values can be set as targets for these stages, but economic and practical considerations may dictate that the scheduled water quality objectives are less stringent in the short or even medium term. For example, rehabilitating a few kilometres of stream impacted by historical acid mine drainage might require expenditure of millions of dollars and the cost benefit of such expenditure has to be considered.

Rather than a formulaic approach, this section contains a suggested process for setting guidelines for an HD area. The outcomes will be tailored for each particular situation, but it is recommended that the general process be followed in each case.

1. Identify the main stressors impacting the HD water which in turn will assist in identifying the key pollutants that need to be managed

2. Review available WQ data. This will confirm which are the key pollutants and which water quality indicators are within acceptable ranges.

3. Based on the WQ data, determine the extent of the HD reach or area and, where possible, break this up into sub-sections with different degrees of impact. Include consideration of the extent of downstream effects that may occur during intermittent high flow events

4. Review options for improvements to water quality and determine which is appropriate for the site under consideration. Options for a series of improvement levels are detailed below but these are not mandatory.
    a. Level 1
        i. Biota only present intermittently but reduction of key pollutants achieves a specified improvement. Acutely toxic events may still occur.
    b. Level 2
        i. Basic ecosystem of very resilient species present. No acutely toxic impacts occurring.

ii. Set a series of guideline values that preclude acute impacts on biota from key pollutants e.g. pH >5, DO saturation >30%.

c. Level 3
   i. More diverse ecosystem present, not just highly resilient species.
   ii. Guideline values designed to mitigate longer term biological impacts, e.g. DO saturation >50%, toxicants at 80% of species protection level.

d. Level 4
   i. Moderately disturbed equivalent ecosystem.
   ii. Guideline values for all indicators based on MD methods.

The levels described are largely applicable to key pollutants.

5. For indicators of water quality not directly related to the site-specific pollutant or degrading processes, the methods for deriving guideline values at the MD level of protection may apply, or guideline values from MD waters in adjacent catchment could be defaulted to. For example, this could apply to nutrient indicators in a HD area impacted by acid-mine drainage, where site-specific HD guideline values are developed only for pH, conductivity and metals.

6. Apply one of these options to each of the identified sub-sections of the HD zone. Include consideration of downstream reaches that may be affected by occasional flow events

7. For some HD areas, following consideration of economic and practical issues, the final water quality objectives may be less stringent than the recommended draft guidelines. In a few cases it may be necessary to classify some reaches of the HD area as remaining in their current condition, with a halt of any further decline, for the foreseeable future. Such a decision may be the only economically viable alternative. However, the process by which this is determined needs to be transparent.

5.3 Deriving local water quality guideline values and objectives for Great Barrier Reef coastal / marine waters

The derivation is applicable to all open coastal waters, mid-shelf waters and off-shore waters north of 24 .29’.54”S to 10 .10’. 66”S and within the east and west boundaries of the Great Barrier Reef Marine Park and Great Barrier Reef World Heritage Area.

The following has been adopted by Great Barrier Reef Marine Park Authority (GBRMPA) in localising water quality guidelines for different coastal/marine waters throughout the Great Barrier Reef. The guidelines form a basis for scheduling as water quality objectives under the EPP Water. Further details on datasets used in particular regions is contained in region reports published on the Department’s website.

In deriving local guidelines for open coastal, mid-shelf and offshore marine waters, GBRMPA reviewed Australian Institute of Marine Science (AIMS) data (including continuous logger data) from the Marine Monitoring Program (MMP) and Long-Term Monitoring Program (LTMP). All data are collected and analysed (including for seasonal trends) in accordance with an approved Quality Assurance and Quality Control manual available at the GBRMPA website.

The approach taken to localise water quality guidelines for different waters throughout the GBR has been to use locally applicable water quality data from the AIMS monitoring programs and compare this, for particular waters and water types, against the corresponding GBRMPA water quality guidelines (GBRMPA, 2010), for the same water type.

5.3.1 Plume line derivation

The plume line defines the waters at higher risk of impact by flood plumes, and land-derived contaminants they transport. The plume line is used to determine expected water quality condition and thus modifies their level of protection, management intent and the method used in localising the water quality guideline values. The plume discharge area from waters discharging to Great Barrier Reef waters is mapped from the southern to the northern limit of GBR waters, bounded by the plume line that is derived from a smoothed version of the 'high' and 'very high' risk classes of modelled outputs from the risk assessment element of the Reef Plan Scientific Consensus Statement 2013 (Waterhouse et al. 2013). See EPP Water mapping methodology 2018.

5.3.2 Marine waters seaward of the plume line

Waters seaward of the plume line are generally expected to be in natural or near natural condition in terms of their water quality, and are ascribed an HEV level of protection.

- Where review of water quality data indicates local water quality condition was better than the GBRMPA (2010) ecosystem support guideline values for the given water type, and there was sufficient data to do so, percentiles were set to maintain this better water quality condition (e.g. by specifying 20-50-80th percentiles, including any seasonal split where applicable). These are then recommended as the basis for updated water quality objectives under the EPP (Water and Wetland Biodiversity).

- If percentiles based on local water quality data were worse than the GBRMPA (2010) ecosystem support guideline values, then the GBRMPA guidelines are adopted as the basis for updated water quality objectives.

For indicators not covered by the GBRMPA guidelines, reference should be made to the applicable QWQG or ANZG 2018.

5.3.3 Marine waters landward of the plume line

The approach for GBR waters landward of the plume line follows a similar approach to the above. Waters landward of the plume line are at higher risk of impact from land-based activities and contaminants carried by flood plumes. These waters are given an SD level of protection which has an associated management intent to improve towards HEV condition.

- Where review of water quality data indicates local water quality condition is better than the GBRMPA (2010) guideline values for the given water type, and there was sufficient data to do so, percentiles are set to maintain this better water quality condition (e.g. by specifying 20-50-80th percentiles, including any seasonal split where applicable). These are then recommended as the basis for updated water quality objectives under the EPP (Water and Wetland Biodiversity).
- If percentiles based on local water quality data are worse than the GBRMPA (2010) ecosystem support guidelines, then the GBRMPA (2010) guidelines are adopted as the basis for updated water quality objectives. Waters landward of the plume line are at greatest risk from poor water quality and are generally found to not meet GBRMPA (2010) guidelines.

Hence, for these waters the intent is to improve water quality over time to achieve GBRMPA (2010) water quality guideline values.

For indicators not covered by the GBRMPA guidelines, reference is made to the applicable QWQG or ANZG 2018.

5.3.4 Comparison of test site data with EPP Water WQOs (or water quality guideline values)

The same process as per previous sections is recommended. However, some parameters in marine waters have single values specified as an annual (or seasonal) mean, rather than median. The mean water quality value of several independent samples at a particular monitoring ('test') site should be compared against the applicable water quality objective. The sample number is preferably five or more samples for within season comparison, and five or more [preferably 24 or more over two years] samples taken during wet and dry seasons for annual mean comparisons. While seasonal means are estimated based on biotic responses, the relationship is not as strong as it is for annual mean values. They are provided in relevant EPP Water schedule documents as indicative objectives to allow comparison with single season collected data sets. Wet and dry seasons can start and end at different times of the year. Seasonal dates indicated are generally applicable. Applying these values for any management action should take both of these matters into account.

5.4 Derivation of groundwater quality guideline values

This section provides guidance on the approach taken to identifying environmental values, water quality indicators and guidelines as a basis for WQOs in groundwaters.

Policy context

The *Environment Protection Act 1994* identifies that groundwater quality is an environmental value to be protected. Therefore, the intrinsic environmental value of groundwater should be protected, and the groundwater quality should be maintained within the range of natural quality variations, established through baseline characterisation, to ensure that no adverse effect on groundwater quality occur. In the absence of scheduled data, the default management intent is that there should be 'no change' to the natural variation in groundwater quality. From the QWQG, no change in the natural variation in groundwater quality is deemed to have occurred if there are no detectable changes to the 20^{th}, 50^{th} and 80^{th} percentiles of the natural distribution of values.

Where review of local data indicates that some groundwater systems are clearly impacted (e.g. through application of nitrogen fertilisers) then in these cases, the management intent would be to improve quality, and more stringent percentiles may be used to derive guideline values.

Further policy guidance is provided in materials supporting the national water quality guidelines (ANZG 2018). In particular, refer to the National Water Quality Management Strategy (NWQMS) policy paper *Guidelines for groundwater quality protection in Australia*, available from http://www.waterquality.gov.au/guidelines/groundwater.

> *Protection of groundwater quality is imperative to ensure the protection of healthy ecosystems and maintenance of environmental values as well as for future economic and population growth*.' (*Australian Government,* 2013;1)
>
> *'These guidelines support a national approach to groundwater quality protection that applies to all groundwater in Australia, regardless of the current or potential uses of the groundwater. The national application of the guidelines will enable management of groundwater quality of aquifers, as well as their connected surface water systems, across traditional management boundaries. Groundwater quality protection also*

applies to groundwater that extends under coastal waters. (Australian Government, 2013;5)

This complements the policy established for groundwaters in the ANZECC 2000 guidelines:

> *Groundwater is an essential water resource for many aquatic ecosystems, and for substantial periods it can be the sole source of water to some rivers, streams and wetlands. Groundwater is also very important for primary and secondary industry as well as for domestic drinking water, particularly in low rainfall areas with significant underground aquifers.*
>
> *Generally, these Guidelines should apply to the quality both of surface water and of groundwater since the environmental values which they protect relate to above-ground uses (e.g. irrigation, drinking water, farm animal or fish production and maintenance of aquatic ecosystems). Hence groundwater should be managed in such a way that when it comes to the surface, whether from natural seepages or from bores, it will not cause the established water quality objectives for these waters to be exceeded, nor compromise their designated environmental values. An important exception is for the protection of underground aquatic ecosystems and their novel fauna. Little is known of the lifecycles and environmental requirements of these quite recently discovered communities, and given their high conservation value, the groundwater upon which they depend should be given the highest level of protection. 'As a cautionary note the reader should be aware that different conditions and processes operate in groundwater compared with surface waters and these can affect the fate and transport of many organic chemicals. This may have implications for the application of guidelines and management of groundwater quality.' (*ANZECC & ARMCANZ 2000, The Guidelines, Box 1.2; p1-2)

Identification of environmental values: At aquifer level, the bore installation records available in the DNRME water licences database[3] provide the basis for deriving some human-use EVs. The bore installation records give the commencement and expiry date of the licence, stipulate the source of the water (aquifer name in the case of groundwater), list the equipment used in the bore, and detail how the water from each bore is to be used, (i.e. stock, domestic, irrigation, urban). It thus informs the derivation of EVs.

The aquatic ecosystem protection EV is always identified, as stated in the EPP (Water and Wetland Biodiversity).

Indicators: The main indicators for which data are available are pH, salinity, recorded as both Electrical Conductivity (EC) and Total Dissolved Solids (TDS), as well as the major ions, as these were historically of most interest for agricultural and domestic use. Toxicant indicators are in principle the same as those for surface waters and where data are available, values would be compared to surface water guidelines, i.e. ANZG 2018. Typical indicators include: Sodium, Calcium, Magnesium, Bicarbonate, Chloride, Sulfate, Nitrate, Electrical Conductivity, pH, Hardness, Alkalinity, Silica, Fluoride, Iron, Manganese, Zinc, Copper, Sodium adsorption ratio, Total Nitrogen (TN), and Total Phosphorus (TP).

Nitrate is a good indicator of total nitrogen as virtually all groundwater nitrogen is in this form because chemical reactions in the unsaturated zone remove other forms of nitrogen while nitrate is mobile enough to be transported to the groundwater (Freeze and Cherry 1979; Canter 1997; Bouwman et al. 2005). There are very few TP measurements in the Queensland Groundwater Database (GWDB) as TP is rarely measured due to

[3] Information on water licences is at https://data.qld.gov.au/dataset/water-entitlements.

concentrations being usually low in Queensland groundwaters. This is because most of the phosphorus binds to particles in the soil and unsaturated zone, restricting its movement to the aquifer (Holman et al. 2008).

There is limited information on dissolved oxygen (DO) in groundwater (or any other gases), as it tends to be disturbed in the process of sampling and therefore difficult to measure except by probe. DO is generally low in groundwater because the oxygen gets used up in chemical reactions.

Indicators for groundwater biota (stygofauna) are not currently available. Hose et al (2015) note that:
'*Stygofauna are generally adapted to stable environmental conditions, including water quality. Changes to water quality that are beyond the range of conditions normally experienced by stygofauna pose a threat to their surviva*l.'

Hence identification of current (pre-impact) water quality characteristics is a starting point for stygofauna habitat maintenance.

Aquifer mapping definition of groundwater segments: EPP (Water and Wetland Biodiversity) groundwater water type mapping is compiled using the most current groundwater datasets. These include the Australian Government geospatial data portal at https://data.gov.au/, Groundwater Alluvial Boundaries QLD (published 9/12/02), Detailed Surface Geology QLD (published 24/5/18), and additionally some individual geological and aquifer layers which were mapped for the Great Artesian Basin Water Resource Assessment (Ransley and Smerdon 2012) obtained from www.ga.gov.au. Queensland bore attribution data, and chemistry zone delineation within each of the aquifer classes vary according to region.

To enable mapping of overlying systems, the aquifers in a relevant region (e.g. the Burdekin and Fitzroy regions) were broadly grouped into a system of aquifer classes, based on the divisions used by Smerdon et al. (2012), (e.g. alluvial, fractured rock, Great Artesian Basin [GAB], pre GAB). All bores used in the study were attributed to a specific aquifer, and therefore class, and groundwater water quality data are used to spatially define chemistry zones of broadly comparable water quality within each aquifer class, included in EPP (Water and Wetland Biodiversity) mapping. Current baseline water quality was then calculated for each zone, represented by percentiles of parameters recorded in the GWDB.

Reference data: Groundwater quality varies considerably between basins and aquifers and to a lesser but still significant extent within aquifers. Where sufficient data exist, water quality guidelines are developed at aquifer/sub-aquifer level (chemistry zones) based on existing condition. This is done using groundwater quality data sourced from the Queensland Groundwater Database, data sourced through the Office of Groundwater Impact Assessment (OGIA) or from local monitoring data by a recognised entity.

Following the definition and mapping of chemistry zones (refer **Aquifer mapping** above), the groundwater quality data are used to calculate a range of percentiles for available indicators for each aquifer or chemistry zone.

These percentiles are used as a basis for deriving guidelines specific to each identified aquifer. For most areas of most aquifers, there is little or no data that would allow us to determine whether or not any anthropogenic impacts have already occurred. Therefore, the default principle in setting groundwater guidelines is that there should be no deterioration from existing quality, as expressed by the aquifer specific percentiles. In areas where it is known that human impacts have occurred, mostly in alluvial aquifers, guidelines are, if data is available, based on percentiles of historical pre-disturbance data.

Guideline values:

- ***HEV and SD Groundwaters (i.e. where there is no evidence of human disturbance)***

The 20/50/80th percentiles of the waters at a site should not be significantly different than the 20/50/80th percentiles for the aquifer class and chemistry zone in which the site is located

- ***MD Groundwaters (i.e. where there are known human impacts)***

The 20/50/80th percentiles at a site should be consistent with predevelopment 20/50/80th percentiles. Where no historical data is available, an improvement on current quality should be achieved based on expert opinion and also the defined values on the groundwater. The guideline value could be based on more stringent percentiles of the current data e.g. the median should be reduced until it complies with the existing 40th or 30th percentile.

Where there is potential for groundwater to be impacted by activities such as various mining and extractive activities, the regional aquifer guideline values may not be appropriate due to specific local geology and other local factors. In this situation, the procedures detailed in the DES Groundwater Quality Assessment Guideline should be followed:
https://www.publications.qld.gov.au/dataset/groundwater-quality-assessment-guideline

Comparison of test site data with EPP (Water and Wetland Biodiversity) WQOs (or water quality guideline value)

The following protocols are recommended when comparing water quality (at a 'test' site) with the corresponding aquatic ecosystem water quality objective (WQO). The management intent for groundwaters is that there should be 'no change' to existing water quality, i.e. no change in the natural range of values. No change is deemed to have occurred if there are no detectable changes to the 20th, 50th and 80th percentiles of the natural distribution of values.

For HEV and SD waters:

- Where the WQO is expressed as a 20th–50th–80th percentile range of values (e.g. Total N: 0.065–0.1–0.125 mg/L), the 20th–50th–80th percentile distributions of the test data should meet the specified range of values. Ideally, the sample number is a minimum of 24 test values over the relevant period (12 months if a continuous activity or alternatively a shorter period for activities where discharge occurs for only part of the year). The detailed testing regime for HEV and SD waters is stated in the QWQG (2009), Appendix D.2.1.

For MD and HD waters:

- The median value (e.g. concentration) of preferably five or more independent samples at a monitoring (test) site should be compared against the corresponding aquatic ecosystem WQO (WQOs in these waters are typically expressed as a single figure).

For toxicants in water: unless otherwise stated, WQOs for toxicants are derived from the ANZG (2018) default guideline values for the corresponding level of species protection. The ANZG (2018) recommends that the 95th percentile of test data is compared against the default guideline value. As the proportion of test values that is required to be less than the default guideline value is high, the ANZG indicates that a single observation greater than the default guideline value is considered an exceedance. Further information: Refer to the QWQG, the Queensland Monitoring and Sampling Manual (2018), and the ANZG (2018) for more details.

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Appendix 1: Deriving flow stratified guideline values

Rationale

In a broad qualitative sense, flows in freshwater streams and estuaries can be classified into high, low and nil flows under prevailing conditions at time of sampling. Water quality generally differs between these flow conditions. Table 3 summarises these flow conditions and the water quality characteristics of each. The table includes notes on how these flow conditions affect water quality at time of sampling.

Table 2 Characteristics of flow conditions for freshwater streams and estuaries

Water type	Flow condition	Description	Definition	Water quality
Freshwater streams	High flow	Event type flows that occur during and shortly after significant rainfall	Upper 5-20% of flows, depending on stream type and climate	Generally elevated turbidity and nutrients. Highly variable quality during the event
	Low flow	Flows less than high flows but greater than nil flow	<95-80% of flows (depending on stream type and climate) but > nil flow	Low turbidity and nutrients, more consistent quality
	Nil flow	No surface flow present	No surface flow present	Low turbidity, other indicators variable. Conductivity and nutrients may increase due to evaporative concentration. DO may be very low.
Estuaries	High flow	Event conditions where freshwater inflows result in drop in salinity. Event duration and intensity will determine level and extent of effect on the estuary.	Salinity used as surrogate for flow. Determined at each site by salinity threshold at which freshwater impacts are observed.	Events of freshwaters entering an estuary result in rapid but usually short-term impacts on estuary water quality, particularly reduced salinity, reduced dissolved oxygen, increased turbidity and increased nutrients
	Low flow	Freshwater inflows are less than high flow conditions. Salinity variation in the estuary driven by tidal fluctuation.	Salinity used as surrogate for flow. Determined at each site by salinity threshold at which no freshwater impacts are observed.	Water quality regulated mainly by internal estuary processes
	Nil flow	No freshwater inflows to estuary. Salinity will approach levels of seawater by tidal exchange and may become hypersaline in upper estuary due to evaporative concentration.	Salinity used as surrogate for flow. Salinity may be greater than that normally observed during low flow condition.	Water quality regulated mainly by internal estuary processes. Salinity gradually increases and may become hypersaline in upper reaches

Water quality guideline values have traditionally been derived using data that is collected mainly during low flows. Comparison of low flow-based guideline values with water quality under high flows or nil flows is problematic, akin to comparing apples with oranges. The simplest approach to dealing with this issue is to mandate that low flow guidelines should not be applied under high or nil flow conditions. This is valid but does not address the issue of how to assess water quality under these other flow conditions.

An alternative is to derive separate guideline values appropriate to each flow condition, although this is complicated by the fact that water quality is more variable under high and nil flow conditions.

The approach adopted in this guideline is to:

1. Separate flows into high and low flows (including nil flows). Note this is done differently in freshwater and estuaries.
2. Derive water quality data sets based on the adopted flow separation
3. Derive separate guideline values for high and low flow based respectively on the high and low flow water quality data sets.

The following sections detail the approaches used to firstly separate high and low flow conditions and secondly the development of guideline values for high flows.

Flow separation in Freshwaters

The approach to define different flow conditions used widely in recent water quality objective reports is based on percentiles of flow (flow exceedance probabilities). For each flow gauge in a basin for which WQOs are being developed, the historic discharge data is accessed (Queensland Government Water Monitoring Information Portal) and used to plot flow exceedance probability of daily mean discharge in cubic meters per second (cumecs). An example is provided in Figure 4. From these plots, the approximate exceedance probability where discharge rapidly begins to increase is identified, and the discharge value at that point is used as an identifier between high and low flow conditions. After a large number of these plots had been derived, some general rules that can be used as default values were developed to identify high and low flow conditions from exceedance probabilities. The following are defaults based on flow exceedance probabilities applied to certain climate and catchment types—

- in large inland, drier catchments such as the Fitzroy and Burdekin, the default is to assign high flows as the upper 10th percentile of daily mean flows;
- in coastal and wetter catchments such as southeast Queensland and the Wet Tropics, the default is to assign high flow as the upper 20th percentile of daily mean flows; and
- in small and more arid catchments, the default to assign high flow is the upper 5th percentile of daily mean flows.

These defaults provide general guidance, but local conditions should be considered when determining flow conditions.

Figure 4 below shows an example of the method for assigning high or low flow discharge values. The default of the upper 10th percentile of daily mean discharge is shown (left of the red line), equal to flows greater than 17 cumecs. Samples collected during these flow rates of 17 cumecs or greater would be high flow data, while samples collected at less than 17 cumecs would be low flow data. (Flow separation based on the 5th and 20th percentile flow values would be determined similarly).

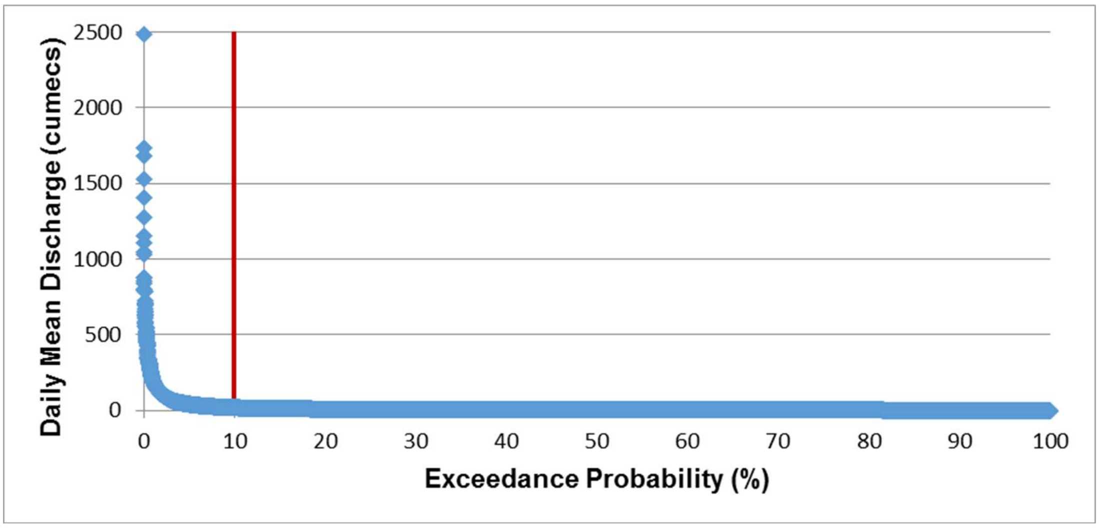

Figure 4 Flow vs Exceedance Probability at Urannah on the Broken River (Burdekin Basin), QLD.

Where extensive data sets for water quality and flow are available, a more site specific separation of flows can be undertaken. In this approach, water quality indicator values are plotted against flow to produce a water quality to flow relationship. A typical relationship as shown in Figure 5, with flow vs total suspended solids (TSS). Values are shown on log scales as this displays the spread of values more clearly. While there is obvious variability, there are also clear differences in the spread of values between low and high flows. In this example, the low/high flow divide might be placed at around 1.0 cumec, above which elevated concentrations of TSS persist above 100 mg/L.

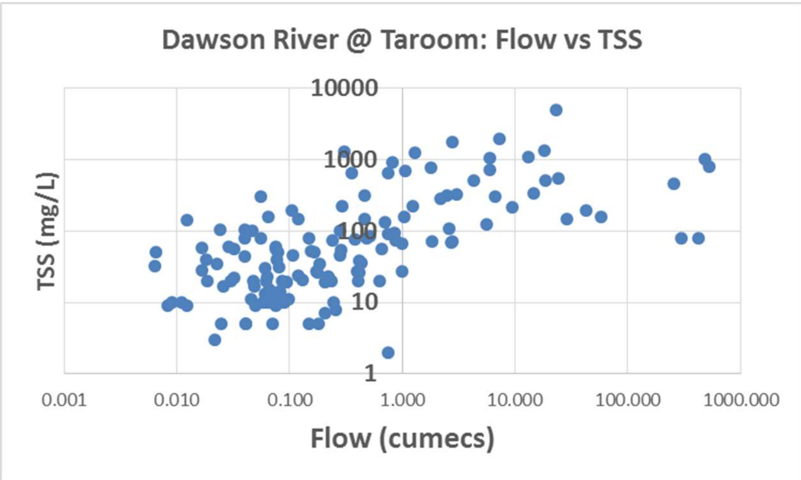

Figure 5 Flow vs Total Suspended Solids at Taroom on the Dawson River (Fitzroy Basin), QLD. Note axes are log-scale.

Another example in shown in Figure 6. In this case the indicator (conductivity) decreases under high flows. In this example a line of best fit is added to better quantify the water quality vs flow relationship. In this case the low/high divide might be placed at around 2 cumecs.

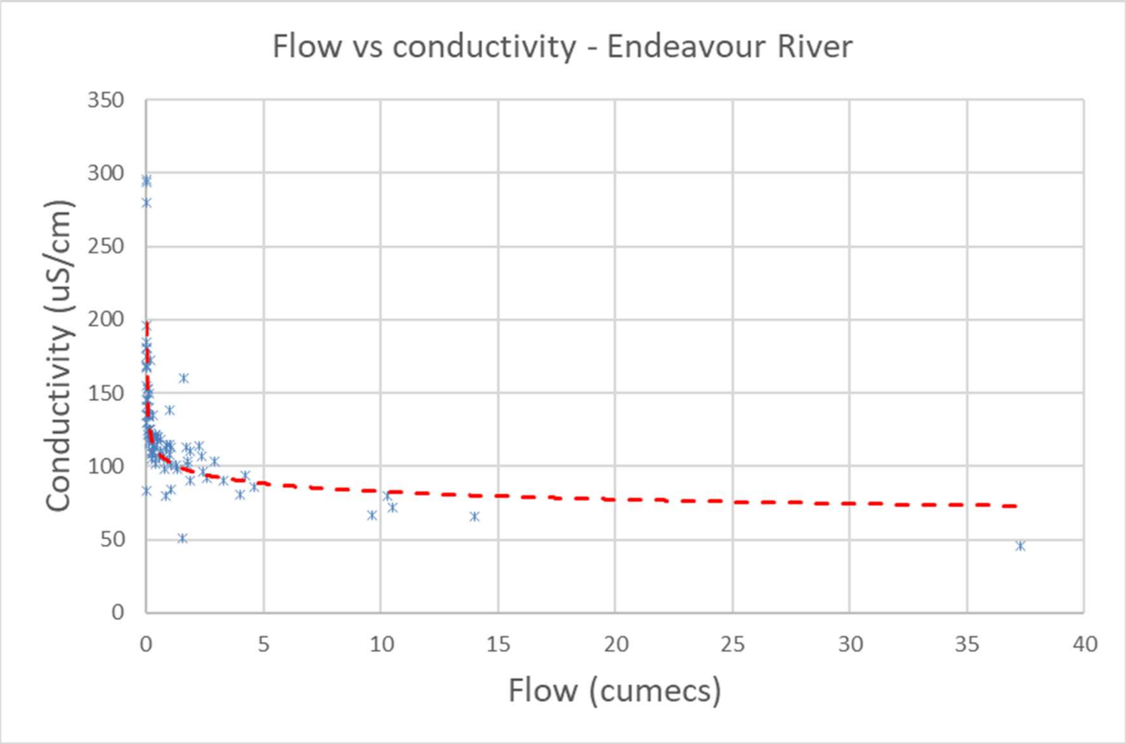

Figure 6: Flow vs conductivity in the Endeavour River, north Queensland

Developing guidelines for high flow in freshwaters

In most Queensland catchments, landscapes have been heavily modified since European settlement. This means that water quality during rainfall events is significantly worse than under pre-European conditions due to excessive erosion and contaminated runoff. For this reason, in moderately disturbed waters, default high flow guidelines are based on the 30th percentile of current high flow condition. This requires a greater improvement in water quality be achieved under high flow conditions than under low flow conditions, where the 40th percentile is used to determine the default draft water quality objective. The difference between percentiles used to determine high and low flow water quality objectives has the implication that a significant proportion of water quality degradation occurs during high flows, but also that significant improvements can occur under these same conditions with management interventions. Many landscape management and streambank stabilisation works undertaken to improve water quality will have greatest effect during high flow conditions where runoff is reduced and potential pollutants prevented from entering waterways, highlighting the potential for improvement during these flow events.

This guideline value is simply derived from the 30th percentile of the high flow data set.

Application of a high flow guideline in freshwaters

Given the inherent variability in water quality under high flow conditions, comparison of the guideline value with a single high flow test sample is inappropriate. Ideally, the guideline value should be assessed against the median of a series of samples taken over the course of the high flow event, or samples from several high flow events. When only a few test samples are available, the outcome of a comparison with the guideline value should be taken as indicative only, depending also on the extent of any exceedances.

Flow separation in estuaries

For southeast Queensland estuaries, conductivity has been used as a surrogate for direct measurement of flow to conduct flow separation for draft WQOs. There are few flow gauges in SEQ that provide daily mean flow data entering estuaries. However, conductivity is measured with each sample collection, so a paired dataset of results is already available. Conductivity of estuaries responds to rainfall by decreasing during rainfall events and higher flow periods, and slowly rising to approach conductivity levels similar to seawater during dry periods. This relationship makes conductivity a good surrogate for flow. These methods can be applied in estuaries of other basins where similar datasets of conductivity/salinity and water quality parameters are available.

To determine a flow separation, at each monitoring point water quality parameters are individually plotted against conductivity to produce a surrogate flow-response curve. In lower and mid-estuary reaches, many water quality parameters respond to high flows (lower conductivity) with a rapid increase in concentration due to higher concentrations of sediments and nutrients in runoff. In upper estuaries, which are poorly flushed and particularly those with point source discharges, water quality parameters respond to high flows by lowering in concentration as the build-up of nutrients in the estuary is diluted or displaced by runoff with lower concentrations.

From the surrogate flow-response curves, an approximate conductivity value for separating low and high flows is chosen. Each water quality parameter may respond a bit differently to changes in conductivity, but a value which approximates a response for the most parameters is chosen. Turbidity, Secchi depth, Total P and FRP tended to show the strongest responses to changes in conductivity for SEQ estuaries and particular attention was given to these parameters. See Figure 7 below for an example of surrogate flow-response curves.

Sample sites along the estuary with similar conductivity response values were grouped to form ‘zones’ and draft water quality objectives were derived for each of these zones using the methods outlined in Section 5.2.4.2. For each zone, the conductivity response value determines if a sample is low or high flow, with conductivity values higher than the value classed as ‘low flow’ and lower conductivity values classed as ‘high flow’.

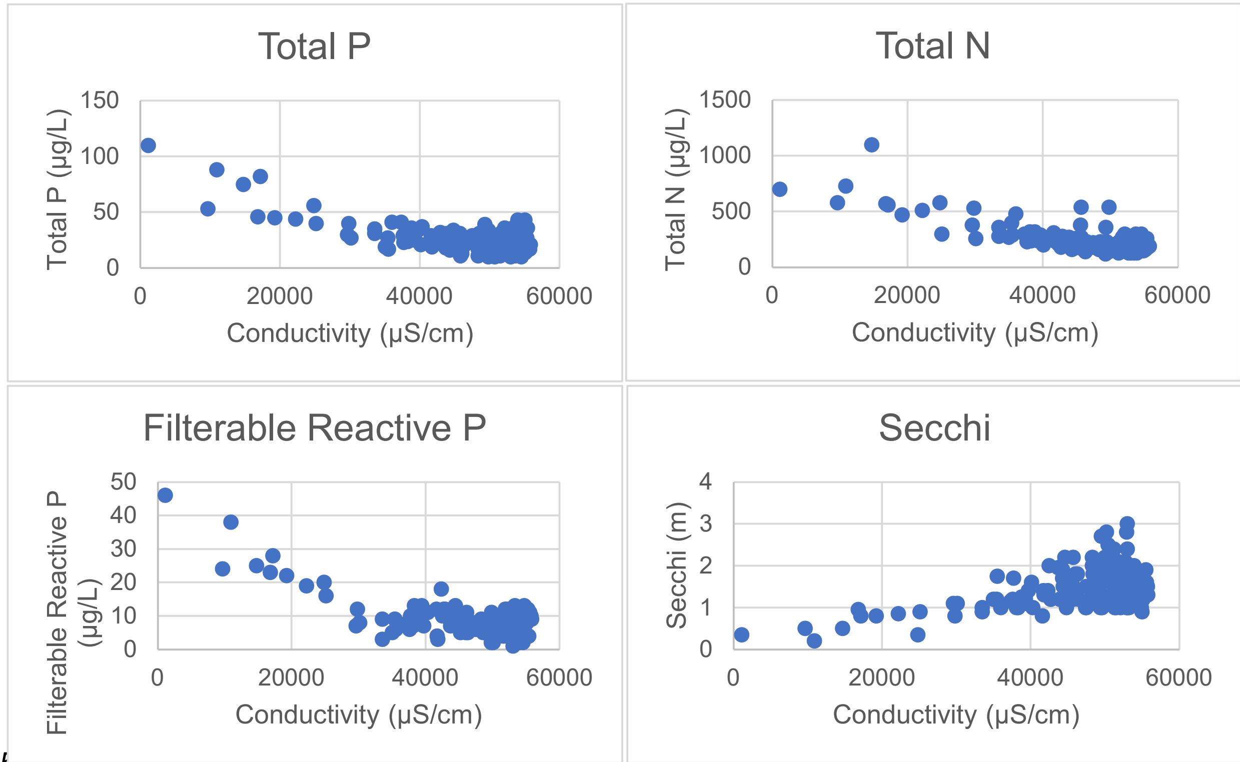

Figure 7 Example of surrogate e flow response curves from Coomera River 4.0km. The conductivity response value selected for this site was 40 000 µS/cm.

Developing guideline values for high flow in estuaries

Similar to freshwaters, high flow guideline values for estuaries at the moderately disturbed level of protection are determined by the 30th percentile of current high flow conditions. High flow events are generally a degrading impact on estuaries, particularly those with disturbed catchments. Applying the 30th percentile of current high flow condition recognises the need for improving water quality during high flow events, and matches the level of improvement applied to freshwater high flows.

Application of a high flow guideline value in estuaries

Given the inherent variability in water quality under high flow conditions, comparison of the guideline value with a single high flow test sample is inappropriate. Ideally, the guideline value should be assessed against the median of a series of samples taken over the course of the high flow event, or samples from several high flow events. When only a few test samples are available, the outcome of a comparison with the guideline value should be taken as indicative only, depending also on the extent of any exceedances.

Appendix 2: Toxicant guidelines

Toxicant indicators and default guideline values (DGVs) are stated in ANZG 2018 or derived from specific studies by a recognised entity. The DGVs for toxicants are determined by direct testing of the impacts (both lethal and sub-lethal) of the toxicant on target organisms. DGVs for metals may be locally derived where natural background levels of metals exceed ANZG 2018 DGVs.

The DGVs for different levels of species protection are applied according to the current or desired ecosystem condition and associated level of protection. The levels of species protection for which DGVs are typically derived are 99%, 95%, 90% or 80%.

In Queensland, ANZG 2018 toxicant guidelines are applied as follows:

Ecosystem protection level	Toxicant Guideline – ANZG 2018 level of species protection applied
High Ecological Value waters	99% level of species protection
Slightly Disturbed waters	99% level of species protection
Moderately Disturbed waters	95% level of species protection[1]
Highly Disturbed waters	On a case by case basis but a level of 80%, 90% or 95% level of species protection

1. *Subject to ANZG 2018 advice on bioaccumulation/other effects identified*

Comparison of test site data with WQOs (or water quality guideline values)

For assessing monitoring data against toxicant guidelines/objectives (in waters and sediments), the QWQG refers to the ANZECC (2000), now ANZG (2018), protocols. For toxicants in water, the ANZG recommends the comparison of the 95th percentile of monitoring data against the DGV. As the proportion of test values that is required to be less than the DGV is high, ANZG indicates that a single observation greater than the default guideline value is considered an exceedance.

Appendix 3: Guideline values for freshwater salinity and major component ions

Guideline values based on physical-chemical data

Salinity (measured as conductivity)

Salinity values in fresh waters show very significant variation across different regions of the state. This is related mainly to natural variations in geology and rainfall climate. In order to set relevant guidelines for salinity, this variability needs to be addressed. The approach taken in the QWQG was to divide up the state into zones within each of which the range of salinity was reasonably consistent. A total number of 18 zones were identified and separate guideline values set for each zone. Appendix G in the QWQG describes in detail the process used to identify these zones.

Due to the great spatial variability in salinity, the default approach of setting guideline values based on data from a few unimpacted reference sites is not appropriate. Instead, the QWQG salinity guideline values were based on percentiles calculated from many sites within each region. Only sites known to be significantly impacted by human activity were excluded. The guideline value for each region is set at the 75^{th} percentile of the salinity data (expressed as conductivity) from all suitable sites within that region. This process is described in detail in Appendix G in the QWQG.

Compliance with the salinity guidelines is through comparison of the median of test data with the guideline value.

The QWQG continue to be appropriate for general assessment of salinity within a region. However, given the spatial variability even within regions, it may be appropriate to derive more localised guideline values. The approach to setting a localised guideline value would be similar to that used for setting regional guidelines except that the base data set would be confined to the waterbody/s in question. This restricted base data set would need to meet criteria set out in the QWQG Appendix G (including a data from a range of flow conditions), so in some cases it may be necessary to collect additional data to develop a valid local guideline.

Component ions

These include the main ionic species that account for most of the salinity content of freshwaters (Na, Mg, Ca, Cl, CO_3, HCO_3, SO_4 etc.). Guidelines for these can be set according to the approach used to determine guideline values for overall salinity.

Guideline values based on biological impacts

Published data on the impacts of increased salinity on freshwater macroinvertebrates suggest that significant impacts start to occur concentrations ranging from >800µS/cm (Horrigan et al 2005) to 1500µS/cm (Hart et al 1991, Nielsen et al 2003). Prasad et al (2012) recommend values of <2000µS/cm for protection of 95% of species and <900µS/cm for protection of 99% of species.

Even the lower of these values exceeds typical conductivity ranges in most Queensland streams. For this reason it is preferable in most cases to derive guideline values based on the physical-chemical data rather than use the biological thresholds which, if applied, would allow significant quality deterioration in most streams.

In streams where conductivity naturally exceeds these thresholds then again, guideline values would be based on physical-chemical data. However, where human impacts have caused exceedances of the biological thresholds, then at a minimum, the lower of the biological thresholds should be applied as the guideline value.

References

Hart, B.T., Bailey,P., Hortle, K., James, K., and McMahon, A. (1991). A review of salt sensitivity of the Australian freshwater biota. Hydrobiologia 210, 105-144.

Horrigan, N., Choy, S., Marshall, J., and Recknagel, F. (2005). Response of stream macroinvertebrates to changes in salinity and the development of a salinity index. Marine and Freshwater Research, 56, 828-833.

Nielsen, D.L., Brock, M.A., Rees, G.N., and Baldwin, D.S. (2003). Effects of increasing salinity on freshwater ecosystems in Australia. Australian Journal of Botany, 51, 655-665.

Prasad, R., Vink, S., Mann, R., Nanjappa, V. & Choy S. (2012). Assessing the ecotoxicology of salinity on organisms in seasonally flowing streams in the Fitzroy Catchment: Australian Coal Association Research Program (ACARP) Project C18033 Extension.

Appendix 4: Salinity in coastal and estuary waters

Coastal waters

Table 4 shows salinity/conductivity values and ranges at a site 5km offshore from the Gold Coast. These values are based on monthly data collected over a period of 20 years

Table 4 Seawater salinity and conductivity in southern Queensland

	Median	**25 – 75 %ile range**
Salinity (mg/L) (ppt)	35.2	33.2 – 36.4
Specific Conductivity (@ 25°C, mS/cm)	54.5	53.0 – 55.2

These provide a baseline of typical seawater salinity in the state’s southern coastal areas. No equivalent data is available for Qld tropical offshore marine waters but data from more inshore sites near Plane Ck and the Gregory River during dry weather give similar values. These values can be used as a seawater baseline.

Estuaries

Salinity in estuary waters reflects the admixture of tidally advected coastal seawater with freshwater inflowing to the head of the estuary, generally resulting in a gradient of increasing salinity towards the mouth. Salinity values in estuaries could be expected to range from near zero up to the coastal values.

However, in estuaries, evaporation also plays a role, so that during extended periods of dry weather, estuary salinity values may exceed those found in coastal waters, a condition termed hypersalinity.

DES monitoring programs in subtropical Queensland estuaries have rarely recorded hypersaline values. However, in tropical areas, salinity values in mid to upper estuary reaches can naturally exceed 40 mg/L for periods of time during the dry season, with occasional extreme values up to around 50 mg/L. Estuaries in the Gulf of Carpentaria may experience higher values still, but very little data is available.

Based on DES data collected over 30 years in a range of estuaries, some general guidance on assessing hypersalinity is provided below.

Table 5:Hypersalinity guidelines for estuaries

General guidelines for hypersalinity in estuaries	
Region	Trigger for investigation
Subtropical Qld	Median value >37mg/L Single value >40mg/L
Tropical Qld	Median value >40mg/L Single value >45mg/L

Biological effects of hypersalinity

Literature information on the impacts of hypersalinity on estuary biota suggest that measurable declines in fish species diversity can occur at salinity values above 50mg/L (Cyrus *et al* 2011; Molony *et al* 2006).

References

Cyrus, D., Jerling, H., Mackay, F. and Vivier, L. (2011). Lake St Lucia, Africa's largest estuarine lake in crisis: Combined effects of mouth closure, low levels and hypersalinity. South African Journal of Science, 102 (3/4)

Molony, B. W. and Parry, G.O. (2006). Predicting and managing the effects of hypersalinity on the fish community in solar salt fields in north-western Australia. J.Appl. Ichthyol. 22, 109-118

Salinity/Conductivity conversion equations

$$\text{Conductivity} = -0.0043 \cdot \text{Salinity}^2 + 1.6742 \cdot \text{Salinity} + 0.1116$$

$$\text{Salinity} = 0.0015 \cdot \text{Conductivity}^2 + 0.5782 \cdot \text{Conductivity} - 0.0421$$

Conductivity (mS/cm @ 25°C)

Salinity (mg/L) or (ppt)

Appendix 5: pH guideline values

pH in freshwaters

pH in freshwater is naturally variable depending on local geology, groundwater inputs, flow regime and other factors. Median pH can vary from below 5 in streams with high levels of humic substances up to around 8.5 in streams in calcareous catchments or with high levels of productivity. To allow for this natural variation, pH guideline values usually cover a wide range e.g. 6.5 – 8.0. Such ranges are a useful guide for assessing individual pH values but are less suitable for assessing systemic changes in pH. For example, if the median pH value at a site was say 7.6, then an increase in the median up to 8.0 or down to 6.5 would be a significant change and might be indicative of environmental harm, even though the site still complied with the general 6.5 – 8.0 guideline.

In practice however, pH assessment is usually limited to comparison with broad range guidelines. The QWQG has recommended pH guideline value ranges for freshwaters, based largely on the ANZECC 2000 Guidelines.

If required, more localised pH guideline values can be developed by following a process similar to that applied to other physical-chemical indicators. Briefly, pH data from creeks in the area of interest are compiled (data from creeks with significant anthropogenic impacts are excluded). The compiled data is then checked to determine that the data is internally consistent. If not, then the data may need to be partitioned and separate guideline values developed for sub-sections of the local area.

The 20^{th} and 80^{th} percentiles are calculated from the finalised compiled data and these form the basis of the local guideline value. The compliance protocol is that the median of test data should remain within the 20-80 percentile range. The median should be based on at least 5 samples.

A localised guideline value is more appropriate for assessment of systemic shifts in pH, and so is desirable from that perspective. In streams with atypical pH environments, e.g. in streams with high levels of humic acids, development of localised guidelines may be a necessity.

pH in coastal waters

pH values in coastal waters i.e. waters with full seawater salinity, lie within a fairly narrow range. pH ranges in Queensland coastal waters are summarised in Table 6. This data is based on 748 pH readings (collected by DES since 2000) from ten coastal sites between Moreton Bay and the Daintree River. pH data was only included if the conductivity at the time of sampling was within the seawater range (defined here as a specific conductivity of 50-55 mS/cm).

Table 6: pH ranges in Queensland coastal waters

Percentiles	pH
2	7.81
20	8.07
50	8.18
80	8.28
98	8.44

The QWQG recommend a pH range of 8.0 – 8.4 for coastal waters, which is a reasonable general guide. The values in Table 6 provide some more specific guidance for assessing pH in seawater. Median values that falling outside the 20-80 percentile range would be a trigger for further investigation. Individual values outside the 2 – 98 percentile range would be a trigger for further investigation. Median values outside the 2 – 98 percentile range may be an indication of environmental harm.

pH in estuaries

pH in estuaries is strongly related to salinity concentrations, although other factors can have an effect (e.g. photosynthesis, presence of dissolved organic matter). Salinity concentrations in estuaries are spatially and temporally variable, dependant on antecedent freshwater inflows, and therefore pH also is highly variable. DES data from Queensland estuaries show that at conductivity values in the range of 5 to 55 mS/cm, pH varies from around 7.0 up to 8.4. Values <7.0 are unusual. Thus, the QWQG recommends a pH range of 7.0 – 8.4. Given the extent of natural variation in estuary salinity, and hence in pH, it is difficult to provide more specific guidance.