Healthy Land & Water

Report Card | Methods Manual

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About this document

The aim of this document is to outline the structure of the Ecosystem Health Monitoring Program (EHMP) and annual Report Card. It presents a rationale for the Report Card framework and each of the indicators and describes the approach used for calculating the *Environmental Condition Grade*, *Waterways Benefits Rating* and *Priority Actions.*

It is a 'live' document that will be updated as the program evolves.

About Healthy Land & Water

Healthy Land & Water is an independent organisation dedicated to improving and protecting South East Queensland's environment.

As experts in research, monitoring, evaluation and project management, we deliver innovative and science-based solutions to challenges affecting our landscapes, waterways and biodiversity.

Healthy Land & Water came to life after two of the region's most experienced natural resource management groups – Healthy Waterways and SEQ Catchments – merged to form one entity in June 2016. We are now best-placed to act as an enabler and facilitator of change, to provide solutions and connect others, and to drive and influence decisions, policy and actions.

At Healthy Land & Water, we believe that maintaining healthy landscapes and waterways is not just important for wildlife and ecosystems. A healthy environment also supports a vibrant economy, strong livelihoods, great lifestyles and the happiness and well-being of the community. Through our work, we encourage people to examine and change their behaviours for the benefit of the natural world and for the people and places we love.

Fundamentally, we help people understand the values and condition of South East Queensland's environment so we can ensure the sustainable use of our natural environment long into the future.

Acknowledgements

The material contained in this publication is produced for general information only. It is not intended as professional advice on specific applications. It is the responsibility of the user to determine the suitability and appropriateness of the material contained in this publication to specific applications. No person should act or fail to act on the basis of any material contained in this publication without first obtaining specific independent professional advice. Healthy Land & Water and the participants of our network expressly disclaim any and all liability to any person in respect of anything done by any such person in reliance, whether in whole or in part, on this publication. The information contained in this publication does not necessarily represent the views of Healthy Land & Water or the participants of our network.

Traditional Owner Acknowledgement

We acknowledge that the place we now live in has been nurtured by Australia's First Peoples for tens of thousands of years. We believe the spiritual, cultural and physical consciousness gained through this custodianship is vital to maintaining the future of our region.

Contact details

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1 Introduction

The ***Ecosystem Health Monitoring Program (EHMP)*** is a comprehensive and scientifically robust waterway monitoring program managed by Healthy Land & Water. The EHMP has monitored and assessed the health of South East Queensland's (SEQ's) creeks, rivers, estuaries and Moreton Bay since 2000 (Figure 1). Annually the monitoring and modelling results are synthesised and communicated via the ***South East Queensland*** *(SEQ)* ***Report Card.***

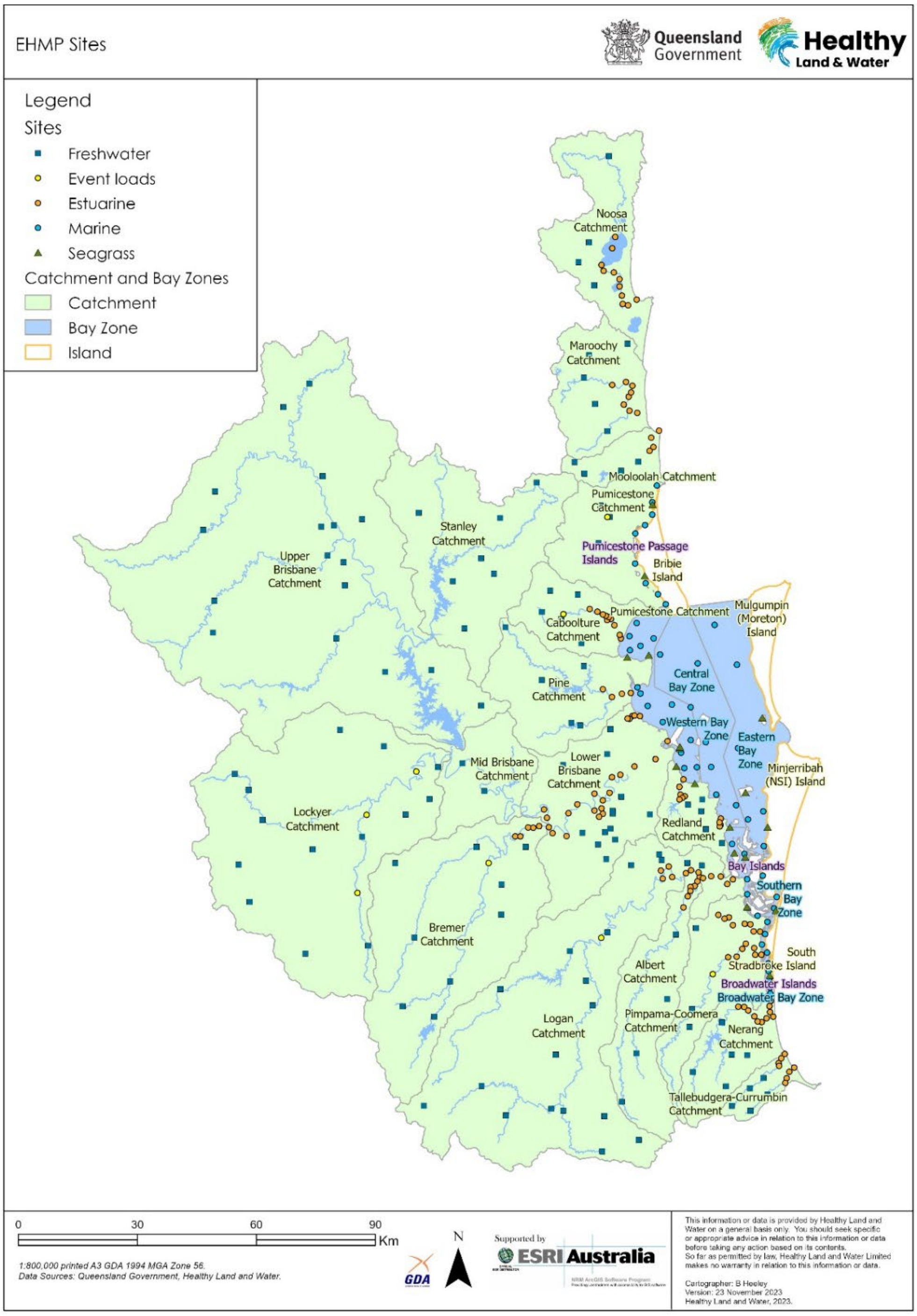

Figure 1: Current EHMP sites across SEQ that supports the Report Card environmental condition element.

1.1 Regional goal and objectives

The monitoring program has been designed to assess progress towards the regional goal for waterway management in SEQ:

"Enhance community quality of life by fostering stewardship to protect and restore waterway health."

The regional goal was developed in consultation with the Healthy Land & Water network members and stakeholders and designed to account for the four goals of the Resilient Rivers Initiative (Council of Mayors, 2015). The regional goal can be broken into three goals (each of which corresponds to the three elements of the Report Card); each goal has a set of specific objectives (Table 1). Through the encouragement of members to achieve these objectives, Healthy Land & Water makes it clear that progress toward any objective should not be obtained via the detriment of any other (e.g. increasing recreational access to the detriment of key riparian habitat).

Table 1: Goals and objectives of the EHMP and Report Card.

Goals and objectives	Report card component
Goal 1: Enhance community quality of life	
Objectives: • Improve and optimise community access, interaction, and satisfaction with their use of waterways. • Maintain and improve the economic benefit that waterways provide for commercial and recreational fishing. • Maintain and improve the contribution of waterways in providing low-cost drinking water. • Maintain and improve the economic benefit generated by recreation.	⇨ WATERWAYS BENEFIT RATING
Goal 2: Foster stewardship	
Objectives: • Maintain and improve the extent to which society is willing and able to behave in ways that protect and restore waterways (e.g. adoption of best management practice).	⇨ ACTIONS
Goal 3: Protect and restore waterway health	
Objectives: • Maintain and restore key habitats (riparian, wetlands, seagrass, mangroves, and coral). • Minimise sediments and nutrient inputs to waterways. • Maintain and improve water quality. • Maintain and restore functionality of key processes.	⇨ ENVIRONMENTAL CONDITION GRADE

Goals and objectives	Report card component
• Maintain and restore resilient and healthy aquatic communities.	

1.2 Aims and scope of the monitoring program

The aims of the monitoring program and Report Card are to:

- Inspire action.
- Identify priority areas for investment and support members to identify and implement actions.
- Provide an assessment of the effectiveness of management actions and progress towards targets.
- Provide data relevant for researchers, managers and the wider community that contributes to greater understanding of waterways.

The focus is on six main management themes:

1. Land.
2. Construction Site.
3. Riparian and In-Stream.
4. Community and Tourism.
5. Stormwater.
6. Point Source Management.

1.3 Report Card framework

Healthy Land & Water synthesises data from EHMP monitoring and modelling program to produce the SEQ Report Card (Figure 2), which provides an easy-to-understand assessment of the health of our catchments and waterways and highlights any issues that require intervention.

This section summarises the Report Card framework, the indices that are measured and how they are scored for each catchment and bay zones. Additional detail on individual indicators (including definitions, rationale, data collection methods, benchmarks and score calculations) can be found in section 0 and section 0. Detail on data source can be found in section 0. A summary list of all Report Card indicators and data sources can be found in Appendix 0.

The Report Card is designed around three key elements:

1. **Environmental Condition (0 to 1 score, Very Poor to Excellent rating):** These scores are developed for 18 catchments and 5 zones of the bay, using 25 indicators that are combined into a single overarching index of environmental condition. Previously this was reported in grades (A-F) between 2000 - 2022. In 2023, the reporting was modernised to reflect results rather than grades. This is further described in sections 1.3.1and 0.

2. **Waterways Benefits (1 to 5 stars rating):** These rates are developed for 18 catchments, using six indicators that are combined into a single overarching index of social and economic benefits that the wider community receive from their waterways. This is further described in sections 1.3.2 and 0.
3. **Actions (recommendations):** This describes the barriers and drivers for individuals and groups helping to protect and improve waterways, how and where management actions should be applied and their impact on waterway health. This is further described in section 1.3.3.

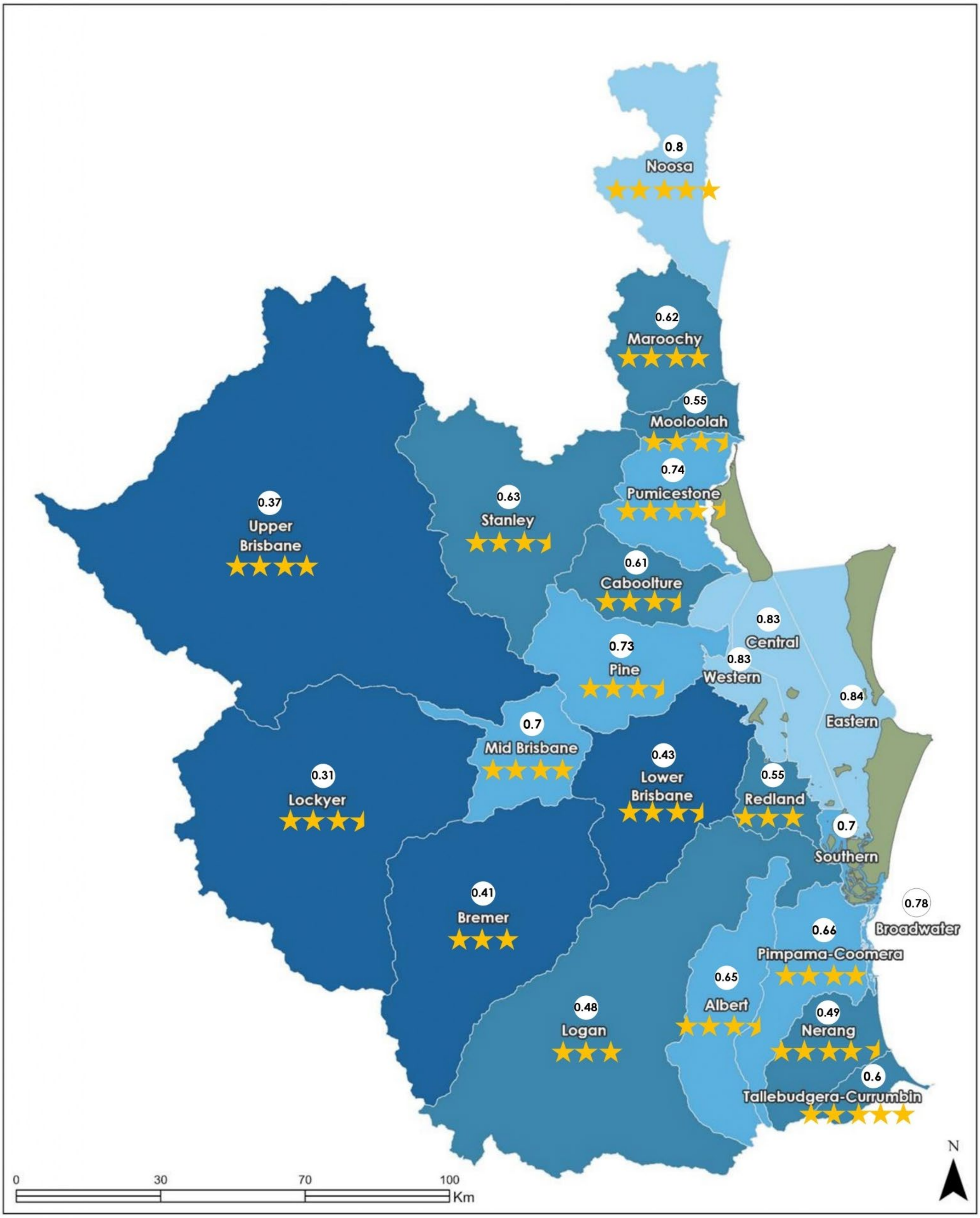

Figure 2: Report Card 2023 environmental condition score and waterway benefit rating results for 18 reporting catchments and 5 bay zones.

1.3.1 Environmental condition (0 to 1 score, Very Poor to Excellent rating)

The Environmental Condition element is comprised of multiple indicators, assessing key freshwater, estuarine and marine aspects of the SEQ waterways (Figure 3). Indicators are assessed against established guidelines and benchmarks, resulting in a single score for each catchment and bay zone. The data used to calculate the score is an integration of EHMP monitoring, modelling and remote sensing, and assesses progress towards the **program's objectives**:

- Restoring and maintaining key habitats (i.e. riparian vegetation)1.
- Reducing pollutant loads (i.e. sediment and nutrients) entering waterways.
- Improving and maintaining water quality.
- Restoring and maintaining key ecosystem processes.
- Restoring and maintaining resilient and healthy aquatic communities (i.e. fish populations).

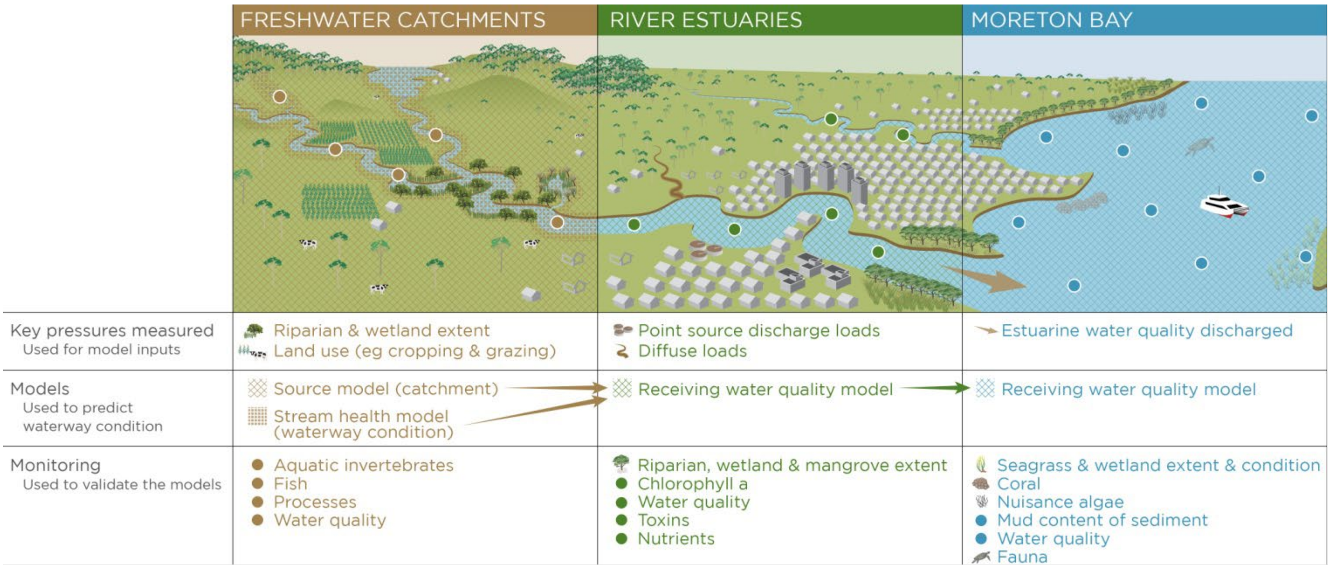

Figure 3: Conceptual diagram summarising the environmental condition element of the SEQ Report Card.

The Overall Environmental Condition Scores

The environmental condition scores are reported in 18 catchments and 5 bay zones listed in Table 2 and are rated as the following:

- **Excellent**: Conditions meet all guidelines. All key processes are functional and critical habitats are in near pristine condition.
- **Very Good**: Conditions meet guidelines for most of the reporting area. Most key processes are slightly impacted, and most critical habitats are intact.
- **Fair**: Conditions are close to meeting guidelines in most of the reporting area. Key processes are impacted but still functional and critical habitats are impacted.
- **Poor**: Conditions meet few of the guidelines in most of the reporting area. Many key processes are not functional and most critical habitats are impacted.
- **Very Poor**: Conditions do not meet the set guidelines. Most key processes are not functional and most critical habitats are severely impacted.

[1] Introduced in 2015.

Table 2: The environmental condition reporting zones (see Figure 2 or the Report Card website)

Catchment			Rosette
Coastal	Northern	Noosa	Figure 4a
		Maroochy	
		Mooloolah	
		Pumicestone	
	Central	Caboolture	
		Pine	
		Lower Brisbane	
		Redland	
	Southern	Logan	
		Albert	
		Pimpama-Coomera	
		Nerang	
		Tallebudgera-Currumbin	
Western		Stanley	Figure 4c
		Upper Brisbane	
		Mid Brisbane	
		Lockyer	
		Bremer	Figure 4b

Bay	Rosette
Western Bay	Figure 5
Central Bay	
Eastern Bay	
Southern Bay	
Broadwater	

1.3.1.1 Catchment Scores

The environmental condition scores for each of the 18 catchments is calculated using 23 indicators (Figure 4). The definition and rationale for each indicator is presented in their relevant sub-sections of Section 0.

For coastal catchments (except the Bremer catchment) (Figure 4a), the overall score is made up of:

- Freshwater communities and process – 20% (Section 1.6).
- Pollutant load – 20% (Section 1.7).
- Estuarine water quality – 20% (Section 1.8).
- Freshwater habitat – 20% (Section 1.10).
- Estuarine habitat – 20% (Section 1.10).

For the Bremer catchment (Figure 4b), the overall score is made up of:

- Freshwater communities and process – 20% (Section 1.6).
- Pollutant load – 20% (Section 1.7).
- Estuarine water quality – 40% (Section 1.8).
- Freshwater habitat – 20% (Section 1.10).

For western catchments (Figure 4c), the overall score is made up of:

- Freshwater communities and processes – 40% (Section 1.6).
- Pollutant load – 20% (Section 1.7).
- Freshwater habitat – 40% (Section 1.10).

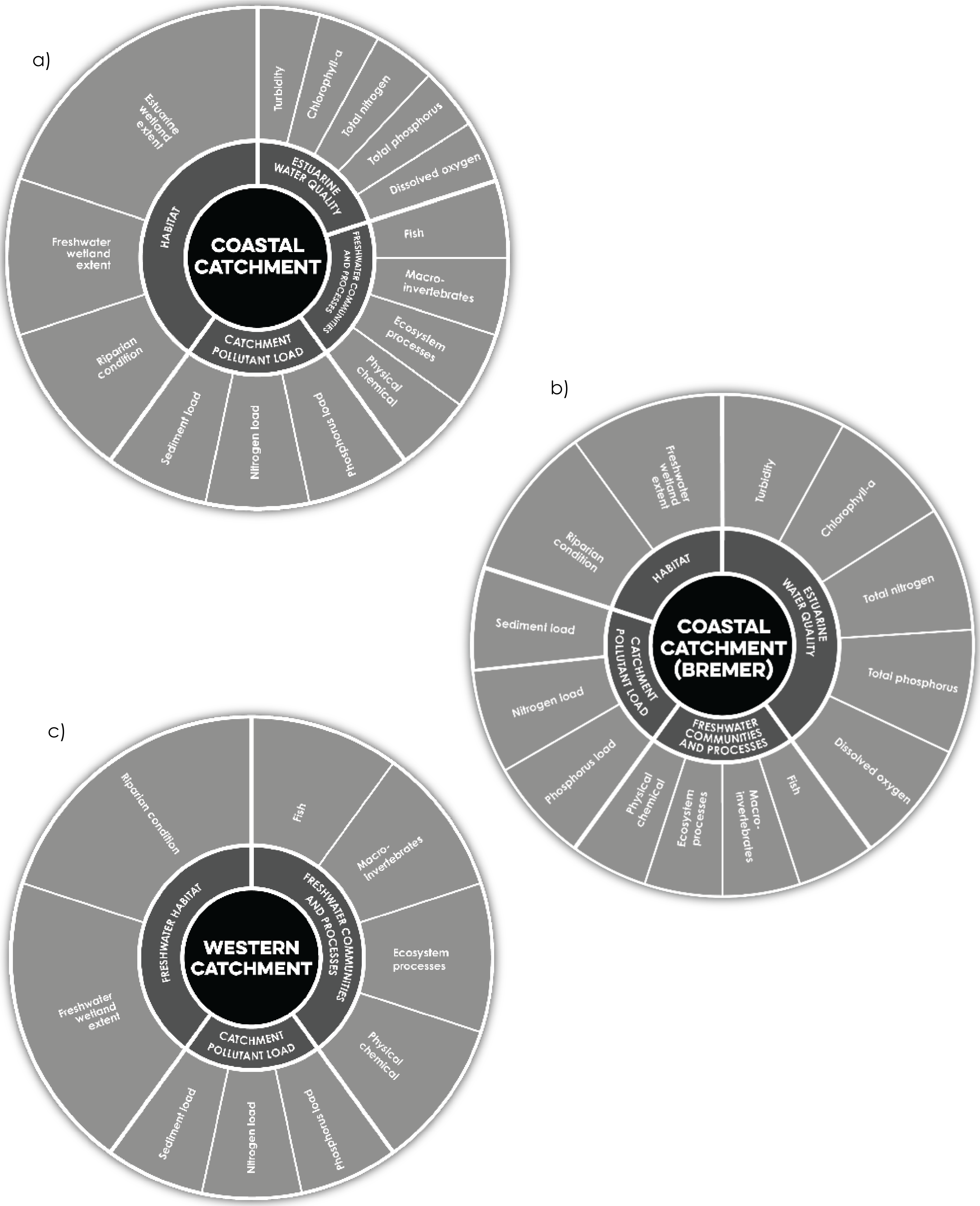

Figure 4: Rosette diagram showing the 23 indicators (lightest grey) that are combined into a single overarching environmental condition score for each of the catchment reporting zones. Note that indicators for coastal catchments and western catchments are weighted differently. To revisit the list of catchments, see Table 2.

1.3.1.2 Bay Zones Scores

The environmental condition scores for each of the 5 bay zones is calculated using 8 indicators (Figure 5). The definition and rationale for each indicator is presented in their relevant sub-sections of Section 0.

For bay zones, the overall score is made up of:

1. Marine water quality – 50% (Section 1.8.6.2)
2. Marine habitat – 50% (Section 1.9.4)

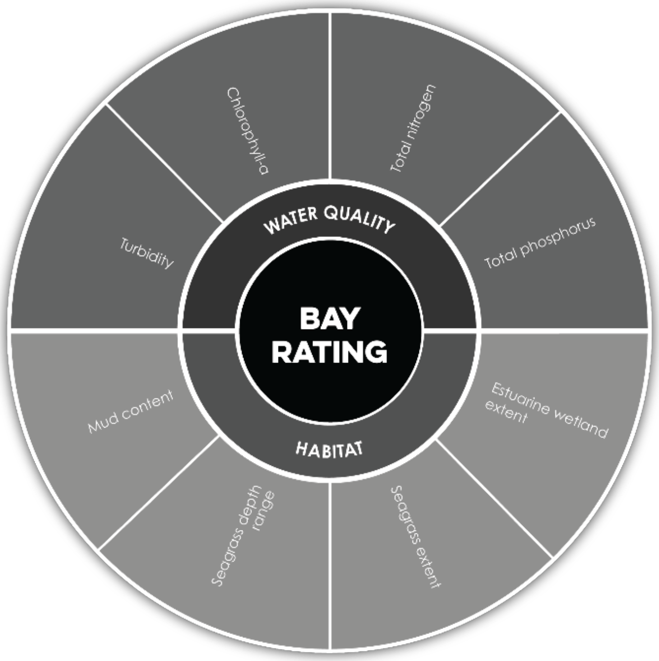

Figure 5: Rosette diagram showing the 8 indicators (light grey) that are combined into single overarching environmental condition rating for each of the bay reporting zones.

1.3.2 Waterways benefits (1 to 5 stars rating)

The Waterway Benefits element (introduced in 2015) helps to better understand how the social and economic benefits that waterways provide which will be affected by changing environmental conditions. The score for each indicator is calculated using data collected through a range of methods including community surveys and economic assessments. The following components are measured, resulting in a single star rating for each catchment:

- Community satisfaction with local waterways.
- Appropriate access to local waterways.
- Personal benefits residents derive from using local waterways.
- Community motivation to use and protect waterways.
- Economic benefits generated through recreation.
- Contribution relevant catchments make to providing clean low-cost drinking water.

The Overall Waterways Benefits Stars Rating

The waterways benefits stars ratings are reported in 18 catchments listed in Table 3 and are rated as the following:

- ★★★★★ **(5-stars) Maximum benefits:** Local community fully satisfied with local waterways, including their accessibility and usability. Maximum financial benefit from recreational use and low-cost drinking water.
- ★★★★ **(4-stars) Very high benefits:** Local community highly satisfied with local waterways, including their accessibility and usability. Very high financial benefit from recreational use and low-cost drinking water.
- ★★★ **(3-stars) High benefits:** Local community generally satisfied with local waterways, including their accessibility and usability. High financial benefit from recreational use and low-cost drinking water.
- ★★ **(2-stars) Moderate benefits:** Moderate accessibility and usability of waterways limits community use and satisfaction. Moderate financial benefit due to moderate recreational use and higher-cost drinking water.
- ★ **(1-star) Minimum benefits:** Minimal accessibility and usability of waterway result in little to no social or recreational benefits for the community. Minimum financial benefit due to low recreational use and highest-cost drinking water.

Table 3: The waterways benefits rating reporting zones (see Figure 2 or the Report Card website)

Catchment			Drinking water catchment
Coastal	Northern	Noosa	Non-drinking water
		Maroochy	Drinking water
		Mooloolah	Drinking water
		Pumicestone	Non-drinking water
	Central	Caboolture	Non-drinking water
		Pine	Drinking water
		Lower Brisbane	Non-drinking water
		Redland	Drinking water
	Southern	Logan	Drinking water
		Albert	Drinking water
		Pimpama-Coomera	Non-drinking water
		Nerang	Drinking water
		Tallebudgera-Currumbin	Non-drinking water
Western		Stanley	Drinking water
		Upper Brisbane	Drinking water
		Mid Brisbane	Drinking water
		Lockyer	Drinking water
		Bremer	Drinking water

The waterway benefits stars rating for each of the 18 catchments is calculated using 6 indicators (Figure 6). There are no benefits ratings calculated for bay zones.

For drinking water catchments (Table 3), the overall score is made up of:

- Social benefits – 60% (Section 1.11.1).
- Economic benefits – 40% (Section 1.11.2).

For non-drinking water catchments (Table 3), the overall score is made up of:

- Social benefits – 75% (Section 1.11.1).
- Economic benefits – 25% (Section 1.11.2).

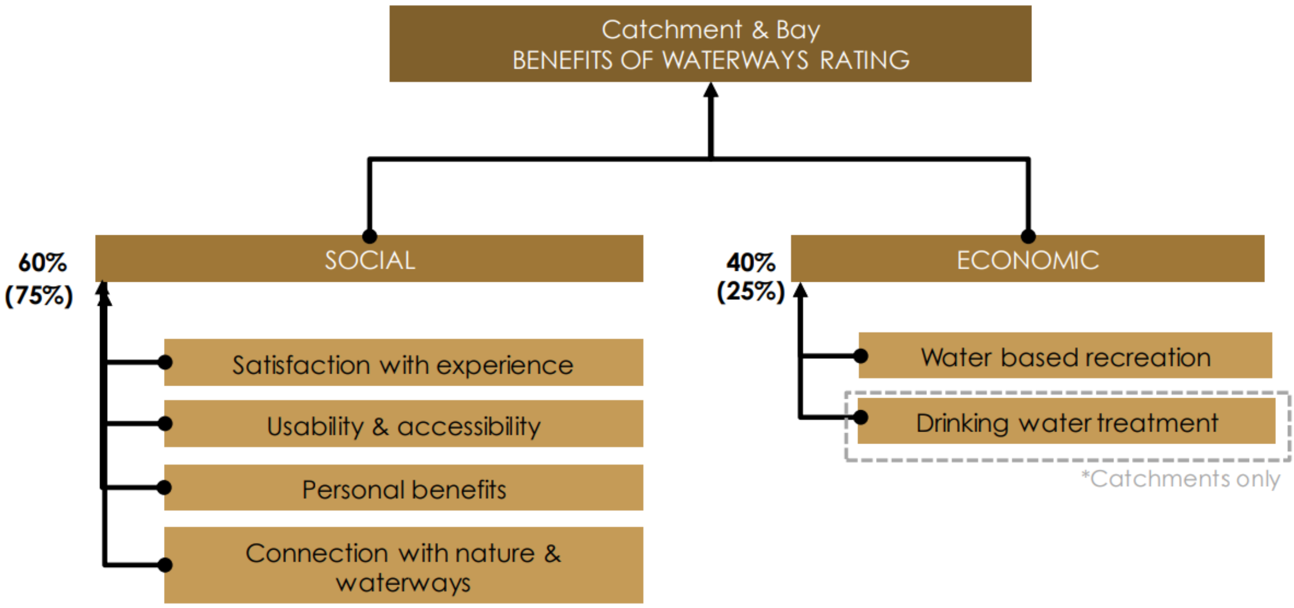

Figure 6: Diagram showing the 6 indicators (lightest brown) that are combined into a single overarching waterways benefit rating for each of the catchment reporting zones.

1.3.3 Actions

Actions undertaken by the community to protect and restore waterway health enhances the benefits that waterways provide. Healthy Land & Water is working with the community, local and state governments, water utilities, SEQ Catchments Members Association (SEQCMA) and the Council of Mayors (SEQ) to prioritise action in each catchment.

We are developing regional decision support tools to assess the threats to environmental values within each catchment. Specifically, the environmental values and objectives are (as defined by our members):

- Restore and maintain key habitats (i.e. riparian vegetation).
- Reduce pollutant loads (sediment and nutrients) entering waterways.
- Improve and maintain water quality.
- Restore and maintain key ecosystem processes.
- Restore and maintain resilient and healthy aquatic communities (i.e. fish populations).

These tools help prioritise focus areas for action and support decision-makers in developing and implementing targeted, effective catchment management actions.

Program background

Since 2000, the EHMP has assessed the ecological condition of waterways in SEQ and the results have been used to produce an annual Report Card. When first established, the EHMP was recognised as a world-class environmental monitoring and reporting program (Dennison and Abal, 1999; Bunn *et al*, 2010).

1.4 Program revised in 2015

In 2015, the monitoring program was revised to keep up with major advances in water quality automated monitoring and predictive modelling. This would help to create a program that reports on not only condition, but also on the drivers of ecosystem health, management responses to address issues and social and economic benefits (Smith, 2014). This new approach means the program now:

- Capitalises on the significant investment in predictive models made by the Healthy Land & Water partners over the past decade.
- Takes advantage of the substantial waterway health dataset amassed since the EHMP's inception by using these data to calibrate and validate the models.
- Utilises affordable automated water quality monitoring equipment to provide a superior understanding of water quality (while minimising costs).
- Provides stakeholders with information they need to effectively manage their catchments and waterways while recognising the need to ensure public funds are effectively allocated to address community priorities.

This optimised program has numerous advantages compared to the original program, as it delivers a holistic, triple-bottom-line approach to waterway management, including:

- Incorporating ambient and load-based monitoring to allow the impact of wet weather events to be monitored and better understood.
- Integrating monitoring and modelling giving capacity to:
    - Establish water quality and catchment load benchmarks for management.
    - Quantify changes in rural and urban land management practices.
    - Quantify the impact of such changes and other management actions.
    - Track progress towards agreed management targets.
    - Explore the efficacy of different management scenarios.
- Providing data on social and economic values of waterways and demonstrates how different activities effect these values.

1.5 How the revised program framework was developed

To ensure the monitoring program and Report Card had maximum impact with a broad audience (government, community groups, industry, and general public), it was designed to closely align with the aims and objectives that Healthy Land & Water members have for SEQ waterways. This ensures the monitoring results being published in the Report Card, and the management activities that are subsequently applied, are fully linked to the aspects of waterways that member's value and are committed to protecting or restoring.

The steps to develop the revised monitoring program and Report Card framework are outlined in Figure 7.

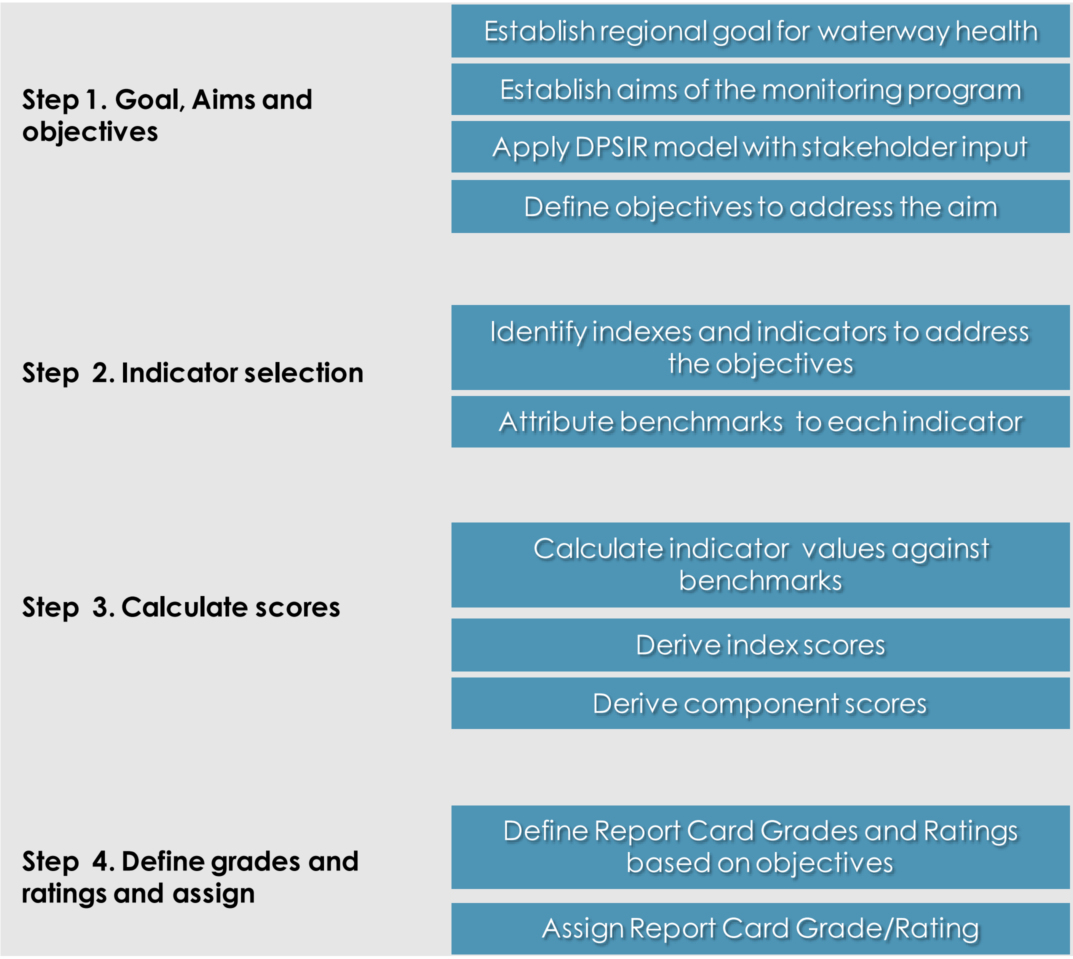

Figure 7: Approach to the development of the EHMP and Report Card.

The goals, aims and objectives of the program were developed (Step 1) based on the outcomes of two independent reviews of the EHMP (Smith, 2014) and a series of workshops with stakeholders in 2012. The goals, aims and objectives are an adaptation of the DPSIR Framework (Driving forces, Pressures, State, Impacts and Responses), which is typically applied to assess and manage environmental problems.

The ***socio-economic and socio-cultural forces*** are driving human activities which increase or mitigate pressures on the environment. ***Pressures*** are the stresses that humans place on the environment. ***State****, or* ***state of the environment***, is the condition of the environment. ***Impacts*** are the effects of environmental degradation. ***Response*** refers to the responses by society to the environmental state.

The **driver** for many members to committing to improving waterway condition is the social and economic elements the community derive from waterways and the corresponding changes in lifestyles and livelihoods that result from improvements to waterway condition. The **pressures** on waterway condition in SEQ are the anthropogenic factors that result in changes to waterway condition. These have been identified by members and include elements like increase diffuse and point source pollutant loads, climatic changes and physical alterations to waterway habitats. The **state** is the environmental condition of the waterways. This is essentially what Healthy Land & Water has reported on previously through the EHMP. The **impacts** are the changes in the benefits that the community derives as a result of changes in waterway condition. The **response** to changing condition and benefits are the improvements in stewardship and the adoption of Best Management Actions in the six management themes identified by members. Increasing adoption of best management practice will lead to a reduction in the pollutant loads and other pressures on waterway condition.

With this structure, the monitoring program provides members with an understanding of the condition of SEQ waterways, as well as datasets to better assist members in making informed catchment management decisions. Understanding the changes to the key pressures on waterways will aid in the interpretation of changes in waterway condition (Figure 8). Understanding the link between waterway condition and the resultant socio-economic benefit will help to generate community engagement and inform the development of cost-effective and targeted management actions.

Figure 8: The EHMP and Report Card guiding framework.

Environmental Condition Scores

Healthy Land & Water synthesises monitoring, modelling and remote sensing to produce the SEQ Report Card annually, which provides an easy-to-understand assessment of the health of our catchments and waterways and highlights any issues that require intervention.

This section provides the definitions, rationale, data collection methods, benchmarks and score calculations for each indicator used to calculate the Environmental Condition scores. In most cases, an index is made up of more than one indicator. If an index has multiple indicators, the score is generally calculated by averaging across all indicators within the index.

1.6 Freshwater communities and processes components

The condition of freshwater stream communities and ecological process reflects overall stream condition and health (*Simth et al.,* 2001). This component includes 12 indicators that are condensed into four indices:

1. Physical and chemical index reflect stream water quality.
2. Ecosystem process measures reflect the vigour or 'pulse' of a stream.
3. Aquatic bug communities (insects, crustaceans, snails, etc) are very sensitive to disturbance.
4. Fish communities reflect a range of environmental disturbances and provide a measure of stream condition due to their mobility, long life and position near the top of the food chain.

Each of these indicators are further described below. These indicators are monitored and modelled across South-East Queensland on a rotational basis as shown in Figure 9 and see Section 1.13 and Section 1.14.

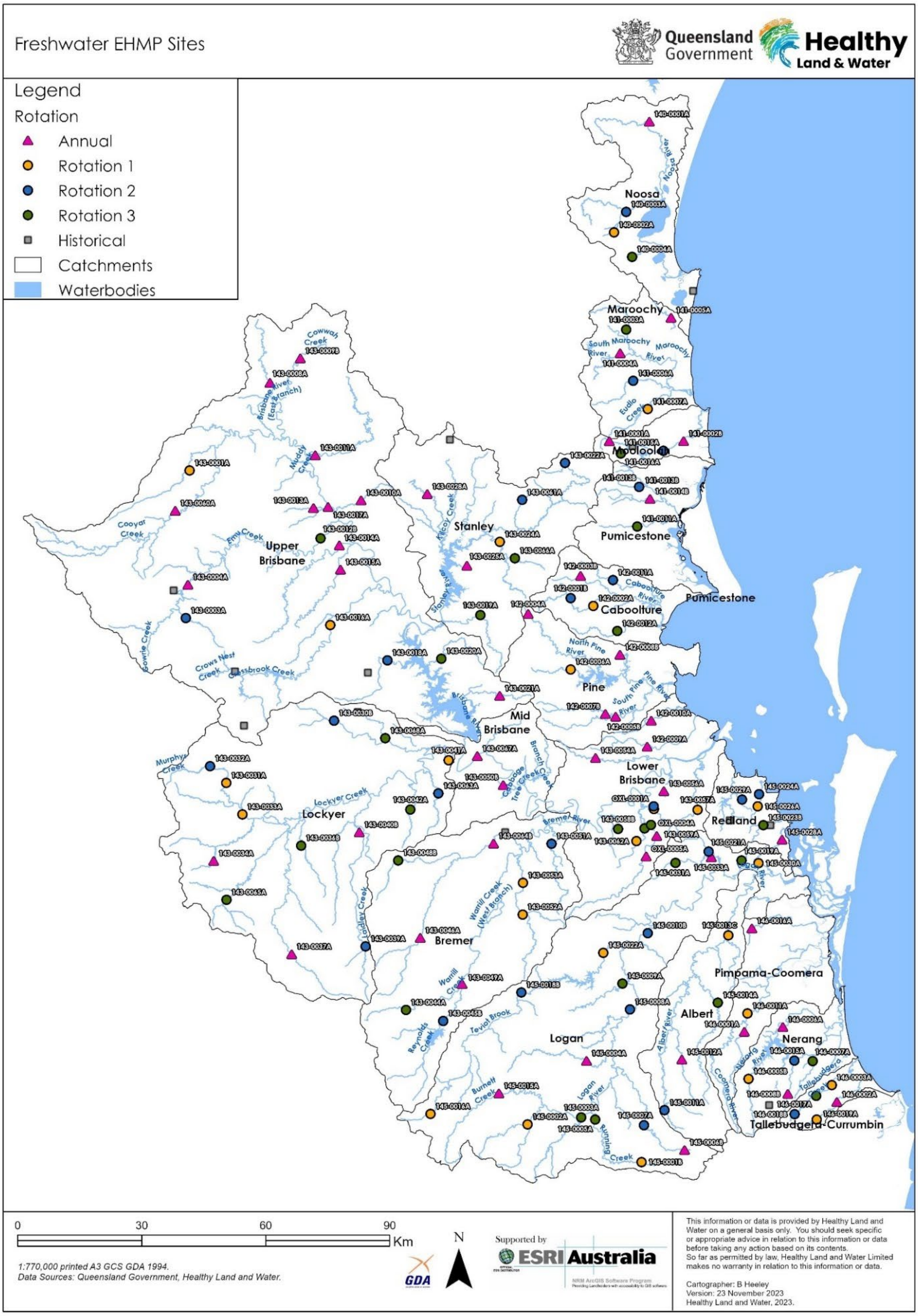

Figure 9: Freshwater EHMP monitoring sites.

1.6.1 Physical and chemical index

Water quality refers to the physical and chemical properties of the water column. The variation and range of water quality in a waterway influences the types of organisms present in a system (Smith *et al.*, 2001).

This index is a combination of four indicators:

1. pH.
2. Electrical conductivity.
3. Ambient water temperature.
4. Ambient dissolved oxygen.

1.6.1.1 pH indicator

The term pH is an abbreviation for "potential hydrogen". It is a measure of the concentration of free hydrogen ions [H+] or the acidity of the water. The pH scale is based on the logarithm of the reciprocal of [H+] and ranges from 1.0 (highly acidic) through 7.0 (neutral) to 14.0 (highly alkaline). As such, water with a pH of 5.0 has ten times the concentration of free hydrogen ions as water with a pH of 6.0.

Rationale

The pH of streams usually varies naturally between catchments due primarily to differences in catchment geology and vegetation. The pH of streams in SEQ generally ranges from about 4.5 in the tannin-stained streams associated with coastal 'wallum' heath, to near 9.0 in streams at the headwaters of some catchments.

Rapid changes in pH can be associated with the disturbance of acid-sulphate soils, or with the discharge of acidic drainage from coal mines. These are known to have adverse effects on the ionic balance and respiratory efficiency of fish and aquatic invertebrates. Agricultural runoff has also been shown to cause reductions in stream pH, which can lead to increases in the toxicity of ammonia and heavy metals within stream sediments and a reduction in the survival rates of aquatic organisms, particularly juvenile stages. Some species, such as the endangered Oxleyan Pigmy Perch, *Nannoperca oxleyana,* have specific pH requirements for survival.

Data collection methods

Field data is collected once per year at 76 freshwater EHMP sites (Section 1.13).

Field measures of pH are taken at a depth of approximately 10cm, using a handheld TPS WP-81 Conductivity-pH-Temperature meter fitted with a (K=1.0) pH sensor. The pH calibration of the meter is checked daily against 4.0 and 6.87 pH standards and the meter is re-calibrated if readings vary more than ±0.1 pH units from the true value.

Score calculation

The pH field measures are converted to 'distance from guideline' scores using the traditional EHMP method, involves the use of a static guideline table of ecosystem health guidelines and worst-case scenario values (Section 1.6.5.1).

1.6.1.2 Electrical conductivity indicator

Conductivity is a measure of the ability of water to conduct an electrical charge, which is primarily dependent upon the concentration of ions in the water. Those ions are commonly associated with mineral salts, so electrical conductivity is usually closely related to salinity.

Rationale

Conductivity can affect both the community structure and function of freshwater ecosystems. Elevated conductivity levels are known to influence nutrient cycling, rates of primary production and respiration and the survival of riparian vegetation, aquatic macroinvertebrates and fish. Increased conductivity may also reflect the presence of pollutants from sources such as wastewater treatment plants (WWTPs), urban road runoff and agricultural runoff.

Data collection methods

Field data is collected once per year at 76 EHMP freshwater sites (Section 1.13).

Field measurements of conductivity are taken at a depth of approximately 10cm, using a handheld TPS WP-81 Conductivity-pH-Temperature meter fitted with a (K=1.0) conductivity sensor. The conductivity calibration of the meter is checked daily, and the meter is re-calibrated using a two-point (0 and 1,413µS) calibration procedure.

Score calculation

The conductivity field measures are converted to 'distance from guideline' scores using the traditional EHMP method, involves the use of a static guideline table of ecosystem health guidelines and worst-case scenario values (Section 1.6.5.1).

1.6.1.3 Ambient water temperature indicator

This indicator is a combination of two temperature measures:

- Diel maximum ambient water temperature: the highest (95^{th} percentile) water temperature over a 24-hour period.
- Range of ambient water temperature: the change in temperature of the typical stream water over a 24-hour period.

Rationale

Like conductivity, water temperature regulates aspects of both the community structure and function of aquatic ecosystems. For example, chemical attributes such as oxygen solubility and pH are sensitive to changes in water temperature. High temperatures cause a decrease in the level of dissolved oxygen (DO) available for aquatic organisms. As such, changes have a strong influence on ecosystem functions such as primary production and respiration. Fish and aquatic invertebrates are also sensitive to temperature changes with large temperature variations having deleterious effects on reproduction and survival.

Water temperature varies naturally as part of normal daily and seasonal cycles. However, more dramatic changes in temperature often occur as a result of human activities. Such changes are particularly noticeable in small streams where the loss of overhanging riparian streamside vegetation can lead to a marked increase in both water temperature and temperature range. High maximum temperatures and large temperature ranges can have adverse effects on an organism's growth, metabolism, reproduction, mobility and migration, which may lead to a decline in species richness and diversity.

Data collection methods

Field data is collected once per year at 76 freshwater EHMP sites (Section 1.13).

Field measurements of ambient water temperature are taken from mid-stream, using TPS WP-82Y Dissolved Oxygen-Temperature meters fitted with an YSI 5739 DO probe with inbuilt thermistor. The water temperature feature of these meters is checked weekly and calibrated against a laboratory-grade mercury thermometer.

Ambient water temperature is recorded at each site every ten minutes for a 24-hour period. The sensor is placed in a PVC housing fitted with a small water pump that expels water from the housing. Inlet ports, fitted with a foam filter to prevent the passage of debris into the housing, provide the flow of water through the housing. This assembly is attached to a stake to hold it above the substrate when deployed in the field.

Minimum and maximum water temperatures are calculated as the 5^{th} and 95^{th} percentiles respectively.

The diel (24 hour) range of water temperature is calculated as the difference between the maximum and minimum values.

Score calculation

The water temperature field measures are converted to 'distance from guideline' scores using the traditional EHMP method, involves the use of a static guideline table of ecosystem health guidelines and worst-case scenario values (Section 1.6.5.1 and Section 1.6.5.2).

1.6.1.4 Ambient dissolved oxygen (DO) indicator

This indicator is a combination of two dissolved oxygen (DO) measures:

- Diel minimum ambient DO: the lowest (5^{th} percentile) DO over a 24-hour period.
- Range of ambient DO: the change in DO of typical stream water over a 24-hour period.

Rationale

DO concentration is a measure of the availability of oxygen to aquatic organisms. Oxygen is a fundamental requirement for aquatic organisms that respire aerobically; and the concentration of DO affects the distribution, physiological activity and behaviour of aquatic animals. The DO concentration of less than 2mg/L is likely to have deleterious effects on aquatic invertebrates and fish.

The concentration of DO limits, and is limited by, the ecological processes of primary production and respiration that produce and consume oxygen, respectively. DO concentration is highly dependent on temperature and fluctuates over a 24-hour period under natural conditions. Under some conditions (e.g. low flow, high temperatures), high biological oxygen demand associated with plant respiration and microbial decomposition can lead to very low DO concentrations and a large diel DO range. Large daily fluctuations in DO place pressure on ecological function.

Data collection methods

Field data is collected once per year at 76 freshwater EHMP sites (Section 1.13).

Field measurements of ambient DO concentration are taken mid-stream, using TPS WP- 82Y Dissolved Oxygen-Temperature meters fitted with an YSI 5739 DO probe. The DO feature of these meters is re-calibrated weekly using a two-point (0 and 100% oxygen saturation) calibration procedure, and then tested against several other newly calibrated WP-82Y meters. The calibration of each meter is then tested again before and after use in the field. All calibration data is recorded for quality assurance purposes.

DO concentration is recorded at each site every ten minutes for a 24-hour period. As for ambient water temperature readings described above, to ensure a constant flow of the DO sensor, it is placed in a PVC housing fitted with a small water pump that expels water from the housing. Inlet ports, fitted with a foam filter to prevent the passage of debris into the housing, provide the flow of water through the housing. This assembly is attached to a stake to hold it above the substrate when deployed in the field.

Minimum and maximum DO concentrations are calculated as the 5th and 95th percentiles respectively. The diel (24 hour) range of DO concentration is calculated as the difference between the maximum and minimum values.

Score calculation

The DO field measures are converted to 'distance from guideline' scores using the traditional EHMP method, involves the use of a static guideline table of ecosystem health guidelines and worst-case scenario) values (Section 1.6.5.1 and Section 1.6.5.2).

1.6.2 Ecosystem processes index

Benthic metabolism refers to the rates of primary production (i.e. photosynthesis) and respiration occurring at, and just below, the sediment-water interface of water bodies. The primary organisms responsible for these processes in this microhabitat are algae and bacteria.

This index is a combination of two indicators:

1. Gross primary production (GPP).
2. Daily respiration (R24).

1.6.2.1 Gross Primary Production (GPP) indicator

Rationale

Rates of instream production and respiration increase with anthropogenic disturbance such as riparian vegetation removal and agricultural runoff (Udy *et al.* 2001). The removal of stream-side vegetation, for example, results in less shading, increases in instream light intensity, and consequent increases in algal production. Increased amounts of algae are then available for decomposition, resulting in an increased rate of respiration.

Data collection methods

Field data is collected once per year at 76 freshwater EHMP sites (Section 1.13).

Both gross primary production (GPP) and daily respiration rate (R24) are quantified from the net change in DO within two transparent plastic, dome-shaped chambers each isolating a portion of the stream bed and its associated benthos. Depending on the dominant substrate at a site, either one or more cobbles are sealed within the chambers using a plastic 'lid', or the chambers are pushed into the sediment to a measured depth to create a water-tight seal. A TPS WP-82Y Dissolved Oxygen-Temperature meter fitted with a YSI 5739 DO probe records DO and temperature within each chamber every ten minutes for 24 hours. A Whale 12V in-line pump recirculates water through the chambers and past the DO sensor to account for minor consumption of O_2 by the sensor. Prior to, and during, fieldwork, sensors are calibrated weekly and serviced fortnightly. Calibration of the sensors involves both a temperature and two-point (0% and 100%) DO calibration, followed by a cross-check of their calibration against other sensors.

Rates of change in DO concentration over time (g O_2 L^{-1} hr^{-1}) are multiplied by chamber volume and divided by substrate surface area to obtain rates of oxygen consumption and production (g O2 m^{-2} hr^{-1}) associated with the processes of respiration and production, respectively. Respiration rates are calculated by converting the rate of consumption of DO during the night to a rate of carbon release (g C m-2 day-1), assuming that one mole of carbon is equivalent to one mole of oxygen (i.e. 1 g O2 = 0.375 g C). Net primary production is calculated similarly and, assuming respiration to be constant during the 24-hour period of data recording, gross primary production (GPP, g C m^{-2} day^{-1}) is calculated by adding the amount of carbon fixed during the day to the amount released during the night by respiration.

Score calculation

The GPP field measures are converted to 'distance from guideline' scores using the traditional EHMP method, involves the use of a static guideline table of ecosystem health guidelines and worst-case scenario values (Section 1.6.5.1).

1.6.2.2 Daily respiration (R24) indicator

See description for Gross Primary Production (GPP) indicator above.

1.6.3 Aquatic macroinvertebrates community index

Aquatic bugs (or macroinvertebrates) are animals without back- bones that live in the water and are large enough to see with the naked eye (e.g., beetles, bugs, shrimp, snails). Aquatic bugs are one of the most commonly used biological indicators of stream ecological condition, because they are very sensitive to disturbances (Marshall *et al.* 2001). These animals are ideally suited to biological monitoring because they are common, widespread, and easily sampled.

This index is a combination of three indicators:

1. Number of taxa.
2. PET richness.
3. SIGNAL score.

1.6.3.1 Number of taxa indicator

Number of taxa refers to the number of macroinvertebrate taxa collected in a sample, excluding cladocerans, ostracods, copepods and spiders.

Rationale

Number of taxa is a direct measure of taxa richness, which generally increases with ecological condition. A high number of taxa within a site indicate that the various water quality, habitat, and food requirements of those taxa have been met locally in recent times.

Data collection methods

Field data is collected once per year at 76 freshwater EHMP sites (Section 1.13).

A representative sample of the aquatic macroinvertebrate fauna is collected from 'edge' habitat at each site and the presence/absence of (primarily family-level) taxa is determined. Edge habitat is defined as habitat along the water's edge, including backwaters and undercuts, where there is little or no flow, and few or no submerged/emergent macrophytes. Each sample is collected from a 10m length of 'edge' habitat. The length need not be continuous as all forms of edge habitat are required to be sampled in proportion to spatial occurrence over a 100m length of stream within which the sample is collected.

Samples are collected with a 250µm mesh dip net fitted to a 250mm x 250mm x 250mm triangular frame attached to a 2m handle. Three short, upward sweeps of the net are made perpendicular to the bank for every metre of stream bank sampled. Once collected, the sample is rinsed, emptied into a bucket and then evenly divided into two sorting trays. Two people pick macroinvertebrates from separate trays for 30 minutes with the objective of collecting the greatest diversity of taxa, and about ten individuals of each taxon. No formal identifications are undertaken in the field, so 'taxa' at this stage essentially refers to 'visually similar animals'. The animals picked by each person are placed into separate labelled vials containing 70% methylated spirits and transported back to the laboratory for further processing. The residues from 10% of field processed samples are retained for assessment of the representativeness of each field workers picking.

In the laboratory, all animals picked from samples by each person in the field are identified and counted using a stereo dissecting microscope. The only aquatic macroinvertebrates not identified to family level are:

- Porifera, Nemertea and Nematoda (identified to phylum).
- Oligochaeta, Polychaeta, Ostracoda, Copepoda and Branchiura (identified to class).
- Cladocera, Collembola and Acarina (identified to order).
- Chironomidae (identified to sub-family).

The laboratory identifications and counts of all staff are tested via independent identification and enumeration of taxa within a random 10% subsample of preserved samples.

A single set of taxa presence/absence data is obtained for each site by pooling the results obtained from each of the two worker's samples. Three aquatic bugs indicators are calculated based on the taxa presence/absence dataset.

Score calculation

The number of taxa measures are converted to 'distance from guideline' scores using the traditional EHMP method, involves the use of a static guideline table of ecosystem health guidelines and worst-case scenario values (Section 1.6.5.1).

1.6.3.2 PET richness indicator

PET richness refers to the number of families collected in a sample belonging to one of the three particularly sensitive orders of aquatic insects: Plecoptera (stoneflies), Ephemeroptera (mayflies) and Trichoptera (caddisflies).

Rationale

The abundance of individuals within PET taxa shows a marked decline with anthropogenic disturbance and is thus useful as an early warning indicator of a decline in stream health (ref Karr & Chu 1999). It should be noted that Plecoptera are naturally rare in SEQ, so in this area PET richness essentially refers only to families of Ephemeroptera and Trichoptera. This index is calculated simply as the number of taxa belonging to the Plecoptera, Ephemeroptera and Trichoptera orders.

Data collection methods

As per number of taxa indicator above.

Score calculation

As per number of taxa indicator above.

1.6.3.3 SIGNAL score indicator

SIGNAL stands for 'Stream Invertebrate Grade Number - Average Level', refers to a bioassessment scoring system for stream macroinvertebrates from Australian rivers (Chessman 1995, 2003).

Rationale

The score gives an indication of water quality based on the sensitivity of different macroinvertebrate families. This is a simple means of assessing waterway health using a biotic indicator. The SIGNAL score for a macroinvertebrate sample is calculated by averaging pollution sensitivity grades for invertebrate families present. Waterway sites with high SIGNAL scores are likely to have high dissolved oxygen, low turbidity, and low levels of nutrients.

Data collection methods

As per number of taxa indicator above.

Score calculation

As per number of taxa indicator above.

1.6.4 Fish community index

Fish are common and familiar animals of freshwater environments, and fish communities reflect a range of natural and human-induced disturbances through changes in abundance and species composition. Ecological assessments based on fish community structure have the advantage over more traditional physical and chemical indices (e.g. conductivity, turbidity and nutrients) in that fish provide an integrated measure of stream condition due to the mobility, relatively long-life and high trophic level of the animals involved (Kennard *et al.* 2001). Data on fish communities is also valuable as it is of direct public interest, especially to recreational fishers and aquarium fish hobbyists, and required for the conservation of biodiversity.

This index is a combination of three indicators:

1. Percentage of native species expected (PONSE).
2. Ratio native species expected: observed (O/E50).
3. Proportion of alien fish.

1.6.4.1 Percentage of Native Species Expected (PONSE) indicator

Percentage of Native Species Expected (PONSE) refers to the number of native fish species observed to occur at a site expressed. It is expressed as a percentage of the number of native fish species expected to occur at a physically similar site under minimally disturbed conditions.

Rationale

Waterway sites with low PONSE (%) are likely to have disturbances due to land use, water chemistry, riparian and channel degradation and deterioration of in-stream habitat condition (Bunn & Smith 2002).

Data collection methods

Field data is collected once per year at 76 EHMP freshwater sites (Section 1.13).

A combination of backpack electrofishing, followed (where practical) by seine-netting, is used to determine the relative abundance of individual fish species at each site. Electrofishing is conducted using a Smith-Root model 12, or LR-24, backpack electrofisher fitted with a 28cm anode ring supporting a dip net of 10mm (stretched) mesh. Pulse width and frequency are kept fixed at 2µs and 100Hz respectively, and output voltage is varied according to the conductivity of water at each site. A table of conductivity-voltage settings is used as a starting point for setting output voltage on each sampling occasion. Seine-netting is conducted using a 10m long (1.5m drop) pocket seine of 10mm (stretched) mesh. All fishing is undertaken in accordance with Animal Ethics approval to ensure, as far as practical, that fish are not injured in any way.

The extent of fishing at each site is based on dividing the habitat at each site into different units based primarily on flow conditions (e.g. riffle, run, pool), and ensuring that at least one full habitat unit of each type is fished intensively. If only one habitat unit is present at a site, two examples of that habitat unit are fished in an attempt to maintain an average length of fished stream of 75m (about 20 stream widths) and an electrofishing 'power-on' time of 900secs. As the majority of streams within the study area only flow intermittently, two sections of pool habitat are most commonly fished. Seine-netting can generally only be used infrequently due to a high abundance of woody debris and other obstacles hindering effective hauling of the net.

As backpack electrofishing involves field staff wading through water whilst surrounded by a dangerous (400 W continuous) electric field, this activity is led only by highly trained and experienced staff. All electrofishing is conducted in strict accordance with the *Australian Code of Electrofishing Practice* as a minimum standard.

Counts of the number of each fish species caught are recorded as fish are captured. Captured fish are retained in temporary storage until the completion of fishing within each habitat unit to prevent the occurrence of recaptures. When fishing has been completed, or recaptures are deemed to be improbable, fish are released alive back into the stream near where they were caught. A small number of specimens of any fish unable to be confidently identified at the time of capture are euthanized and retained for laboratory identification. Specimens of several difficult to identify genera are routinely retained for this reason; notably *Ambassis, Hypseleotris, Mugil and Philypnodon*.

A single set of relative abundance data is obtained for each site on each sampling occasion by pooling the results obtained for each habitat unit and mode of fishing (electrofishing, seine netting). This is the 'observed' data.

The 'expected' data for number of native fish species is predicted by a static numeric model, which uses details of each site in terms of elevation, distance from river mouth, distance from source and stream width as input. This underlying model was developed using regression tree analysis and, as it uses several abiotic parameters as input, results inherently account for the primary source of natural spatial variation.

Score calculation

The PONSE measures are converted to 'distance from guideline' scores using the traditional EHMP method, involves the use of a static guideline table of ecosystem health guidelines and worst-case scenario values (Section 1.6.5.1).

1.6.4.2 Ratio of Native Species Observed: Expected (O/E_{50}) indicator

Ratio of observed to expected native species refers to the native fish species observed to occur at a site in relation to the native fish species expected to occur at a physically similar site under minimally disturbed conditions.

Rationale

The O/E_{50} differs from PONSE and proportion of alien fish, in that observed and expected species are compared on a species-by-species basis rather than simple counts of species. This greater resolution allows better interpretation of what changes in fish communities may have occurred.

Data collection methods

As per percentage of native species expected (PONSE) indicator above.

Score calculation

As per percentage of native species expected (PONSE) indicator above.

1.6.4.3 Proportion of alien fish indicator

Rationale

Proportion alien fish refers to the number of individual fish of species originating from outside of Australia expressed as a percentage of total alien fish catch at each site. Individuals of species translocated to SEQ streams from elsewhere in Australia (e.g. golden perch *Macquaria ambigua)* are not included as alien fish.

Data collection methods

As per percentage of native species expected (PONSE) indicator above.

Score calculation

As per percentage of native species expected (PONSE) indicator above.

1.6.5 Score calculation

At each monitoring site, freshwater overall site score is derived by averaging values across all indicators within four indices (see Section 1.6.5.1 Traditional EHMP calculation). For site that monitoring data do not exist, model estimation of four indices will be used in deriving freshwater overall site score (see Section 1.6.5.4 Stream Health Model). The freshwater overall score for each reporting catchment is derived based on averaging freshwater overall site score from both monitor data and modelled data Figure 10.

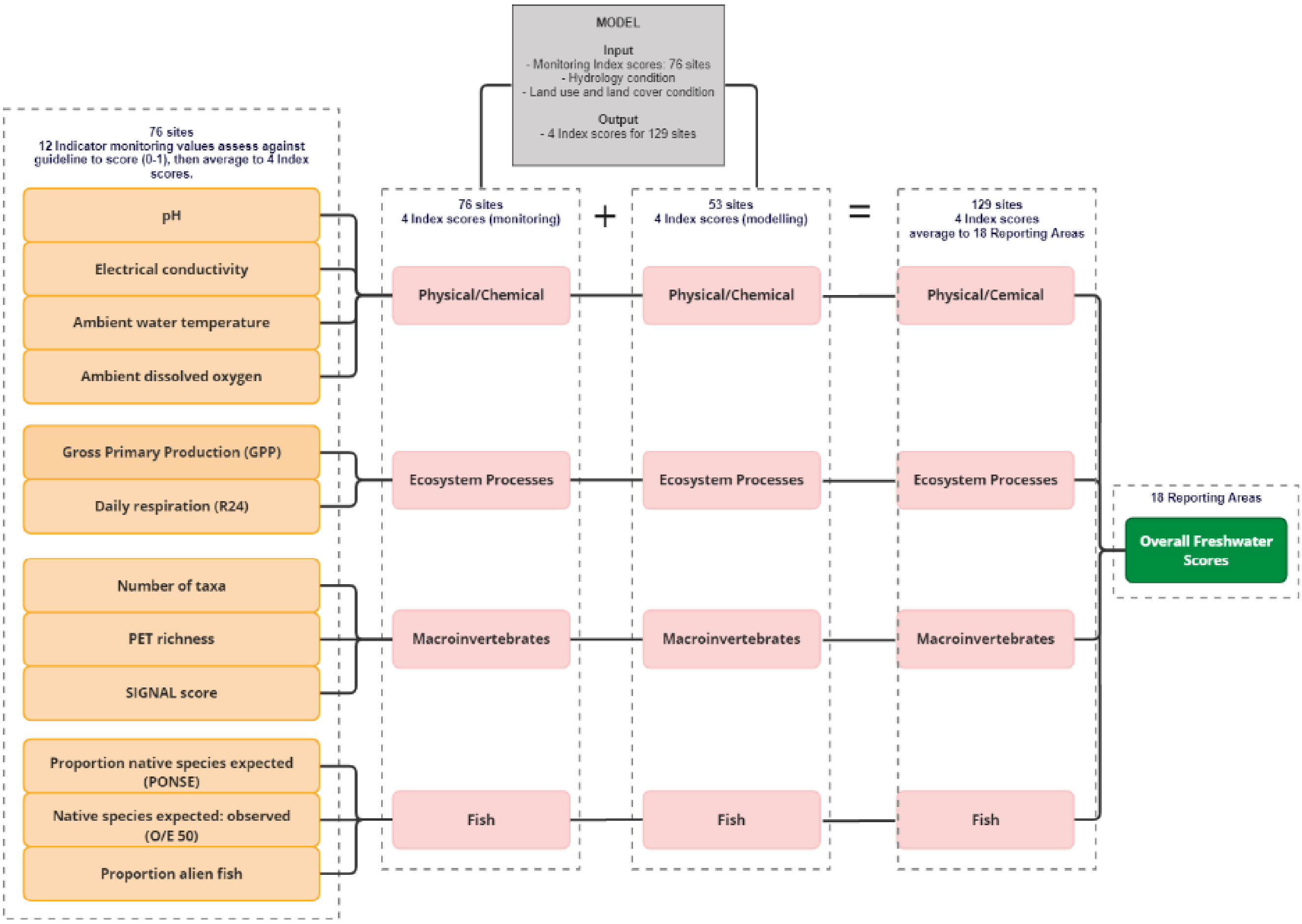

Figure 10: Flowchart diagram showing freshwater score calculation steps.

1.6.5.1 Traditional EHMP score calculation for all indicators [2]

The traditional freshwater indicators are calculated based on a 'distance from guideline' value. The 'distance from guideline' approach is used because it can most sensitively identify changes (improvements or declines) in water quality, regardless of compliance status. This enhances the indicators sensitivity to track changes in response to management intervention.

The calculation of standardised scores for four freshwater communities and processes indices involves the use of a static guideline table of ecosystem health guidelines and worst-case scenario values.

Guideline values and worst-case scenario values

Guideline values were derived from either the 20th and/or 80th percentile of empirical data for minimally disturbed reference sites as part of the DIBM3 project or from theoretical limits (Moss *et al.*, 2001). These values indicate the expected values of each indicator for streams in "healthy" condition (Table 4).

Worst case scenario values were derived from either the 10th and/or 90th percentile of data for all sites and assessment periods associated with the freshwater EHMP, or theoretical limits of the indicator. Worst Case Scenario values indicate the expected value of each indicator for streams in the unhealthiest condition.

[2] Except temperature and DO indicators. For more information about the score calculation for these indicators, please go to section 3.1.5.2.

Stream classes

Both guideline and Worst-Case Scenario values were derived independently for different groups of streams with similar physical conditions (i.e. stream classes) so that standardised scores account for the majority of natural spatial variation in the values of each indicator. Stream classes were identified using clustering analysis of assessment sites based on elevation, stream channel gradient, stream order and mean annual rainfall and were checked against the results of similar analyses based on fish catch data. Four different stream classes were identified (Upland, Lowland, Coastal, and Tannin-stained), and each Freshwater site is allocated to one of those classes. Indicator values for each site are only compared to guideline and Worst-Case Scenario values for the same stream class.

The spatial boundary of each water type is defined by the Queensland Government as part of the Environmental Values and Water Quality Objectives scheduling (latest 2022). Maps and associated documents can be found on their website: https://www.ehp.qld.gov.au/water/policy/seq-moretonbay.html. This framework was used to group different stream classes to the Report Card freshwater sites.

Table 4: The Queensland Water Quality (biological) guideline and worst-case scenario (WCS) values used for all indicators of the freshwater communities and processes component.

Indicator	Upland		Lowland or coastal		Tannin-stained		Operand	Unit
	Guideline	**WCS**	**Guideline**	**WCS**	**Guideline**	**WCS**		
Physical and Chemical index								
pH (min)	6.5	4.5	6.5	4.5	5	3	≥	[H^+]
pH (max)	8.5	10.5	8.5	10.5	8.5	10.5	≤	[H^+]
Conductivity	400	1041	400	1870	400	1870	≤	$\mu S\ cm^{-1}$
Temp (max)	18	NA	22	NA	22	NA	≤	°C
Temp (range)	4	NA	4	NA	4	NA	≤	°C
DO (min)	30	NA	20	NA	20	NA	≥	% saturation
DO (range)	30	NA	50	NA	50	NA	≤	% saturation
Ecosystem Processes index								
GPP	0.25	0.8	0.5	1.3	0.5	1.3	≤	$g\ C\ m^{-2}\ day^{-1}$
R24	0.15	0.7	0.35	1.2	0.35	1.2	≤	$g\ C\ m^{-2}\ day^{-1}$
Aquatic Macroinvertebrates Community index								
Number Taxa	22	0	22	0	11	0	≥	Number
PET Richness	5	0	4	0	3	0	≥	Number
SIGNAL	4.6	1	4	0	4	0	≥	Number
Fish Community index								
PONSE	100	0	100	0	100	0	≥	%
Ratio = O/E	1	0	1	0	1	0	≥	Ratio (number)
Prop. Alien Fish	0	100	0	100	0	100	=	%

Calculating distance from guideline values

Calculation of each standardised score involves an initial comparison of each indicator value against the corresponding guideline and Worst-Case Scenario value (Table 4). Indicator values satisfying the criteria specified are awarded a score of 1.0 whilst and "worse" than/equal to the Worst-Case Scenario (WCS) are awarded a score of 0.0. The score for all other values is calculated using the equation:

$$Score = 1 - \left|\frac{(Indicator\ value\ at\ a\ site) - \ Guideline)}{(WCS - Guideline)}\right|$$

Two examples of the calculation of standardised scores follow:

Example 1: Conductivity (lowland stream)

Indicator value = 1000 µS cm^{-1}

Guideline value = 400 µS cm^{-1}
WCS = 1870 µS cm^{-1}

$$1.0 - \left|\frac{(1000 - \ 400)}{(1870 - 400)}\right| \equiv \ 1.0 - \left|\frac{(600)}{(1470)}\right| \equiv \ 1.0 - |0.41| = 0.59$$

Therefore, the indicator score is **0.59.**

Example 2: Number of taxa (upland stream)

Indicator value = 17 taxa

Guideline value = 22 taxa
WCS = 0 taxa

$$1.0 - \left|\frac{(17 - 22)}{(0 - 22)}\right| \equiv \ 1.0 - \left|\frac{(-5)}{(-22)}\right| \equiv \ 1.0 - |0.23| = 0.77$$

Therefore, the indicator score is **0.77.**

1.6.5.2 Traditional EHMP calculation for temperature and DO indicators

The temperature and DO scores use pass/fail thresholds (Table 5) in relation to guideline values (Table 4). This method places more emphasis on whether or not temperature range and minimal DO values passes ecosystem health guideline criteria (rather than temperature maximum and DO range scores). Failure in either of these indices represents a more deleterious condition rather than failure in terms of the other two indicators in the Freshwater PhysChem index (pH and conductivity). A standardised score is not calculated; instead, one of the four indicator score options presented in Table 5 are assigned (use guideline values presented in Table 4 and Table 5. Note: this score is not standardised as per the other indicators.

Two examples of calculating scores are as follows:

Example 1: Temperature (upland)

Indicator values = 17 to 19 °C

Guideline Temperature MAX for upland = 18 °C (***Temp Max value > guideline = 'Fail')***
Guideline Temperature Range for upland = 4 °C (***Temp Range value < guideline = 'Pass')***

Therefore, the indicator score is **0.8**

Example 2: Temperature (tannin-stained)

Indicator values = 19 to 21 °C

Guideline Temperature MAX for tannin-stained = 22 °C (***Temp Max value < guideline = 'Pass'***)
Guideline Temperature Range for tannin-stained = 4 °C (***Temp Range value < guideline = 'Pass'***)

Therefore, the indicator score is **1.0**

Table 5: Scores for water temperature and dissolved oxygen based on pass/fail criteria.

Water temperature				Dissolved oxygen			
		Temp. (maximum)				**DO (minimum)**	
		Pass	*Fail*			*Pass*	*Fail*
Temp (range)	*Pass*	1.0	0.8	**DO (range)**	*Pass*	1.0	0.3
	Fail	0.5	0.0		*Fail*	0.8	0.0

1.6.5.3 Calculation for four index scores

The scores for each indicator are averaged to calculate the four freshwater indices (as listed in Table 4). The scores are then averaged across sites within each reporting area and indices to provide a single score for each of the reporting areas.

1. Freshwater Physical and chemical index (average of 4 indicators).
2. Freshwater Ecosystem Processes index (average of 2 indicators).
3. Freshwater Macroinvertebrates Community index (average of 3 indicators).
4. Freshwater Fish Community index (average of 3 indicators).

1.6.5.4 Stream Health Model estimation for four index scores

Stream Health model used to predict index scores

A Stream Health Model (Section 1.14) is used to estimate the score for each index (i.e. physical and chemical, ecosystem processes, macroinvertebrates and fish) at 129 representative sites across SEQ (Figure 10). The model is validated with Freshwater EHMP monitoring data collected once per year at 76 freshwater sites.

1.7 Pollutant load components

Three major pollutants of concern in waterways are sediments, nitrogen, and phosphorus. Specifically:

- Excess sediments (suspended solids) in waterways reduces light penetration which restricts growth of aquatic plants, smothers benthic organisms and transports nutrients and contaminants.
- Excess nutrients (nitrogen and phosphorus) in our waterways stimulates growth of macrophytes and algae (including cyanobacteria) to nuisance proportions, which can displace endemic species, diminish light availability to benthic species, and cause excessive fluctuations in pH and dissolved oxygen which can stress and eliminate sensitive species.

As such, this component includes three indicators:

1. Sediment load.
2. Nitrogen load.
3. Phosphorus load.

1.7.1 Sediment load indicator

Rationale

Sediment loads are eroded remnants of material like mud or sand that is transported through the environment by water or wind. The sediment found in SEQ waterways most commonly comes from exposed soils in poorly managed catchment areas, eroded creeks, riverbanks (Wallbrink 2004, Hancock and Caitcheon, 2010, Olley *et al.* 2013) and construction sites.

Exposed soils are easily eroded during rainfall events and the runoff enters waterways. Excess sediments in waterways cause a variety of environmental impacts including reduced light penetration in the water column which restricts the productivity of aquatic plants, smothering of benthic organisms and transport of contaminants like nutrients and heavy metals. Sediment enters our waterways in the runoff following rainfall events. A process that is accelerated by poor catchment management. Once in the waterways, sediments are readily resuspended by water flow.

Data collection methods

SEQ Source Catchment Models estimate annual sediment loads (Section 1.16). The model is built upon a network of nodes throughout the SEQ catchments. Nodes are typically located at the confluence of streams and represent the sediment loads for that sub-catchment. The models are validated using field data collected at 8 catchment loads EHMP sites (Section 1.15). Sediment load in runoff for the node at the end of each Report Card catchments is reported in sediment load (kg/year), and is standardised to the associated catchment area (ha) in sediment yield (kg/year/ha):

$$Total\ Sediment\ yield\ (kg/yr/ha) = \frac{Total\ sediment\ load\ (kg/yr)}{catchment\ area\ (ha)}$$

Score calculation

The scores are standardised by scaling to the range of possible values across the region. Total Sediment yield is assessed against the Best-Case Scenario (BCS) and the Worst-Case Scenario (WCS). BSC is the model node in SEQ with the lowest (10 percentile) sediment yield in SEQ in an average rainfall year (i.e. 2014/15). WCS is the model node in SEQ with the highest (90 percentile) sediment yield in SEQ in an average rainfall year (i.e. 2014/15). The following formula is used:

$$Catchment\ Sediment\ Load\ Indicator = \frac{(Total\ Sediment\ yield\ ) -\ BCS}{(WCS - BCS)}$$

1.7.2 Nitrogen load indicator

Rationale

Nitrogen is derived from natural ecological events such as organic litter fall, weathering and from human sources (e.g. sewage outfalls, adsorbed to sediment runoff from cleared land, fertiliser runoff and industrial and agricultural effluents). Excess nitrogen in our waterways can stimulate the growth of macrophytes and algae (including cyanobacteria) to nuisance proportions. Blooms of these can displace endemic species, diminish light availability to benthic species, and cause excessive fluctuations in pH and DO which can stress and eliminate sensitive species. Biologically available nutrients are precursors to algal blooms, especially when those nutrients are normally limiting.

Data collection methods

SEQ Source Catchment Models estimate annual total nitrogen loads (Section 1.16). The model is built upon a network of nodes throughout the SEQ catchments. Nodes are typically located at the confluence of streams and represent the nitrogen loads for that sub-catchment. The models are validated using field data collected at 8 catchment loads EHMP sites (Section 1.15). Total nitrogen load in runoff for the node at the end of each Report Card catchments is reported in total nitrogen load (kg/year), and is standardised to the associated catchment area (ha) in total nitrogen yield (kg/year/ha):

$$Total\ Nitrogen\ yield\ (kg/yr/ha) = \frac{Total\ nitrogen\ load\ (kg/yr)}{catchment\ area\ (ha)}$$

Score calculation

The scores are standardised by scaling to the range of possible values across the region. Total Nitrogen yield is assessed against the Best-Case Scenario (BCS) and the Worst Case Scenario (WCS). BSC is the model node in SEQ with the lowest (10 percentile) nitrogen yield in SEQ in an average rainfall year (i.e. 2014/15). WCS is the model node in SEQ with the highest (90 percentile) nitrogen yield in SEQ in an average rainfall year (i.e. 2014/15). The following formula is used:

$$Catchment\ Nitrogen\ Load\ Indicator = \frac{(Total\ Nitrogen\ yield\ ) - \ BCS}{(WCS - BCS)}$$

1.7.3 Phosphorus load indicator

Rationale

Phosphorus is derived from natural ecological events such as organic litter fall, weathering, and from human sources (e.g. sewage outfalls, adsorbed to sediment run off from cleared land, fertiliser runoff, and industrial and agricultural effluents). Excess phosphorus in our waterways can stimulate the growth of macrophytes and algae (including cyanobacteria) to nuisance proportions. Blooms of these can displace endemic species, diminish light availability to benthic species, and cause excessive fluctuations in pH and DO which can stress and eliminate sensitive species. Biologically available nutrients are precursors to algal blooms, especially when those nutrients are normally limiting.

Data collection methods

SEQ Source Catchment Models estimate annual total phosphorus loads (Section 1.16). The model is built upon a network of nodes throughout the SEQ catchments. Nodes are typically located at the confluence of streams and represent the phosphorus loads for that sub-catchment. The models are validated using field data collected at 8 catchment loads EHMP sites (Section 1.15). Total phosphorus load in runoff for the node at the end of each Report Card catchments is reported in total phosphorus load (kg/year), and is standardised to the associated catchment area (ha) in total phosphorus yield (kg/year/ha):

$$Total\ Phosphorus\ yield\ (kg/yr/ha) = \frac{Total\ phosphorus\ load\ (kg/yr)}{catchment\ area\ (ha)}$$

Score calculation

The scores are standardised by scaling to the range of possible values across the region. Total Phosphorus yield is assessed against the Best-Case Scenario (BCS) and the Worst-Case Scenario (WCS). BSC is the model node in SEQ with the lowest (10 percentile) phosphorus yield in SEQ in an average rainfall year (i.e. 2014/15). WCS is the model node in SEQ with the highest (90 percentile) phosphorus yield in SEQ in an average rainfall year (i.e. 2014/15). The following formula is used:

$$Catchment\ Phosphorus\ Load\ Indicator = \frac{(Total\ Phosphorus\ yield) - BCS}{(WCS - BCS)}$$

1.8 Estuarine water quality components

Water quality in estuarine and marine areas refers to the physical and chemical properties of the water. The variation and range of water quality influences the types of organisms that will live and grow in an estuary. This component includes 5 indicators:

1. Turbidity.
2. Total nitrogen.
3. Total phosphorus.
4. Dissolved oxygen.
5. Chlorophyll a.

Each of these indicators are further described below. These indicators are monitored and modelled across South-East Queensland at 143 estuarine sites (once per month for eight months per year—February, March, May, August, September, October, November and December) through the Estuarine-Marine EHMP monitoring program as shown in Figure 11 and see Section 1.17 and Section 1.18.

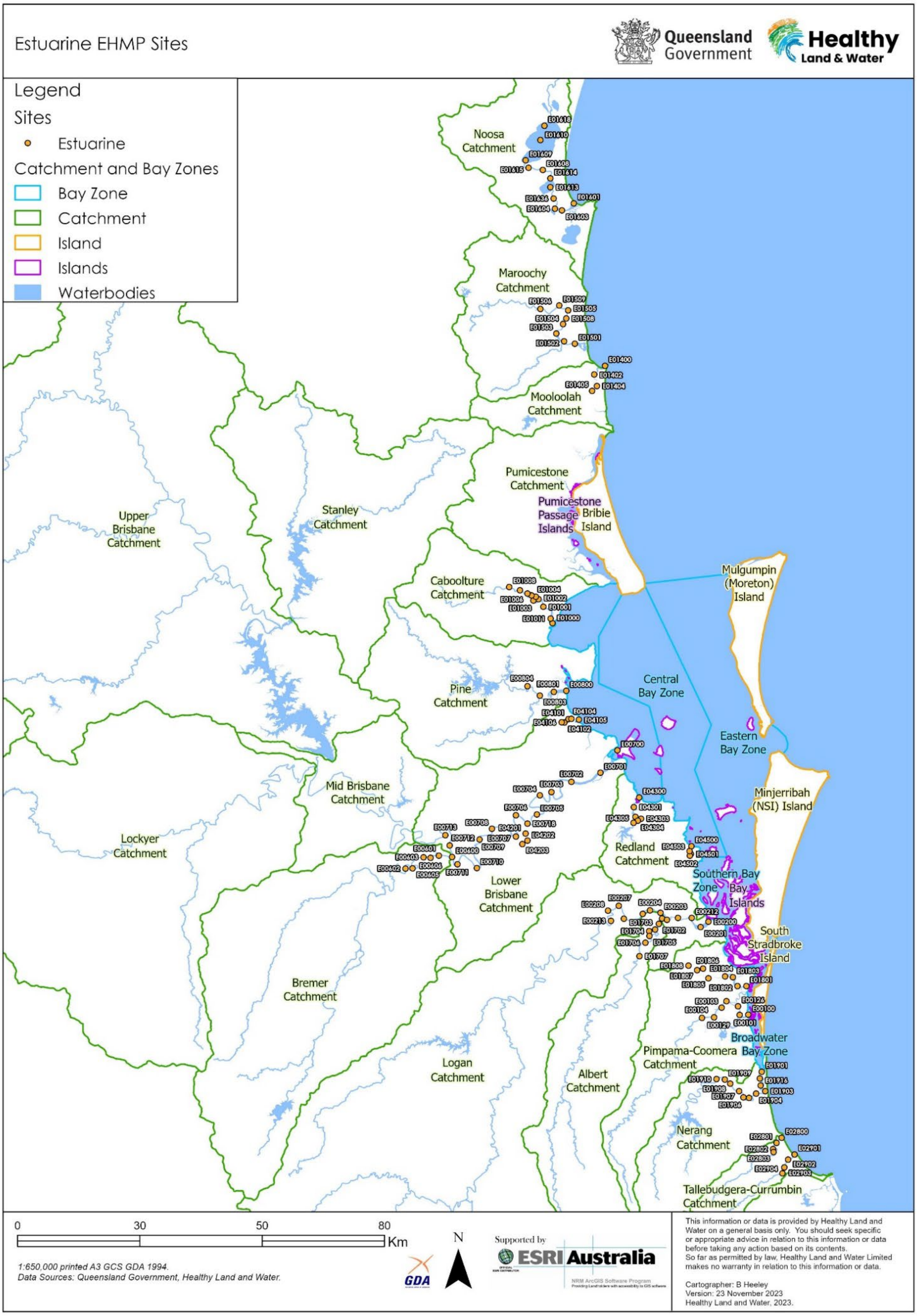

Figure 11: Estuarine EHMP water quality monitoring sites.

1.8.1 Turbidity indicator

Turbidity is the measure of light scattering by suspended particles in the water column, providing an indirect indication of light penetration.

Rationale

Excess amounts of suspended particles can contribute to environmental damage, including reduced light penetration through the water column, smothering of benthic organisms like corals and seagrass, irritation of fish gills and transportation of contaminants. Changes to the availability of light within the water column influence the ability of aquatic plants to photosynthesise. Sediment enters our waterways through erosion and runoff accelerated by catchment alterations. Once in the waterways, fine sediments are readily resuspended by wave and tidal energy.

Data collection methods

Annual medians of turbidity are predicted using the TUFLOW Receiving Water Quality Models (Section 1.18) and validated using turbidity data collected monthly at 143 estuarine EHMP sites (eight months per year only —February, March, May, August, September, October, November and December) (Section 1.17).

In the field, turbidity is measured with a YSI turbidity sensor which forms part of a handheld, portable multi-parameter sonde connected to a data recorder. The turbidity sensor consists of an LED, near infrared light source for illuminating the sample and a photodiode to detect the intensity of light scattered by suspended particles in the water column. The wavelength of light used is between 830 and 890nm as specified by the International Standards Organization (ISO). The photodiode detects scattered light at 900nm from the light source in accordance with ISO standards. The output from the sonde's turbidity sensor is processed by the sonde's software and is recorded in Nephelometric Turbidity Units (NTUs).

Score calculation

The annual medians of turbidity are converted to 'distance from guideline' scores. This involves the use of a static guideline table of ecosystem health guidelines and worst-case scenario values.

1.8.2 Total nitrogen indicator

Nitrogen and phosphorus are nutrients essential to biota in waterways. Specifically, nitrogen is present in animal and plant tissue chiefly as proteins.

Nitrogen is present in waters in both particulate and dissolved forms. Particulate forms include those bound up in living organisms, organic compounds like proteins and those bound to suspended particulate matter like clay and detritus. Dissolved nitrogen may either be inorganic nitrate (NO_{3-}), nitrite (NO_{2-}), ammonia (NH4+) or organic (e.g. urea; dissolved proteins). The EHMP measures dissolved inorganic nitrogen (DIN = NO_{3-} + NO_{2-} + NH4+) and total nitrogen (TN) concentrations (dissolved + particulate forms).

Rationale

Nitrogen is derived from natural ecological events such as oceanic upwelling, litter fall, weathering and from human sources (e.g. sewage outfalls, leaching from cleared land, fertiliser runoff and industrial and agricultural effluents). In a highly populated area like the Moreton Bay catchments, nutrients largely result from wastewater discharges and diffuse urban runoff.

Excess nutrients in our waterways can stimulate the growth of macrophytes and algae (including cyanobacteria) to nuisance proportions. Blooms of these can displace endemic species, diminish light availability to benthic species (e.g. seagrass and coral communities) and cause excessive fluctuations in pH and DO which can stress and eliminate sensitive species.

Healthy Land & Water monitors surface water nutrient concentrations in Moreton Bay to assess the spatial and temporal extent of nutrient loads in the Bay and, determine if biological processes are able to sequester nutrients at the same rate they are being delivered. Biologically available nutrients are precursors to algal blooms, especially when those nutrients are normally limiting. They can be compared with biological indicators like phytoplankton growth, seagrass maximum depth limit and seagrass distribution.

Data collection methods

Annual medians of total nitrogen are predicted using the TUFLOW Receiving Water Quality Models (Section 1.18) and validated using total nitrogen data collected monthly at 143 estuarine EHMP sites (eight months per year only —February, March, May, August, September, October, November and December) (Section 1.17).

Water samples taken from a site are separated into total nutrient samples and soluble nutrient samples. A clean plastic bucket is used to collect the sample. The bucket is cleaned thoroughly before sampling and is rinsed rigorously in sample water at least three times at each site. The sample is taken from just below the surface. Care is taken to keep the bucket free of contaminants from skin and motor exhaust with a lid that is placed on top. Total nutrient samples are poured directly from the bucket into a 250ml plastic bottle. The bottle, including the lid, is rinsed with at least 60ml of sample water at each site before sampling. Soluble nutrient samples are filtered for the determination of FRP and dissolved nitrogen. Water samples are filtered under pressure from a 60ml syringe through a 0.45μm membrane filter. The syringe is rinsed prior to sample collection three times with sample water from the bucket. At sites with large amounts of suspended sediments, a glass fibre pre-filter is used to remove large particles. All samples are transported on ice in a dark insulated container and are placed in a freezer immediately upon return to laboratories.

Total nutrient samples analysed for TN (total nitrogen) and TP (total phosphorus) are oxidised/digested using a simultaneous persulfate procedure at 1210C with an initial pH of 13 and a final pH of about two. If this digestion method does not fully digest all sediment bound nutrients, a Kjeldahl Procedure is used to digest the sample. This method uses a much higher temperature (360°C) with a pH ten times more acidic than that obtained by the persulfate method. Note this technique is particularly used for waters high in particulate matter or refractory compounds that occur from flood conditions. After digestion, analyses for TN and TP are performed using the FIA and photochemical methods (APHA, 1998). TN and TP concentration of each sample is reported in mg/L.

Soluble nutrient samples are analysed for NO_{3-}, NO_{2-}, NH_3 and FRP simultaneously using an automated LACHAT 8000QC flow injection analyser (FIA) using photochemical methods and reported in mg/L.

Score calculation

The annual medians of total nitrogen are converted to 'distance from guideline' scores. This involves the use of a static guideline table of ecosystem health guidelines and worst-case scenario values.

1.8.3 Total phosphorus indicator

Nitrogen and phosphorus are nutrients essential to biota in waterways. Specifically, phosphorus is contained in cell walls and energy transporting molecules.

Phosphorus is present in water in both particulate and dissolved forms. Particulate forms include those incorporated into plant and animal matter, and those bound to suspended particulate matter like clay and detritus. Dissolved phosphorus includes inorganic orthophosphates, polyphosphates, organic colloids and low molecular weight phosphate ethers. The EHMP measures the concentration of total phosphorus (TP) and filterable reactive phosphorus (FRP), which is similar to dissolved phosphorus.

Rationale

See rational for total nitrogen indicator above.

Data collection methods

See methods for total nitrogen indicator above.

Score calculation

See score calculation for total nitrogen indicator above.

1.8.4 Dissolved oxygen indicator

Dissolved oxygen (DO) concentration is a measure of the oxygen in a water body.

Rationale

Many estuarine and marine processes are dependent on the concentration of DO in the water. DO concentration in a water body is affected primarily by the rate of transfer from the atmosphere but also by oxygen-consuming (e.g. respiration) and oxygen-releasing (e.g. photosynthesis) processes. Organic matter, such as sewage effluent or dead plant material that is readily available to microorganisms has the greatest impact on DO concentrations. Microorganisms use water column DO during decomposition of the organic matter. DO concentration in the water column is highly dependent on temperature, salinity and biological activity. Consequently, DO concentrations under natural conditions may change substantially over a 24 hour period.

Variations in DO concentrations may affect many organisms such as fish, invertebrates and microorganisms, which depend upon oxygen for surviving. The oxygen requirements of aquatic organisms vary widely depending on which species, their life stage and different metabolic requirements.

Data collection

Annual medians of dissolved oxygen are predicted using the TUFLOW Receiving Water Quality Models (Section 1.18) and validated using dissolved oxygen data collected monthly at 143 estuarine EHMP sites (eight months per year only —February, March, May, August, September, October, November and December) (Section 1.17).

In the field, DO is measured with a YSI DO sensor which forms part of a handheld multi probe sonde attached to a data recorder. The sensor comprises of a membrane covered Clark-type probe. The probe measures the current associated with the reduction of oxygen as it diffuses across a Teflon membrane that is proportional to the partial pressure of oxygen in the sample. DO is measured as a concentration in mg/L and recalculated using temperature to return percentage saturation (%).

Score calculation

The annual medians of dissolved oxygen are converted to 'distance from guideline' scores. This involves the use of a static guideline table of ecosystem health guidelines and worst-case scenario values.

1.8.5 Chlorophyll a indicator

Chlorophyll a (chl-a) is a pigment found in photosynthetic organisms. It is an essential molecule for the process of photosynthesis (the conversion of light energy to chemical energy resulting in the consumption of carbon dioxide and the production of oxygen). In surface waters, chl-a is present in phytoplankton such as cyanobacteria, diatoms and dinoflagellates. Because chl-a occurs in all phytoplankton, it is commonly used as a measure of phytoplankton biomass.

Rationale

Chlorophyll a is measured as an indicator of phytoplankton biomass. Phytoplankton biomass is largely influenced by the availability of nutrients, light and optimal water temperature. By measuring phytoplankton biomass we are provided with an indication of the nutrient and light conditions present at the time of sampling and their resulting biological effect. Under certain environmental conditions, in particular elevated light and high nutrients, phytoplankton blooms can result. When phytoplankton blooms decay, the resulting bacterial activity can reduce DO concentrations in the water column, possibly leading to fish kills.

Data collection

Annual medians of chlorophyll a are predicted using the TUFLOW Receiving Water Quality Models (Section 1.18) and validated using chlorophyll a data collected monthly at 143 estuarine EHMP sites (eight months per year only —February, March, May, August, September, October, November and December) (Section 1.17).

Phytoplankton is collected in the field by filtering a known volume of water through a Whatman 1µm GFC glass microfibre filter paper. The sample is filtered through the filter paper under suction, with care taken to ensure that the pressure does not exceed half atmospheric pressure. Too much suction can disrupt the chloroplasts within the phytoplankton cells, potentially degrading the chlorophyll.

The amount of water filtered is subject to the level of turbidity at the sampling site. The greater the particulate matter in the water column, the less water can be filtered. Water is filtered until the flow through the filter paper at half atmospheric pressure is reduced to a trickle. The filter paper is then removed and blotted dry to remove excess moisture. The filter paper is placed into a 15ml graduated screw cap polypropylene tube. Each tube contains 0.01g magnesium carbonate which acts as a buffer during the extraction process.

During collection and storage, exposure of the samples to light is avoided. Samples are immediately wrapped in aluminium foil after filtering and placed on ice in a dark, insulated container to lower the sample temperature and prevent chlorophyll degradation. In the laboratory the samples are placed into a freezer for storage before analysis.

Chlorophyll a is then extracted from each sample using the following procedure (developed in accordance with the Standard Methods for the Examination of Water and Wastewater) (APHA, 1998). All tubes are inspected for weaknesses that may allow liquid to leak. 6ml of 90% acetone is added to each sample. Samples are placed in a freezer for 10 to 15 minutes to lower the temperature of the acetone. Samples are removed and macerated using a mechanical tissue grinder at approximately 2000rpm for 20 seconds. Grinding the sample disrupts the cells containing chlorophyll and allows the complete extraction of the pigment. The sample is kept cold during maceration by a chilled water bath below 5°C. 90% acetone is then added to the sample tube to reach a volume of 10ml. Samples are placed back into a freezer for 12 to 24 hours before analysis to allow for full extraction of chlorophyll.

The chlorophyll *a* concentration of each sample is then measured, using the following procedure. Each sample is centrifuged for five minutes at 3900rpm, this ensures that all sediment is concentrated at the base of the tube and allows the supernatant to be decanted from the tube with a relatively low risk of sediment transfer. After centrifugation, the supernatant is transferred into a thoroughly clean glass cuvette. The absorbance of the extract is measured at a wavelength of 663nm, followed by the absorbance at 750nm. This accounts for any absorbance at 663nm that is due to turbidity. Chlorophyll a concentration is then calculated according to the equation stated in the Standard Methods for the Examination of Water and Wastewater (APHA, 1998) and reported in µg/L.

Score calculation

The annual medians of chlorophyll a are converted to 'distance from guideline' scores. This involves the use of a static guideline table of ecosystem health guidelines and worst-case scenario values.

1.8.6 Score calculation

1.8.6.1 Score calculation for all indicators

The estuarine and bay water quality indicators are calculated based on an area-weighted 'distance from guideline' value. The 'distance from guideline' approach is used because it can most sensitively identify changes (improvements or declines) in water quality, regardless of compliance status. This enhances the indicators sensitivity to track changes in response to management intervention.

The calculation of standardised scores for five estuarine and bay water quality indicators involves the the use of a static guideline table of ecosystem health guidelines and worst-case scenario values.

Guideline values and worst-case scenario values

The Queensland Water Quality guideline values used are presented in Table 6 (see SEQ Basins). The guidelines were developed and scheduled in 2010 by Queensland Government. They were derived from empirical data from minimally disturbed reference sites and are typically defined as the 20th and/or 80th percentile. The guideline values are currently under review by the Queensland Government.

Worst case scenario values were derived using EHMP estuarine-marine data between 2000-2015 (Table 6). They were derived from either the 10th and/or 90th percentile of empirical data for all the sites for associated water types.

Water types

Both guideline and worst-case scenario values were derived independently for different water types with similar physical conditions (i.e. water types) so that standardised scores account for the majority of natural spatial variation in the values of each indicator.

The spatial boundary of each water type is defined by the Queensland Government as part of the Environmental Values and Water Quality Objectives scheduling (latest 2022). Maps and associated documents can be found on their website: https://www.ehp.qld.gov.au/water/policy/seq-moretonbay.html. This framework was used to allocate different water types to the Report Card estuaries and bay water quality sites.

Table 6: The Queensland Water Quality guideline and worst-case scenario (WCS) values used for all indicators of the estuarine water quality component.

Water type	Turbidity		Dissolved oxygen		Total Nitrogen		Total Phosphorus		Chl-a	
	Guideline	WCS (0.9)	Guideline	WCS (0.9)	Guideline	WCS (0.9)	Guideline	WCS (0.9)	Guideline	WCS (0.9)
SEQ estuaries (exc. Noosa)										
Enclosed coastal	6	13	90	82.1	0.2	0.5	0.02	0.1	2	5.4
Mid estuary	8	82	85	57.8	0.3	1.3	0.025	0.5	4	12.1
Upper estuary	25	89	80	54.1	0.45	1.5	0.03	0.5	8	18.3
Noosa River estuary										
Enclosed coastal	4	5	90	90.9	0.24	0.29	0.015	0.018	1.8	2
Mid estuary	8	24	85	87.5	0.38	0.51	0.016	0.02	2.5	2.9
Upper estuary	22	56	85	84.4	0.75	0.77	0.02	0.025	5	5.3
SEQ bays										
Pumm Pass Outer	6	13	90	88	0.22	0.35	0.025	0.03	2.6	4.8
Pum Pass Central	10	20	95	82	0.33	0.48	0.023	0.03	4	6
Western Bay	6	16	95	92	0.2	0.32	0.03	0.08	1.6	6.5
Central Bay	5	7	95	94	0.16	0.21	0.02	0.033	1	3
Eastern Bay	1	5	95	95	0.16	0.18	0.016	0.02	1	2
Southern Bay	7	25	95	90.9	0.2	0.32	0.024	0.055	2	5
Broadwater	6	12	90	90	0.19	0.28	0.022	0.03	2.5	3.5

Calculating distance from guideline values

Predicted annual medians of estuarine water quality indicators are converted to a 'distance from guideline' value using the following equation:

$$Distance\ \% \quad = \frac{(Annual\ median\ of\ water\ quality\ indicator\ at\ site) - Guideline}{(WCS - Guideline)}$$

If annual medians fall below guideline levels (i.e. they are compliant) then they are assigned a distance value of '0'. If they fall above WCS levels, they are assigned a distance value of '1'.

Calculating scores values by catchment

Estuarine water quality scores are then calculated by catchment, calculating the average distance value:

$$Water\ quality\ indicator\ score\ = 1 - \Sigma \left| \frac{Distance\ \%}{Area} \right|$$

1.8.6.2 Hydrodynamic & Water Quality Model estimation for five indicator scores

Tuflow-FV-AED2 models are used to estimate the annual median concentration for each indicator (i.e. turbidity, total nitrogen, total phosphorus, dissolved oxygen, chlorophyll a) across major estuaries and the Moreton Bay in SEQ (Section 1.18). Each indicator value is interpolated from its coordinate position (AMTD) towards the next monitoring site position within its estuary or bay. As a result, indicator value in concentrations for each site are interpolated at intervals of every 100 meters within the model boundary. The model is validated with Estuarine Marine EHMP monitoring data collected at 143 estuarine sites and 41 bay sites (Section 1.17).

1.9 Bay water quality components

Water quality in estuarine and marine areas refers to the physical and chemical properties of the water. The variation and range of water quality influences the types of organisms that will live and grow in an estuary. This component includes 4 indicators:

1. Turbidity.
2. Total nitrogen.
3. Total phosphorus.
4. Chlorophyll a.

Each of these indicators are further described below. These indicators are monitored and modelled across South-East Queensland at 41 bay sites (once per month for eight months per year—February, March, May, August, September, October, November and December) through the Estuarine-Marine EHMP monitoring program as shown in Figure 12 and see Section 1.17 and Section 1.18.

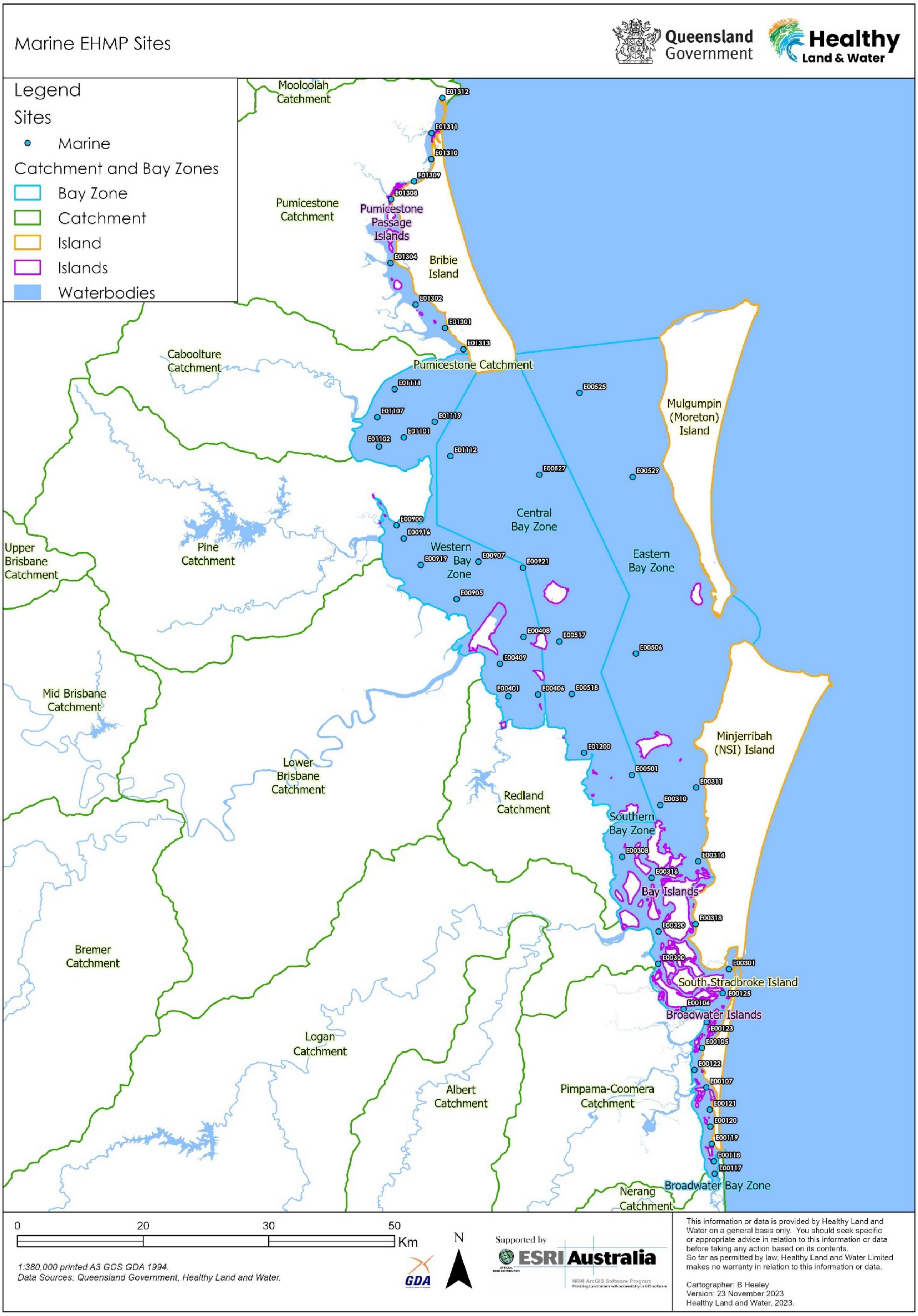

Figure 12: Marine EHMP water quality monitoring sites.

1.9.1 Turbidity indicator

See description for turbidity indicator in **Section *1.8.1*** above.

1.9.2 Total nitrogen indicator

See description for total nitrogen indicator in **Section *1.8.2*** above.

1.9.3 Total phosphorus indicator

See description for total phosphorus indicator in **Section *1.8.3*** above.

1.9.4 Chlorophyll *a* indicator

See description for chlorophyll *a* indicator in **Section *1.8.5*** above.

1.10 Habitat components

The habitat component of the report card scores includes a range of terrestrial, intertidal, aquatic and marine features. Habitats provide a variety of critical functions and services including the provision of habitat for aquatic organisms, coastal protection and bank stabilisation, carbon sequestration and nitrogen processing and removal. A variety of habitat components are reported for each catchment and bay zone. A breakdown of each of the components and the relevant catchment or bay zone types is shown in Figure 13. Each of habitat components are explained in below sections.

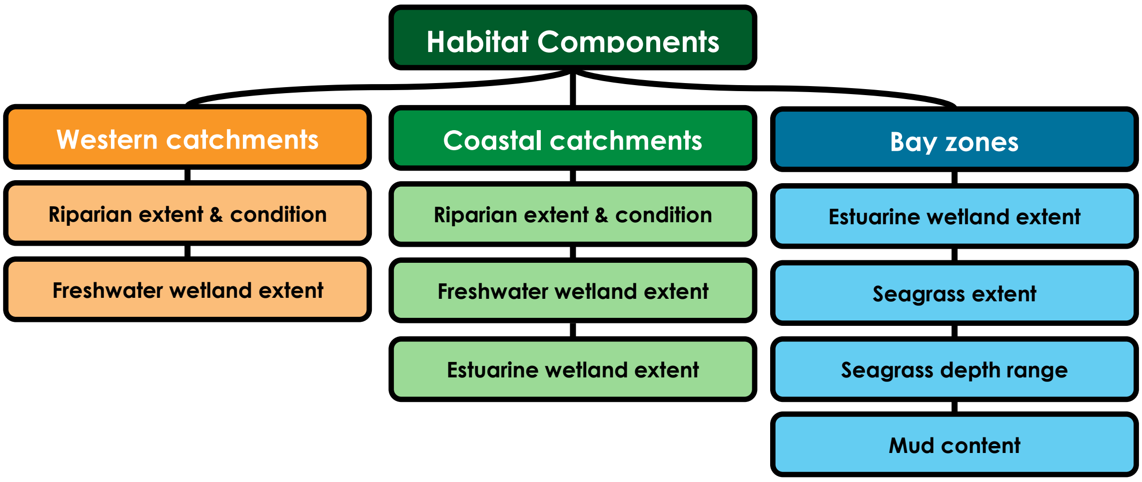

Figure 13: Habitat components relevant to report card zones. To revisit the list of catchments, see **Table 2**.

1.10.1 Riparian extent and condition indicator

Rationale

Riparian vegetation is a critical component of a waterway. It provides habitat for a wide variety of organisms, prevents erosion of riverbanks and act as a filter to minimise sediments and nutrients entering the waterway. Riparian zones are also important wildlife corridors that provide refuges for many land-based organisms as well as providing essential habitat for aquatic species. Removal of riparian habitat reduces biodiversity and productivity of the system and can lead to a reduction in water quality through increased input of sediments and nutrients.

The presence of riparian vegetation also contributes to the social and economic benefits the community derives from waterways. Bushwalkers and wildlife observers all cite the naturalness of waterways as key components of their willingness to travel and pay for their recreational pursuits. Key freshwater habitats are under increasing threat from the physical removal associated with population increases and the increase in pollutant loads from changing catchment land uses.

Data collection methods

Riparian areas of SEQ defined using a 50m buffer zone applied to a combination of topographic drainage line data for streams of order 1 or higher, and riverine or lacustrine wetlands as mapped by the Queensland Wetlands Program (Environmental Protection Agency, 2005; Healy et al., 2022). Indicator statistics were generated at the sub-catchment scale based on the Australian Hydrological Geospatial Fabric (Geofabric).

There are four riparian indicators that form part of the riparian score:

1. Woody vegetation cover excluding non-woody remnant areas.
2. Woody vegetation regrowth within non-remnant areas.
3. Woody remnant vegetation clearing.
4. Median spatial bio condition score.

Score calculation

The sub-indicators are equally weighted; therefore each indicator has a weight of 25%.

The percentage agreement approach to indicator scoring was adopted for all four key indicators. The final score is based on the number of sub-catchments above or below the threshold for each respective catchment for each indicator. See Figure 14 as an example of the percentage agreement approach, where each dot would represent a sub catchment within that catchment where four sub catchments are above the threshold.

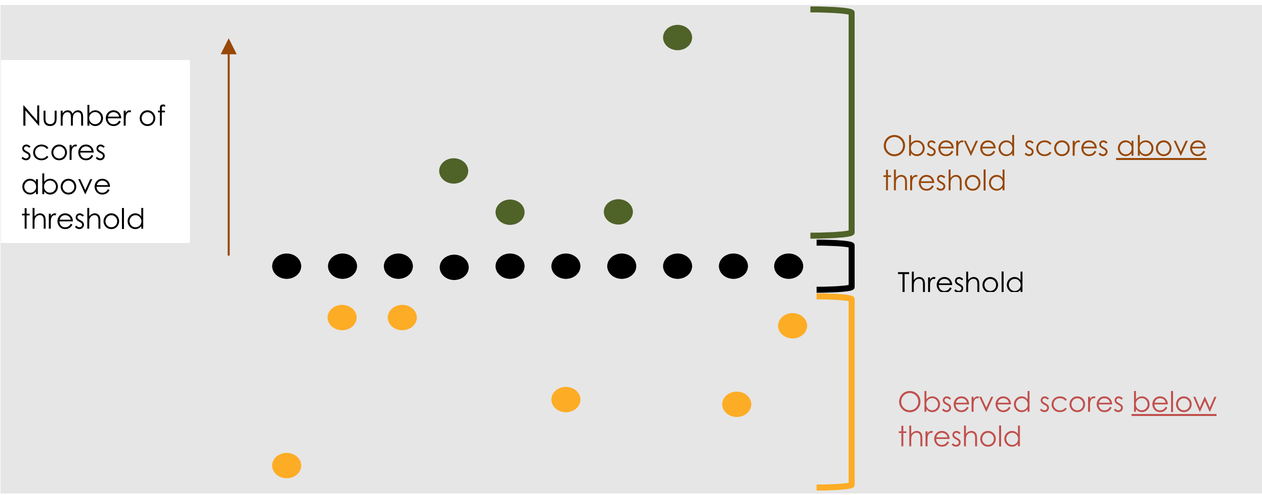

Figure 14: Percentage agreement approach to indicator assessment.

All of the percentage agreement values are then averaged for each catchment to calculate the single riparian score.

1.10.1.1 Riparian woody vegetation cover

Rationale

A decline in the ecosystem health of Australia's Moreton Bay, a Ramsar wetland of international significance, has been attributed to sediments and nutrients derived from catchment sources (Bunn *et al.*, 2007; Leigh *et al.,* 2013). A recent analysis of catchment suspended sediment loads found that sediment yield per unit area from a catchment containing no woody riparian vegetation is predicted to be between five and ten times that of a fully vegetated channel network, with a best estimate of seven times (Olley *et al.*, 2023).

Riparian woody vegetation cover represents the proportion of land-area within the riparian zone mapped as woody vegetation. Riparian woody vegetation extent is estimated by the Queensland Government Department of Environment and Science (DES) using data from the State-wide Landcover and Trees Study (SLATS) (DES, 2018). The extent of woody riparian vegetation is calculated as a percentage of total riparian area. Note that areas of non-woody remnant vegetation have been excluded from the calculations of this indicator.

Score calculation

The indicator was evaluated using the percentage agreement approach and a threshold of 80% for all catchments (Olley *et al.,* 2023).

1.10.1.2 Riparian woody vegetation re-growth

Rationale

Re-growth of woody vegetation following disturbance within riparian areas assists in the restoration of catchments. Re-growth areas may represent both areas under active restoration that include riparian vegetation planting and threat management activities or those undergoing natural regeneration.

This indicator represents the rate of riparian woody regrowth within areas mapped as non-remnant. As part of the SLATS dataset series, DES map woody vegetation change which includes areas of woody regrowth. The extent of regrowth within non-remnant areas is calculated as a percentage of total non-remnant riparian areas.

Score calculation

This indicator was evaluated using the percentage agreement approach and a threshold of >0% for all catchments. Due to the minimal number of sub-catchments where woody vegetation regrowth is occurring the data was scaled using the standard Report Card scoring approach.

1.10.1.3 Remnant riparian woody loss by land-clearing

Rationale

Clearing of both remanent and re-growth vegetation is a key threat to riparian ecosystems and associated freshwater habitats.

This indicator represents the rate of riparian remanent woody vegetation loss by land-clearing. As part of the SLATS dataset series DES map woody vegetation change which includes areas of woody clearing. The extent of clearing within remnant areas is calculated as a percentage of total non-remnant riparian areas.

Score calculation

This indicator was evaluated using the percentage agreement approach and a threshold of 0% for all catchments. Due to the minimal number of sub-catchments where clearing of remnant areas is occurring, the data was scaled using the standard Report Card scoring approach.

1.10.1.4 Median Spatial Bio Condition score

Rationale

The spatial bio condition dataset maps the predicted condition of vegetated terrestrial ecosystems to describe their biodiversity. This indicator measures the relative capacity of ecosystems to support species expected to occur in undisturbed reference sites (DES 2021). Therefore, this indicator represents the biodiversity perspective of riparian condition.

Score calculation

This indicator was assessed using the median value for the riparian zone within each sub-catchment. The median value was selected as there was a skewed distribution of pixel values within south-east Queensland. This indicator was evaluated using the percentage agreement approach and a threshold of 0.6 for all catchments. This threshold was selected as according to the bio condition classes, values of 0.6-1 include advanced regrowth and good quality remnant vegetation whereas values 0-0.6 are non-remnant with attributes significantly below the benchmark (DES 2021).

1.10.2 Wetland extent indicator

Rationale

Wetlands are critical components of coastlines, waterways and landscapes. They provide habitat for a wide variety of organisms, prevent erosion and act as a filter to minimise sediments and nutrients entering waterways. They are important habitat corridors that provide refuges for many organisms as well as providing essential habitat.

The presence of wetlands also contributes to the social and economic benefits the community derives from waterways. Bushwalkers and wildlife observers all cite the naturalness of waterways as key components of their willingness to travel and pay for their recreational pursuits. Key wetland habitats are under increasing threat from the physical removal associated with population increases and the increase in pollutant loads from changing catchment land uses.

Data collection methods

Freshwater and estuarine wetland extents are calculated every four years, with data derived from the Department of Environment and Heritage Wetland Info program. Extent values are standardised to calculate a catchment score. The Queensland Wetlands Program, established in 2003 by the Australian and Queensland governments supports projects and programs that enhance the use and sustainable management of Queensland's wetlands. The Program routinely maps wetland extent and type, with datasets available for 200*1, 2005, 2009, 2013, 2017 and 2019*. Details of methods are provided in the Department of Environment and Science's Wetland Mapping and Classification Methodology.

The wetland extent indicator used in the Report Card is a summary of data from Queensland Wetlands Program. This indicator uses the following wetland types as indicators where relevant for that catchment type (see Figure 13):

- Freshwater: vegetated freshwater swamp (palustrine) systems which are wetlands with more than 30% emergent vegetation cover, or waterbodies less than eight hectares and less than two metres deep. Note that lacustrine and riverine wetlands are not included in the wetland indicator as they are covered under the riparian indicator.

- Estuarine: intertidal areas are periodically inundated by sea water, dominated by salt tolerant vegetation including mangroves, salt flat or salt marsh communities. Coastal waters that are also components of the estuarine wetland system were not included in the analysis.

The results do not include artificial, highly modified, or slightly modified wetlands, such as those converted to cane paddocks or lacustrine wetlands formed by dams across stream channels.

Score calculation

The current area of each wetland type for each catchment is converted to a ratio of pre-cleared wetland area using the following formula:

$$Weltand\ ratio = \frac{Current\ wetland\ area}{Pre - cleared\ wetland\ area}$$

The ratio is then be scaled to the range of possible data across the region using the following formula.

$$Wetland\ habitat\ extent\ indicator\ = 1 - \left|\frac{(Wetland\ ratio - \ BCS)}{(BCS - WCS)}\right|$$

Where BCS (Best Case Scenario) is the catchment with the highest catchment wetland ratio and WCS (Worst Case Scenario) is the catchment with the lowest catchment wetland ratio.

1.10.3 Seagrass depth range indicator

Rationale

Seagrass is a critical component of coastal ecosystems. It increases primary productivity, supports complex food webs, provides habitat for numerous species including fish, prawns and other invertebrates, provides sea floor stability and filtering sediments and nutrients.

The most common factor leading to seagrass loss is an increase in suspended sediments from terrestrial inputs and sediment resuspension leading to a long-term reduction in light.

The seagrass depth range (SDR) is the difference in elevation (meters) between the upper and lower depth record of the seagrass *Zostera muelleri* at a site. The SDR as an indicator of ecosystem health is based on the assumption that the shallow distributional limit of seagrass is determined by the tolerance of the seagrass to desiccation at low tide and that the deeper the distributional limit is determined by light availability.

The SDR provides an indication of water clarity at a site, as the depth to which seagrass can grow is directly dependent on the penetration of light through the water. By regularly measuring the depth range, the effect of temporal changes in water quality on seagrass meadows can be inferred. This provides the EHMP with link between change in water quality through Moreton Bay and the effects it has on biological systems.

Data collection methods

Seagrass depth range is measured at 18 sites bi-annually by the monitoring program. *Zostera muelleri* is used as the indicator species, as it is the most abundant seagrass in Moreton Bay. It has minimal seasonal variation in distribution and responds to changes in light availability. Contingency monitoring can also occur in response to a major environmental event (e.g. flood or algal bloom). The presence of other seagrass species, macroalgae (e.g. *Caulerpa taxifolia*) and the toxic cyanobacterium *Lyngbya majuscula* is noted along the transect, as well as geomorphological features such as sandbars, deep holes and evidence of disturbance (bait worming holes, propeller scars etc).

To measure the depth range, Figure 15 demonstrates a simplified illustrated diagram of how SDR is calculated:

- Height elevations are recorded in Australian Heigh Datum (AHD) using Real Time Kinematic (RTK) Global Navigation Satellite Systems (GNSS) and a handheld Leica datalogger. RTK units reference their own position relative to local base stations and satellites and are periodically serviced and checked for their accuracy on recorded known Permanent Survey Marks (PSM).
- The depth range and general profile of the seagrass bed is determined along a main transect using RTK surveying techniques. Ten replicate transects, approximately 10m apart, five on either side of the main transect, are surveyed to record the upper and lower distributional limits. Percentage seagrass and algal cover is assessed and recorded at these distribution limits and various locations along the main transect. The RTK unit is checked for accuracy during seagrass assessment periods on PSM.
- At deeper sites and during flood conditions, a video camera system is used to assess the seaward Zostera extent. The RTK is then used on the camera assesses transect replicates to record AHD elevation for the SDR calculation.

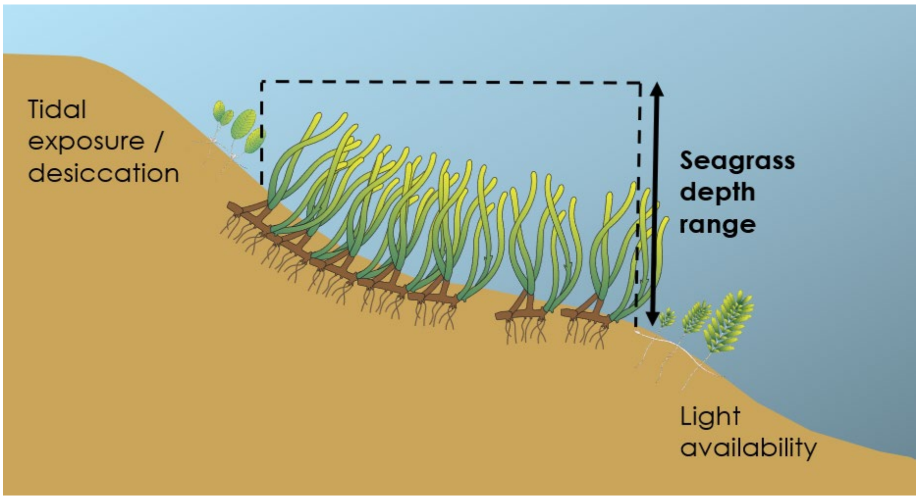

Figure 15: Schematic diagram illustrating how seagrass depth range is measured for the Report Card noting that only *Zostera muelleri* is used as the indicator species.

Score calculation

The seagrass depth range indicator for each Bay zone is calculated using guideline and worst-case scenario values (WCS) for each Bay zone (see below). The minimum value for each zone between 1999 and 2023 is considered the WCS. The guideline value is derived from water quality guidelines (DES 2022).

$$\boldsymbol{Seagrass\ depth\ range\ indicator} = \mathbf{1} - \left|\frac{(\boldsymbol{Seagrass\ depth\ range} - \boldsymbol{Guideline})}{(\boldsymbol{WCS} - \boldsymbol{Guideline})}\right|$$

The guidelines for different bay zones are shown in Table 7.

Table 7: The Queensland Water Quality (seagrass) guideline used for Seagrass depth range indicator based on DES 2022

Location	Guideline (m AHD)
Bramble Bay and Southern Deception Bay	1.9
Central Bay	2.2
Deception Bay	3
North Pumicestone	0.8
South Pumicestone	1.2
Southern Bay	1.3

1.10.4 Seagrass extent indicator

Seagrass extent is measured approximately every three years using a combination of field sampling and remote sensing. Field data is collected through the monitoring program and by citizen science groups. Seagrass extent is expressed as the percentage of seagrass present compared to the 2004 map of seagrass extent in Moreton Bay.

*This is the proposed methodology for future Reports Cards, another temporary methodology is currently being used based on a categorisation approach.

Data collection methods

The extent of seagrass is measured in Moreton Bay using a combination of field sampling and remote sensing. Field sampling is used to calibrate images taken from the satellite imagery. It is also used as the primary sampling technique in the more turbid or deeper areas of the bay where satellite imagery doesn't penetrate the water column. Field sampling is conducted by the Queensland Government Department of Environment and Science (DES) and Healthy Land & Water with Earth Watch volunteers. The remote sensing component is conducted by the University of Queensland (UQ) Biophysical Remote Sensing Group. Both field sampling and the remote sensing methods follow the techniques outlined in Kovacs *et al.* (2022). Seagrass extent is proposed to be assessed every three years.

The seagrass extent for a sampling year for each relevant reporting area is expressed as the percentage of seagrass present compared to the 2004 map of seagrass extent in Moreton Bay, using the following formula:

$$Seagrass\ ratio = \frac{Current\ seagrass\ area}{2004\ seagrass\ area}$$

Score calculation

The ratio for each zone will then be scaled to the range of possible data across the region using the following formula.

$$\boldsymbol{Seagrass\ habitat\ indicator} = \mathbf{1} - \left|\frac{(\boldsymbol{Seagrass\ ratio} - \boldsymbol{BCS})}{(\boldsymbol{BCS} - \boldsymbol{WCS})}\right|$$

1.10.5 Mud content indicator

Rationale

The characteristics of sediments within bay and estuarine environments have a strong influence on the distribution and abundance of aquatic organisms and overall ecosystem function. Sediments in Moreton Bay are comprised of terrestrial sediments including mud and sand delivered via rivers, biogenic sediments produced by marine organisms such as oysters and coral and marine quartzose sands transported via the tidal deltas.

Fine sediment or 'mud' is transported to the Bay episodically during flood events. Mud can smother sandy habitats and bring pollutants to the Bay such as metals, hydrocarbons, pesticides and nutrients. The resuspension of mud by tidal currents and wave action can also increase water column turbidity, decreasing light availability on the seafloor. This affects the distribution and condition of seagrass and other photosynthetic organisms in the Bay.

Since the 1970's, the area of mud within the bay has increased substantially. The expansion corresponds to an increase in the rate of supply of fine sediments to the Bay as a consequence of historical and ongoing land use changes in the catchment. This has resulted in the historical loss of seagrass and oyster reefs in some areas of the Bay. Routine monitoring of sediment types within the Bay supports our understanding of trends in the distribution and remobilisation of sediments, including the impacts and recovery from floods.

Data collection methods

Bottom sediments have been routinely collected (every four years) in Moreton Bay, the Gold Coast Broad Water and Pumicestone Passage since 2011. In 2015, sampling increased to include 223 sites (

Figure **16**). Sediments are collected using an Ekman Grab sampler. Grain size is measured using a laser diffraction particle size analyser. Since 2019, a penetrometer has also been used to estimate the distribution and volume of unconsolidated sediments in the Bay. Key outputs of this monitoring campaign include particle size distribution by site, mud content by site (%), mud extent (km^2), mud penetration depth (m) and deposit characterisation (consolidated, layered, unconsolidated).

The spatial extent (km^2) of sediment types (clean sand, sand, muddy sand, sandy mud, mud) is estimated using interpolation in ARC GIS. The extent of each sediment type is determined by inverse distance weighted interpolation to the power of four of the percent mud at each site. Areas with mud fractions of 50% or higher are then summed to determine total surface area of mud, which includes sandy mud and mud. This allows for estimates of the trends in the extent (expansion/contraction) of mud to be derived.

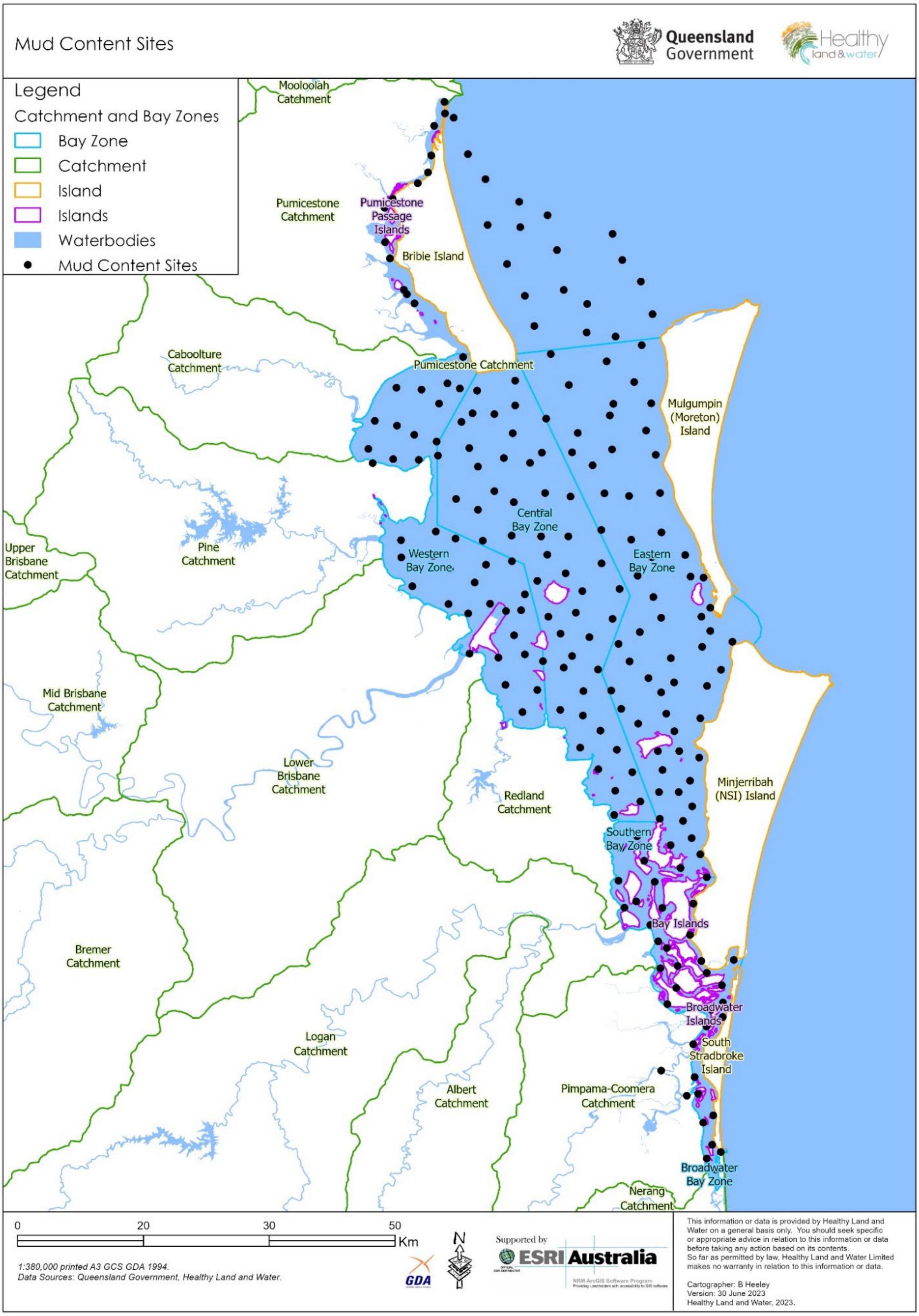

Figure 16: Mud content indicator site locations following expanded field sampling campaign (2015-–present).

Score calculation

The annual mud score for individual Bay regions is calculated based on the percentage of change of average sediment mud content from the Worst-Case Scenario (WCS).

$$\boldsymbol{Mud\ content\ indicator = 1 - \left|\frac{(Average\ \%\ change\ in\ mud\ content\ from\ WCS\ by\ reporting\ zone)}{(100)}\right|}$$

2015 is considered the Worst-Case Scenario. In 2011 and 2013 major floods delivered large quantities of mud to Moreton Bay. The distribution of mud in Moreton Bay surveyed in 2015 reflects the high fine sediment loads of in 2011 and 2013 and subsequent accumulation in the Bay.

Waterways benefits ratings

This section provides a definition and rationale for each indicator used to calculate the Waterways benefit rating. It also describes the methodology for regional data collection and score calculation for each indicator.

Note that in some cases, an index is made up of more than one indicator (see summary table in Appendix 0) If an index has multiple indicators, the score is generally calculated by averaging across all indicators within the index.

1.11 Core questions

Waterways provide important benefits such as clean and safe drinking water, nursery habitats for recreational and commercial fishing and a reliable water source for agricultural productivity. Recreation activities in and around waterways help to improve physical health and wellbeing and contribute approximately $5 billion to the region's economy annually. (Note: $5 Billion estimate calculated from the social survey - value of recreation x number of SEQ residents)

1.11.1 Social benefit to community

The level of social benefit a waterway provides the local community reflects two things:

- The community's willingness and ability to continue using local waterways and experience the associated mental health, physical health and cultural benefits.
- The community's willingness and ability to support and participate in activities that improve the condition of local waterways.

Indices

The purpose of including the social indicators in the Report Card is to help encourage individuals, industry, communities of practice and governments to act in ways that improve or sustain the condition of catchments and the services they provide.

We measure four indicators of social benefit which have been included to help managers identify the elements of communities in each catchment that facilitate action (

Figure **17**).

These include:

1. Satisfaction with experience of local waterways.
2. Usability and accessibility.

3. Personal benefits.
4. Connection with nature and waterways.

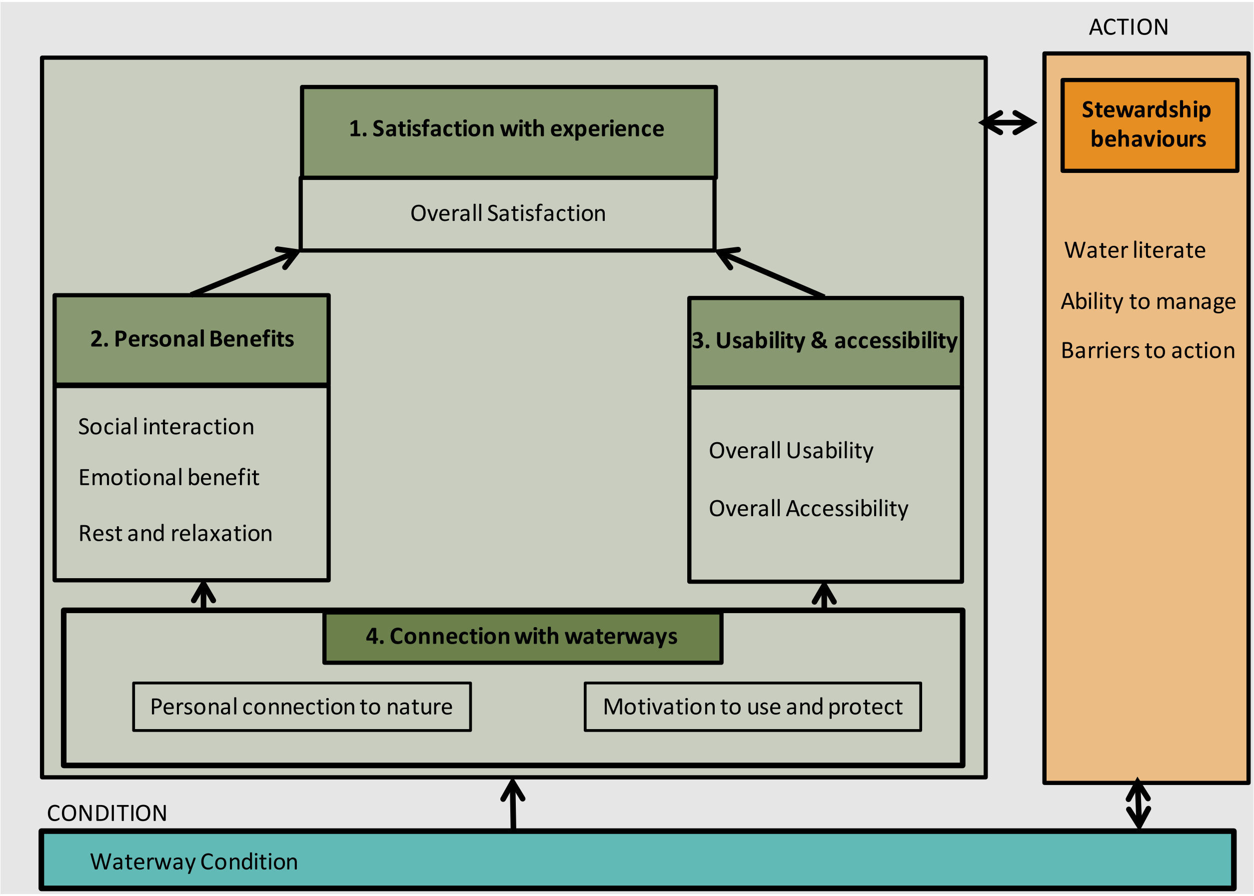

Figure 17: Framework for the four social benefit indices used in the Report Card.

Data collection and scoring

A community survey of South-East Queensland residents is carried out annually. This provides a representative subsample of the population within each reporting zone. The survey is administered through a 15-minute online survey hosted by University of Queensland. Survey respondents are recruited using two methods being, via a panel and a social media survey. Recruited respondents are adults (18+) living in South-East Queensland. Annually the survey receives over 3000 responses. Their responses are then used to calculate indicator scores as the percentage of survey respondents within a catchment who positively report satisfaction with the experience, personal benefits derived from waterways, satisfaction with usability and accessibility of local waterways, and connection with waterways.

1.11.1.1 Satisfaction with experience index

Definition

This index measures the community's satisfaction with their experiences of the local waterways. Satisfaction indicates the extent to which local waterways are delivering benefits that the community want and expect.

The satisfaction a person derives from waterways is the positive emotional state they gain directly from the use of waterways. Individual satisfaction with our waterways is a measure of the extent to which our actual use of waterways meets our desired use of a waterway. People are more satisfied with waterways when they can use waterways in ways to ensure they receive the expected benefits from that use.

For example, a commercial fisher will likely be satisfied only if an adequate amount of their target species is caught. A recreational fisher, however, may be satisfied even if no fish are caught, if the experience allowed them to relax or spend time with family or friends. Alternatively, dissatisfaction occurs when an expectation is not met.

Rationale

Satisfaction can be gained from a visit to or particular use of a waterway. The collective experiences of people using particular waterways can provide a measure of the overall community satisfaction with that waterway.

Managers can use a measure of satisfaction to identify priority areas to increase community understanding regarding the expected use of waterways while improving the attributes of the waterway that facilitate that use (ability to use).

People that are satisfied with waterway experiences will continue to use waterways for that purpose, maximising the multiple benefits they can derive. Satisfaction also indicates the likelihood that a particular use will be maintained or increased, or whether it may be a one-off activity.

Other benefits associated with increased satisfaction include return visits to particular waterways. This may improve personal mental and physical health, or a closer attachment to a place or cultural experience. It may also be a community impact such as improved social cohesion. Increased satisfaction may also drive increased willingness or ability to undertake stewardship behaviours.

Data collection methods

In the Healthy Land & Water Community Benefits Survey, facilitated by the University of Queensland (see section 1.23), people are asked to indicate their overall satisfaction with local waterways on a seven-point Likert scale, ranging from "Strongly disagree" (=1) to "Strongly agree" (=7). The construct 'Overall satisfaction' is used, and this is made up of four survey statements/questions:

Overall Satisfaction:

1. Overall, I am satisfied with my local waterways.
2. My local waterways are close to my ideal.
3. I am delighted with my experiences with my local waterways.
4. I am very satisfied with my decisions to use/visit my local waterways.

Score calculation

The steps are:

1. For each respondent, calculate their construct means = (Question1+Question2+Question3+Question4)/4.
2. For each catchment, calculate the % of respondents whose construct mean value were equal to or above 4.5.

This calculation results in a ratio, which becomes the score (between 0 and 1). No standardisation is performed on this indicator.

1.11.1.2 Usability and accessibility index

Definition

The community's perception of how usable and accessible their local waterways are. Individual's perceptions of usability relate to how much effort it takes people to interact with waterways. Accessibility refers to people's perceptions of how easy of difficult it is to access waterways for their desired use of them. This is significant as using waterways provides mental health, physical health, and cultural benefits to the community.

Rationale

The degree to which waterways are useable will influence the amount of social and economic benefits people derive from them. Recreating in and around waterways can improve our physical and mental health and our social cohesion by providing places for people to come together (e.g., at riverside parks). Measuring useability can also help to identify the catchments where waterway condition, perceptions of safety or other enabling factors reduce useability of waterways.

Useability of waterways will ultimately affect the rate of use of waterways within the catchment. Waterway useability is affected by available infrastructure (e.g. boat ramps, bike paths), as well as being strongly related to waterway condition. As a proxy, monitoring 'ability to use' captures the physical attributes of waterways that inhibit or enable use of waterways and their associated benefits.

Interaction with nature can affect health and wellbeing, through the pathways of air quality, physical activity, social contacts, and stress. The outcomes of this effect will be dependent upon the type of recreational use as well as the type of waterway where the recreational use occurs.

Data collection

In the Healthy Land & Water Community Benefits Survey (section 1.23) people were asked to indicate their satisfaction with the usability and accessibility of local waterways on a seven-point Likert scale, ranging from "Strongly disagree" (=1) to "Strongly agree" (=7). Two constructs made up of four questions each is used:

Overall Usability:

1. I get a lot out of using my local waterways.
2. I find my local waterways easy to use.
3. It doesn't take much effort to use my local waterways.
4. I would like to use my local waterways more often.

Overall Accessibility:

1. I find it easy to access my local waterways.
2. Accessing my local waterways is simple.
3. It is fairly straightforward to get to my local waterways.
4. My local waterways are easy to access.

Score calculation

The steps are:

1. For each respondent, calculate their construct means = (Question1+Question2+Question3+Question4)/4.
2. For each catchment, calculate the % of respondents whose construct mean value were equal to or above 4.5.
3. For each catchment, calculate the indicator scores = (Construct1+Construct2)/2.

This calculation results in a ratio, which becomes the score (between 0 and 1). No standardisation is performed on this indicator.

1.11.1.3 Connection with waterways index

Definition

The level of personal connection the local community has with nature. Communities with high levels of connection tend to be more motivated to use and protect waterways and do gain psychological benefit from doing so.

Rationale

Connection to waterways and natural environments is an important component of physical and mental health. Health and wellbeing are increased with exposure to local waterways through enhanced opportunities for exercise and increased sense of place and strengthened cultural ties and social connection. In addition, communities are more likely to act to manage and revitalise waterways when there is a high degree of connectedness with, and value of waterways.

Data collection

In the Healthy Land & Water Community Benefits Survey (Section 1.23) people were asked to indicate their level of connection with their local waterways on a seven-point Likert scale, ranging from "Strongly disagree" (=1) to "Strongly agree" (=7). Two constructs made up of three–four questions are used:

Motivation to use and protect waterways (previous called "Integrated regulation"):

1. Using local waterways is part of the way I have chosen to live my life.
2. Using local waterways is a fundamental part of who I am.
3. Using local waterways is an integral part of my life.

Personal Connection to Nature (previously called "Nature relatedness"):

1. I always think about how my actions affect the environment.
2. I take notice of wildlife wherever I am.
3. My relationship to nature is an important part of who I am.
4. I feel very connected to all living things and the earth.

Score calculation

The steps are:

1. For each respondent, calculate their construct means = (Question1+Question2+Question3)/3 or (Question1+Question2+Question3+Question4)/4
2. For each catchment, calculate the % of respondent construct means that were equal to or above 4.5.
3. For each catchment, calculate the indicator scores = (Construct1+Construct2)/2.

This calculation results in a ratio, which becomes the score (between 0 and 1). No standardisation is performed on this indicator.

1.11.1.4 Personal Benefits index

Definition

The level of personal benefits local residents gains from using their waterways. Personal benefits arise when waterways act as a place of rest and relaxation, a place to socialise with friends and family, or a place from which they derive a positive emotional benefit.

Rationale

Having a local place in nature to socialise with friends and family and for rest and relaxation is a key component of physical and mental health. It contributes to having an increased sense of place and strengthened cultural ties and social connection. Communities are more likely to act to manage and revitalise waterways when there is a high degree of value and personal benefits associated with their waterways.

Data collection

In the Healthy Land & Water's Community benefit Survey (section 1.23) people were asked to indicate the level of personal benefits they get from their local waterways on a seven-point Likert scale, ranging from "Strongly disagree" (=1) to "Strongly agree" (=7). Three constructs made up of four questions are used:

Social interaction and connection (previously called "Social value"):

1. I am happy when I visit or use local waterways with my friends.
2. I find using my local waterways more interesting when my friends are with me.
3. It is more interesting to use my local waterway as part of a group.
4. Social outings at my local waterways make them more interesting.

Emotional benefit (previously called "Fascination"):

1. My local waterways have fascinating features.
2. There is a lot to explore and discover at my local waterways.
3. My local waterways are exciting.
4. My local waterways are fascinating.

Rest and relaxation (previously called "Being-away"):

1. Spending time using my local waterways gives me a break from my day-to-day routine.
2. My local waterways are a place to get away from it all.
3. Using my local waterways helps me to relax.
4. Using my local waterways helps me to get relief from everyday stress.

Score calculation

The steps are:

1. For each respondent, calculate their construct means = (Question1+Question2+Question3+Question4)/4.
2. For each catchment, calculate the % of respondents whose construct mean value were equal to or above 4.5.
3. For each catchment, calculate the indicator scores = (Construct1+Construct2+Construct3)/3.

This calculation results in a ratio, which becomes the score (between 0 and 1). No standardisation is performed on this indicator.

1.11.2 Economic benefit to community

Waterways have the capacity to provide significant economic benefits to the local community. For example, the frequency of visits and type of recreation carried out on and beside waterways has an economic value to the community.

In addition, the amount of sludge treated in the production of drinking water reflects the quality of water entering a drinking water treatment plant, and therefore the economic value of a drinking water catchment to the community who derive benefit from it.

Indices

- Drinking water value (N/A for non-drinking water catchments).
- Water-based recreation value.

Data collection and scoring

Drinking water value is calculated annually using Seqwater sludge data based on kg/ML removed for each Water Treatment Plant (WTP).

The amount of water-based recreation carried out over the year is estimated using data from the annual Community Benefits survey of South-East Queensland residents (described above). The dollar value is calculated by multiplying the frequency of each recreational activity by an estimate of its value. The value of the activities has been derived from the literature.

1.11.2.1 Drinking water treatment index

Definition

Clean drinking water is essential for supporting the health and quality of life of the SEQ community. Drinking water is collected from many of the catchments in the region and chemically treated to remove pathogens, sediments, and unusual tastes and odours in water treatment plants. The quality of the water that enters the treatment plants is a function of the ability of the catchment to reduce the pollutant loads. This function lowers the quantity of chemicals required to treat the water and the alum sludge by-product produced, which is costly to manage.

Rationale

Minimising the cost of drinking water in the face of increasing supply and demand and, increasing pressures on catchment areas is a priority to ensure the ongoing health of the community.

The Australian Drinking Water Guidelines (NHMRC 2011) states that, "The most effective means of assuring drinking water quality and the protection of public health is through adoption of a preventive management approach that encompasses all steps in water production from catchment to consumer." The guidelines recognise that the first barrier to clean drinking water is the condition of the catchment. This indicator measures the contribution that each catchment has to minimising the costs of managing and disposing alum sludge, a bioproduct of delivering safe drinking water. Healthy Land & Water will work closely with Seqwater to ensure that it is in alignment with the considerable work they have completed in recent years in this field.

Data collection

Seqwater is legislatively required to report the quantity of alum sludge generated to the National Pollution Inventory and Queensland Waste Data System for each Water Treatment Plant (WTP). This varies as the volume of water supplied varies, as distinct from capital costs which remain fixed even though water supply volume changes. For the purpose of this indicator, the quantity of alum sludge produced, being weighed dry tonnes, per quantity of treated drinking water produced for each WTP has been used.

Data from Seqwater indicates that the amount of sludge produced from catchments in poor condition is generally higher than those in good condition. The quantity of alum sludge by-product per megalitre of drinking water produced (kg/ML) can therefore serve as a proxy for the water quality entering the plant. Multiple years of alum sludge production per megalitre of water is available. The data from 2013–2023 for all Seqwater water treatment plants has been used to calculate the best-case scenario and worst-case scenario. To calculate these the 90th percentile of this data was used to establish worst-case scenario, and the best-case scenario is based on the 10th percentile of alum sludge production per megalitre of water.

The quantity of sludge produce per WTP is calculated using the following equation:

$$Sludge\ Produced\ (kg/ML) = \frac{Wet\ Sludge\ (T)}{Water\ Produced\ (ML)} x\ 1000$$

Annual sludge production (kg/ML) is calculated for the reporting year. This value is then used to calculate a four-year rolling average sludge production value for scoring. This is done to minimise inter-yearly variability, as full sludge removal usually occurs every 3–4 years. High variability in sludge produced was leading to high variability in scores from year to year. This method was therefore adopted to try and minimise this variability.

WTPs which produce less sludge per megalitre of water indicates that less chemical treatment is required per ML to supply drinking water. This implies that water quality in that catchment is delivering a higher benefit to society. In theory, residents should pay less for drinking water which is sourced from catchments in good condition as the cost of treatment and alum sludge disposal is lower. This delivers a financial benefit to the community.

Score calculation

The Best-Case Scenario (BCS) assumes minimal alum treatment is required to produce drinking water at a WTP and therefore generates little sludge. This indicates that raw water delivered from the catchment is of suitable quality for drinking with little treatment. This is expressed as a score which is calculated using the following equation:

$$Drinking\ Water\ Index \quad = 1 - \frac{(Sludge\ Produced\ (kg/ML) - BCS)}{(WCS - BCS)}$$

The closer the score is to 1, the greater the benefit received from catchment water quality.

Not all catchments have a WTP and therefore not every catchment receives a drinking water score. The allocation of each WTP to a catchment is based on the catchment which provides the source water for the WTP. A catchment can therefore have multiple WTP allocated to that catchment for scoring purposes.

1.11.2.2 Water based recreation index

Definition

Waterways are used for multiple recreational activities:

- Boating and sailing.
- Walking, cycling, or running.
- Picnics and BBQs.
- Recreational fishing.
- Rowing, kayaking, and canoeing.
- Scuba diving and snorkelling.
- Surfing, kite-surfing and sail boarding.
- Swimming.
- Enjoying nature e.g. birdwatching, conservation, photography and camping.
- Recreational fishing.

Rationale

Recreation in an around waterways is very popular in South-East Queensland, providing an economic benefit to the community generated through expenditure. Moreton Bay, freshwater reservoirs, creeks, and estuaries in South-East Queensland provide a substantial diversity in recreational opportunities which generates significant revenue to the local economy.

Methods

The ability of a catchment/waterway to contribute an economic benefit relies on two aspects:

1. The number of people visiting/using a waterway.
2. The costs associated with accessing the waterway to undertake a specific activity.

In the Healthy Land & Water Community Benefit Survey (section 1.23) people were asked to select their preferred type and frequency of recreational pursuits in and around waterways. Specifically, the survey question was:

How often do you use South East Queensland's waterways for the following purposes? Almost every day/ every week/ every month/ once or twice a year/every few years/never.

- Boating, sailing.
- Walking, cycling, or running.
- Picnics, BBQs.
- Recreational fishing.
- Rowing, kayaking, canoeing.
- Scuba diving, snorkelling.
- Surfing, kite-surfing, sail boarding.
- Swimming.
- Enjoying nature e.g. birdwatching, conservation, photography, camping.

Response to this question was used to estimate to following measure:
Total number (#) of visits per annum.

The costs associated with each of the specific recreational activities included in the community survey were then multiplied to calculate the expenditure per visit using the following formula:

$$Expenditure\ associated\ with\ each\ activity\ per\ person\ per\ cacthcment\ = \frac{\#\ visits\ per\ anuum\ \times estimated\ cost\ per\ visit}{\#\ number\ of\ respondants}$$

Table 8: Water based recreation index - respondents' answers allocated to the following frequencies.

Survey answer category	Frequency per year allocated	
Almost every day	260	(i.e. weekdays only)
Every week	52	
Every fortnight	26	
Every month	12	
Once or twice a year	1.5	
Every few years	0.333	

Table 9: Water based recreation index - estimated expenditure per visit for each activity.

Recreation type	Estimated cost per visit	Source
Boating and sailing	$173	Marsden and Jacobs (2013)
Walking and running	$1.90	Qld Health (2011)
Picnics and BBQ's	$62	Ag Economics (2010)
Recreational fishing	$85	Pascoe et al (2014)
Rowing, kayaking and canoeing	$30.21	Ag Economics (2010)
Surfing, kite surfing and sail boarding	$30.21	Griffith University (2012)
Swimming	$16.90	Ag Economics (2010)
Cycling	$2.52	
Jet skiing and water-skiing	$60	

Total annual expenditure per catchment is calculated by summing the expenditure for each of the recreational pursuits. The total expenditure per catchment is then standardised by population. The Waterway Recreational Index is then calculated using the following formula:

$$Waterway\ Recreational\ Indicator = 1 - \left|\frac{(Catchment\ expenditure\ ratio - BCS)}{(WCS - BCS)}\right|$$

BCS (Best Case Scenario) is the catchment with the highest catchment expenditure ratio. WCS (Worst Case Scenario) is the catchment with the lowest catchment expenditure ratio.

1.12 Additional research questions

Each year as part of the social benefits monitoring additional research questions is added to the survey. These questions are developed in partnership with the social scientist that sit on the Healthy Land & Water Social Scientific expert panel.

In 2023 the additional research focuses were,

- What affect do crowds have on peoples use and enjoyment of waterways.
- Current water literacy.
- Satisfaction with current strategies and practices for waterway management.
- Forms of stewardship activities being undertaken by residents.

The answers to these questions help inform the key messaging as well as supporting the organisations and network members research interests.

Report Card data sources

1.13 Freshwater EHMP monitoring

The freshwater EHMP was first implemented in the austral spring of 2002 with data then collected twice yearly (austral spring and autumn) from 135 sites until 2014. The freshwater EHMP measures 12 indicators to assess the health of the freshwater streams and rivers, these indicators are then condensed into four stream health indices (Physical Chemical, Ecosystem Processes, Macroinvertebrates, and Fish) (Table 10). In 2015, an integrated monitoring and modelling approach was implemented for the SEQ Report Card. Since then, field data have been collected once per year in austral autumn at 76 of the original sites, with the full 129 sites sampled on a 3-year rotation.

The current freshwater EHMP program samples 76 freshwater sites once per year in austral autumn, under a partnership between Queensland Government and Health Land and Water. Each year the sites consist of 49 'fixed' sites sampled each year and one of three sets of 27 rotating sites sampled once every three years (Figure 10 and Table 11). Using this protocol, 129 sites will be assessed every three years. Monitoring is currently carried out by Queensland Government Department of Environment and Science scientists.

Table 10 Parameters measured at all sites of the freshwater EHMP monitoring program.

Index	Indicator	Unit
Physical Chemical		
	pH (min)	$[H^+]$
	pH (max)	$[H^+]$
	Conductivity	µS cm^{-1}
	Temperature (max)	°C
	Temperature (range)	°C
	Dissolved Oxygen (min)	% saturation
	Dissolved Oxygen (range)	% saturation
Ecosystem Processes		
	Gross Primary Production	g C m^{-2} day^{-1}
	Daily Respiration (R24)	g C m^{-2} day^{-1}
Fish		
	Percentage of native species expected (PONSE)	%
	Ratio native species expected:" observed (O/E_{50})	Ratio (number)
	Proportion of alien fish	%
Bugs		
	Number Taxa	Number
	PET Richness	Number
	SIGNAL	Number

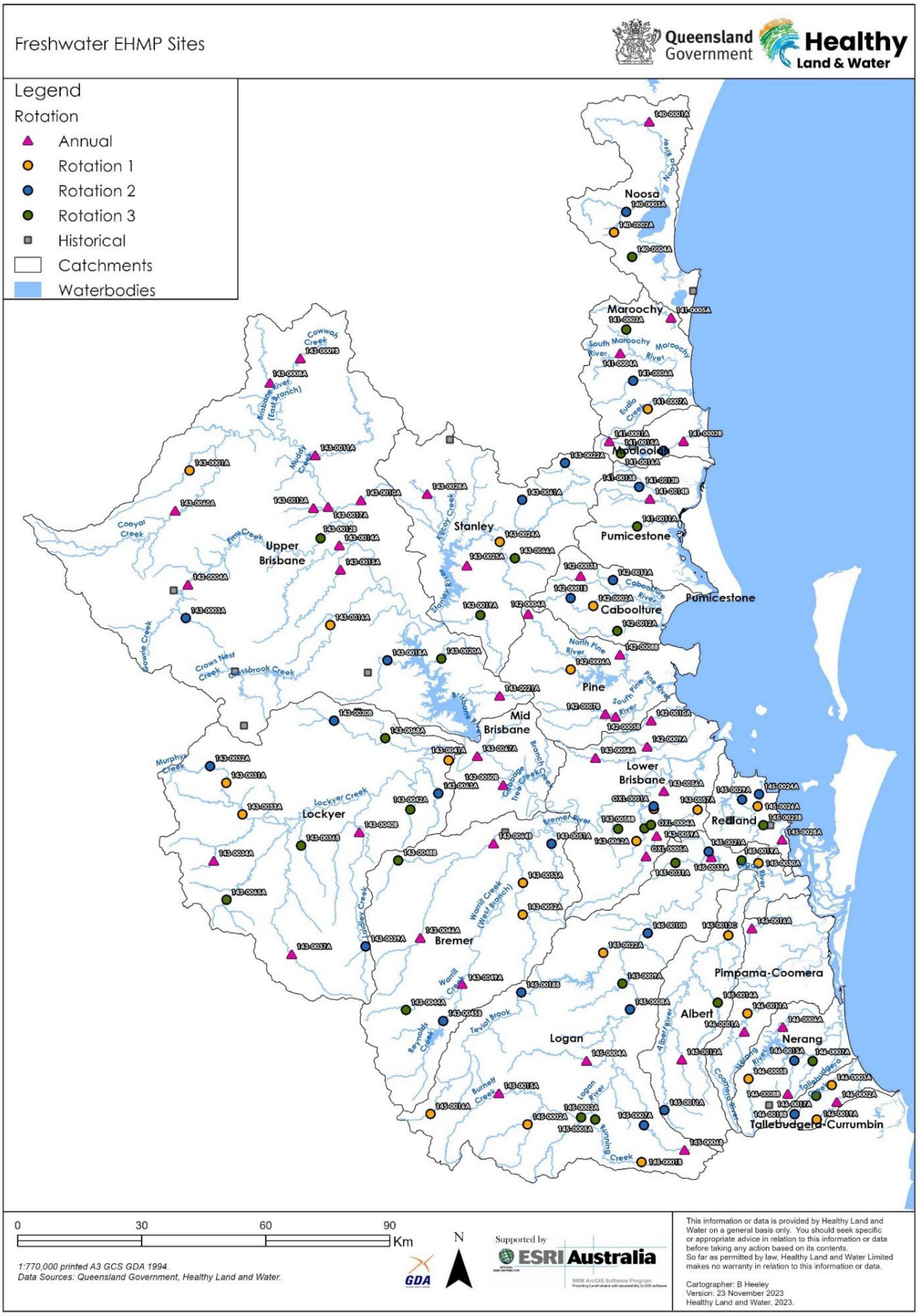

Figure 18: Location of the 129 freshwater monitoring sites.

Table **11:** Geographic coordinates (WG84 datum) of the 49 'fixed' freshwater sites—sampled annually.

Site code	Waterway	Site name	Longitude	Latitude
140-0001	Noosa River	Cooloola Way, Coops Corner, Cooloola	153.00720	-26.05719
141-0001	Mooloolah River	Harris Road, Diamond Valley	152.92030	-26.75220
141-0002	Mooloolah River	Westaway Road, Meridan Plains	153.08170	-26.75180
141-0004	South Maroochy River	Colemans Road, Yandina	152.94390	-26.56080
141-0005	Doonan Creek	Doonan Bridge East Road, Peregian Springs	153.05450	-26.48360
141-0014	Coochin Creek	Bruce Highway, Beerwah	153.00880	-26.87750
142-0003	Wararba Creek	Campbells Pocket Road, Wamuran	152.85790	-27.04482
142-0004	North Pine River	Mount Brisbane Road, Mount Pleasant	152.74400	-27.12760
142-0005	South Pine River	Carter Court, Bunya	152.93410	-27.35090
142-0007	Cedar Creek	Edward Allison Park	152.91170	-27.34510
142-0008	Sideling Creek	Forbes Road, Kurwongbah	152.94340	-27.21631
142-0009	Kedron Brook	Grinstead Park, Royal Parade, Alderley	153.00260	-27.41626
142-0010	Cabbage Tree Creek	Phillip Vaughan Park, Carseldine	153.01140	-27.35964
143-0004	Emu Creek	'Rae Burn', Blackbutt Road, Pierces Creek	152.00460	-27.06410
143-0008	Brisbane River	Western Branch Road, Mount Stanley	152.18290	-26.62520
143-0009	Brisbane River	Eastern Branch Road, Mount Stanley	152.24880	-26.57197
143-0010	Kangaroo Creek	Kangaroo Creek Road, Moore	152.38090	-26.88060
143-0011	Monsildale Creek	Monsildale Creek Road, Linville	152.28140	-26.78268
143-0013	Wallaby Creek	Himstedts Road, Moore	152.27740	-26.89723
143-0014	Maronghi Creek	Turtle Creek Road, Harlin	152.33360	-26.97856
143-0015	Ivory Creek	Ivory Creek Road, Ivory Creek	152.33610	-27.03113
143-0017	Brisbane River	Arababy Creek Road, Moore	152.30940	-26.89513
143-0021	Northbrook Creek	Red Cedar Picnic Grounds, Dundas	152.68210	-27.30570
143-0025	Oaky Creek	Westvale Road, Westvale	152.61080	-27.02265
143-0028	Sheepstation Creek	Crossing No 2, Kilcoy - Murgon Road, Kilcoy	152.52460	-26.86690
143-0034	Stockyard Creek	Stockyard Creek Road, Stockyard	152.06060	-27.66460
143-0037	Blackfellow Creek	Glen Rock Regional Park, East Haldon	152.23010	-27.86752
143-0040	Laidley Creek	Railway Bridge, Gordon Street, Forest Hill	152.37700	-27.60235
143-0046	Bremer River	Adams Bridge, Rosevale	152.50950	-27.83204
143-0049	Warrill Creek	Kalbar Connection Road, Kalbar	152.60030	-27.93221
143-0050	Brisbane River	Summerville Road East, Borallon	152.68980	-27.49970
143-0054	Enoggera Creek	Mount Nebo Road, Enoggera Reservoir	152.89050	-27.44070
143-0056	Norman Creek	Ekibin Park South, Arnwood Place, Annerley	153.03880	-27.51293
143-0059	Oxley Creek	Brookbent Road, Pallara	153.02330	-27.61050
143-0060	Cooyar Creek	Kooralgin Gilla Road, Kooralgin	151.97710	-26.90320
143-0064	Bremer River	Haigslea-Amberley Road, Walloon	152.66880	-27.62689
143-0067	Mid Brisbane	Brisbane River, Wivenhoe Pocket Road, Fernvale	152.63350	-27.43680
145-0004	Canon Creek	Kooralbyn Road, Kooralbyn	152.87080	-28.09940
145-0006	Christmas Creek	Christmas Creek Road, Lamington	153.08390	-28.29325
145-0012	Cainbable Creek	Cainbable Creek Road, Kerry	153.07790	-28.09650
145-0015	Burnett Creek	Boonah Rathdowney Road, Maroon	152.68030	-28.17010
145-0028	Moogurrapum Creek	Syracuse Street, Redland Bay	153.29570	-27.61840
145-0033	Scrubby Creek	Queens Road, Kingston	153.14200	-27.65680
146-0001	Back Creek	Back Creek Road, Witheren	153.21370	-28.03612
146-0002	Currumbin Creek	Craigs Crossing, Currumbin Valley	153.41480	-28.18880
146-0006	Nerang River	Latimers Crossing, Gilston	153.29740	-28.02590
146-0008	Mudgeeraba Creek	Austinville Road, Austinville	153.30820	-28.17120
146-0016	Pimpama River	Upper Ormeau Road, Kingsholme	153.23010	-27.81150
OXL-0005	Oxley Creek	Johnson Road, Larapinta	153.00040	-27.65474

Table 12: Geographic coordinates (WG84 datum) of the 'rotating' freshwater sites—sampled once every three years.

Rotation	Site code	Waterway	Site name	Longitude	Latitude
1	140-0002	Sandy Creek	Cootharaba Road, Cootharaba	152.93040	-26.29785
1	141-0007	Eudlo Creek	Bruce Highway service road, Forest Glen	153.00370	-26.68207
1	141-0013	Bluegum Creek	Roys Road, Beerwah	152.98520	-26.85120
1	142-0002	Caboolture River	Litherland Road, Upper Caboolture	152.88570	-27.10980
1	142-0006	Kobble Creek	Mount Samson Road, Dayboro	152.83570	-27.24776
1	143-0001	Yarraman Creek	Gibsons Road, Yarraman	152.00840	-26.81554
1	143-0016	Cressbrook Creek	Esk-Crow's Nest Road, Biarra	152.31380	-27.15133
1	143-0024	Neurum Creek	Neurum Road, Mount Archer	152.68250	-26.97070
1	143-0031	Murphys Creek	Mill Road, Upper Lockyer	152.08780	-27.49490
1	143-0033	Lockyer Creek	Back Flagstone Road, Iredale (Helidon)	152.12280	-27.56320
1	143-0041	Lockyer Creek	Pointings Bridge, Lowood	152.57130	-27.44530
1	143-0052	Purga Creek	Ipswich-Boonah Road, Peak Crossing	152.73190	-27.78081
1	143-0053	Purga Creek	Purga School Road, Purga	152.73280	-27.71210
1	143-0057	Bulimba Creek	Stackpole Street, Wishart	153.11210	-27.55300
1	143-0062	Blunder Creek	Carolina Parade, Forest Lake	152.97920	-27.62140
1	145-0001	Running Creek	Mount Gipps Road, Mount Gipps	152.99010	-28.31903
1	145-0002	Mount Barney Creek	Seidenspinner Road, Mount Barney	152.74270	-28.23727
1	145-0013	Albert River	Chardon Bridge Road, Cedar Creek	153.17870	-27.82590
1	145-0016	Teviot Brook	Head Road, Carneys Creek	152.53200	-28.21460
1	145-0022	Teviot Brook	Brooklands Bridge, Undullah Road, Kagaru	152.90750	-27.86400
1	145-0026	Hilliards Creek	Industry Court, Cleveland	153.24270	-27.54580
1	145-0030	Native Dog Creek	Stern Road, Carbrook	153.24460	-27.66950
1	146-0003	Tallebudgera Creek	Robinson Park, Tallebudgera Valley	153.40380	-28.15170
1	146-0005	Nerang River	Numinbah Community Hall, Numinbah Valley	153.22300	-28.13840
1	146-0011	Coomera River	Maybury Creek Road, Clagiraba	153.22060	-27.99600
1	146-0019	Currumbin Creek	Long Tan Road, Currumbin Valley	153.37090	-28.22660
1	OXL-0002	Stable Swamp Creek	Bale Street, Rocklea	153.01740	-27.55130
2	140-0003	Kin Kin Creek	Galloways Lane, Cootharaba	152.95690	-26.25320
2	141-0006	Petrie Creek	Coronation Avenue, Nambour	152.97220	-26.62043
2	141-0013	Bluegum Creek	Roys Road, Beerwah	152.98520	-26.85120
2	141-0015	Mooloolah River	Rustic Cabin, Steve Irwin Way, Glenview	153.03800	-26.77250
2	142-0001	Caboolture River	McNamara Road, Rocksberg	152.83630	-27.09290
2	142-0011	Lagoon Creek	Appaloosa Close, Caboolture	152.92810	-27.05360
2	143-0003	Pierces Creek	Blackbutt Road, Pierces Creek	152.00010	-27.13650
2	143-0018	Esk Creek	'Glen Rock', Falls Road, Esk	152.43790	-27.22820
2	143-0022	Stanley River	River Road, Booroobin	152.82410	-26.79887
2	143-0030	Buaraba Creek	Buaraba Creek Road, Buaraba	152.32190	-27.35930
2	143-0032	Murphys Creek	Odin Street, Murphys Creek	152.05280	-27.45810
2	143-0039	Laidley Creek	Peacocks Bridge, Mulgowie Road, Townson	152.39090	-27.85021
2	143-0045	Reynolds Creek	'Yarramolong' camp ground, Charlwood	152.55960	-28.01237
2	143-0051	Bundamba Creek	George Palmer Park, Sealy Street, Silkstone	152.79450	-27.62690
2	143-0061	Stony Creek	Stony Creek Day Use Area, Stony Creek	152.73090	-26.87940
2	143-0063	Plain Creek	Schulz Road, Coolana	152.54910	-27.51765
2	145-0007	Christmas Creek	Burgess Park, Lamington	152.99550	-28.23910
2	145-0008	Logan River	Il-Bogan Bridge, Beaudesert	152.96530	-27.98743
2	145-0010	Logan River	Cusack Lane, Jimboomba	153.00390	-27.82130
2	145-0011	Albert River	Kerry Road, Darlington	153.04030	-28.20650
2	145-0018	Teviot Brook	Old Beaudesert Road, Coulson	152.72900	-27.95026
2	145-0021	Slacks Creek	Meakin Park, Meakin Road, Slacks Creek	153.13600	-27.64421
2	145-0024	Hilliards Creek	Francis Street, Ormiston	153.24560	-27.51920
2	145-0029	Coolnwynpin Creek	Glover Drive, Alexandra Hills	153.20890	-27.53120
2	146-0015	Mudgeeraba Creek	Little Nerang Road, Mudgeeraba	153.32220	-28.09860
2	146-0018	Tallebudgera Creek	Tallebudgera Creek Road, Tallebudgera Valley	153.32310	-28.21520
2	OXL-0001	Rocky Waterholes	Cobden Street, Moorooka	153.01680	-27.54560
3	140-0004	Ringtail Creek	McKinnon Drive, Ringtail Creek	152.96970	-26.35080
3	141-0003	Maroochy River	Wegner Road, North Arm	152.95720	-26.50890
3	141-0011	Tibrogargan Creek	Rapkins Road, Beerburrum	152.98090	-26.93700
3	141-0016	Mooloolah River	King Road, Mooloolah Valley	152.94520	-26.77850
3	142-0012	Burpengary Creek	Koel Drive, Narangba	152.93750	-27.16460
3	143-0012	Emu Creek	Grieves Road, Colinton	152.29280	-26.96295
3	143-0019	Reedy Creek	Mount Byron Road, Mount Byron	152.63990	-27.12990
3	143-0020	Sandy Creek	Wivenhoe - Somerset Road, Crossdale	152.55540	-27.22460

Rotation	Site code	Waterway	Site name	Longitude	Latitude
3	143-0036	Deep Gully	Ropeley Rockside Road, Ropeley	152.25050	-27.63100
3	143-0042	Woolshed Creek	Warrego Highway, Hatton Vale	152.48810	-27.55270
3	143-0044	Warrill Creek	Villis Bridge, Niebling Road, Tarome	152.47840	-27.98860
3	143-0048	Western Creek	Rosewood-Laidley Road, Grandchester	152.46140	-27.66316
3	143-0058	Bullockhead Creek	Progress Road, Wacol	152.93960	-27.59496
3	143-0065	Heifer Creek	Gatton-Clifton Road, West Haldon	152.08850	-27.74910
3	143-0066	Delaney Creek	Dewhurst Road, Mount Delaney	152.71500	-27.00615
3	143-0068	Buaraba Creek	Rocky Gully Road, Coominya	152.43360	-27.39750
3	145-0003	Logan River	Ian Tilley Park, Rathdowney	152.85940	-28.22200
3	145-0005	Running Creek	'Dulbolla', Running Creek Road, Rathdowney	152.88990	-28.22680
3	145-0009	Allan Creek	Allan Creek Road, Gleneagle	152.94880	-27.93120
3	145-0014	Canungra Creek	Wonglepong Bridge, Wonglepong	153.15640	-27.97260
3	145-0019	California Creek	Gavin Way, Cornubia	153.20760	-27.66320
3	145-0023	Eprapah Creek	Springacre Road, Thornlands	153.25510	-27.58660
3	145-0031	Scrubby Creek	Campden Street, Browns Plains	153.06400	-27.66840
3	146-0007	Bonogin Creek	Gunsynd Drive, Mudgeeraba	153.36210	-28.09980
3	146-0017	Tallebudgera Creek	Smailes Park, Tallebudgera Valley	153.36960	-28.17510
3	OXL-0003	Blunder Creek	King Avenue, Willawong	152.99700	-27.59360
3	OXL-0004	Oxley Creek	Beatty Road, Acacia Ridge	153.01060	-27.58580

1.14 Freshwater stream health modelling

The Stream Health Model is a suite of statistical models developed to predict annual freshwater communities and processes scores for each of the four freshwater indices at 129 sites across SEQ—the four indices are:

1. Physical and chemical.
2. Ecosystem processes.
3. Macroinvertebrates.
4. Fish.

The four indices' models were developed based on a Geographic Information system (GIS) approach used by Sheldon *et al.* (2012) and the methodology is described in Peterson (2014). Conditional inference forest (CIF) models were fit using all existing freshwater EHMP data plus 49 additional predictor variables, derived from land use, vegetation cover and rainfall datasets (see Petersen (2014) for full list of predictor variables and their importance to each CIF model). Each reporting year predictor variables are updated with the latest available datasets. This version of the Stream Health Model (developed in 2014/2015) is viewed as an interim step to develop a predictive model that can be used to estimate ecosystem health throughout the SEQ freshwater stream network in future years.

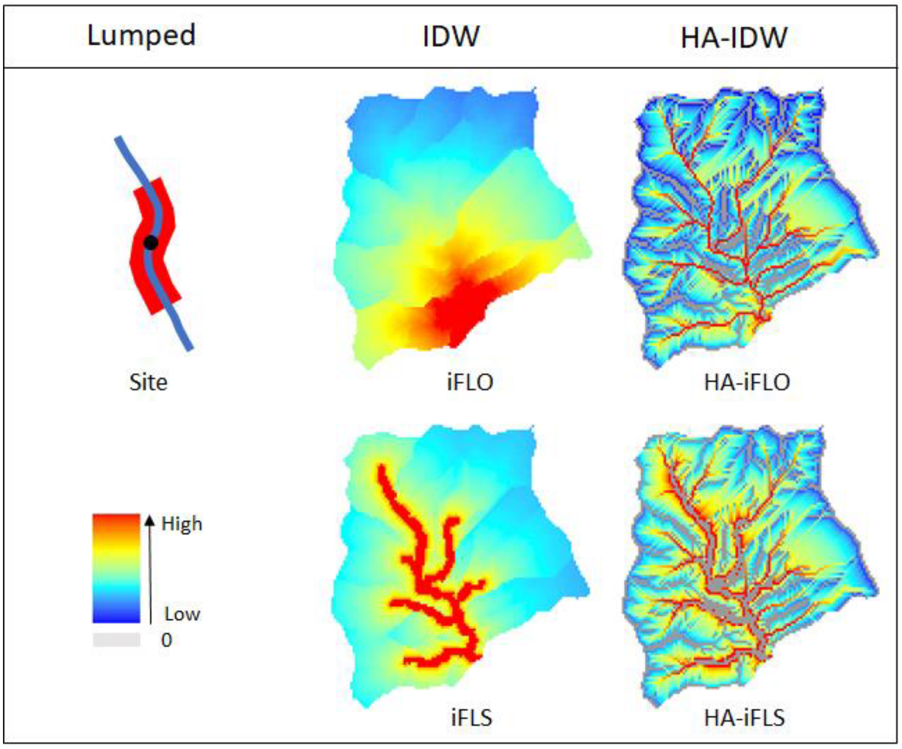

Figure 19: Graphical representation of the spatial scales of the predictor variables used in the Stream Health model. (a) The lumped site-scale attributes are non-spatial and represent the land area within 50m of the survey site, extending approximately 300m up- and down-stream. (b) The inverse-distance-weighted (IDW) catchment attributes account for the proximity of land use and include inverse-flow length to the stream (iFLS) and inverse-flow-length to the site (iFLO). (c) The hydrologically active inverse-distance-weighted (HA-IDW) catchment attributes account for both the proximity of land use and the potential for hydrologic activity; they include hydrologically active inverse-flow length to the stream (HA-iFLS) and to the site (HA-iFLO).

1.15 Catchment loads EHMP monitoring

Long-term monitoring of sediments, nitrogen and phosphorus loads generated in SEQ catchments began in 2007, as part of the SEQ Event Monitoring Program under a partnership between Queensland Government and Health Land and Water. The Program aimed to better inform catchment non-urban diffuse source pollutant loads exported from monitored areas to SEQ waterways. The estimated loads account for pollutants transported past these monitored sites, and do not represent the loads discharged from the entire catchment to Moreton Bay. The unmonitored portion of the catchment or sub-catchments may also contribute, transform, or degrade pollutants before they discharge to Moreton Bay.

Catchment pollutant loads associated with rainfall events are monitored at eight sites (Figure 13 and Figure 20). Water quality sampling is conducted monthly during periods of base flow conditions and more frequently throughout major flow 'events' (Table 14). Monitoring is currently carried out by Queensland Government Department of Environment and Science scientists.

Table 13: Geographic coordinates (WG84 datum) of 8 catchment loads sites.

Catchment	Site code	Station name	Station no.	Longitude	Latitude
Pimpama-Coomera	CRR	1460031	Coomera River at Riverstone Crossing	153.27298	-27.9158
Pumicestone	COO	141010A	Coochin Creek at Mawsons Road	153.0034	-26.87712
Caboolture	CAB	142001A	Caboolture River at Upper Caboolture	152.8911	-27.0979
Bremer	AMB	143108A	Warrill Creek at Amberley	152.7	-27.66353
Lockyer	LCM	143209B	Laidley Creek at Mulgowie	152.364231	-27.72995
Lockyer	RRR	143210B	Lockyer River at Rifle Range Road	152.51636	-27.45528
Lockyer	LCW	143229A	Laidley Creek at Warrego Highway	152.389003	-27.55315
Logan	YAR	145014A	Logan River at Yarrahappini	152.98778	-27.83361

Table 14: Parameters measured at all sites of the catchment loads monitoring program.

Type	Parameter
Flow	Stream height
	Rating curves
Water quality	Total nitrogen
	Organic nitrogen
	Dissolved inorganic nitrogen
	Oxidised nitrogen
	Ammonia
	Total phosphorus
	Dissolved reactive phosphorus
	Suspended sediments

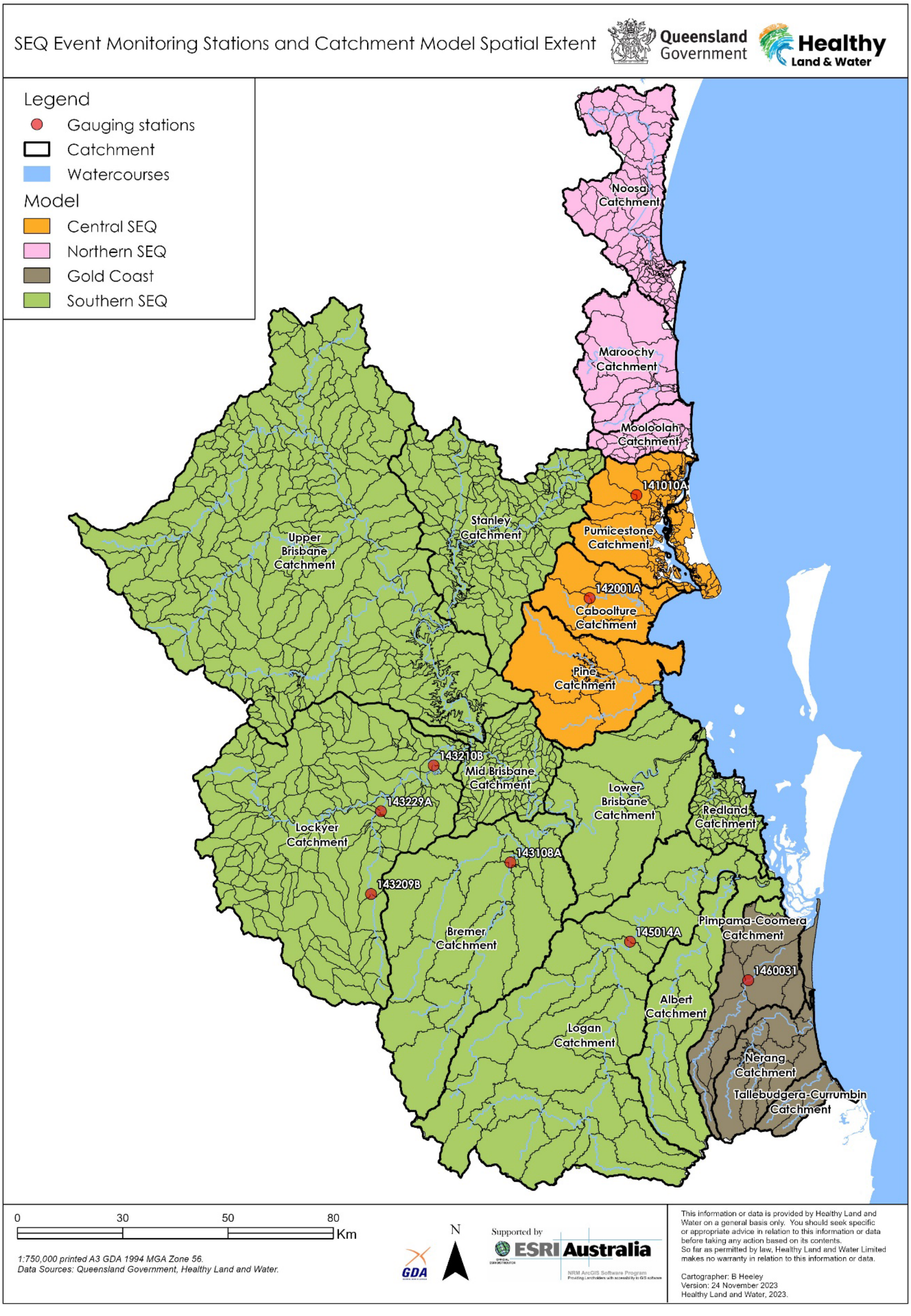

Figure 20: Catchment loads EHMP (also known as SEQ event monitoring program) monitoring sites and four SEQ catchment models spatial extent.

1.16 Catchment loads modelling

The SEQ Source Catchment Models enable Healthy Land & Water to quantify diffuse (non-point source, non-urban) pollutant loads export from catchments and understand the effect of management interventions in reducing those loads over time. Since 2014/15, the SEQ catchment total annual sediment, nitrogen, and phosphorus loads have been estimated through four catchment models using the Source modelling framework, being the Northern SEQ, Central SEQ, Southern SEQ and Gold Coast models (Figure 20). Source catchment models run annually using datasets from SEQ Event Monitoring Program (Section 1.15), local councils, and utilities as part of the modelling update. The modelled loads represent the loads discharged from the entire catchment areas and its sub catchments and used to calculate a catchment pollutant load score for each reporting zones.

In the past, SEQ catchments loads have been modelled extensively using the Environmental Management Support System (EMSS) modelling framework (Cuddy *et al.* 2004) which was a precursor to the Source modelling framework (Argent et al., 2008; eWater CRC, 2009) and is now being widely used throughout Australia. The Source modelling framework (Argent *et al.* 2008) provides the ability to simulate current catchment characteristics and hydrological responses to rainfall, in addition to evaluating the impacts of land use change and the implementation of best management practices on pollutant loads. The Source framework is not a single model, but a framework in which groups of different models can be selected and linked such that the most suitable model to describe a particular aspect of the catchment can be used.

The development of the SEQ Source catchment models require transforming the physical catchment information into a mathematical form that is used to convert rainfall to runoff and calculate subsequent pollutant loads (Figure 21). The outcome is a numerical description of the physical features that represent the land-based framework, hydrological processes, and pollutant load generation aspects of the catchment. Following the model construction phase, calibration and verification is required annually to ensure the constructed numerical model adequately represents the study area. Key features of the model include:

- A digital elevation model (DEM) for sub-catchment delineation.
- Land use data from Queensland Land use Mapping Project (QLUMP).
- Climate data extracted from the SILO database including daily rainfall and daily potential evapotranspiration (PET) data.
- Major water storages details include discharges and water quality data for calibration including any point source, storages and extractions. SEQ key storage dynamics outlets data of Wivenhoe, Somerset, North Pine and Hinze dams, plus water extractions at Mt Crosby weir, North Pine Dam and Hinze dam from Seqwater.
- Hydrological data from Queensland Water Monitoring Information Portal (WMIP).
- Non-point sources (diffuse) water quality concentrations were derived for event and dry weather parameters representing an analysis of the catchment loads monitoring program (Section 1.15). Point sources were not included in the catchment model but were incorporated in the linked Receiving Water Quality Model (Section 1.18).
- Event Mean Concentration (EMC) and Dry Weather Concentration (DWC) data for pollutant export model parameterisation and calibration.

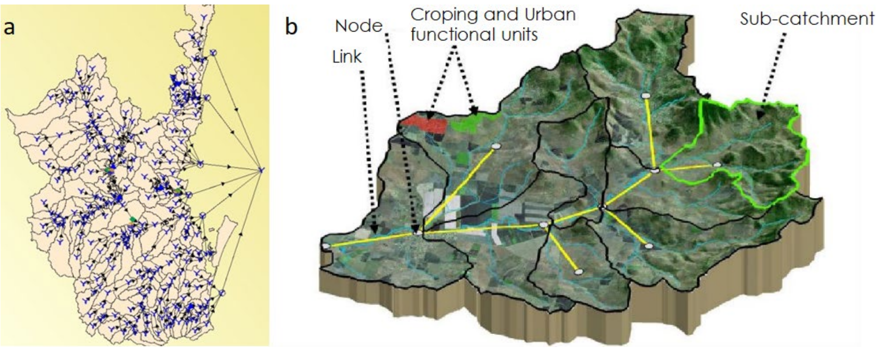

Figure 21: a) Schematic of the SEQ Source catchment model showing, sub-catchments, nodes and links. b) Conceptual diagram of the Source Catchment model (courtesy of eWater).

1.17 Estuarine–marine EHMP monitoring

Several characteristics of surface waters are monitored *in situ* and surface water samples are collected for analysis of chlorophyll-*a* and nutrient concentrations (Table 15) at each of 182 estuarine–marine sites (Table 16 and Figure 22) during eight months of each year (February, March, May, August, September, October, November and December). Monitoring is currently carried out by Queensland Government Department of Environment and Science scientists.

Water samples collected for quantifying chlorophyll-*a* concentrations are analysed by DES and water samples collected for quantifying nutrient concentrations are analysed at the Queensland Urban Utilities SAS Laboratory, Darra.

The TUFLOW model simulates water levels, speed and direction, temperature, salinity and suspended sediment and water quality processes. The model has been built to respond to tidal movements, atmospheric pressure and benthic roughness as well as pollutant loads from the SOURCE catchment model (Section 1.16).

Table 15: Parameters measured at all sites of the estuarine–marine monitoring program.

Source	Parameter
In situ	Temperature
	Salinity
	pH
	Secchi depth
	Turbidity
	Dissolved oxygen
Water samples	Chlorophyll-*a*
	Total Nitrogen
	Organic Nitrogen
	Dissolved Inorganic Nitrogen
	Oxidised Nitrogen
	Ammonia
	Total Phosphorus
	Dissolved Reactive Phosphorus

Figure 22: Estuarine-Marine EHMP water quality monitoring sites.

Table 16: Geographic coordinates (WG84 datum) of the 182 estuarine–marine sites to visited eight times per year.

Report Card zone	Site code	Longitude	Latitude
Albert River	E01701	153.23940	-27.69527
	E01702	153.23354	-27.70501
	E01703	153.22656	-27.71531
	E01704	153.21554	-27.71833
	E01705	153.21613	-27.72705
	E01706	153.20879	-27.73959
	E01707	153.19783	-27.76437
Bramble Bay	E00900	153.07996	-27.26433
	E00905	153.14437	-27.34339
	E00907	153.16771	-27.30338
	E00916	153.08771	-27.27839
	E00919	153.10604	-27.30672
	E00921	153.21535	-27.30961
Bremer River	E00600	152.85370	-27.58234
	E00601	152.82930	-27.57976
	E00602	152.76792	-27.60332
	E00603	152.80118	-27.58300
	E00605	152.78120	-27.60324
	E00606	152.81424	-27.58374
Brisbane River	E00700	153.15711	-27.38647
	E00701	153.12607	-27.42777
	E00702	153.07266	-27.44452
	E00703	153.03612	-27.46298
	E00704	153.01481	-27.46894
	E00705	153.00928	-27.50427
	E00706	152.97069	-27.50581
	E00707	152.97059	-27.54459
	E00708	152.92681	-27.53063
	E00709	152.90411	-27.55034
	E00710	152.89888	-27.60250
	E00711	152.86352	-27.59555
	E00712	152.84900	-27.56096
	E00713	152.84143	-27.54208
	E00718	152.99202	-27.52108
Cabbage Tree Creek	E04101	153.06735	-27.32909
	E04102	153.05987	-27.33582
	E04104	153.07254	-27.32876
	E04105	153.08653	-27.32997
	E04106	153.05471	-27.33526
Caboolture River	E01000	153.03788	-27.15300
	E01001	153.02142	-27.12315
	E01002	153.01250	-27.10940
	E01003	153.00306	-27.11176
	E01004	153.00716	-27.10494
	E01005	152.99947	-27.10208
	E01006	152.99205	-27.09903
	E01007	152.97835	-27.09281
	E01008	152.95863	-27.08676
	E01011	153.03475	-27.14503
Central Bay	E00501	153.33229	-27.53197
	E00517	153.25435	-27.38872
	E00518	153.26787	-27.44508
	E00527	153.23310	-27.21000
	E01112	153.13778	-27.19004
	E01200	153.28110	-27.50830
Coomera River	E00100	153.39757	-27.87157
	E00101	153.38179	-27.87187
	E00103	153.34866	-27.85852
	E00104	153.31257	-27.87724
	E00126	153.37886	-27.85624
	E00127	153.35753	-27.84671
	E00129	153.33443	-27.87623
Currumbin Creek	E02901	153.48258	-28.12789

Report Card zone	Site code	Longitude	Latitude
	E02902	153.47043	-28.13749
	E02903	153.46353	-28.15190
	E02904	153.46042	-28.16274
Deception Bay	E01101	153.08780	-27.17000
	E01102	153.06110	-27.18000
	E01107	153.05947	-27.14838
	E01111	153.07782	-27.11839
	E01119	153.12105	-27.15341
Eastern Banks	E00506	153.33657	-27.40198
	E00310	153.36256	-27.56434
	E00311	153.40113	-27.54561
	E00314	153.40330	-27.62470
	E00525	153.27610	-27.12250
	E00529	153.33308	-27.21248
Eprapah Creek	E04500	153.29329	-27.56238
	E04501	153.29203	-27.57704
	E04502	153.29027	-27.58004
	E04503	153.28990	-27.57140
Logan River	E00200	153.32428	-27.70098
	E00201	153.30996	-27.71108
	E00202	153.24809	-27.69773
	E00203	153.23649	-27.68477
	E00204	153.21677	-27.68036
	E00205	153.20390	-27.68685
	E00206	153.16886	-27.69537
	E00207	153.15972	-27.67189
	E00208	153.14007	-27.68065
	E00211	153.26842	-27.69379
	E00212	153.29369	-27.69408
	E00213	153.14512	-27.69937
Maroochy River	E01501	153.07924	-26.64053
	E01502	153.05943	-26.63596
	E01503	153.04500	-26.62170
	E01504	153.05720	-26.60420
	E01505	153.06681	-26.57900
	E01506	153.01560	-26.57690
	E01508	153.06321	-26.59392
	E01509	153.05042	-26.57023
Mooloolah River	E01400	153.13427	-26.68119
	E01402	153.11472	-26.69680
	E01404	153.11958	-26.71827
	E01405	153.11069	-26.72714
Nerang River	E01901	153.42207	-27.97625
	E01903	153.42876	-28.01197
	E01904	153.41162	-28.01622
	E01905	153.39896	-28.02447
	E01906	153.38838	-28.02319
	E01907	153.38060	-28.01175
	E01908	153.36435	-27.99817
	E01909	153.35439	-27.99043
	E01910	153.33890	-27.98985
	E01912	153.41859	-27.98863
	E01916	153.42010	-28.00170
Noosa River	E01601	153.07731	-26.38294
	E01603	153.05557	-26.39602
	E01604	153.04241	-26.39276
	E01608	153.02003	-26.32148
	E01609	152.98857	-26.30410
	E01610	153.01593	-26.26670
	E01613	153.03425	-26.35340
	E01614	153.03391	-26.33691
	E01615	152.99414	-26.31788
	E01618	153.02310	-26.24060
	E01636	153.04014	-26.37400
Oxley Creek	E04201	152.98860	-27.53936
	E04202	152.99188	-27.55210

Report Card zone	Site code	Longitude	Latitude
	E04203	152.98243	-27.55833
Pimpama River	E01801	153.39389	-27.81918
	E01802	153.37778	-27.81889
	E01803	153.36950	-27.80261
	E01804	153.35480	-27.80131
	E01805	153.32444	-27.80474
	E01806	153.31431	-27.78690
	E01807	153.30333	-27.78994
	E01808	153.28760	-27.78176
Pine River	E00800	153.06323	-27.27751
	E00801	153.04031	-27.27938
	E00803	153.01488	-27.28638
	E00804	152.99186	-27.26885
Pumicestone Passage	E01301	153.13202	-27.05273
	E01302	153.10056	-27.02759
	E01304	153.07350	-26.98299
	E01308	153.07417	-26.91469
	E01309	153.09866	-26.89552
	E01310	153.11712	-26.87166
	E01311	153.11740	-26.84376
	E01312	153.12909	-26.80587
	E01313	153.15173	-27.07551
Southern Bay	E00106	153.38764	-27.78309
	E00125	153.42965	-27.76598
	E00300	153.36063	-27.73449
	E00301	153.43635	-27.74034
	E00308	153.32179	-27.61984
	E00316	153.35342	-27.64226
	E00318	153.40052	-27.69196
	E00320	153.36072	-27.69991
Tallebudgera Creek	E02800	153.45877	-28.09744
	E02801	153.44934	-28.10680
	E02802	153.44280	-28.11811
	E02803	153.44408	-28.12387
The Broadwater	E00105	153.40738	-27.82464
	E00107	153.41203	-27.86708
	E00117	153.42110	-27.95974
	E00118	153.42002	-27.94629
	E00119	153.41789	-27.92772
	E00120	153.41636	-27.90924
	E00121	153.41582	-27.89098
	E00122	153.39932	-27.84831
	E00123	153.41243	-27.79701
Tingalpa Creek	E04300	153.19726	-27.47320
	E04301	153.18749	-27.49083
	E04302	153.19021	-27.50840
	E04303	153.20088	-27.51191
	E04304	153.19463	-27.51568
	E04305	153.18698	-27.51939
Waterloo Bay	E00401	153.19975	-27.44762
	E00406	153.23174	-27.44584
	E00408	153.21602	-27.38408
	E00409	153.19093	-27.41285

1.18 Estuarine-marine hydrodynamic & water quality modelling

Estuary models

Intimately linked with the Moreton Bay TUFLOW FV–AED model, are the high-resolution estuarine models. The models are fully three dimensional and simulate water levels, current speed and direction, temperature, salinity and suspended sediment (TUFLOW FV) and water quality processes including dissolved oxygen, nutrients and algae (AED). High-resolution models of the Logan, Albert, Brisbane, Bremer, Pine, Caboolture, Mooloolah, Maroochy estuaries and Pumicestone Passage have been built and calibrated, and the Brisbane River model mesh is presented as an example (Figure 23).

All estuarine models included the influence of atmospheric exchange, tidal forcing, bed roughness, sediment fluxes, catchment inflows (as predicted by the Source model) and extractions (where appropriate), point source discharges (such as wastewater treatment plant discharges) and localised diffuse pollutant loads. The fate and transport of these loads was simulated by TUFLOW FV and AED, and model predictions were compared against EHMP data.

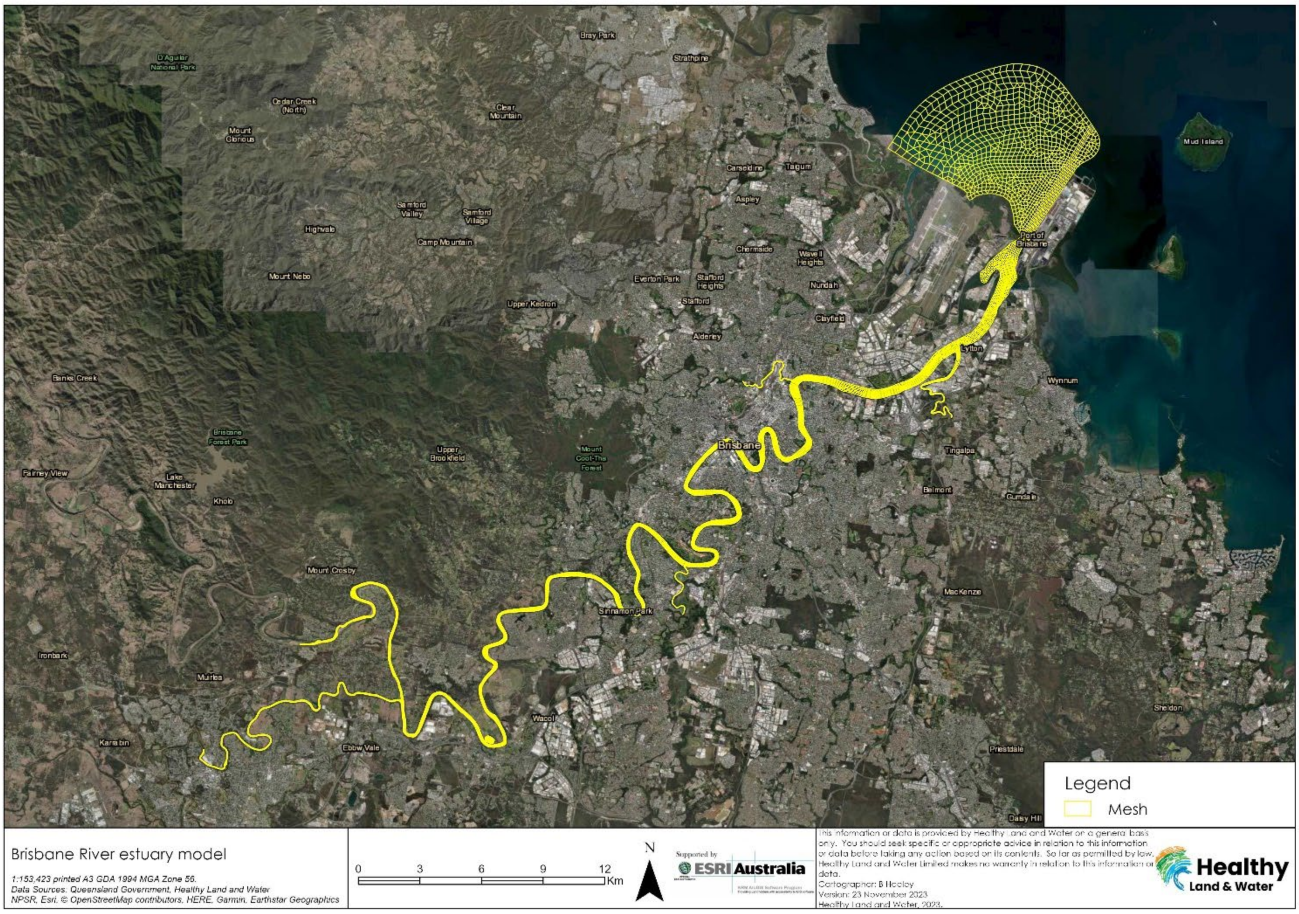

Figure 23: Mesh layout for the high-resolution Brisbane River Estuary model.

Bay model

The Moreton Bay TUFLOW FV model is a finite volume model that responds to tidal, atmospheric and bed roughness forcing to simulate water levels, current speed and direction, temperature, salinity and suspended sediment in three spatial dimensions. It is a state-of-the-art model that is parallelised and runs on both workstation and supercomputing facilities. The model includes almost 9,000 mesh elements and outside Moreton Bay, covers the entire SEQ coastline from Noosa to the Gold Coast (Figure 24: Model extent depicting mesh elements for SEQ). It also includes representations of all major estuaries that drain to Moreton Bay.

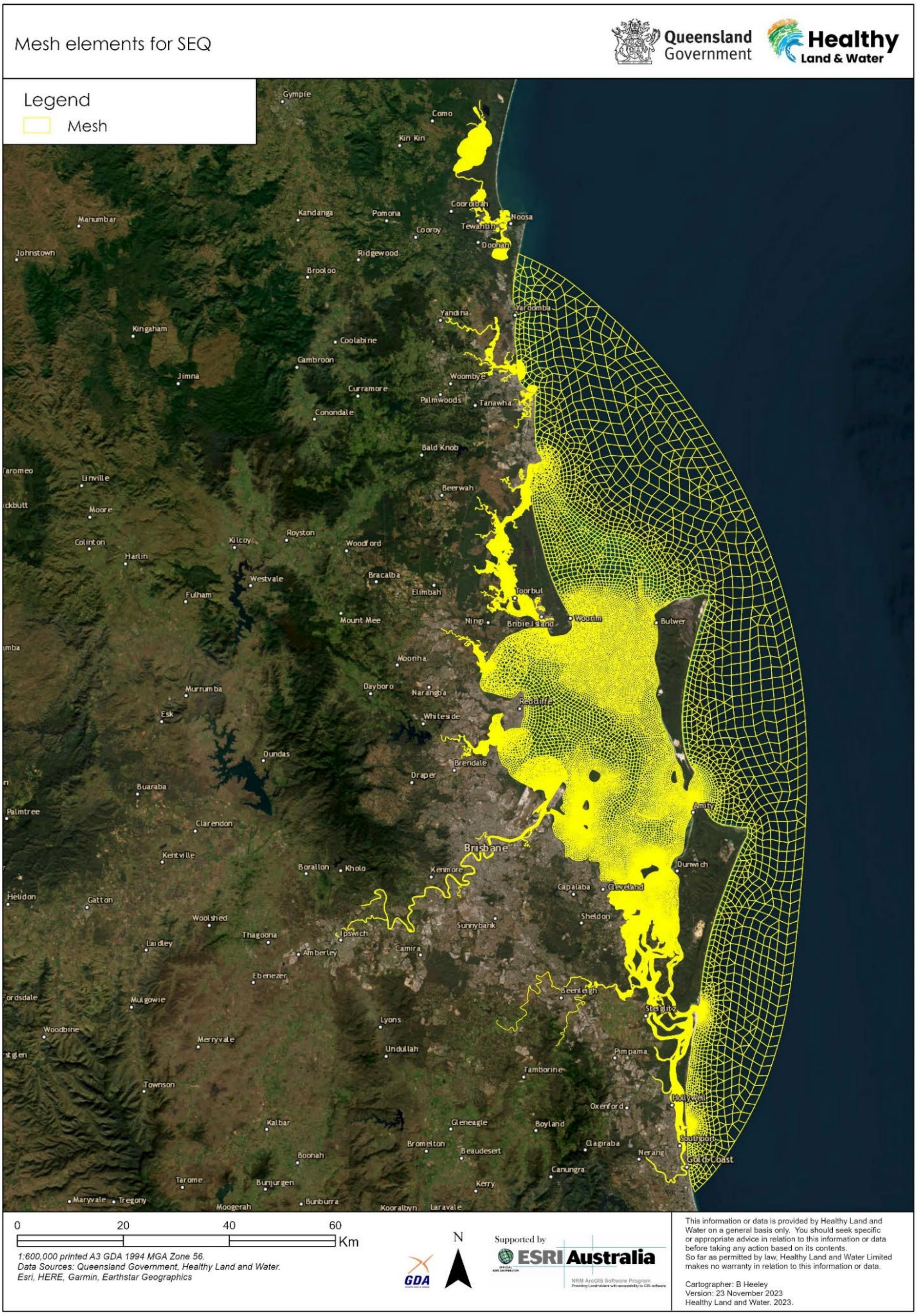

Figure 24: Model extent depicting mesh elements for SEQ

The Moreton Bay model is linked to the Source catchment model of SEQ so that all surface runoff and wastewater treatment plant flows and loads are delivered to the Bay model. This linkage is achieved via a combination of direct connections to Source and flows and loads modelled from the detailed estuarine models (Figure 26).

The Moreton Bay model has been extensively calibrated to dedicated current and water level measurements, and an example of a current calibration is presented (Figure 25). Measurements are blue lines and model predictions are red.

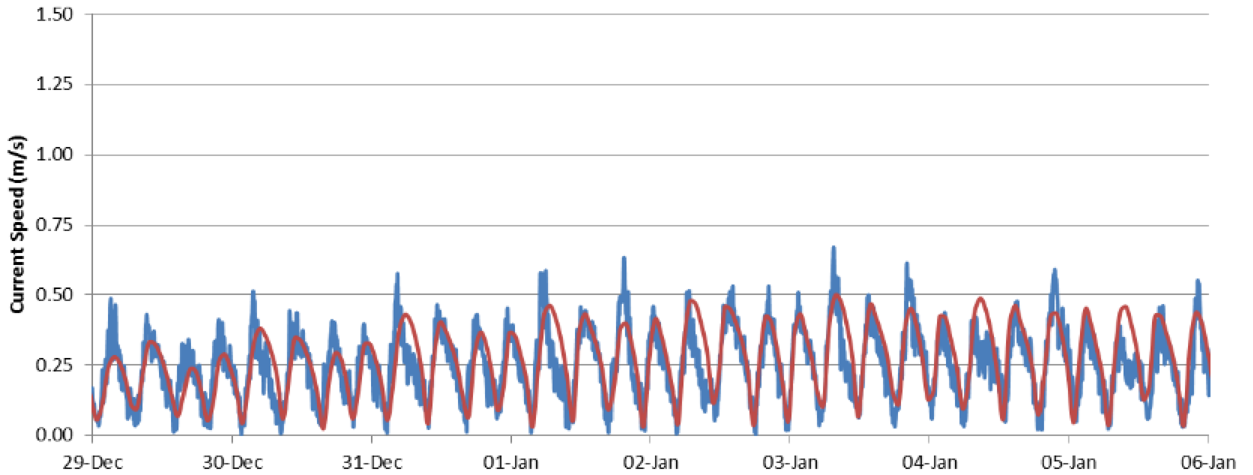

Figure 25: Modelled and measured current speeds at a location in Moreton Bay.

The Aquatic EcoDynamics (AED) water quality model was linked to TUFLOW FV and was set to simulate a range of environmental parameters, including dissolved oxygen, nutrients and algae. The processes captured included catchment delivery of pollutants, point source discharges, atmospheric exchange and sediment fluxes. Model predictions are also validated with measurements (primarily EHMP data) to ensure adequate model performance.

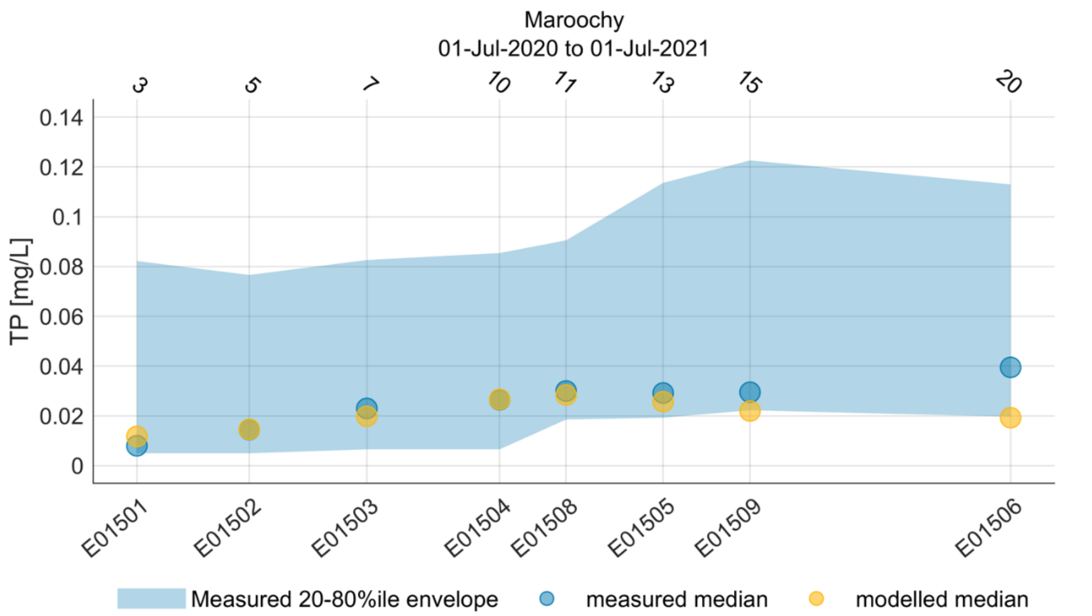

Figure 26: Comparison between modelled and measured water quality medians (total nitrogen) for the Maroochy River Estuary—2021.

1.19 Riparian vegetation mapping

The riparian analysis used the following data sources:

- The extent of freshwater riparian vegetation is mapped every three years (or when new data is available) using Sentinel-2 satellite imagery (SLATS). It is defined as the Foliage Projection Cover (FPC) (essentially woody vegetation) present within a 50m buffer zone adjacent to the freshwater edge. Resolution is at $10m^2$ pixels.
- The stream network was derived from the Queensland Governments (25m x 25m) Digital Elevation Model for the region with a stream initiation threshold of 0.1kms (product of the Health Land and Water "Stream Order Mapping" study.
- The sub catchments were derived from the Australian Hydrological Geospatial Fabric.
- Spatial predicted bio condition mapping produced by the Queensland Herbarium.

1.20 Wetland habitat mapping

Freshwater Wetland and Estuarine Wetland by the Wetlands team at the DES.

1.21 Seagrass depth range EHMP monitoring

Seagrass depth range at 18 sites is assessed twice per year (

Table 18). Measurements are undertaken by Queensland Government DES scientists.

In addition, citizen science programs collect seagrass cover data at more than 4000 sites throughout Moreton Bay (Table 17). These programs engage 30–40 people each year (see Wildlife Queensland Coastal Citizen Science and Science Under Sail). Frequency and locations vary year to year.

Table 17: Data collected for the seagrass monitoring.

Source	Parameter
DES	Seagrass depth range *(Zostera muelleri)* (m)
DES and citizen science programs	Seagrass species (% cover)
	Macroalgae (% cover)
	Toxic cyanobacteria *Lyngbya majuscula* (% cover)
	Geomorphological features (% cover)

Table 18: Seagrass depth range sites

Bay Zone	Site Code	Site Name	Longitude	Latitude
Waterloo Bay	E02001	Gallaghers Point	153.09834	-27.01106
Deception Bay	E02002	Deception Bay	153.05398	-27.19612
Eastern Banks	E02003	Crab Island	153.39821	-27.33306
Waterloo Bay	E02004	Fisherman Island 1	153.18751	-27.40305
Waterloo Bay	E02005	Wynnum	153.17927	-27.44412
Waterloo Bay	E02006	Birkdale	153.22646	-27.48321
Eastern Bay	E02007	Peel Island	153.35592	-27.50329
Eastern Bay	E02008	Pelican Banks	153.41255	-27.58169
Central Bay	E02009	Victoria Point	153.3161	-27.58226
Southern Bay	E02010	Long Island	153.35554	-27.64998
Southern Bay	E02011	Behms Creek	153.36051	-27.76307
Broadwater	E02012	The Bedroom	153.434	-27.77122
Broadwater	E02016	Northern Broadwater 2	153.41913	-27.91865
Deception Bay	E02017	Godwin Beach	153.11257	-27.08619
Southern Bay	E02018	Pannikin Island	153.32777	-27.64055
Waterloo Bay	E02019	Fisherman Island 2	153.18833	-27.39953
Deception Bay	E02020	Deception Bay 2	153.1087	-27.19146

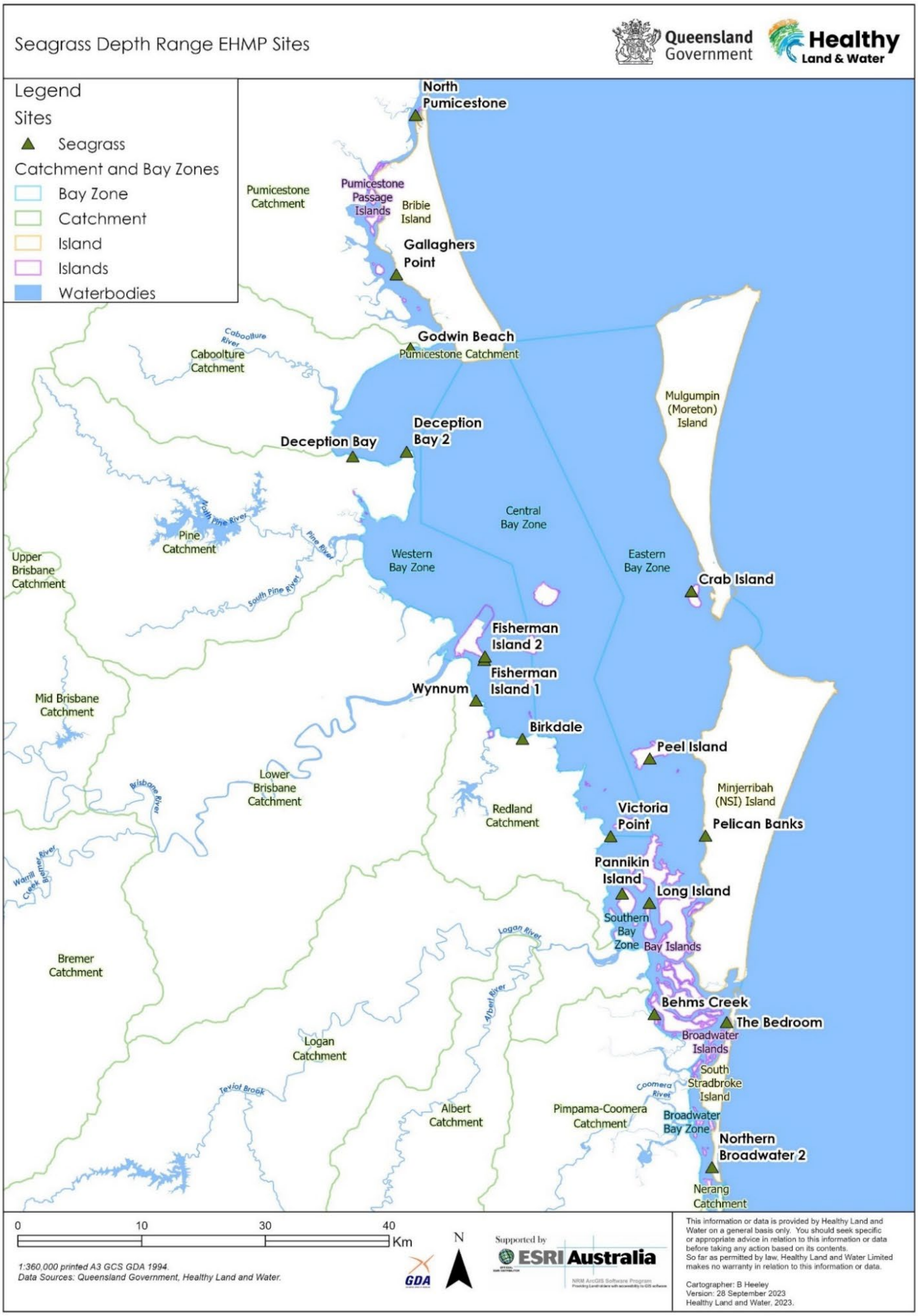

Figure 27: Seagrass depth range monitoring sites.

1.22 Mud content mapping

Bottom sediments have been routinely collected (every four years) in Moreton Bay, the Gold Coast Broad Water and Pumicestone Passage. Sediments are collected using an Ekman Grab sampler. Grain size is measured using a laser diffraction particle size analyser. Since 2019, a penetrometer has also been used to estimate the distribution and volume of unconsolidated sediments in the Bay. Key outputs of this monitoring campaign include particle size distribution by site, mud content by site (%), mud extent (km^2), mud penetration depth (m) and deposit characterisation (consolidated, layered, unconsolidated). The spatial extent (km^2) of sediment types (clean sand, sand, muddy sand, sandy mud, mud) is estimated using interpolation in ARC GIS.

1.23 Community benefits survey

A community benefits survey of SEQ residents is undertaken annually (commenced 2015) to collect data on the attitudes and behaviours that underpin the community's expectations and actions towards using and valuing local waterways. It is designed to provide a representative subsample of the population within each reporting zone for the Health Land and Water Report Card.

The focus of the survey is to collect data on the following:

- Satisfaction:
  - Overall Satisfaction measures how satisfied respondents are with their local waterways experience (use in or near).
- Useability & accessibility:
  - Overall Accessibility measures the perceptions of respondents about the accessibility of their local waterway.
  - Overall Usability captures whether respondents feel that their local waterways are usable and don't take much effort to use.
- Personal benefit:
  - Social value captures the value respondents get from using their local waterways with others such as friends or family.
  - Being Away captures a conceptual idea rather than a physical transformation. It emphasises a location that helps the respondent to relax, gives them a break and provides an escape from their everyday routines.
  - Fascination conceptualises a location which is thoroughly absorbing for the respondent. Examples can include fishing, bird-watching or going for a walk.
- Connection with nature:
  - Integrated Motivation occurs when motives for using waterways are fully in line with one's personal values and needs.
  - Nature relatedness measures an individual's connection to the natural world (environment).
- To what extent do people (across the 18 catchment areas in SEQ) use local and SEQ waterways for recreation?
  - Are residents using local waterways or other waterways in SEQ for recreation?
  - Which activities, and how frequently, do residents undertake these activities on or next to waterways?

Questions feature seven-point Likert scale questions (1 = Strongly Disagree to 7 = Strongly Agree) and open text boxes. The survey is administered through a 15-minute online survey coordinated by UQ and administered by Qualtrics on their survey platform. Healthy Land & Water also run a concise version of the survey on social media to get more responses in catchment with lower response numbers. Survey respondents are recruited using panel data (more than 3000 people per year) and are adults (18+) living in South-East Queensland, and via social media platforms. It is designed to provide a representative subsample of the population within each catchment.

For further detail refer to:

- Johnston, K. & Beatson, A. (2016) 2016 Social Science Survey Report *(report to Healthy Waterways* 11 October 2016), Queensland University of Technology, Brisbane, pp 211.
- Johnston, K. & Beatson, A. (2015) 2015 Social Science Survey Report *(report to Healthy Waterways*), Queensland University of Technology, Brisbane.
- Dean, A & Schult T. (2022) SEQ Catchment Waterways Benefits 2022 Research Report (*report to Healthy Land & Water)*, Queensland University of Technology, Brisbane.
- Dean, A & Schult T. (2023) SEQ Catchment Waterways Benefits 2023 Research Report (*report to Healthy Land & Water)*, University of Queensland, Brisbane.

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Appendix – Summary of measures for all Report Card indicators

Table 19**:** Environmental Condition - Catchments

Component	% of score		Index	Indicator/s	% of score		Unit	Data source	Start year	Frequency assessed	Standardisation method	Standardisation calculation	Benchmarks, BCS, WCS
	Coastal	Western			Coastal	Western							
Freshwater communities and processes (Section 3.1)	20%	40%	PhysChem	Phosphorus load in runoff	1%	3%		Stream health model (QUT) & EHMP freshwater program	2002	Annually	Distance from benchmark	1-| (index value at site guideline)/(WCS-guideline) |	Benchmarks and WCS values for Freshwater
				Elec conductivity	1%	3%		Stream health model (QUT) & EHMP freshwater program	2002	Annually	Distance from benchmark	1-| (index value at site guideline)/(WCS-guideline) |	Benchmarks and WCS values for Freshwater
				Ambient water temp	1%	3%		Stream health model (QUT) & EHMP freshwater program	2002	Annually	Distance from benchmark	1-| (index value at site guideline)/(WCS-guideline) |	Benchmarks and WCS values for Freshwater
				Ambient DO	1%	3%		Stream health model (QUT) & EHMP freshwater program	2002	Annually	Distance from benchmark	1-| (index value at site guideline)/(WCS-guideline) |	Benchmarks and WCS values for Freshwater
			Ecosystem processes	GPP	3%	5%	g C m-2-day-1	Stream health model (QUT) & EHMP freshwater program	2002	Annually	Distance from benchmark	1-| (index value at site guideline)/(WCS-guideline) |	Benchmarks and WCS values for Freshwater
				R24	3%	5%	g C m-2-day-2	Stream health model (QUT) & EHMP freshwater program	2003	Annually	Distance from benchmark	1-| (index value at site guideline)/(WCS-guideline) |	Benchmarks and WCS values for Freshwater
			Fish	PONSE	2%	3%	%	Stream health model (QUT) & EHMP freshwater program	2004	Annually	Distance from benchmark	1-| (index value at site guideline)/(WCS-guideline) |	Benchmarks and WCS values for Freshwater
				Ratio = O/E	2%	3%	Ratio (number)	Stream health model (QUT) & EHMP freshwater program	2005	Annually	Distance from benchmark	1-| (index value at site guideline)/(WCS-guideline) |	Benchmarks and WCS values for Freshwater
				Prop. Alien fish	2%	3%	%	Stream health model (QUT) & EHMP freshwater program	2006	Annually	Distance from benchmark	1-| (index value at site guideline)/(WCS-guideline) |	Benchmarks and WCS values for Freshwater
			Bugs	Number taxa	3%	5%	Number	Stream health model (QUT) & EHMP freshwater program	2007	Annually	Distance from benchmark	1-| (index value at site guideline)/(WCS-guideline) |	Benchmarks and WCS values for Freshwater
				PET richness	3%	5%	Number	Stream health model (QUT) & EHMP freshwater program	2008	Annually	Distance from benchmark	1-| (index value at site guideline)/(WCS-guideline) |	Benchmarks and WCS values for Freshwater
				SIGNAL	3%	5%	Number	Stream health model (QUT) & EHMP freshwater program	2009	Annually	Distance from benchmark	1-| (index value at site guideline)/(WCS-guideline) |	Benchmarks and WCS values for Freshwater
Pollutant load (Section 3.2)	20%	20%	Catchment pollutant load	Sediment load in runoff	7%	7%	Tonnes/year/ha	SOURCE model	2015	Annually	Distance from best case	1-((Value -BCS)/(BCS-WCS)	90th percentile of all sub-catchments in SEQ over 8 years (incl 2011)

				Nitrogen load in runoff	7%	7%	Tonnes/year/ha	SOURCE model	2015	Annually	Distance from best case	1-((Value -BCS)/(BCS-WCS)	90th percentile of all sub-catchments in SEQ over 8 years (incl 2011)
				Phosphorus load in runoff	7%	7%	Tonnes/year/ha	SOURCE model	2015	Annually	Distance from best case	1-((Value -BCS)/(BCS-WCS)	90th percentile of all sub-catchments in SEQ over 8 years (incl 2011)
				Turbidity	4%		NTU	Tuflow models (RWQM) & EHMP estuarine/marine program	2000	Annually	Distance from WQO	Sum | ((annual median - guideline)/(WCS - guideline))/area |	QLD water quality guidelines
				Dissolved oxygen	4%		% Sat	Tuflow models (RWQM) & EHMP estuarine/marine program	2000	Annually	Distance from WQO	1-sum | ((lower guideline-annual median)/(lower guideline-lower WCS))/area |	QLD water quality guidelines
				TN	4%		mg/L	Tuflow models (RWQM) & EHMP estuarine/marine program	2000	Annually	Distance from WQO	1-sum | ((lower guideline-annual median)/(lower guideline-lowerWCS))/area |	QLD water quality guidelines
				TP	4%		mg/L	Tuflow models (RWQM) & EHMP estuarine/marine program	2000	Annually	Distance from WQO	1-sum | ((lower guideline-annual median)/(lower guideline-lowerWCS))/area |	QLD water quality guidelines
Estuarine water quality (Section 3.3)	20%	-	Estuarine water quality	Chl-a	4%		mg/L	Tuflow models (RWQM) & EHMP estuarine/marine program	2000	Annually	Distance from WQO	1-sum | ((lower guideline-annual median)/(lower guideline-lowerWCS))/area |	QLD water quality guidelines
				Freshwater wetland extent	13%	20%	Pre-clear ratio	QLD Gov Wetlands Program	2015	Every 4 years	Distance from best case	1-((Value -BCS)/(BCS-WCS)	Pre-clear
			Freshwater habitat	Riparian extent	13%	20%	Extent and condition	SLATS (QLD Government QLD Herbarium	2015	Every 4 years	Percentage agreement to threshold	N/A	Woody vegetation - 80% Regrowth - 0% Clearing - 0% Median Bio Condition 60%
Habitat (Section 3.5)	40%	40%	Estuarine habitat	Estuarine wetland extent	13%		Pre-clear ratio	QLD Gov Wetlands Program	2015	Every 4 years	Distance from best case	1-((Value -BCS)/(BCS-WCS)	Pre-clear

Table 20: Environmental Condition – Bay Zones

Component	% of score	Index	Indicator/s	% of score	Unit	Data source	Start year	Frequency assessed	Standardisation method	Standardisation calculation	Benchmarks, BCS, WCS
	Bay			Bay							
Bay Water quality (Section 3.4)	50%	Bay water quality	Turbidity	12.50%	NTU	Tuflow models (RWQM) & EHMP estuarine/marine program	2000	Annually	Distance from WQO	Sum | ((annual median - guideline)/(WCS - guideline))/area |	QLD water quality guidelines
			TN	12.50%	mg/L	Tuflow models (RWQM) & EHMP estuarine/marine program	2000	Annually	Distance from WQO	Sum | ((annual median - guideline)/(WCS - guideline))/area |	QLD water quality guidelines
			TP	12.50%	mg/L	Tuflow models (RWQM) & EHMP estuarine/marine program	2000	Annually	Distance from WQO	Sum | ((annual median - guideline)/(WCS - guideline))/area |	QLD water quality guidelines
			Chl-a	12.50%	mg/L	Tuflow models (RWQM) & EHMP estuarine/marine program	2000	Annually	Distance from WQO	Sum | ((annual median - guideline)/(WCS - guideline))/area |	QLD water quality guidelines
Habitat (Section 3.5)	50%	Bay habitat	Seagrass extent	12.50%	Extent of SG/2004 SG extent	DES layer	2015	Every 4 years	Distance from benchmark	1-((seagrass ratio -BCS)/(BCS-WCS)	BCS = 2004 extent
			Seagrass depth range	12.50%	m	EHMP	1993	Annually	Distance from benchmark	1-(value-guideline)/(WCS-guideline)	WCS = min value 1999-2014
			Estuarine wetland extent	12.50%	Pre-clear ratio	QLD Gov Wetlands Program	2015	Every 4 years	Distance from best case	1-((Value -BCS)/(BCS-WCS)	Pre-clear
			Mud content	12.50%	%	EHMP	2015	Every 4 years	Distance worst case	1-(average-change from WCS)/100	WCS=2015 extent

Table 21**:** Waterways Benefits – Catchments

Component	% of score: Drinking water catchments	% of score: Non-drinking water catchments	Index	Indicator/s	% of score: Drinking water catchments	% of score: Non-drinking water catchments	Unit	Data source	Start year	Frequency assessed	Standardisation method	Standardisation calculation	Benchmarks, BCS, WCS
Social benefit to community	60%	75%	Satisfaction with experience of local waterways		20%	19%	% of local residents	HLW community survey (EHMP - QUT)	2015	Annually	N/A	N/A	N/A
			Usability and accessibility	Overall usability	10%	9%	% of local residents	HLW community survey (EHMP - QUT)	2015	Annually	N/A	N/A	N/A
				Overall accessibility	10%	9%	% of local residents	HLW community survey (EHMP - QUT)	2015	Annually	N/A	N/A	N/A
			Personal benefits	Social interaction	7%	6%	% of local residents	HLW community survey (EHMP - QUT)	2015	Annually	N/A	N/A	N/A
				Emotional benefit	7%	6%	% of local residents	HLW community survey (EHMP - QUT)	2015	Annually	N/A	N/A	N/A
				Rest and relaxation	7%	6%	% of local residents	HLW community survey (EHMP - QUT)	2015	Annually	N/A	N/A	N/A
			Connection with waterways	Personal connection to nature	10%	9%	% of local residents	HLW community survey (EHMP - QUT)	2015	Annually	N/A	N/A	N/A
				Motivation to use and protect	10%	9%	% of local residents	HLW community survey (EHMP - QUT)	2015	Annually	N/A	N/A	N/A
Economic benefit to community	40%	25%	Drinking water treatment	Sludge	20%		kg/ML	Seqwater	2015	Annually	Distance from best case	1-| (sludge produced-BCS)/(WCS-BCS) |	BCE=0kg, WCS=478kg/MG
			Recreational value of local waterways	Recreational value	20%	25%	$/person	HLW community survey (EHMP - QUT)	2015	Annually	Distance from best case	1-| (value-BCS)/(WCS-BCS) |	BCE=$3000/person, WCS=4$0/person

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