The Partnership Program Design for the Development ofReport Cards

Phase 2, Version 5

June 2016

June 2016 Phase 2, Version 5, prepared by Nicole Flint, based on Version 4 (Nicole Flint and Don Cook) and earlier Versions 3 (Nicole Flint), 2 (Nicole Flint) and 1(Mary-Anne Jones, Luke Ukkola and Rachel Eberhard)

Acknowledgements

This version and earlier versions were completed with the help of Nathan Johnston and benefited from the advice of the Science Panel of the Fitzroy Partnership for River Health (FPRH). The earlier work of CQUniversity in developing an Ecosystem Health Index and Rachel Eberhard Consulting in assessing stewardship models contributed to major components in this program design.

This report succeeds Phase 1 versions and three earlier Phase 2 versions which constituted the main instructions for the Partnership program design prior to this updated compilation. Phase 1 versions were developed and collated by Rachel Eberhard, Nathan Johnson, Andrew Moss and John Platten.Phase 2 Version 1 was prepared by Mary-Anne Jones, Luke Ukkola and Rachel Eberhard. Phase 2 Version 2 and Phase 2 Version 3 were prepared by Nicole Flint. Raster graphics were developed by Sam Price and other diagrams by Kate Moore.

Version control

Version	Change from previous	Date	Comment
1	First release	May 2013	
2	Annual review	August 2014	
3	Drinking Water Reporting	October 2014	
4	Annual review	June 2015	
5	Annual review	June 2016	

Acronyms and abbreviations

BMP	Best Management Practice
BOM	Bureau of Meteorology
BSC	Banana Shire Council
CQU	Central Queensland University
CSG	Coal Seam Gas
DERM	Qld. Department of Environment and Resource Management
DNRM	Qld. Department of Natural Resources and Mines
DPSIR	Driving force-Pressure-State-Impact-Response framework
EC	Electrical Conductivity
EHMP	Ecosystem Health Monitoring Program
EHI	Ecosystem Health Index
EHP	Qld. Department of Environment and Heritage Protection
FBA	Fitzroy Basin Association
FRP	Filterable Reactive Phosphorous
GBRMPA	Great Barrier Reef Marine Park Authority
JCU	James Cook University
NATA	National Association of Testing Authorities
NH4	Ammonia
NOx	Nitrogen Oxides
pH	acidity or alkalinity of a solution, lower values are more acid
QLUMP	Qld. Land Use Mapping Program
RRMMP	the Reef Rescue Marine Monitoring Program
RRC	Rockhampton Regional Council
SAR	Sodium Adsorption Ratio
SO4	Sulfate
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids

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Executive Summary

This document reports the program design for developing the Ecosystem Health Index and Report Cards of the Fitzroy Partnership for River Health (the Partnership). It also contains recommendations to progress the program design for future reporting years. This report has been endorsed by the Partnership's independent Science Panel.

The assessment program design

The assessment program design is an essential part of delivering the annual Report Card. It provides the specifications for achieving the Report Card objective. The Driving force-Pressure-State-Impact-Response (DPSIR) framework adopted for this Report Card is widely used, including in Australian State of Environment reporting (EHP 2012).

The focus of this and previous reports involved three main DPSIR components:

- State and Impact (condition) of freshwaters, estuary and marine waters
- Responses (incorporating stewardship management actions – under development)
- Driving forces/pressures (as additional information)

The Partnership

The Partnership was formally launched in February 2012. Its purpose is to serve as the official governing body to collaboratively develop and implement integrated waterway monitoring and reporting for the Fitzroy Basin. The Partnership comprises an affiliation of various organisations that have an interest in water quality and aquatic ecology of the Fitzroy Basin and adjacent estuarine and marine waters. It currently involves 21 organisations including government, resources and energy companies, agricultural bodies, CQUniversity and the Fitzroy Basin Association.

The Partnership's vision is for improved waterway management across all water-user sectors with a program of integrated monitoring and reporting that will better inform the community about aquatic ecosystem health at a basin-wide level.To achieve this improved waterway management, the Partnership administers a program (the Program) for coordinating and integrating data from various institutions to develop an annual Report Card for the Fitzroy Basin. Over 20 monitoring schemes are involved in collecting environmental data across the Fitzroy Basin and beyond, including testing carried out in adjacent marine waters for the combined state and federal government's 'Reef Plan' initiative (www.reefplan.qld.gov.au).

Ecosystem Health Index for the Fitzroy Basin

An index of ecosystem health using measurable indicators (EHI) was developed for the Fitzroy Basin and framed to be easily communicable to the public. An EHI is a measure against which the condition of an ecosystem can be scaled, and is created by standardizing and condensing information from a variety of individual indicators. The EHI for the Fitzroy Basin was framed to be easily communicable to the public. It involves a colour-coded score-card method of A-E grades for rating the indicators of ecosystem health.

Freshwater

Eleven freshwater catchment areas are assessed each year. Each catchment reporting area is scored on four assessment categories describing the river state; Physical-Chemical, Nutrients, Toxicants and Ecology. These incorporate the indicators of salinity, pH, sulfate concentrations and turbidity (Physical-Chemical), nitrogen and phosphorus concentrations (Nutrients), macroinvertebrate community composition (Ecology) and heavy metal concentrations (Toxicants).

Estuary

The estuarine assessment is performed in the same format as for freshwater but is based on only three assessment categories; Physical-Chemical, Nutrients and Ecology. Estuary indicators include dissolved oxygen and turbidity (Physical-Chemical), nitrogen and phosphorus concentrations (Nutrients), chlorophyll *a* and barramundi recruitment (Ecology). The estuarine reporting area involves three assessment zones: upper, middle and lower, each of which have specific benchmarks and Worst Case Scenarios (WCSs) for rating the indicators. Toxicants, including heavy metals, are not currently examined because no suitable data are available.

Marine zone

In previous years, the Fitzroy Basin Report Card included a marine zone assessment based on results of the Reef Rescue Marine Monitoring Program (Johnson et al. 2011).

Following a recommendation from the Science Panel, a decision was made by the Management Committee to discontinue Marine Zone reporting from 2014-15 onwards. The reason for this is that it was considered that the results were already available via Reef Plan, and these could simply be referred to as additional information instead of being repeated.

Drinking water

In 2014, the Partnership agreed to develop a new reporting mechanism for raw and treated drinking water. Drinking water reports have been prepared by applying the Australian Drinking Water Guidelines (NHMRC, NRMMC 2011) to data provided by Councils and other suppliers of water to townships.

Agricultural use

In 2015, the Partnership launched a further reporting mechanism, describing suitability of Fitzroy Basin water for livestock and crops. Agricultural use reports apply the Australian “Water quality for irrigation and general water use” and “Livestock drinking water quality” guidelines (ANZECC &ARMCANZ 2000) to all water quality data in the FPRH database.

A similar scoring methodology is used in reporting for the agricultural use and drinking water reports.

Future direction

The Science Panel supports the principle of continuing improvement for the future direction of the Partnership's monitoring and assessment program. It is envisaged that reporting will shape future management planning strategies to maintain or improve water quality and thus aquatic ecosystem health of the Fitzroy Basin.

In 2015-16, the Fitzroy Partnership has commenced a three-yearly strategic review of its operations. The review identified a need for streamlining of processes and increased efficiency, including of monitoring. This component of the review is supported by the completion of the Monitoring Efficiency Review which provided potential areas for increased efficiency of environmental monitoring (Flint et al., 2016).

Indicators of driving forces, pressures and impacts are recommended for incorporation in the Report Card.The need to incorporate indicators that reflect ecological processes is increasingly important. Additional condition indicators required for future Report Cards include riparian vegetation cover, instream connectivity, native fish species (observed: expected), exotic fish species (presence, size, distribution), bank condition, aquatic weeds (percentage cover) and change in natural stream flow. The Science Panel recommended adopting locally relevant macroinvertebrate thresholds for the Fitzroy. Results from current CQU macroinvertebrate research will likely facilitate the development of these thresholds for use in the forthcoming Report Card. Further research in this area has also been proposed.

The Partnership intends to develop a tiered process for stewardship reporting, which will influence this reporting in the futureReport Cards. Other report carding initiatives in Queensland are currently developing such reporting and the outcomes for those report cards may be helpful in the development of similar reporting for the Fitzroy.

The Science Panel foresees that prospective outputs from research and monitoring programs and further program development will be important for evaluating the risks of impacts and expanding reporting to include information on linkages between pressures and stressors and ecosystem health condition for the long-term in reporting on indicators of ecosystem health of the Fitzroy Basin. These may involve predictive models to ascertain relationships or expand current models to accommodate specifics for the Fitzroy. Other important considerations for future reports identified include groundwater influence on base flows (particularly in hot spot areas), and moving towards trend analysis using major drivers such as rainfall distribution and flows to provide context.

1 Introduction

This report documents the design of the program for assessing and reporting on waterway health of the Fitzroy Basin (the Program) on behalf of the Fitzroy Partnership for River Health (the Partnership). Assessment and reporting on river, estuary and marine health of the Fitzroy Basin are the key areas of responsibility for the Partnership (Figure 1-1).

The Partnership is a collaborative body whose main purpose is to develop an integrative waterway monitoring and reporting program that will improve water resource management within the Fitzroy Basin and promote community awareness of waterway health. Partners include the three levels of government, i.e. local, state and federal, resources and energy companies, agricultural bodies, environmental consultants, CQUniversity (CQUni) and the Fitzroy Basin Association (FBA).

The Partnership was officially launched in February 2012 with the initial focus being the waterway-health reporting products. The first Report Card for the Fitzroy Basin was released in May 2013 for the year from July 2010 to June 2011. Since then a further four Report Cards have been released. TheseReport Cards were derived entirely from existing data. The process involved in producing the Report Cards helps to identify research and development needs for future reporting in the Fitzroy Basin.

The program design has been endorsed by the Partnership's Science Panel and developed through collaborative efforts of all project team members involved in Partnership assessment projects since 2012. Major projects that contributed to the program design include the development of an EHI by CQUni and a set of stewardship measures by Eberhard Consulting.

In summary, the purpose of this document is to provide details of the program design used to produce the Partnership's Ecosystem Health Index andReport Cards. It also provides recommendations for further development in the program design for subsequent Report Cards.

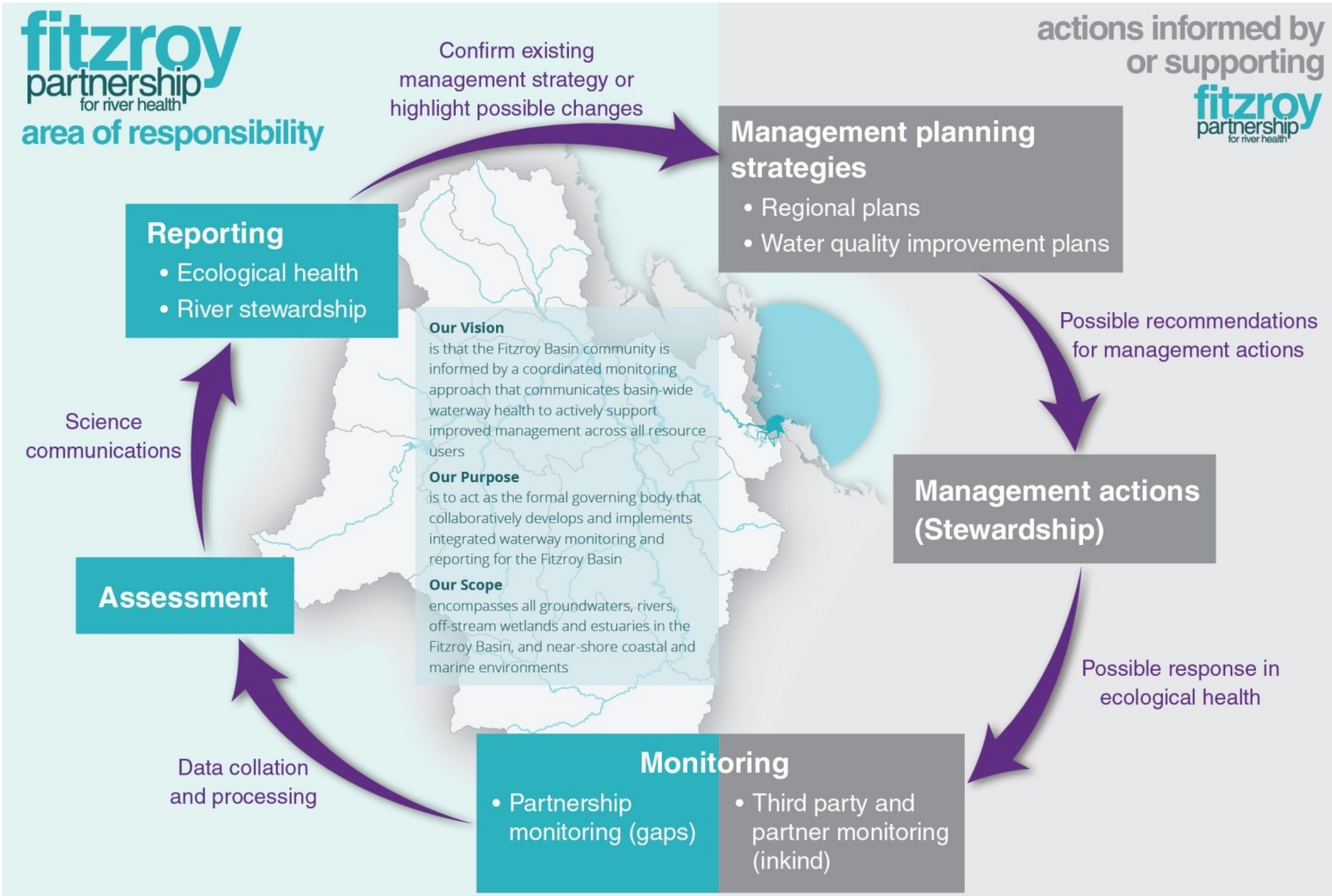

Figure 1-1: The area of responsibility and actions informed by or supporting the Fitzroy Partnership

1.1 Objectives and roles

The objectives for the Partnership's reporting program are to achieve a credible ecosystem health Report Card for waterways of the Fitzroy Basin while supporting continuous improvement in monitoring and assessment of aquatic ecosystem health.

Reporting is informed by an EHI developed by CQUniversity, the Fitzroy Partnership Project Team and the Science Panel. Eberhard Consulting derived an approach for stewardship reporting for the Partnership's program.

The Fitzroy Partnership Project Team includes the Science Leader who directs the development of technical details in reporting and is the link between the Science Panel and the Project Team. The Science Integration Officer collates, manages and develops programs to integrate and assess the large amount of data involved in the reporting program. A Science Project Officer may also be contracted from time to time when required to assist with specific tasks such as the current monitoring efficiency review. Legitimacy is achieved through demonstrating an unbiased system that meets standards of political and procedural fairness. The following steps were implemented to ensure that the reporting program is fair and transparent:

- The selection and use of assessment methods to deliver the agreed reporting framework were determined through the research of reputable third party entities, namely CQUni and Eberhard Consulting.
- The Science Panel of independent and accomplished scientists in disciplines related to the assessment of ecosystem health and water quality was employed to provide advice and oversee assessment methods.

1.2 Science Panel

The Science Panel plays a key role in providing technical credibility and quality assurance mechanisms to the science underlying Partnership reporting products. The Science Panel comprises scientific specialists with appropriate skills across the following areas:

- Fitzroy catchment resource management and water quality
- Relevant water quality expertise for key sectors – mining, water supply
- Freshwater and marine water biochemistry and toxicology
- Freshwater and marine aquatic ecology
- Data and information integration, analysis, synthesis, reporting and communication

A synopsis for each of the Science Panel member's skills and experience can be found on the Partnership's website (www.riverhealth.org.au).The role of the Science Panel is to provide independent, comprehensive, and unbiased scientific and technical advice relevant to the needs of the Partnership. The Science Panel has been integral in establishing the framework for the Partnership in the years leading up to the launch of the Fitzroy Partnership for River Health in February 2012. During the developmental phase of the annual Report

Cards the Science Panel meets on numerous occasions throughout the year to consider and endorse matters relating to the intricacies of producing Report Cards, ensure fairness and transparency in reporting, and ensure credibility of results through scientific rigour and independence.

1.3 The framework for the program design

The framework for the assessment program design is the Driving force-Pressure-State-Impact-Response (DPSIR) model (Figure 1-2), which has been used in the Queensland State of Environment reporting (EHP 2012). The DPSIR was recommended by CQUni and endorsed by the Science Panel in October 2012. A CQUni review of reporting frameworks identified the benefits of using DPSIR over other causal chain frameworks(Flint et al. 2013). The continuing relevance of the model is supported by its use as the basis of new reporting systems such as the iClimate project (Poloczanska et al. 2012).

The following explains the DPSIR components in terms of the catchment landscape.*Driving forces* include the natural influences of climate, landform, geology and hydrology, as well as the human effects of land and water use. The main driving forces relevant to the Fitzroy Basin are listed in earlier documents (e.g. Jones et al. 2000; Johnston et al. 2008; Jones and Moss 2011; Flint et al. 2013).

Driving forces set the scene for the upkeep of ecosystems within the landscape or catchment. They influence the *pressures* that are exerted by humans on the environment. Human pressures include land and water practices that are often influenced by climate conditions. For example, drought is a natural driving force that results in excessive use of water for domestic and industrial purposes. Such a phenomenon creates pressure for the aquatic ecosystems that are reliant on a particular water source. By reducing the freshwater resource, s*tressors* like high salinity, may arise that ultimately change the *state* (or condition) of the waterway in terms of physical, chemical and ecological condition.

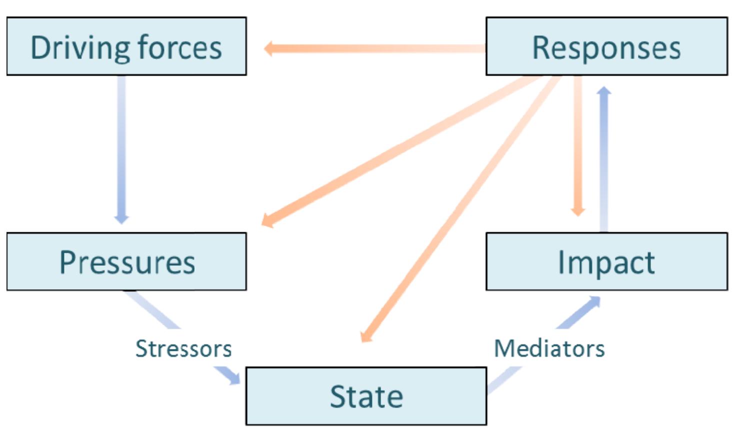

Figure 1-2: The Driving forces-Pressures-State-Impacts-Responses (DPSIR) model

Examples of impacts on aquatic ecosystems include growth of undesirable species (such as algal blooms or aquatic weeds), impaired health of biota and/or the decline in extent or quality of habitats. Impacts on environmental values are typically interrelated, and one may directly or indirectly create another. A *mediator* moderates an impact. An example is the buffering capacity of streams (measured as total alkalinity), which determines the potential impact from change in hydrogen ions (measured as pH).

*Responses*are human activities that deal with the driving forces, the pressures, the state or the impact itself. The 'responses' component corresponds to management actions and is an important element of the framework. Examples of management actions aimed at mitigating impacts and improving or maintaining the state of the ecosystem, include regulatory or legislative instruments, voluntary or stewardship measures, improved community awareness and rehabilitation.

The Partnership has identified a priority research project to map causal linkages and develop indicators for driving forces and pressures in the Fitzroy Basin. That researchwouldidentify driving forces and pressures indicators that can be included in Partnership reporting in the medium term.

1.4 The reporting areas

The condition of three geographic zones: freshwater, estuary and marine were originally reported. In 2014-15 the marine zone reporting was discontinued following a decision by the Management Committee. The freshwater zone was separated into 11 catchment reporting areas that correspond with Queensland Government monitoring. As noted by Flint et al. (2013), the Fitzroy Basin holds a complexity of geography, geology, climate and land use. In part, this can be attributed to the overall size of the drainage area, which covers >142,000 km^2 and isabout twice the size of Tasmania. One way to deal with the spatial heterogeneity is to break the entire basin into smaller catchment areas. Flint et al. (2013) indicated that classification of the basin into smaller reporting areas would partially address the high variability among catchments.

1.5 The data

Data used in the assessments for Report Cards produced to date have been sourced from various information systems across a number of organisations that are responsible for monitoring waterways within the Fitzroy Basin. Each organisation has its own style and requirements for data management. Data-sharing options were offered to these organisations to facilitate the provision of data from each (Appendix 1). The options for provision of data were:

1. "as is" without restriction on access, i.e. in the public domain,
2. with a formal data sharing agreement in place (Appendix 2),
3. licensed under a restrictive use license agreement.

Most organisations chose option 2, which had provisions to de-identify data including the organisation and sampling location. Some were content with option 1, and option 3 was not selected by any partner organisation.

Partner organisations currently include:

- Anglo American
- Arrow Energy
- BHP Billiton Mitsubishi Alliance (BMA)
- Central Highlands Regional Council (CHRC)
- Cockatoo Coal Limited
- Cotton Australia
- CQG Consulting
- CQUniversity
- Ensham Resources
- Fitzroy Basin Association (FBA)
- Gladstone Area Water Board (GAWB)
- Glencore
- Jellinbah Resources
- New Hope Coal
- Peabody Energy
- The Queensland Government
- Queensland Resources Council (QRC)
- Rio Tinto
- Rockhampton Regional Council (RRC)
- Santos GLNG
- Wesfarmers

Thedata used for reporting are from existing programs that monitor the Basin's rivers and their tributaries and the Fitzroy River estuary, and relate only to natural waterways. Ground water data are not currently included in Partnership's reporting although ground water depth is reported in the "Additional information" section of the website. Marine zone reporting is now also provided here.

The dataincludesfield measurements taken using standard collection methods (DERM 2009) and samples analyzed at National Association of Testing Authorities (NATA) accredited laboratoriesafter they had been collected in the field and transferred to the laboratory using standard methods (DERM 2009). Industry licenses stipulate these requirements.

There are benefits and disadvantages of using existing data (Table 1-1). The use of existing data by the Partnership to date has provided a better understanding of knowledge gaps and improvements for future reporting.A Monitoring Efficiency Review activity, completed in March 2016, investigated the additional monitoring required to address the spatial and temporal "patchiness" of the data provided by Partners, and identified duplication of reporting that may be streamlined across the Basin in future years. The results of the review are currently being considered for implementation by the Management Committee.

Table 1-1: The benefits and disadvantages of using existing data

Benefits	Disadvantages
Data are available for a timely assessment and reporting	There are spatial and temporal limitation in the representativeness of the data
Cost savings are realised as extra resources are not expended to obtain the data	Lack of uniformity in formats and configuration of datasets is a limitation for timeliness
Improvements can be identified for current and future monitoring programs	Higher data variability may exist because of different monitoring equipment, laboratories and methods to acquire the data
A large and diverse array of data are collared into one system for future access	Low ability to address questions about the circumstances around the data acquisition, quality and management

2 The driving forces and pressures

Causal linkages and indicators for driving forces, pressures and responses have not yet been developed for inclusion in the Ecosystem Health Index for the Fitzroy Basin. A project proposal to address this knowledge gap has been prioritised by the Science Panel and the Management Committee. At this time, driving forces and pressures are included in the report as additional information. An animation describing the causal links between human actions and the environment using the DPSIR framework has recently been added to the Partnership's website.

2.1 Driving forces and pressures

Driving forces

Unlike the earlier years of Partnership reporting which were strongly influenced by the 2010-12 La Niña events, during 2014-15 and the previous year (2013-14) the El Nino Southern Oscillation shift into an El Niño state. In eastern Australia, El Niño is often associated with below-average winter and spring rainfall[1].

While rainfall during 2010-12 resulted in some of the biggest floods in living memory, rainfall declined following the conclusion of La Niña in 2013. Serious to severe 43 month rainfall deficiencies are in place through central and western Queensland, in a zone stretching from far north Queensland to northern NSW, as well as in western Victoria[2]. The Partnership's rainfall trend reporting also shows declining rainfall across the Fitzroy Basin until 2013-14 and a slight increase for 2014-15[3].

Pressures

Pressures including land uses (e.g. grazing) and weather patterns (drought) influence groundcover. Groundcover reduces erosion, runoff and the spread of contaminants into downstream environments. In 2014-15 ground cover has increased very slightly from 2013-14[4].

In 2011-12 there were 42 coal mines operating in the Fitzroy Basin, producing 80% of Queensland's 187 million tonnes of saleable coal (Queensland Government 2013a). As a result of high rainfall, 28 of these mines released 17,240 megalitres (ML) of mine-affected

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[1] http://www.bom.gov.au/climate/enso/ Accessed June 2016.

[2] http://www.bom.gov.au/climate/drought/ Accessed June 2015.

[3] http://riverhealth.org.au/report_card/additional-info/rainfall/trend Accessed June 2015.

[4] http://riverhealth.org.au/report_card/additional-info/ground_cover/trend Accessed June 2015.

water during 2011-12 and 34,121 ML in 2012-13[5]. In 2010-11 salinity values remained above long-term averages across the Basin and this was thought to be caused by the influence on base flows of historically high groundwater levels (DEHP 2013).

In contrast, the below average rainfall in the 2013-14 wet season resulted in low stream flow conditions in the inland catchments and the release of only 1,945 ML of mine water[8] (Table 2-1). The Queensland Government's coal mine water release pilot program continued with increased participation in 2013-14 (up from four mines in 2012-13 to eight mines in 2013-14). Mine water releases in 2014-15 included: one compliant release in April 2014, 17 compliant releases in December 2014, 40 compliant releases in January 2015, 15 compliant releases in February 2015 and three compliant releases in March 2015[6]. Volume of mine water released was not published online for 2014-15. An enhanced environmental monitoring program was again implemented for the 2014-15 wet season to monitor any impacts of the pilot on catchment water quality[7].

Table 2-1: Mine water releases as a proportion of overall catchment flow[8]

	2011-12	**2012-13**	**2013-14**
Mine water released (ML)	17,240	34,121	1,945
Total flow at The Gap (ML)	5,716,965	9,458,000	1,610,000
Percentage contribution of mine water to total catchment flow	0.30	0.36	0.12

[5] https://www.fitzroyriver.qld.gov.au/coal-mine-management/201314-mine-water-release-pilot-program-review Accessed May 2016.

[6] http://www.ehp.qld.gov.au/land/mining/water-releases/monthly.php#2014-04 Accessed May 2016.

[7] https://www.fitzroyriver.qld.gov.au/water-quality/enhanced-environmental-monitoring-program-qld/20142015-wet-season-monitoring-results Accessed May 2016.

3 Reporting on indicators of ecosystem health

3.1 Defining ecosystem health

Ecosystem health is typically defined in terms of assessable characteristics that relate to the physical, chemical and biological processes, vigor (activity or rate of processes), organization (complexity of food webs, wealth of biodiversity) and degree of resilience (or capacity to withstand and recover from disturbance) within the ecological system (Rapport et al. 1998).

3.2 The Fitzroy ecosystem health assessment

The Partnership Report Card provides an assessment of 12 reporting areas. The assessment involvesthe freshwater catchments and the estuary (Figure 3-1). The freshwater zone of the Fitzroy Basin is separated into 11 smaller freshwater catchment reporting areas (Table 3-1), to expand the scope of the assessment and reporting to reflect the major catchment divisions within the basin. The estuary zone was chosen based on the FBA's receiving model (Johnston et al. 2008). These catchments and the estuarine reporting areas also match the zones described for the Fitzroy Basin water quality objectives under Schedule 1 of Queensland's Environmental Protection Policy for Water (EPP Water).

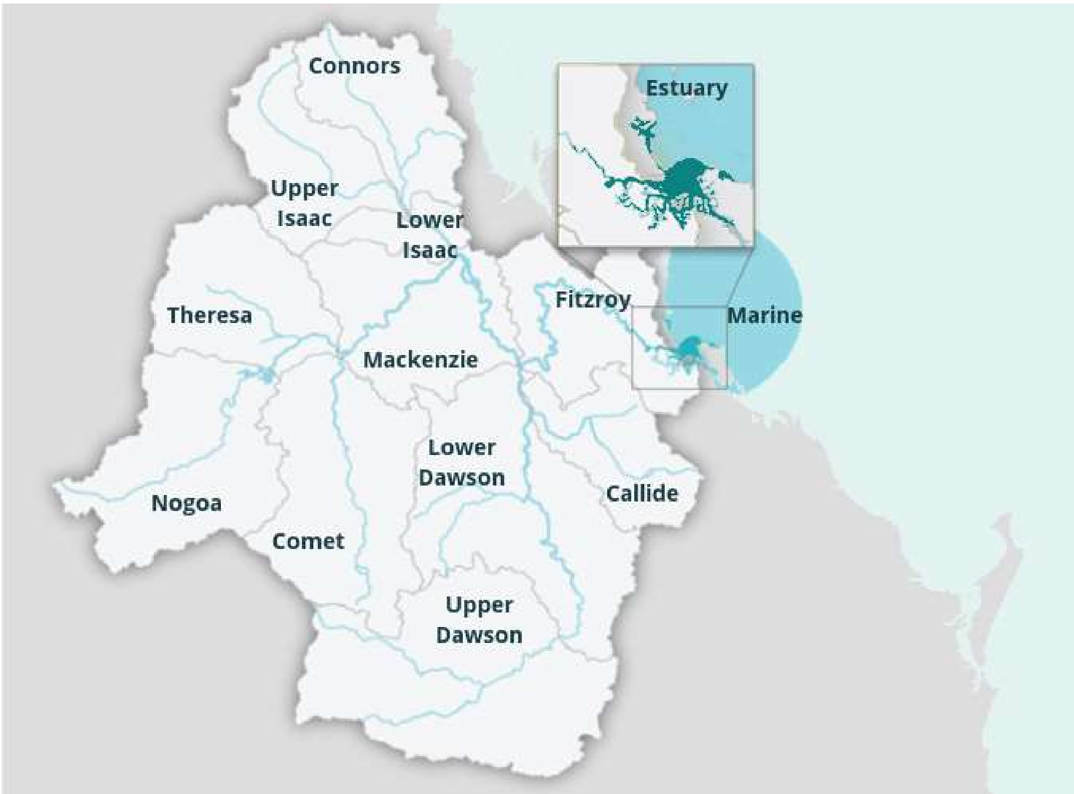


Figure 3-1: The 13 reporting areas, comprising 11 freshwater catchments, the estuary and adjacent marine environment of the Fitzroy Basin(note that the marine zone is no longer included in Report Cards).

3.3 The freshwater system

The condition of rivers and streams varies naturally with flow regime. To partially account for this in the Fitzroy Basin, each freshwater catchment was assessed for two broad flow conditions (low and high flow) during 2010-11. A single flow gauging station was chosen near the end of each catchment (Table 3-1&Figure 3-2) and used to extrapolate flow conditions for the whole of that catchment. Ideally, this determination would have involved a site by site assessment and include stream flow data for individual sites. However, the quantity of sites involved and time constraints restricted this being done, and this expanded approach needs further consideration in future reporting. Flow rate break-points delineating high and low flow were calculated for each of these sites from split-line regression analysis of flow and electrical conductivity (EC) data using the software package Genstat 14 (VSN International, UK).

Table 3-1:The 11 freshwater catchment reporting areas, catchment reporting area sites for determining flow separation and the break point (cumec) for each flow separation

Catchment reporting area	Site Name	Flow regime break-point* (cumec)
Comet	Comet River at The Comet Weir	24
Connors	Connors River at Pink Lagoon	70
Lower Dawson	Dawson River at Beckers	16
Upper Dawson	Dawson River at Taroom	9
Callide	Don River at Rannes Recorder	11
Fitzroy	Fitzroy River at The Gap	41
Mackenzie	Mackenzie River at Coolmaringa	42
Nogoa	Nogoa River at Craigmore	9
Lower Isaac	Isaac River at Yatton	89
Upper Isaac	Isaac River at Deverill	9
Theresa	Theresa Creek at Gregory Highway	3.5

*Flow rate break-point was derived from split-line regression analysis of flow and electrical conductivity (EC) data and in this instance is the flow rate that delineates the high and low flow at each site

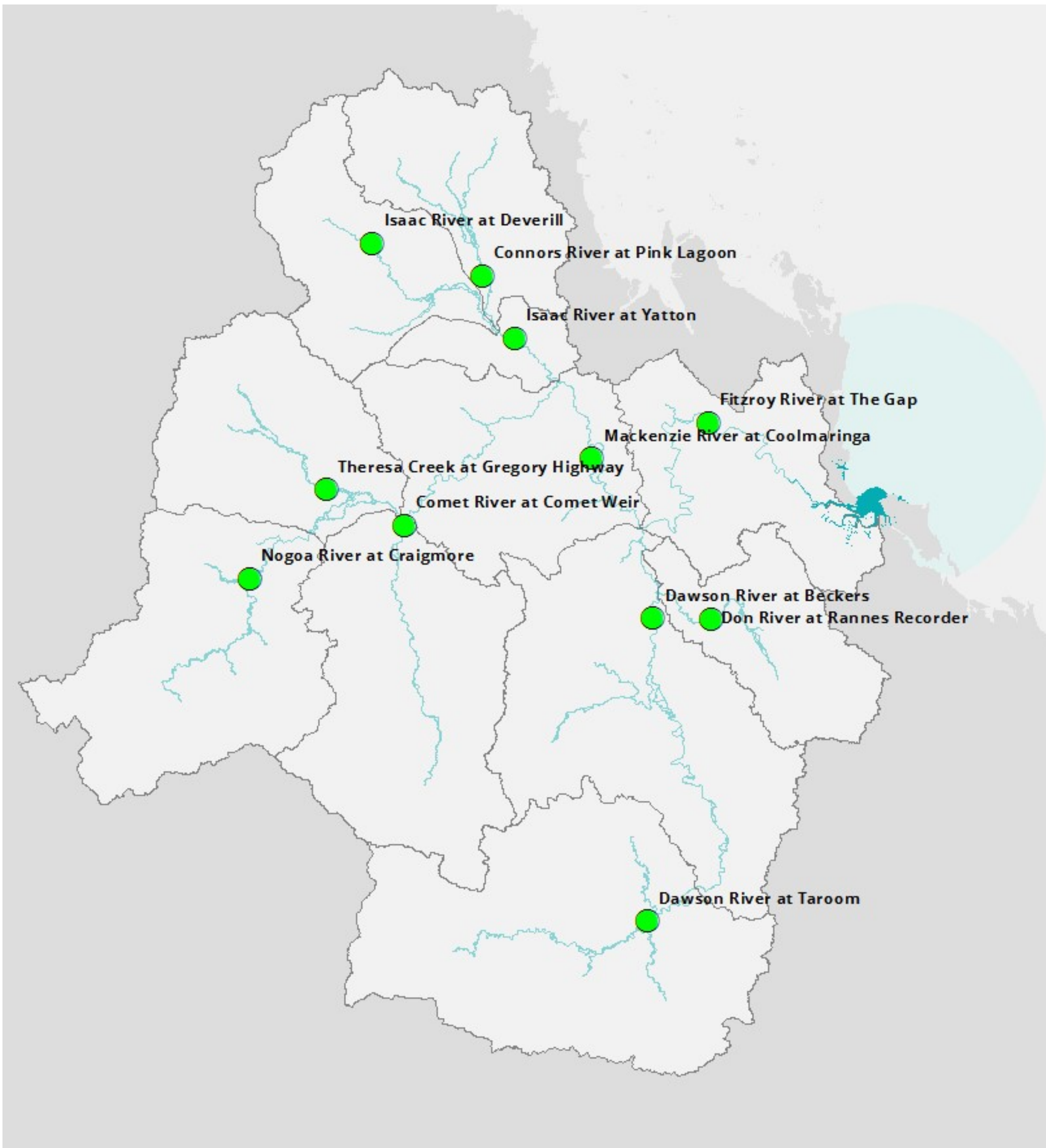


Figure 3-2: The 11 freshwater catchment reporting areas and the gauging stations used to define the flow regimes for the relevant catchments of the Fitzroy Basin

3.3.1 TheEcosystemHealth Index for the catchment reporting areas

An EHI for the Fitzroy Basin was developed byCQUni and reviewed and endorsed by the Science Panel (Flint et al., 2013 and Jones et al., 2013). An EHI is a measure of ecosystem health derived from combining several indicators that relate to the nature and condition of the ecosystem. Determining a set of indicators may relate directly to the state of an ecosystem or refer to the drivers and pressures, impacts or responses that are associated with the ecosystem state (see the DPSIR framework; Figure 1-2). They are rated against thresholds of the preferred and the worst case scenarios. The individual ratings are then combined into an EHI. The use of indices to report on waterway health is widely accepted in the United States (e.g. Bain et al. 2000) and in Australia (e.g. Norris et al. 2007).

The focus for the EHI in this first Report Card involved *condition indicators*. The CQUni project team developed an EHI for the Fitzroy Basin from a series of proposals and refinements over the design phase of the reporting program. The proposals included the following components to score ecosystem condition:

- four assessment categories (Physical-Chemical, Nutrients, Toxicants and Ecology)
- list of potential indicators
- best and worst case scenario benchmarks for chosen indicators
- weighting the overall contribution of categories and selected indicators to the EHI
- a system for combining and scoring indicators

Refinements to these components were guided by the then Science Leader (Dr Mary-Anne Jones) and the Science Project Team. The advice of the Science Panel was incorporated to provide the final endorsed EHI for the Fitzroy Basin for the first (2010-11) and subsequentReport Cards. The full list of potential indicators and recommendations from the CQUni project are given in Part B of their technical review for the development of an EHI for the Partnership (Jones et al. 2013). The indicators selected for the first Report Card are listed in Table 3-3. It is noted that the lack of ecological data led to the EHI initiallyconsisting primarily of water quality indicators.

3.3.1.1 Categories and indicators of the catchment reporting areas

Each catchment reporting area was scored on four assessment categories describing the river state, namely, Physical-Chemical, Nutrients, Toxicants and Ecology (Table 3-3). These incorporated the indicators of salinity, pH, sulfate concentrations and turbidity (Physical-Chemical), nitrogen and phosphorus concentrations (Nutrients), macroinvertebrate community composition (Ecology) and metal concentrations (Toxicants).

To arrive at the chosen indicators, a full list of over 100 potential indicators was first generated by CQUni from a desktop review of previous work. The list was then assessed against selection criteria (Table 3-2) that were developed by CQUni using several sources, including the Science Panel, reports, expert opinion and awareness of other programs (Flint et al. 2013; Jones et al. 2013). More details of the selection process are provided in Jones et al. (2013).

The indicators chosen as high priority by the Science Panel were:

- pH, turbidity (NTU), sulfate andsalinity (EC) at base flow
- nitrate as N, total nitrogen as N, total phosphorus, filterable reactive phosphorus,
- chlorophyll-*a*, macroinvertebrates (PET, taxa richness, SIGNAL index and % tolerant taxa), riparian vegetation (condition, extent, composition and connectivity), instream connectivity, native fish species (observed:expected), exotic fish species (presence, size, distribution), bank condition, freshwater pest plant % cover and flow
- dissolved metals/metalloids and total selenium

These were chosen based on expert opinion of the Science Panel and the Science Project Team in terms of the risks of impacts affecting the aquatic ecosystems of the Fitzroy Basin and the best indicators to assess such impacts. Total Se was chosen because the current guidelines refer to the total form for this element as does the industry licenses for companies that collect such data.

Of the indicators given high priority by the Science Panel, the CQUni project team determined that fish, macrophyte, instream connectivity, riparian vegetation, bank condition and chlorophyll-*a* did not meet the selection criteria due to a lack of existing data. Also, CQUni recommended that total oxidised nitrogen (nitrate + nitrate as N) be substituted for nitrate as N because existing water quality guidelines relate to the former only.

Salinity (EC) at high flow ranked well in the selection criteria, and since data and water quality objectives existed for this indicator, CQUni proposed that it be includedin the EHI but separately to the 'EC at base flow' indicator. However, following advice provided by the Science Panel, all EC data were included within a single indicator in the Physical-Chemical category. The Science Panel endorsed a flow correction approach to score the combined low and high flow EC observations (see Section 9.2.1). The Science Panel also deemed flow to be a driving force indicator to be reported separately and not scored as part of the EHI.

The final list of indicators for the catchment reporting area EHI comprised salinity (EC), sulfate concentrations, turbidity (NTU), pH, nitrogen and phosphorus concentrations, metals and macroinvertebrate community composition (Table 3-3). Data for nutrients, toxicants and macroinvertebrates were included, though limited in the available sample results.

The Science Panel recommended that the number of dissolved metals (which currently stands at 17) be reviewed and reduced if possible. Several current research projects are investigating metal monitoring in the Fitzroy Basin and their results, when available, will assist with this review.

Table 3-2: The indicator selection criteria for the EHI as defined by CQUni scored potential indicators as Yes = 10, Probably = 7.5, Possibly = 5, Probably not = 2.5 and No = 0

Category	Selection criteria	Weighting of selection criteria within category	Weighting of category
Data	SC1 – Reliable data currently available for the Fitzroy Basin	25%	25%
	SC2 – Suitable interpretative algorithms are available	25%	
	SC3 – Errors, reliability and uncertainty in measurement are known and acceptable*	25%	
	SC4 – Temporal and spatial variability can be accounted for	25%	
Interpretation and communication	SC5 – Guidelines/ objectives are in place and relevant to the region*	25%	25%
	SC6 – Used in other monitoring programs (consistent with other regions, states, nations)	25%	
	SC7 – Scientific interpretation is straightforward and meaningful	25%	
	SC8 – Indicators are simple to communicate with good public understanding	25%	
Relevance	SC9 – Important to ecosystem function (will exposure cause serious environmental effects?)	25%	25%
	SC10 – Sensitive to changes in ecosystem function	25%	
	SC11 – Contributes to assessment of ecosystem resilience	25%	
	SC12 – Related to regional, state, national, international policies and management goals	25%	
Practicality and timeliness	SC13 – Feasibility and logistics to measure (monitor and analyse) are consistent with outcome benefits	25%	25%
	SC14 – Time requirements to measure (monitor and analyse) are consistent with outcome benefits	25%	
	SC15 – Costs to measure (monitor and analyse) are consistent with outcome benefits	25%	
	SC16 – Provides an early warning of ecosystem health decline	25%	

Source: Flint et al. (2013)

Table 3-3: The indicators for freshwater used in the EHI for the 2010-11 and subsequent Report Cards

Physical - Chemical Category	**Salinity (EC)**	**pH**	**Turbidity**	**Sulfate**
Indicator descriptions from QWQG (DERM 2009), except sulfate which is from www.env.gov.bc.ca:	A measure of the amount of dissolved salts in the water, and therefore an indicator of salinity. In freshwater, low EC indicates suitability for agricultural use. In salt waters low EC indicates freshwater inflows such as stormwater runoff. Under natural conditions, EC in freshwater systems is highly dependent on local geology and groundwater.	A measure of the acidity or alkalinity of the water. Changes to pH can be caused by a range of potential water quality problems (e.g. low values due to acid sulfate runoff).Extremes of pH (less than 5 or greater than 9) can be toxic to aquatic organisms, although some waterways (e.g. wallum streams) have naturally acid waters (as low as pH 3.6) and ecosystems are adapted to these conditions.	A measure of light scattering by suspended particles in the water column. It can provide an indirect indication of both light penetration and suspended solids but the relationships between turbidity and these other indicators vary in different waters.	Sulfates are discharged into the aquatic environment in wastes from industries that use sulphates and sulphuric acid, such as mining and smelting operations, kraft pulp and paper mills, textile mills and tanneries. Iron sulphides (e.g. FeS) may be exposed to water and atmospheric oxygen by mining or rock excavation, producing sulfuric acid, which contributes sulfate to ground and surface waters. Sulfates are also released during blasting and the deposition of waste rock in dumps at metal mines. This is known as acid rock drainage. The burning of fossil fuels is also a major source of sulfur to the atmosphere. Most of humankind's emissions of sulfur to the atmosphere, about 95%, are in the form of SO_2. Sulfate fertilizers and pesticides are also a major source of sulfate to ambient waters.
Nutrients Category	**Nitrogen (N)**		**Phosphorus (P)**	
Indicator description from QWQG (DERM 2009):	Total nitrogen as N	Oxidised N (nitrate + nitrate as N)	Total phosphorus	Filterable reactive phosphorus
	Includes all forms of nitrogen in a sample	Sum of nitrate nitrogen (NO_3) and nitrite nitrogen (NO_2)	Includes all forms of phosphorus in a sample	Includes all forms of phosphorus that pass through a 0.45µm filter and react with molybdenum blue reagent – this fraction is usually very largely comprised of orthophosphate (PO_4)
	The nutrients N and P are essential for plant growth. High concentrations indicate potential for excessive weed and algal growth. Nutrients in the water column are made up of an inorganic (e.g. nitrate plus nitrite, ammonia and filterable reactive phosphorus) and an organic component, which is bound to carbon (e.g. organic nitrogen). The organic component can be either dissolved or particulate.			
Toxicants Category Indicator description from ANZECC & ARMCANZ (2000):	**Metals/metalloids (**dissolved Al (pH >6.5),dissolved As, dissolved Ag, dissolved B, dissolved Cd, dissolved Cr VI, dissolved Co, dissolved Cu, dissolved Fe, dissolved Pb, dissolved Mn, dissolved Mo, dissolved Hg (inorganic), dissolved Ni, dissolved U, dissolved Zn and total Se) 'Toxicants' is a term used for chemical contaminants that have the potential to exert toxic effects at concentrations that might be encountered in the environment. For specific details on individual metals see 8.3.7 of Vol. 2 ANZECC & ARMCANZ (2000).			

Ecology Indicator description from QWQG (DERM 2009a):	**Macroinvertebrates**		
	PET taxa richness	Taxa Richness	SIGNAL index
	It is generally accepted that three orders of aquatic insects, the **P**lecoptera (stoneflies), **E**phemeroptera (mayflies) and **T**richoptera (caddis flies) – the PET taxa – are highly sensitive to human disturbance. PET richness is the total number of families in these three orders that are present in a sample.	Family richness is the total number of different aquaticmacro-invertebrate families that are present in a sample.	The SIGNAL (**S**tream**I**nvertebrate **G**rade **N**umber **A**verage**L**evel) index allocates a sensitivity grade number based to macroinvertebrate families based on their sensitivity to various water quality changes(Chessman 1995). SIGNAL values range from 1 (most tolerant) to 10 (most sensitive). The SIGNAL index value is calculated by averaging the sensitivity grade numbers of the taxa present in a sample.

Source: Jones et al. (2013)

Additionally, the pesticides: Methoxyethyl mercury chloride(MEMC) and ametryn; the herbicides: hexazinone, tebuthiuron, atrazine and diuron; metals in sediments, and the extent of wetlands were flagged by the Science Panel for future inclusion and potentially special reporting in years 1-2 of the Report Card. Data gaps preclude inclusion in the index.

The Science Panel believes that a complete EHI should include robust ecological indicators. Of the ecological indicators identified by the Science Panel,macroinvertebrate samplingprovided the only available data for the 2010-11 and 2011-12 Report Cards. On consideration of the macroinvertebrate resultsthe Science Panel noted that theassessment of macroinvertebrate data produced inconsistent grades to those of other indicators and suspected this may be due to poor choice of thresholds. Nevertheless, the thresholds used in this first report were the best macroinvertebrate health values at the time.

The Science Panel decided to retainthe macroinvertebrate results in the Report Card as it considers ecological indicators vital to an assessment and reporting of aquatic ecosystem health. However, the Science Panel recommends macroinvertebrate thresholds be updated as soon as locally relevant guidelines are established, noting that there is a current project by CQUni aiming to achieve this outcome.

With the principal of continuous improvement in mind, the panel emphasizedadopting locally relevant macroinvertebrate thresholds for Fitzroy Partnership assessments and reporting in the future. The panel noted that this action has the potential to influence grades and scores for macroinvertebrates in future reporting and highlighted this likelihood now to ensure the transparency of the process.

3.3.1.2 Benchmarks defining the ecosystem health levels for freshwater indicators

Numerical thresholds (or benchmarks) are typically used to define whether an indicator is in a healthy condition or at the other end of the scale, a degraded state.

There are several ways of defining benchmark values for parameters of interest. These include using:

- water quality guidelines
- water quality objectives set down in legislation or policy
- benchmarks of other ecosystem health reporting systems
- analyses of local data
- expert opinion
- theoretical limits in literature
- predictive functions where values are related to levels of other relevant variables.

The EHI benchmarks for the preferred condition (reference benchmarks) and the WCSs for each indicator are listed in Table 3-4 for freshwater.

The reference benchmarks for freshwater indicators correspond to the water quality objectives (WQOs) for protecting ecosystem health within the Fitzroy Basin, as defined under Schedule 1 of the Queensland Environmental Protection Policy for Water (EPP Water). These WQOs are documented for each freshwater reporting area and are publicly available from the Queensland Department of Environment and Heritage Protection (www.ehp.qld.gov.au).

The WCSs for macroinvertebrates, salinity, pH and sulfate in freshwaters are based on published limits pertaining to ecological degradation or biological harm (Table 3-4). The WCSs for Metals are based on the national guideline limits set down to protect 80% of freshwater aquatic species. For turbidity and nutrient indicators, the 90th percentiles of the overall Fitzroy Basin data held by DNRM for natural freshwaters have beenadopted for these indicators. The 90th percentile is the value below which 90% of the data exist. This is a similar approach to that used for freshwaters in the long-standing SEQ EHMP (www.healthywaterways.org).

3.3.1.3 Weighting of the categories and indicators

The weighting of categories and indicators in an EHI is used for moderating or emphasizing the contribution of certain categories/indicators to the overall score. This is simply because the weighted components may have greater importance in terms of assessing the ecosystem health within the assessment area (Bennett et al. 2002).

However, the most simple and straightforward approach is to apply equal weighting to every indicator within each category, and then apply equal weighting to every category in order to generate an overall score. For example, the original proposed EHI in the design for the Fitzroy was made up of four assessment categories that were evenly weighted, i.e. each were awarded 25 per cent of the overall EHI, and each indicator within these categories were awarded an equal per cent of the category score.

The benefit of this approach is that, if in one catchment reporting area there is insufficient data to calculate a score for a particular indicator, then that indicator can be removed and the weightings easily redistributed among the remaining indicators in the category. The downside of this approach is that it does not take into account the greater influence some indicators may have over others in terms of impact on local ecosystem health, or the potential for “double-counting” of impacts (Flint et al. 2013).

With the individual nutrient indicators being interrelated the Science Project Team proposed a change in weighting between the Nutrient and Physical-Chemical categories. The Science Panel endorsed this proposal which involved a reduction in the relative importance of the Nutrient category to 10% and an increase in the Physical-Chemical category to 40%. In effect, this allocated equal apportionment among the combined nutrient indicators and the four Physical-Chemical indicators with each weighing 10%. Together they contributed half of the overall EHI. The final EHI and weighted categories and indicators for the 2010-11 Report

Card assigns 25% each to Ecology and Toxicants categories, 10% to Nutrients and 40% to Physical-Chemical, as shown in Figure 3-3.

Table 3-4: Benchmarks and worst case scenarios for the freshwater indicators

Physical-Chemical Indicators	Benchmark	Worst Case Scenario (WCS)	Notes
Salinity (EC)	WQO Sub-basin low flow specific e.g. EC for Mackenzie at base flow <310 µS/cm	>1500 µS/cm (low flow) >730 µS/cm Callide (high flow) >370 µS/cm (high flow in all except Calllide)	>1500 µS/cm aquatic biota adversely affected (Hart et al. 1991) >730 and >370 µS/cm derived from 90th percentile of catchment data for respective areas
Turbidity (NTU)	WQO All catchments <50 NTU	350 NTU	Note: WQO is taken from the QWQG central coast region lowland streams, which is taken from ANZECC south – east Australia lowland rivers; 50 NTU is already the uppermost range of the ANZECC guide of 6-50 NTU. Realising that the Fitzroy can be a highly turbid system and that the WQO is already the maximum guideline recommended nationally, and that it is above many international recommendations; a WCS was difficult to reference. It was derived from 90th percentile of the whole of catchment data sourced from the DNRM water quality database.
Sulfate (or SO_4)	WQO Sub-basin specific e.g. Mackenzie <10 mg/L	100 mg/L	Cited in ANZECC & ARMCANZ (2000)
pH	WQO pH 6.5-8.5 (All sub-basins)	Diminishing exponential function between 4.5 and 6.5 and 8.5 and 11, with a steeper weighting below 6.5	WCS is based on: Fabbro, L.D.(1999) as well as CQU data accumulated from CSIRO and NHT projects

Nutrient Indicators	Benchmark	Worst Case Scenario (WCS)	WCS Notes
Total Nitrogen as N	WQO e.g. Mackenzie <775 µg/L	>1300 µg/L	WCS derived from 90th percentile of the whole of catchment data, sourced from DNRM water quality database.
Oxidised nitrogen (Nitrate + Nitrate as N)	WQO All sub-basins <60 µg/L	>300 µg/L	WCS derived from the 90th percentile of the entire recordof catchment datafor this indicator sourced from the DNRM water quality monitoring group.
Total Phosphorus	WQO e.g. Mackenzie <160 µg/L	>500 µg/L	WCS derived from 90th percentile of the whole of catchment data, sourced from DNRM water quality database.
Filterable Reactive Phosphorus	WQO All catchments <20µg/L	>170 µg/L	WCS derived from 90th percentile of the whole of catchment data, sourced from DNRM water quality database.

Toxicant Indicator	Sub indicator	Benchmark** (µg/L)	Worst Case Scenario (µg/L)	WCS Source
Metals	Dissolved Ag	0.05	0.20	ANZECC toxicant trigger value for 80 per cent protection of species
	Dissolved Al (pH >6.5)	55	150	ANZECC toxicant trigger value for 80 per cent protection of species
	Dissolved As	13	140	ANZECC toxicant trigger value for 80 per cent protection of species
	Dissolved B	370	1,300	ANZECC toxicant trigger value for 80 per cent protection of species
	Dissolved Cd	0.2	0.8	ANZECC toxicant trigger value for 80 per cent protection of species
	Dissolved Cr VI	1	40	ANZECC toxicant trigger value for 80 per cent protection of species
	Dissolved Co	^2.8	^90	ANZECC (low reliability data trigger)
	Dissolved Cu	1.4	2.5	ANZECC toxicant trigger value for 80 per cent protection of species
	Dissolved Fe	*300	1,600	As per acute toxicity maximum for macroinvertebrates(Warnick and Bell 1969)

	Dissolved Hg (inorganic)	[B] 0.06	5.40	ANZECC toxicant trigger value for 80 per cent protection of species
	Dissolved Pb	3.4	9.4	ANZECC toxicant trigger value for 80 per cent protection of species
	Dissolved Mn	[#]1900	3,600	ANZECC toxicant trigger value for 80 per cent protection of species
	Dissolved Mo	^34	73	Canadian Water Quality Guidelines for the Protection of Aquatic Life
	Dissolved Ni	11	17	ANZECC toxicant trigger value for 80 per cent protection of species
	Dissolved U	^0.5	10	As per ranger uranium mine receiving water standard set by the Environmental Research Institute of the Supervising Scientist
	Dissolved Zn	8	31	ANZECC toxicant trigger value for 80 per cent protection of species
	Total Se	[B] 5	34	ANZECC toxicant trigger value for 80 per cent protection of species
Ecological Indicator	**Sub indicator**	**Benchmark**	**WCS**	**Notes**
Macroinvertebrates	Taxa Richness (edge)	33	23	Fitzroy WQO is based on QWQG Central Coast regional biological WQG where,'The values for these macroinvertebrate biological indicators are based on the QWQG Central Coast regional biological water quality guidelines. They apply to support waters at a moderately disturbed level of protection. Values are provided for 20th and 80th percentiles. The median value of biological indicators at test sites is to be compared and assessed against these values'. Hence the 20 and 80 percentiles of this reference data was set as the benchmark and WCS
	PET taxa Richness (edge)	5	2	
	SIGNAL index (edge)	4.20	3.31	

*No ANZECC guideline for Iron, have used Canadian guideline.

^Co, Mo, U and V are ANZECC low reliability trigger values using chronic data.

[B] bioaccumulation through the food web possible, hence 99% protection trigger value used, as per ANZECC.

**ANZECC toxicant trigger values for slightly-moderately disturbed systems; 99% or 95% protection of species as per ANZECC table 3.4.1.

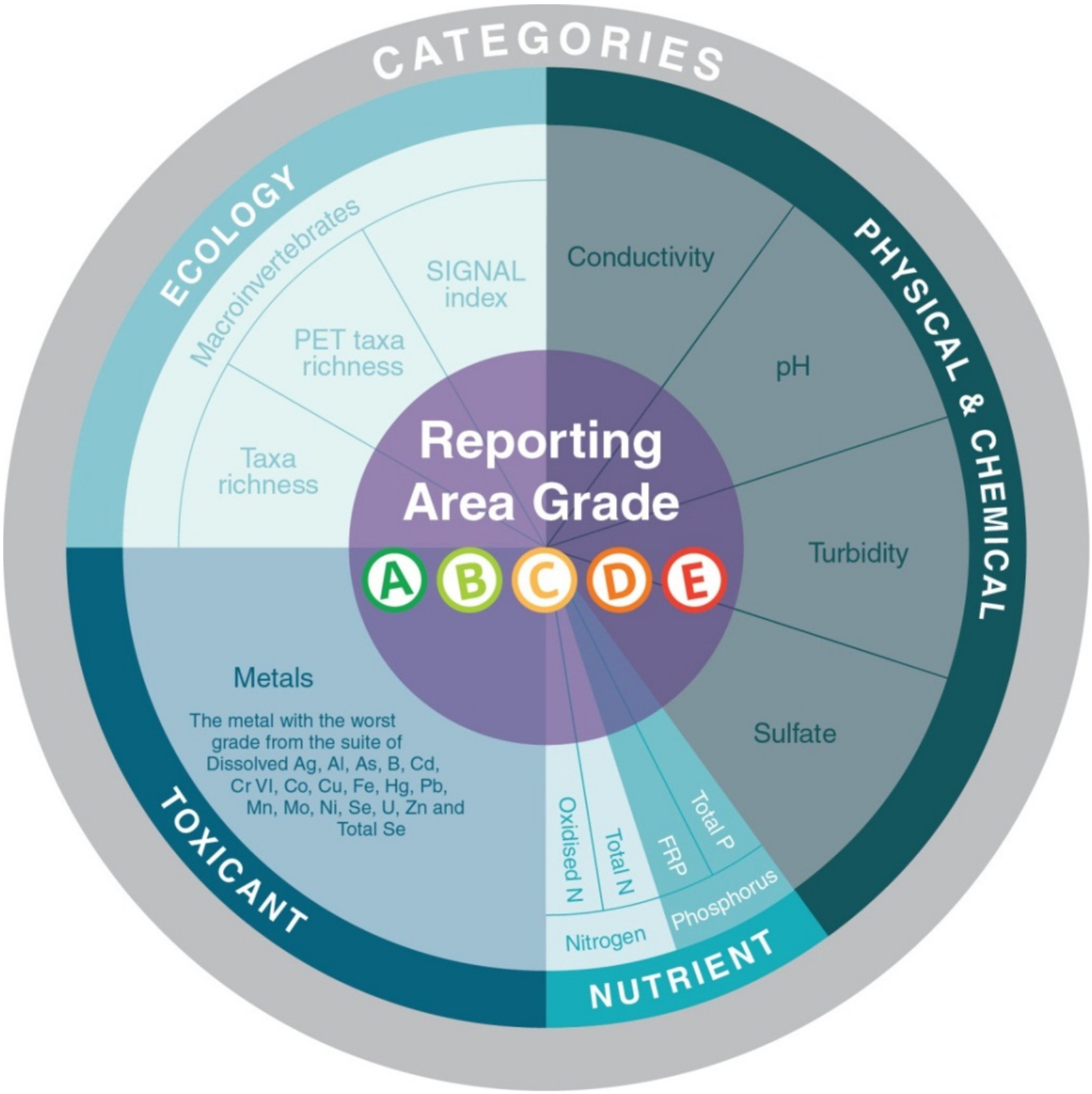


Figure 3-3: The categories and indicators and their weightings for the Fitzroy freshwater (catchment) EHI used in the 2010-11 Report Card

The correct weighting among indicators may need further investigation and resolution. However, this will require further research into ecosystem function and interrelationships between indicators and stressors.

3.3.1.4 The system for scoring the catchment reporting areas

Each indicator is incorporated into the EHI using a standardised scoring system, which allocates each indicator a score between zero and 100. The process is best described as follows:

Step 1: **Sites.**Every sample of a site is rated against the reference and worstcase scenario benchmarks for each indicator. For every indicator, site sample scores are aggregated and then averaged for each site. All site scores are then combined per reporting area and averaged to give separate indicator scores for every reporting area (Figure 3-4).

Step 2: **Reporting areas**. The scores of the different indicators are grouped by ecosystem health category for each reporting area and then averaged to give category scores for every reporting area (Figure 3-5).

Step 3: **The Fitzroy Basin**. The average of these category scores provides the overall catchment score (Figure 3-6).

The exception is “Metals” (toxicant category), which contains several individual metals. During the development of the EHI the Science Panel recommended the worst individual metal score rather than the average of individual metal scores at Step 2 for this indicator. This approach was chosen because one metal alone can make the water toxic, even if all other metals are within guidelines.

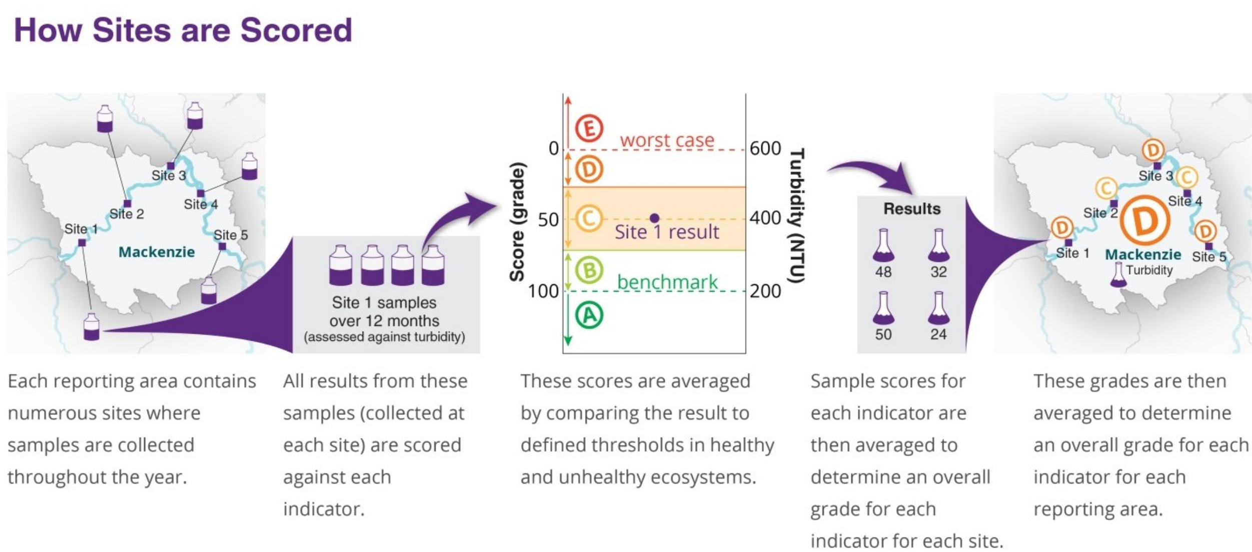
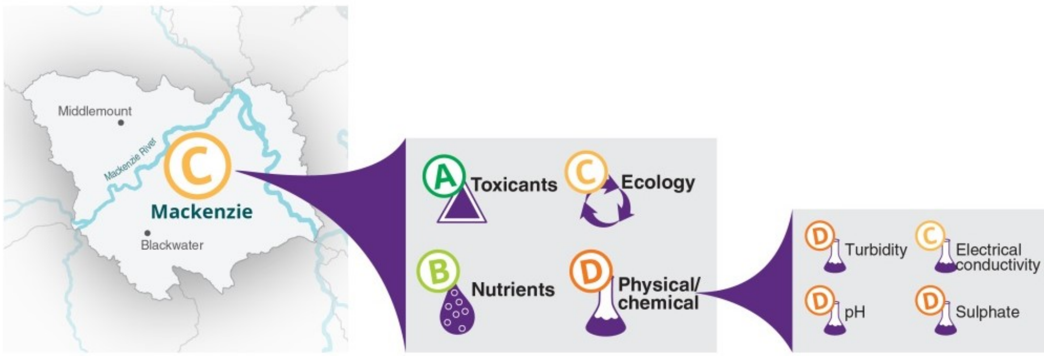


Figure 3-4: Steps in scoring the sites within each reporting area

How Reporting areas are Scored



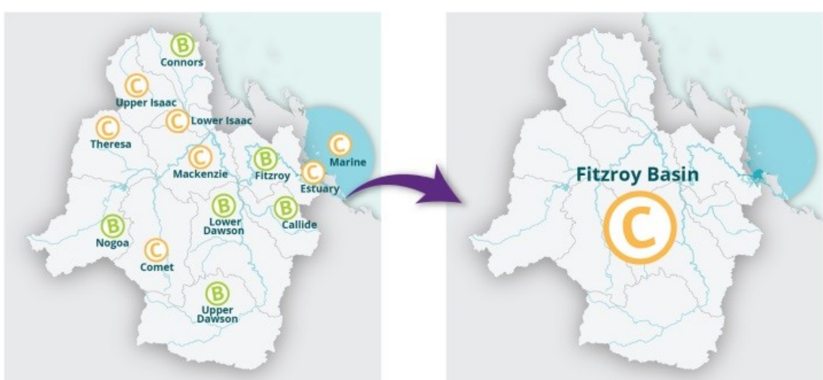
An overall grade for each reporting area is determined by averaging the overall grades for each of the four ecosystem health categories.

The category grades are determined by averaging the overall grades for the indicators within each category.

Grades for each indicator are awarded by averaging scores for each site that falls within that reporting area.

Figure 3-5: Steps in scoring the reporting areas

How the Basin is Scored



Grades for all 13 reporting areas (which are comprised of 11 catchments as well as Estuary and Marine) are averaged to determine an overall grade for the Fotzroy Basin.

Figure 3-6: Steps in the overall scoring of the Fitzroy Basin

The final index is then put in context of an easily communicable product for the public. The Science Project Team developed the scoring method which the Science Panel endorsed. This involvesgrades of A-E that areequal to or between 0 (the WQO – benchmark) and 100 (the WCS). That is: E = 0, A = 100 and a formula to obtain score percentages for grades D to B (Box 1).

Box 1: The scoring process for score percentages to assign grades A-E

- If an indicator result is equal to or better than the benchmark it is awarded a 100
- If a result is equal to or worse than the worst case scenario, then it is awarded a 0
- For other results:

$$Score_i = 1.0 - \left| \frac{(x_i - Benchmark_i)}{(WCS_I - Benchmark_i)} \right| \times 100 \qquad \textit{(Equation 1)}$$

Where, x_i = value of the indicator *i*, $Benchmark_i$ = ecosystem health guideline, objective, trigger value or expert opinion of healthy indicator *i* concentration *and* WCS_I = value of x_i at which ecosystem health would be compromised.

As per the EHMP approach these grades are defined as follows:

A = **Excellent**: Conditions meet all set ecosystem health values; all key processes are functional and all habitats are in near pristine condition.

B = **Good**: Conditions meet all set ecosystem health values in most of the reporting region; most key processes are functional and most habitats are intact.

C = **Fair**: Conditions meet some of the set ecosystem health values in most of the reporting region; some key processes are functional and some habitats are impacted.

D = **Poor**: Conditions are unlikely to meet set ecosystem health values in most of the reporting region; many key processes are not functional and many habitats are impacted.

E = **Fail**: Conditions do not meet set ecosystem health values; most key processes are not functional and most habitats are severely impacted.

The grades are colour-coded to assist with interpretationof the score card as follows:

Score (%)	100	67<B<99	33<C<67	0<D<33	0
Grade	A	B	C	D	E

There are two further “grades” used in reporting in cases where insufficient data are available for scoring. These are:

N = **No data**: No data are available for a given indicator in a given catchment.

X = **Exchanged data**: When no data are available for a given indicator in a given catchment for a particular reporting year, but data have been available for that indicator in previous reporting years, a calculated value is used as a substitute for real data. This is particularly important for Toxicant indicators where the worst score is reported for the catchment. If the missing data is for a previously poorly scoring Toxicant indicator then its absence can artificially drive the grade for the catchment to improve. The Exchanged data value is calculated by:

1. Compiling all site results for the particular indicator at the basin scale
2. Stripping out the sites which do not have annual continuity of data
3. Calculating the basin average score for each year
4. Determining the % change to these yearly scores
5. Applying this % change to the indicator score for the prior year
6. Using this score as the substitute for calculating catchment and basin scores and grades.

The X grade was introduced in 2014 for the 2011-12 report card, when the issue was first apparent, and has been used in subsequent report cards to date. However the Science Panel has been clear in advising that the X grade is a temporary solution only, and that the real issue is the need to ensure that sufficient monitoring occurs to provide data for every indicator in every catchment, each year.

The Science Panel will reassess the efficacy of the X grade in 2016, for the 2014-15 report card and beyond.

3.4 The estuarine reporting area

3.4.1 The EHI for the estuary

The EHI of the estuarine reporting area is similar to the one described above. However, there are some differences as detailedbelow.

3.4.1.1 Categories and indicators of the estuarine reporting area

The estuarine reporting area is scored on three assessment categories: Physical-Chemical, Nutrients and Ecology (Table 3-5). These incorporate the indicators of dissolved oxygen and turbidity (Physical-Chemical), nitrogen and phosphorus concentrations (Nutrients), chlorophyll-*a* and barramundi recruitment (Ecology).In contrast to the catchment reporting, Toxicants, including heavy metals, are not reported in the estuarine area,as no suitable data are currently available.

3.4.1.2 Benchmarks for estuarine indicators

The estuarine indicators were selected by the same process described for the catchment reporting areas (Section 3.3.1.1). The reference benchmarks and WCSs for the estuarine indicators are listed in Table 3-6. It is noted that the estuarine reporting area has three zones: upper, middle and lower, since each has specific WQOs (Table 3-5). Once again, the reference benchmarks correspond to the WQOs for protecting ecosystem health, as defined for the Fitzroy estuarine area in Schedule 1 of the Queensland Environmental Protection Policy for Water (EPP Water) and available from EHP (www.ehp.qld.gov.au). The exception is the reference benchmark for barramundi recruitment numberswhich is obtained from the Info-fish report “Topping up the ‘Crystal Bowl’ for barramundi” (info-fish.net).

The WCS for barramundi recruitment numbers is also obtained from this Info-fish report For DO in the estuary, the WCS relates to published data in terms of biological harm(Jackson et al. 2000), whereas the WCSs for turbidity and nutrient indicatorsare based on the 90th percentiles of the overall Fitzroy estuary data (held by the Queensland Government; Table 3-6). The 90th percentile is the value below which 90% of the data are found. This is a similar approach to that used for freshwaters in the long-standing SEQ EHMP (www.healthywaterways.org).

3.4.1.3 Weighting the categories and indicatorsfor the estuarine reporting area

The categories in theEHI for the estuarine reporting area are apportioned equivalently to that described for the freshwater EHI (Figure 3-3). However, because the Toxicant category is not used in this estuarine index, in effect, the contribution of the remaining categoriesis 33%for Ecology, 13% Nutrients and 53% Physical-Chemical of the overall EHI.

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Table 3-5: The indicators for the estuary in the EHI for the 2010-11 and subsequent Report Cards

Physical - Chemical Category Indicator descriptions from QWQG (DERM 2009a).	**Dissolved Oxygen (DO)**			**Turbidity (NTU)**	
	Essential for life processes of most aquatic organisms. Low concentrations of dissolved oxygen can indicate the presence of excessive organic loads in the system but may occur naturally in stagnant pools. High values can indicate excessive plant production (i.e. eutrophication). Most aquatic organisms require a certain minimum amount of dissolved oxygen in the water in order to survive.			A measure of light scattering by suspended particles in the water column. It can provide an indirect indication of both light penetration and suspended solids but the relationships between turbidity and these other indicators vary in different waters.	
Nutrients Category Indicator description from QWQG (DERM 2009a).	**Nitrogen (N)**			**Phosphorus (P)**	
	Total nitrogen as N	Ammonia as N	Oxidised N (nitrate + nitrate as N)	Total phosphorus	Filterable reactive phosphorus
	Includes all forms of nitrogen in a sample	Includes both ionised and unionised forms of ammonia	Sum of nitrate nitrogen (NO_3) and nitrite nitrogen (NO_2)	Includes all forms of phosphorus in a sample	Includes all forms of phosphorus that pass through a 0.45μm filter and react with molybdenum blue reagent – this fraction is usually very largely comprised of orthophosphate (PO_4)
	The nutrients N and P are essential for plant growth. High concentrations indicate potential for excessive weed and algal growth. Nutrients in the water column are made up of an inorganic (e.g. nitrate plus nitrite, ammonia and filterable reactive phosphorus) and an organic component, which is bound to carbon (e.g. organic nitrogen). The organic component can be either dissolved or particulate.				
Ecology Category Chlorophyll *a* description from QWQG (DERM 2009a). Barramundi recruitment description from Sawynok et al. (2011).	**Chlorophyll *a***			**Barramundi recruitment**	
	An indicator of algal biomass in the water. An increase in chlorophyll-*a* indicates potential eutrophication of the system. Consistently high or variable chlorophyll-a concentrations indicate the occurrence of algal blooms, which can be harmful to aquatic ecosystems.			Recruitment is a key driver of Barramundi stocks.Recruits are defined as fish below legal size that have yet to "recruit" to the fishery. Recruitment is measured by the number of Barramundi caught from January- May that are less than 300mm to the end of March and less than 350mm tothe end of May.	

Table 3-6: The reference (WQO) and worst case scenario (WCS) benchmarks for each indicator in the EHI for estuarine waters

			Upper Estuary		Mid Estuary		Lower Estuary / enclosed coastal	
			WQO	WCS	WQO	WCS	WQO	WCS
Physical/ Chemical	Turbidity (base flow)	*NTU*	30	490	100	440	na	398
	DO	*% Sat*	70-100	<30 or >200	85-100	<30 or >200	90-100	<30 or >200
Nutrients	NH_4 as N	*µg/L*	30	240	10	28	8	29
	NO_xas N	*µg/L*	15	590	10	366	3	250
	TN as N	*µg/L*	450	1400	300	1120	200	760
	TP as P	*µg/L*	40	460	25	360	20	255
	FRP as P	*µg/L*	10	260	8	99	6	66
Ecology	Chl- *a*	*µg/L*	10	20.3	4	5.1	2	4.5
			Whole of estuary					
			Reference benchmark				WCS	
	Barramundi recruitment	*Numbers**	200				10	

DO: dissolved oxygen, N: nitrogen, NOx: nitrate + nitrite, NH4: ammonia, P: phosphorus, WQO: water quality objective, WCS: worst case scenario, TN: total nitrogen, TP: total phosphorus, Chl-*a*: chlorophyll *a*. * number of Barramundi caught from January- May that are less than 300mm to the end of March and less than 350mm tothe end of May.

3.4.1.4 The system for scoring the estuarine reporting area

The system for scoring the estuarine reporting area is the same as that described for the catchment reporting areas (Section 3.3.1.4)

3.5 Sample number

The overall assessment is influenced by the amount of data. For the Report Card, an indicator was assessed providing there was at least one sample representing the indicator at a site, although in practice this was a rare occurrence. It is noted that the EHMP also uses *n* = 1 as a minimum for this purpose. Ratings are used to indicate the sample number in the report as presented in Table 3-7.

Table 3-7: The ratings applied to sample number in the Report Card

Number of samples	Rating
1	poor
2 to 4	fair
>4	good

4 Drinking water reporting

In 2014, the Partnership agreed to develop a new reporting mechanism for raw and treated drinking water. Drinking water reports have been prepared by applying a selection of Australian Drinking Water Guidelines (NHMRC, NRMMC 2011) to data provided by Councils and other suppliers of water to townships. The Australian Drinking Water Guidelines include two different categories of guideline values:

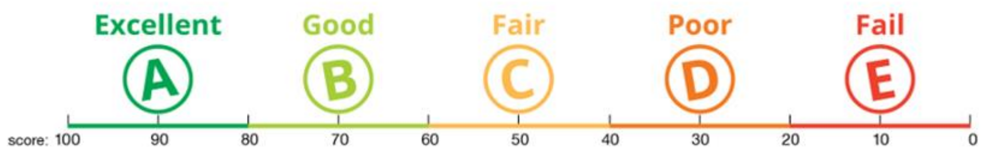
- "A **health**-related guideline value, which is the concentration or measure of a water quality characteristic that, based on present knowledge, does not result in any significant risk to the health of the consumer over a lifetime of consumption; and
- an **aesthetic** guideline value, which is the concentration or measure of a water quality characteristic that is associated with acceptability of water to the consumer; for example, appearance, taste and odour" (NHMRC, NRMMC, 2011).

Raw water comes from natural sources such as creeks, rivers, dams and groundwater and has not yet been treated for use as drinkable water. Councils and other suppliers of water to townships process this raw water to make it more drinkable by treatment which usually includes: flocculation, filtration and disinfection. Treated water is then provided to the community as drinking water and for other uses.

As raw water is not usually intended as drinking water, poor scores for raw water do not suggest that drinking water is contaminated or of poor quality. Raw water grades are provided in the reporting products for interest as they provide some indication of the quality of water in the aquatic ecosystems from which they are drawn. By comparison to the "Treated" grades they also demonstrate how effective modern water treatment processes are at treating water for human consumption. There may be,on occasions, issues with raw water that affect treatment processes, and conversely situations where raw water is of good quality and the costs of treatment are lower.

The Australian Drinking Water Guidelines recognise that occasionally there may be health or aesthetic related test results that fall outside the guidelines and that these results are not necessarily an immediate threat to health. The guidelines do not require a 100% result for all parameters in all cases.

The Partnership uses data provided by Councils to score drinking water against 22 indicators (Table 4-1). Indicators were selected using the same criteria as for the EHI (Flint et al. 2013) and those chosen for inclusion are both currently monitored and have an available guideline for drinking water quality. Grades are provided for both Health and Aesthetic guidelines when possible. Treated water results are only provided when the water has been treated and data are available for analysis. These data are averaged and graded using a similar approach to that taken in the Partnership's Marine reporting, as follows:

- Individual scores are given to each data point for each parameter/indicator based on a pass/fail approach
    - Green thumbs up: Results are within health and aesthetic guidelines
    - Orange thumbs up: Results exceed aesthetic guidelines
    - Red thumbs down: Results exceed health guidelines
- With the exception of electrical conductivity and pH which are described further below, each data point is given a score of 0 or 100 for each of health and aesthetics (based on the pass/fail mechanism). The scores are averaged to give an overall grade to the relevant site for each indicator, for both health and aesthetic characteristics, as illustrated below:
- 

Sometimes there are no data available to assess an indicator or a water source in a particular year. When this is the case a grey N icon is displayed.

- The 22 indicators are weighted evenly and averaged to give an overall site grade, A to E.
- This process is carried out for both
    - Treated water
    - Raw water

For example: Sulfate concentration (mg/L) at Rockhampton is measured monthly throughout 2010. Each measurement of sulfate is given a score of 0 (fail) or pass (100) based on each of the aesthetic (250 mg/L) and health (500 mg/L) guidelines for sulfate. All of the sulfate scores for the year are averaged for the Glenmore site to give both a health and an aesthetic grade for sulfate at Rockhampton in 2010 (A to E). The grades for each of the up to 22 indicators measured at Rockhampton during 2010 are averaged for Health and Aesthetics, using equal weightings in both cases, to provide overall site grades for Rockhampton (A to E). This process is carried out for both treated water and raw water readings from the Rockhampton site. Thus, Rockhampton effectively gets allocated four final grades: Health of treated water, Aesthetics of treated water, Health of raw water and Aesthetics of raw water.

Scoring electrical conductivity: Individual data points are given a pass/fail (100/0) score for each of Health and Aesthetics. However for calculating a site grade for electrical conductivity, each data point is given a score on a sliding scale. For electrical conductivity this scale is as follows:

- Less than 940 μS/cm = 100
- Greater than 940 but less than 1400 = 66
- Greater than 1400 but less than 1875 = 33
- Greater than 1875 = 0

The scores for each data point are then averaged to give a site grade of A to E on the scale described above.

Scoring pH: Similar to electrical conductivity, individual pH data points are given a pass/fail (100/0) score for each of Health and Aesthetics. To calculate a site grade for pH, each data point is given a score on a sliding scale. For pH this scale is as follows:

- Greater than or equal to 6.5 and less than or equal to 8.5 = 100
- Greater than 4.5 and less than 6.5 = (pH reading^2)/(6.5^2)x 100
- Greater than 8.5 and less than 11 = (15 – pH reading)^2)/(6.5^2)x 100
- Less than or equal to 4.5 = 0
- Greater than or equal to 11 = 0

The scores for each data point are then averaged to give a site grade of A to E on the scale described above.

Table 4-1: Drinking water reporting indicators, and health and aesthetic guidelines from the Australian Drinking Water Guidelines. Measures are in mg/L unless otherwise specified (Source: NHMRC, NRMMC, 2011).

Indicator/ Parameter	**Health Guideline**	**Aesthetic Guideline**	**Comments**
Aluminium	c	0.2	Guideline value based on post-flocculation problems;< 0.1 mg/L desirable. Lower levels needed for renal dialysis.No health-based guideline value can be established currently.
Chloride	c	250	From natural mineral salts, effluent contamination. High concentrationsmore common in groundwater and certain catchments.
Escherichia coli	0/100 mL		*Escherichia coli* should not be detected in a minimum 100 mL sample of drinking water.
Colour		15 HU	An important aesthetic characteristic for customer acceptance.Treatment processes can be optimised to remove colour.
Copper	2	1	From corrosion of pipes/fittings by salt, low pH water. Taste threshold3 mg/L. High concentrations colour water blue/green. >1 mg/L maystain fitings. >2 mg/L can cause ill effects in some people.
Cyanide	0.08		From industrial waste and some plants and bacteria.
Electrical conductivity*		940 µS/cm**	Occurs naturally in water and may be elevated by some land uses.
Fluoride	1.5		Occurs naturally in some water from fluoride-containing rocks. Oftenadded at up to 1 mg/L to protect against dental caries. >1.5 mg/L can cause dental fluorosis. >4 mg/L can cause skeletal fluorosis.
Iron	c	0.3	Occurs naturally in water, usually at <1 mg/L, but up to 100 mg/Lin oxygen-depleted groundwater. Taste threshold 0.3 mg/L. Highconcentrations stain laundry and fittings. Iron bacteria cause blockages,taste/odour, corrosion.

Lead	0.01		Occurs in water via dissolution from natural sources or householdplumbing containing lead (e.g. pipes, solder).
Manganese	0.5	0.1	Occurs naturally in water; low in surface water, higher in oxygendepletedwater (e.g. groundwater at bottom of deep storages). >0.1 mg/L causes taste, staining. <0.05 mg/L desirable.
Nitrate	50		Occurs naturally. Increasing in some waters (particularly groundwater)from intensive farming and sewage effluent. Guideline value will protect bottle-fed infants under 3 months from methaemoglobinaemia. Adults and children over 3 months can safely drink water with up to 100 mg/Lnitrate.
Nitrite	3		Rapidly oxidised to nitrate (see above).
Sodium	No value	180	Natural component of water. Guideline value is taste threshold.
Sulfate	500	250	Natural component of water, and may be added via treatmentchemicals. Guideline value is taste threshold. >500 mg/L can have purgative effects.
Total dissolved solids	No value	600	Based on taste: <600 mg/L is regarded as good quality drinking water. 600-900 mg/L is regarded as fair quality 900-1200 mg/L is regarded as poor quality >1200 mg/L is regarded as unacceptable.
Total hardness		200	Expressed as a calcium carbonate equivalent. Hard water requires more soap than soft water to obtain a lather and can cause scale on hotwater pipes and fittings. Caused primarily by the presence of calcium and magnesium ions,although other cations such as strontium, iron, manganese and barium can also contribute.

Trihalomethanes	0.25 e		By-product of chlorination and chloramination. Action to reduce trihalomethanes is encouraged, but must not compromise disinfection, as non-disinfected water poses significantlygreater risk than trihalomethanes.
Turbidity	c	5 NTU	5 NTU is just noticeable in a glass. <0.2 NTU is the target for effective filtration of Cryptosporidium and Giardia. <1 NTU is the target for effective disinfection.
Zinc	c	3	Usually from corrosion of galvanised pipes/fittings and brasses. Natural concentrations generally <0.01 mg/L. Taste problems >3 mg/L.
pH*	c	pH 6.5-8.5	While extreme pH values (<4 and >11) may adversely affect health,there are insufficient data to set a health guideline value. <6.5 may be corrosive. >8 progressively decreases efficiency of chlorination. >8.5 may cause scale and taste problems. New concrete tanks and cement-mortar lined pipes can significantlyincrease pH and a value up to 9.2 may be tolerated providedmonitoring indicates no deterioration in microbial quality.

HU = Hazen units; NTU = nephelometric turbidity units

c insufficient data to set a guideline value based on health considerations

e the concentration of all chlorination byproducts can be minimised by removing naturally occurring organic matter from the source water,reducing the amount of chlorine added, or using an alternative disinfectant (which may produce other byproducts). Action to reducetrihalomethanes and other byproducts is encouraged, but must not compromise disinfection.

Note: All values are as ‘total’ unless otherwise stated.

Note: Routine monitoring for these compounds is not required unless there is potential for contamination of water supplies(e.g. accidental spillage).

* electrical conductivity and pH are scored using a pass/fail mechanisms as for other parameters, but are graded on a sliding scale

** the aesthetic guideline for electrical conductivity has recently been removed from the Australian Drinking Water Guidelines but was in place at the time of the reporting period (2011-12 and 2012-13). Values are now derived from total dissolved solids (TDS) and are an approximation which varies with ionic composition of the water.

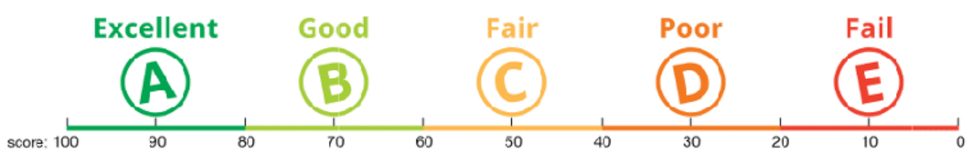
5 Agricultural use reporting

In 2015 the Partnership commenced agricultural use reporting, comparing water quality data to the the Australian “Water quality for irrigation and general water use”(for cropping grades) and “Livestock drinking water quality” guidelines (ANZECC & ARMCANZ 2000). The scoring methodology is similar to that used in reporting for the marine zone and for drinking water reporting, but has been flagged for updating next year.

5.1 Crop Use Reports

Crop use reports use data provided by our partners. Only data from surface water monitored in creeks, rivers and on-stream storages is used. This is surface water available for irrigation. Indicators, thresholds and normalising formula are used to determine grades.

A grade is not the same as a specific irrigation water suitability for a particular water, plant and soil combination. A separate water analysis is required to determine a specific irrigation water suitability.



Sometimes there are no data available to assess an indicator or a water source in a particular year. When this is the case a grey N icon is displayed.

5.1.1 Summary

Crop use reports have been prepared by applying a selection of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality to data provided by partners. The guidelines cover a wide range of parameters for irrigation water suitability but only chemical characteristic that may affect plant growth and contaminants have been used. The Australian and New Zealand Guidelines for Fresh and Marine Water Quality also include pesticides and radiological characteristics and Sodium Adsorption Ratio (SAR) which affects soil stability and behaviour but there is insufficient data available in the Fitzroy Basin to include these parameters in the reports for this report card.

Irrigation is a major agricultural use of water and matching water quality to plants and soils is essential for sustainable long-term production. Plant health and production can be affected by the chemical properties of irrigation water. The impact on production is climate and situation specific. Factors which need to be considered include: the sensitivity of the plant being grown, the properties of the soil under irrigation and their changes under irrigation, soil management and water management practices, climate and rainfall and depth to groundwater.

Groundwater is a significant water source for irrigation in some catchments within the Fitzroy Basin for example, Callide Creek, however, this report deals only with surface water quality from natural waters within creeks, rivers or on-stream storages.

The Partnership uses data provided by companies and government agencies to score surface waters against 22 indicators. Indicators were selected using the same criteria as for the EHI and those chosen for inclusion are commonly monitored and have an available guideline for irrigation water quality. All 22 indicators have the potential to affect soil behaviour or plant growth and the threshold levels adopted are the maximum concentration) of chemical component in the irrigation water which can be tolerated for a short period of time (up to 20 years). Soil type and plant species are key factors for determining production impacts of irrigation water and the report includes some of the common combinations of soil and irrigated crop species present in the Fitzroy Basin.

An irrigation water quality grading is determined using the range of indicators as outlined here. However, the suitability of a given water for irrigation of a specific plant requires a water analysis as some parameters will be limiting for a specific use of a particular irrigation water/ plant combination and also specific management practices may be required. In particular Sodium Adsorption Ratio (SAR) not assessed this year may preclude irrigation.

A predictive tool to assess salinity and soil sodicity (SAR) under irrigation situations based on soil properties, irrigation water composition, rainfall and plant salt tolerance is available as SALF2 Shaw, R. and Kitchen, J. (2015) SALF2 v.0.9.1 Salinity, soil, water, irrigation and plant salt tolerance calculator. Available from salf2calculator@gmail.com

5.1.2 Scoring methodology

Water quality grades are provided for salinity and chemical toxicants of irrigation water.

Salinity is the dissolved salt content of water and is monitored by measuring electrical conductivity (EC). The adopted benchmark value (BM) in the crop use report is the EC of irrigation water that results in a root zone salinity level below which no adverse effect on crop production is expected based on Australian and New Zealand Guidelines for Fresh and Marine Water Quality. The adopted worst case scenario (WCS) value is the EC of irrigation water that results in the root zone salinity level that will cause a 10% loss in production based on the plant salt tolerance data in ANZECC/ARMCANZ (2000) water quality guidelines. Both these values vary for different soil and plant combinations.

Twenty one chemical components were selected from those listed in Australian and New Zealand Guidelines for Fresh and Marine Water Quality as being a potential concern in irrigation. The selected chemical components are those that are routinely measured in surface water in the Fitzroy. The threshold values adopted come from Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Salt tolerance is most commonly a total salt content effect on plant growth and water availability to the plant. For some plants there can be specific ionic composition effects as well under given situations as given the following tables:

Table 4.2.6 Chloride concentrations (mg/L) causing foliar injury in crops of varying sensitivity under spray irrigation

Table 4.2.8 Sodium concentration (mg/L) causing foliar injury in crops of varying sensitivity under spray irrigation

Table 4.2.10 Agricultural irrigation water long-term trigger value (LTV), short-term trigger value (STV) and soil cumulative contaminant loading limit (CCL) triggers for heavy metals and metalloids. (The STVs are more stringent and relate to the direct toxic effect to the standing crop of heavy metals in irrigation water. The STV has been adopted as the benchmark)

For each data point in the Fitzroy Basin, individual scores are given for salinity and each of 21 chemical toxicants.

Scores for electrical conductivity (indicator for salinity) used the following formula:

$$\text{Score} = 100 \times \left(1.0 - \left|\frac{(x - \text{Benchmark})}{(\text{WCS} - \text{Benchmark})}\right|\right)$$

Where: x = sample result for the indicator
Benchmark = water quality objective or guideline
WCS = worst case scenario

Scores for chemical components used a pass/fail scoring method where each data point is given a score of 0 or 100 for each indicator. In this method, if the result for an indicator is better than the threshold it scores 100. If the result is worse than the threshold it scores a 0. The score for each indicator was converted to an overall grade based on the following table.

Grade	Score	Descriptor
A	80 - 100	Excellent
B	60 - 80	Good
C	40 - 60	Fair
D	20 - 40	Poor
E	0 - 20	Fail
N	No data	No data

An overall site score for irrigation water quality is a weighted score calculated using the EC (salinity) score (50%) and the worst scoring chemical component score (50%).

An overall catchment score for irrigation water quality is calculated by the same method. These scores are converted to a grade based on the above table.

5.1.3 Indicators and Thresholds

The selected indicators and thresholds for irrigation water used in this report are based on the Australian and New Zealand Guidelines for Fresh and Marine Water Quality and SALF V2 software.

For electrical conductivity of irrigation water (ECIW), refer to table 4.2.5 from the guidelines. When applying the guidelines, soil type should be considered as soil type significantly affects crop tolerances to the salinity in irrigation water. Consequently, the relevant guideline values for soil and crop combinations commonly encountered in the Fitzroy basin were used as the benchmarks (BM) for scoring electrical conductivity.

The guidelines also include a discussion on the rate of yield decline for crops with increasing salinity. Table 9.2.10 is a compilation of plant salt tolerance data and provides some guidance on yield declines based on average root zone salinity. The worst case scenario (WCS) values used for calculating scores for electrical conductivity were extrapolated from this table. The formula used was:

$$WCS\ EC_{IW} = \frac{BM\ \ EC_{IW}}{EC_{SE\ threshold} : EC_{SE\ 90\%\ yield}}$$

Using cotton on clay as an example, ECSE threshold : ECSE 90% yield = 7.7:9.6 = 0.8.

$$WCS\ EC_{IW} = \frac{4000\ uS/cm}{0.8} = 5000\ uS/cm$$

The use of 90% yield thresholds in defining the WCS is arbitrary. It was assumed that irrigators would consider this level of yield loss as being significant and that the report card should flag situations where this potentially could occur.The thresholds used for all indicators (in µS/cm, µg/L or mg/L) are provided in Table 5-1.

5.1.4 SAR - potential option for the future

Sodium Adsorption Ratio (SAR) is a commonly used index of the sodium hazard of an irrigation water. It is good a prediction of the Exchangeable Sodium Percentage (ESP) of the soil when it has come to equilibrium with the irrigation water composition.

ESP is an important soil property that determines soil behaviour. In particular; soil stability, clay dispersion, soil crusting, hydraulic conductivity and potential for soil erosion. Increased salt content can improve soil structure with moderate ESP levels but surface soils have the salt diluted by rainfall and can disperse readily under raindrop impact.

Thus there is a practical limit to the SAR of an irrigation water to maintain soil structure. While the SAR value varies with soil texture, for most irrigated soils an SAR in excess of 6 will cause some soil degradation.

Incorporating SAR into the next report card is being progressed to give a more comprehensive irrigation water grading from 2015-16.

Table 5-1:Irrigation water reporting indicators and guidelines from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

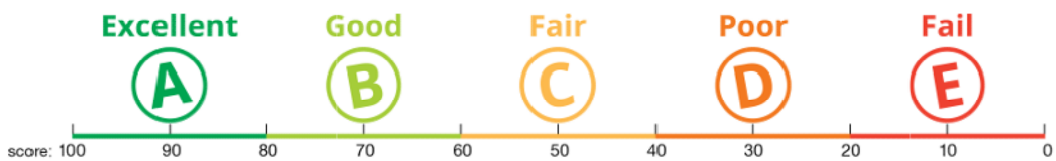
Indicator	Unit	All species thresholds	Cotton on Clay BM/WCS	Lucerne on Loam BM/WCS	Citrus on Sand BM/WCS	Peanuts on Sand BM/WCS
ELECTRICAL CONDUCTIVITY	uS/cm		4000/5000	2700/4600	2900/3900	4400/4800
ALUMINIUM	ug/L	20000				
ARSENIC	ug/L	2000				
BERYLLIUM	ug/L	500				
BORON	ug/L	1000				
CADMIUM	ug/L	50				
CHROMIUM	ug/L	1000				
COBALT	ug/L	100				
COPPER	ug/L	5000				
FLUORIDE	ug/L	2000				
IRON	ug/L	10000				
LEAD	ug/L	5000				
MANGANESE	ug/L	10000				
MERCURY	ug/L	2				
MOLYBDENUM	ug/L	50				
NICKEL	ug/L	2000				
SELENIUM	ug/L	50				
URANIUM	ug/L	100				
VANADIUM	ug/L	500				
ZINC	ug/L	5000				
SODIUM	mg/L		460	230	115	na
CHLORIDE	mg/L		700	350	175	na

BM - benchmark, WCS - worst case scenario

5.2 Stock Drinking Water Reports

Stock drinking water reports use data provided by our partners. Only data from surface water monitored in creek, rivers or on-stream storages is used. This is surface water available for stock to drink. Indicators, thresholds and normalising formula are used to determine grades.

A grade is not the same as a specific suitability test for a particular water source and a separate water analysis is required to determine a specific stock drinking water suitability.



Sometimes there are no data available to assess an indicator or a water source in a particular year. When this is the case a grey N icon is displayed.

5.2.1 Summary

Stock drinking water reports have been prepared by applying a selection of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality to data provided by partners. Only chemical characteristic that may affect animal health have been used. The Australian and New Zealand Guidelines for Fresh and Marine Water Quality also include biological and radiological characteristics but there is insufficient data available in the Fitzroy Basin to include these parameters in the reports.

Livestock watering is a major agricultural use of water and good water quality is essential for successful livestock production. Production in the Fitzroy Basin relies heavily on the use of unprocessed surface water, as well as ground water resources. This report deals only with surface water quality from natural waters within creeks and rivers and on-stream storages.

Many factors influence the suitability of water for livestock watering. Requirements may differ between animal species (generally tolerances decrease in the order sheep, cattle, horses, pigs, poultry), and between different stages of growth and animal condition and climatic conditions.

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality recognise that occasionally there may be test results that fall outside the guidelines and that these results are not necessarily an immediate threat to animal health. The guidelines do not require a 100% result for all parameters in all cases.

The Partnership uses data provided by companies and government agencies to score surface waters against 20 indicators. Indicators were selected using the same criteria as for the EHI and those chosen for inclusion are routinely monitored and have an available guideline for stock drinking water quality.

5.2.2 Scoring methodology

Water quality grades are provided for salinity and chemical composition of stock drinking water.

Salinity is the dissolved salt content of water and is monitored by measuring electrical conductivity (EC). The adopted benchmark value (BM) was the level below which no adverse effect on stock is expected and the adopted worst case scenario (WCS) value was the listed trigger where loss of production and decline in animal health is expected. See Table 4.3.1 Tolerances of livestock to total dissolved solids (salinity) in drinking water of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

Nineteen chemical components were selected from those listed in Australian and New Zealand Guidelines for Fresh and Marine Water Quality as being a concern in livestock drinking water. The selected chemical components are those that are routinely measured in surface water in the Fitzroy. The threshold values adopted come from:

Section 4.3.3 Major ions of concern for livestock drinking water quality; and

Table 4.3.2 Recommended water quality trigger values (low risk) for heavy metals and metalloids in livestock drinking water

For each data point in the Fitzroy Basin, individual scores are given for salinity and each of 19 chemical toxicants.

Scores for electrical conductivity (indicator for salinity) used the following formula:

$$\text{Score} = 100 \times \left(1.0 - \left|\frac{(x - \text{Benchmark})}{(\text{WCS} - \text{Benchmark})}\right|\right)$$

Where: x = sample result for the indicator
Benchmark = water quality objective or guideline
WCS = worst case scenario

Scores for chemical components used a pass/fail scoring method where each data point is given a score of 0 or 100 for each indicator. In this method, if the result for an indicator is better than the threshold it scores 100. If the result is worse than the threshold it scores a 0. The score for each indicator was converted to an overall grade based on the following table.

Grade	Score	Descriptor
A	80 - 100	Excellent
B	60 - 80	Good
C	40 - 60	Fair
D	20 - 40	Poor
E	0 - 20	Fail
N	No data	No data

An overall site score for stock water quality is a weighted score calculated using the EC (salinity) score (50%) and the worst scoring chemical component score (50%).

An overall catchment score for irrigation water quality is calculated by the same method. These scores are converted to a grading based on the above table.

5.2.3 Indicators and Thresholds

The selected indicators and thresholds for stock drinking water used in this report are based on the Australian and New Zealand Guidelines for Fresh and Marine Water Quality. The thresholds used for each indicator (in µS/cm, mg/L or µg/L) are provided in Table 5-2.

Table 5-2Livestock drinking water reporting indicators and guidelines from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

Indicator	Unit	All species threshold	Beef Cattle BM/WCS	Dairy Cattle BM/WCS	Pigs BM/WCS	Horses BM/WCS	Poultry BM/WCS
ELECTRICAL CONDUCTIVITY	uS/cm		5970/7463	3731/5970	5970/8955	5970/8955	2985/4478
ALUMINIUM	ug/L	5000					
ARSENIC	ug/L	5000					
BORON	ug/L	5000					
CADMIUM	ug/L	10					
CHROMIUM	ug/L	1000					
COBALT	ug/L	1000					
COPPER	ug/L		1000	1000	5000	na	5000
FLUORIDE	ug/L	2000					
LEAD	ug/L	100					
MERCURY	ug/L	2					
MOLYBDENUM	ug/L	150					
NICKEL	ug/L	1000					
SELENIUM	ug/L	20					
URANIUM	ug/L	200					
ZINC	ug/L	2000					
CALCIUM	mg/L	1000					
NITRATE	mg/L	400					
NITRITE	mg/L	30					
SULFATE	mg/L	1000					

6 “Trend and compare”functions

The Fitzroy Partnership has now incorporated two new functions into the online ecosystem health report card. The trend function illustrates overall, catchment and estuary scores for each year of reporting. The compare function also allows for the comparison of individual indicators and indicator categories through time.

For 2014-15, the overall score for the Fitzroy Basin is similar to the previous year. An improvement from a C to a B grade was noted for the Theresa catchment, and a decline from a B to a C grade was reported for both the Lower Isaac and the Mackenzie.

7 Additional information

The Fitzroy Partnership also reports on additional informationwhich isnot included in the report card, usually due to limited temporal or spatial extent of associated data. This information is added to the website with a link from the Ecosystem Health Report page, and coversimportant topics for the Fitzroy:rainfall, groundcover, floods and land use.

Rainfall: Annual rainfall data sourced from BOM are averaged and mapped across the 11 Fitzroy Basin catchments for each reporting year. Interannual trend is represented on a line graph and a long-term historical average (1961-1990) is also mapped across the 11 catchments.

Ground cover: Average ground cover is mapped across the 11 catchments for each reporting year using data from the Queensland Bare Ground Index. Similar to rainfall, trend is graphed and long-term average is mapped.

Groundwater: The shallowest groundwater level for the reporting year is mapped with an indexed five-point rating from “deepest” to “shallowest” in comparison to the 10 year long term average. Data are from Queensland Government-monitored bores in the Fitzroy Basin with continuous data sets which are only available in the Callide, Connors, Nogoa and Upper Dawson catchments. A trend graph shows changes in groundwater depth between reporting years.

Floods: The extent of the 2011 flood plume in the Fitzroy marine zone is shown on a map of the Fitzroy Basin from an e-Atlas entry. The highest annual flood peaks for the Fitzroy River at Rockhampton are provided in a column graph produced by BOM.

Land Use: Spatial distribution of land use categories is mapped and a pie chart illustrates percentage land use across the Fitzroy Basin. Categories reported include: grazing, cropping, natural land, forestry and urban, mining and feedlots. Data are sourced from the Queensland Land Use Mapping Program.

Pesticides: Pesticide data for four sub-indicators are assessed against benchmarks and worst-case scenarios (ANZECC 99% and 80% protection of species, respectively). The sub-indicators are: Atrazine, Simazine, Tebuthiuron and Azinphos(methyl). Assessed scores are averaged per site, and then again across all sites at the catchment scale to provide catchment scores and grades for pesticides where data are available.

Fish assemblages: The ratio of Observed to Expected native species (O/E50) is calculated for each site that has fish data available in each catchment. Expected species are derived from the Fitzroy region WQOs supporting document. Each site is assessed and given a score and grade, which are averaged across each catchment to provide catchment scores and grades.

8 Stewardship for the Partnership

The following approach for stewardship reportingwas endorsed by the Science Panel in 2013 as a temporary measure. Reporting is now on hold until a more quantitative stewardship reporting approach can be developed.

8.1 Defining stewardship

The Partnership defines waterway stewardship as the responsible planning and actions taken by individuals, organisations and sectors to minimise impacts on the region's waterways and to protect or restore the ecological health of rivers, wetlands, estuaries and coastal/marine environments associated with the Fitzroy Basin. Stewardship actions include:

- practices that are adopted by individual resource managers which will reduce impacts and protect or restore waterways, e.g. adoption of zero till cropping, mine site management, gully management and restoration
- industry or sector-based initiatives that reduce impacts and protect or restore waterways e.g. adoption of agricultural best management practices, commitment to reef guardian councils program, reduction of discharges to waterways and how waste might be treated
- government initiatives that reduce impacts and protect or restore waterways, e.g. incentives programs such as Reef Rescue, regulation of mine site discharges, land use zoning, maintenance of water treatment infrastructure
- community engagement and educational activities that reduce impacts, protect or restore waterways e.g. waterway monitoring, riparian restoration.

8.2 Objectives of stewardship reporting

The objectives of stewardship reporting are:

- to report aggregated data on the adoption of best practices by resource managers
- to use robust metrics to communicate the relative benefits of different practices
- to showcase significant stewardship initiatives.

8.2.1 Priority sectors

The sectors considered the highest priority for reporting in the Fitzroy (at this time) are grazing, cropping, water supply, point source discharge, coal mines, Mt Morgan mine, CSG activities, ports and infrastructure. The next tier priority sectors for reporting are urban, coastal development, horticulture and shipping.

8.3 Stewardship reporting in the short-term

The Partnership agreed to adopt a case study approach for the short-term. Criteria for the selection of case studies are:

- Case studies are drawn from the priority sectors.
- Case studies showcase stewardship actions are implemented in the Fitzroy in the appropriate reporting period.
- Case studies should be able to provide a robust case for demonstrating actual or anticipated impact on waterway health e.g. evidence-based logic, monitoring data.
- Case studies contribute to defining good or leading stewardship practices for the Fitzroy region (and potentially wider).
- The final selection of case studies will showcase stewardship across a variety of sectors i.e. probably no more than one per sector.
- The final number of case studies that are written-up will need to be appropriate to the resources available.

A template for reporting case studies adopts a 'fact sheet' format with a technical reporting style. Stewardship reporting has now been put on hold pending the development of a quantitative stewardship reporting approach.

8.4 Stewardship reporting for the longer term

The Partnership intends to develop tiered good practice standards for stewardship reporting in future Report Cards. Developing tiered good practice standards for waterway management in the Fitzroy Basin should:

- involve the staged development of reporting standards
- work closely with industry groups and scientists to develop good-practice standards
- support the development of robust good practice standards for key industries
- have wider application than the Fitzroy Basin
- link to the development of Australian and international Water Stewardship standards (Water Stewardship Australia Ltd 2012).

The development of tiered reporting standards across industries requires a substantial effort. Data collection systems and assessment methods would need to be developed and ideally would be consistent with other relevant programs in Queensland.

9 Data management & presentation

9.1 Data management

9.1.1 Data handling, storage and processing

A secure network drive exists on the host organisation’s (FBAs) local network for the storage of the Partnership data. Access to this drive is limited to the Partnership secretariat staff: The Executive Officer and the Science Integration Officer.

The Partnership data are provided in a variety of formats with markedly different configurations among the various data management systems. A standard format and configuration has been developed to bring together the disparate data arrays. As most outputs from partner organisations were compatible with the Microsoft (MS) Excel software, the transfer and organisation of data is automated using MS Excel macros, developed with Microsoft’s Visual Basic for Applications (VBA). Macros automate repetitive tasks, which includes the cutting and pasting of data, synchronizing units of measure, and substituting numerical characters for below limit-of-reporting (LOR) values and blank data fields. The automated tasks reduce processing time and the potential for transcription errors enormously.

9.1.2 Data management system

The services of enQuire (www.enquire.net.au) were enlisted to undertake a review of options suitable for a data management system (DMS) for the Partnership. The preferred options for the Partnership’s DMS were:

- a large volume of data storage
- a web-facing front-end, including public and restricted access
- capacity to customise structure and functions
- ability to input data manually and via spreadsheet uploads
- graphing and reporting functions to allow rapid interpretation of data
- a low cost product
- an open source licence.

The review indicated a custom solution for the DMS, since the commercial solutions that met most requirements had acquisition costs which excluded their purchase in the establishment phase of the Partnership.

9.1.3 MySQL

The MySQL system was ultimately chosen to manage and store the Partnership data. This system was chosen on the basis that it met the sought-after requirements of a

DMS in terms of a suitable system for the Partnership, and was readily available to the Partnership through the web hosting arrangements that were already in place.

MySQL is an open source platform with all the DMS features (listed above) required for managing the Partnership data. The MySQL platform is a popular system among many large corporations because of its open licence, reliability and functionality.

Also, discussions with local Information Technology (IT) experts had revealed that the hosting arrangements for the Partnership website incorporated had included an unlimited access to MySQL databases.

The Partnership MySQL database was configured by Local IT experts prior to it being populated with the processed Partnership data. A server on the FBA network hosts the database concurrently with the Partnership website.

9.1.4 Data access (non-disclosure and approved persons)

Access to the database is confined to the Partnership secretariat, FBA staff: the Executive Officer and the Science Integration Officer. Requests for Partnership data are only approved to third-parties that require the data for technical support in the development of indicators and reporting mechanisms required or desired by the Partnership. All third-party entities must sign non-disclosure agreements to protect the privacy of partners and ensure adherence to data sharing agreements (Appendix 3).

9.2 Data assessment

Programming scripts, written in the PHP language, were developed to extract records from the MySQL database to perform a series of algorithms that provide scores for indicators of ecosystem health (Figure 9-1). These algorithms are based on the data-aggregation method developed by the CQU team, refined by the Science Project Team and endorsed by the Science Panel. Programming scripts transfers the scores into a tabulated sheet of a comma-separated values (.csv) file. This format allows the display of scores as chart objects in the reporting webpages of the Partnership website. Similar coding arranges site-specific details into one downloadable excel workbook for each reporting area. The details include site score, average concentrations, sample numbers and the range of sample scores.

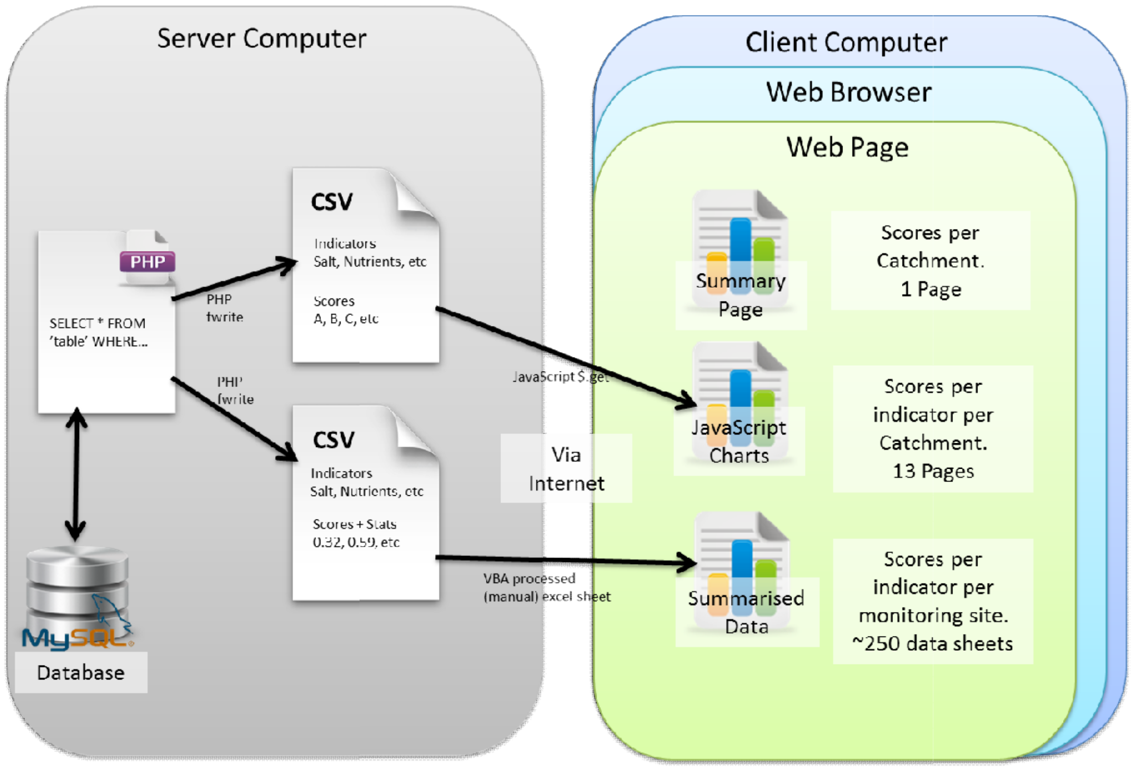


Figure 9-1: The architecture and pathways in transferring information from the database to the web for the Report Card

9.2.1 Correcting the data for flow regime

Date ranges relating to the low and high flow regimes that have been separated by flow break-points (Table 3-1)are applied to the data when querying the database. This allows for scores to be identified as either high or low flow for each indicator. The data for each indicator are then weighted using the formula in Equation 2 (Box).

Box 2: The formula for correcting the data for flow regime

Indicator Score$= (D_H \times S_H) + (D_L \times S_L)$ *(Equation 2)*

Where: D_H= Proportion of days out of the year catchment was in high flow

D_L= Proportion of days out of the year catchment was in low flow

S_H = Indicator catchment score in high flow

S_L = Indicator catchment score in low flow

9.2.2 Site selection and sampling frequency

As identified by Jones et al. (2013), it is important that the relevance and reliability of the data collected in the Fitzroy for particular parameters is carefully handled in order to ensure ecologically relevant reporting. This is especially important in the context that the monitoring data provided to FPRH contains temporal and spatial bias. This bias is a result of site selection and sampling frequency being based on stakeholder and third party objectives rather than being developed and implemented with specific Partnership Report Card objectives in mind.

During data cleaning, flow normalisation techniques are used to reduce seasonal sampling bias (see section 9.2.1) and spatial bias is visualised for each indicator using mapping techniques to demonstrate the issue (see section 9.5), but currently the monitoring bias cannot be effectively accounted for in the reporting process. A related issue is that there is significant duplication of monitoring effort, particularly between regulated companies who have monitoring obligations that support a greater understanding of the condition of the aquatic ecosystems both upstream and downstream of regulated release points. There are also other monitoring programs including the Enhanced Fitzroy Monitoring Program and ReefPlan catchment loads monitoring program currently managed by the Queensland Government.

Both the Science Panel and Management Committee have identified and prioritised the need for investment to additional monitoring to fill gaps, and as a first step an evaluation of the spatial and temporal bias in the existing monitoring program. A project to evaluate and improve site selection and sampling frequency across the Fitzroy Basin is currently underway.

9.3 Data presentation

Data are presented in Partnership reporting products, which includes three main media:

- A post card
- A full colour A5foldout flyer, and
- A website.

Visualisation of the assessment results for the web is similar to the Reef Reporting (www.reefplan.qld.gov.au) in terms of the tiered approach, and to the SEQ EHMP in terms of spatial presentations (www.healthywaterways.org). Tiered or 'wedding cake' delivery allows users access to as much or as little detail as they desire. In this approach, the summary results are presented first. These are a broad sweep, but with other associated content they can be interrogated for more information. It refines in scale from a whole-of-basin score to catchment and indicator scores (Figure 9-2), right down to site scores, average parameter concentrations and other statistics (Figure 9-3).

Figure 9-2: The presentation of the reporting area scores for the Report Card

The spatial aspect allows readers to realise the location and scale of the reporting areas, and also provides context for locals regarding the health of rivers in the catchment they live in. It also provides a meaningful navigation tool that allows the user to switch between reporting areas without the need to access a menu or leave the page they are viewing.

Graphics are kept to a minimal style and follow a graphic designer style guide.

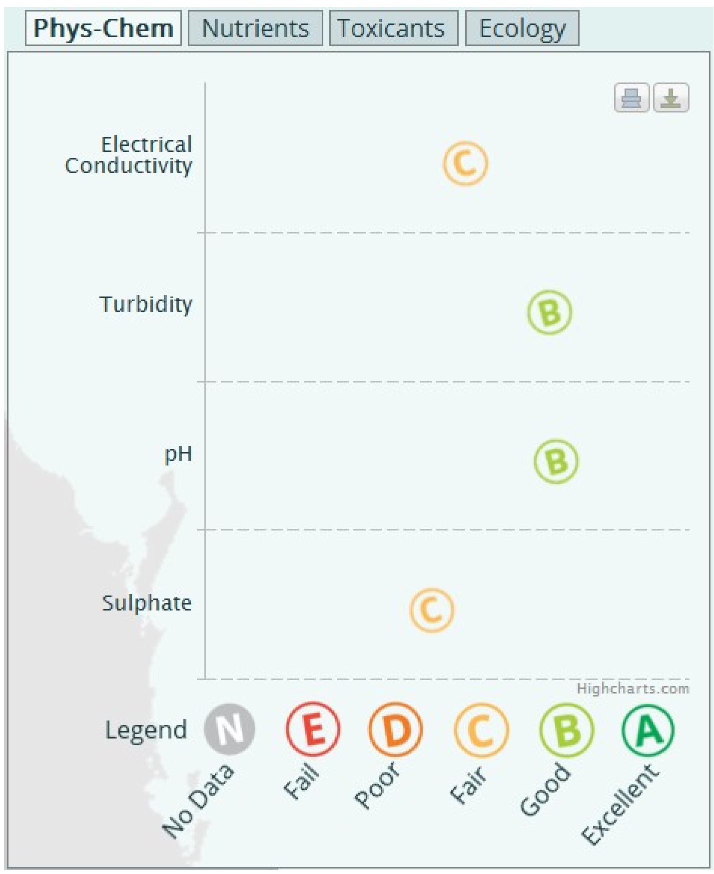


Figure 9-3: The more detailed scores presented on the web for the Report Card

9.4 Quality assurance and quality control (QA/QC)

The development of the assessment methods for the Fitzroy BasinReport Card was overseen by the Partnership secretariat with support of a technical network drawn from the partners, and involving guidance and advice from the Partnership Science Panel, the Science Leader and the Science Project Team.

The assessment process and reporting products required substantial developmental work. To assist in assuring quality products, the project team incorporated time-tested methods of similar programs that have been long-standing, such as the SEQ Healthy Waterways Partnership.

Additionally, a number of manual and automated checks of the accuracy of the assessment were implemented. Even so, time constraints limited the number of QA/QC checks that were possible. Checks for minor errors in data, such as whether the concentrations of dissolved metal fractions closely matched the corresponding total concentrations, were lacking, although this deficiency is not expected to affect scoring. However, it has been noted for incorporation into future QA/QC procedures of the program design.

The data collated in this program are from sources that use NATA accredited laboratories and standard sampling and collection methods (DERM 2009b).

9.5 Assumptions and limitations of the data assessment

The assumptions and limitations in the data assessment are as follows:

- Where results are below the limits of reporting (LOR) of the measuring apparatus, they are recorded as half the LOR, which is a usual method of dealing with <LOR and approved by the Science Panel.
- All water quality indicatorsare from sources that use NATA accredited laboratories for analysis unless otherwise specified, e.g. for indicators normally measured in the field.
- Field sampling of indicators, e.g. dissolved oxygen and temperature, are from sources that use standard monitoring techniques (DERM 2009b).
- Chromium (Cr) is assumed to be present as Cr (VI) species for all sample results. This assumption is based on the precautionary principal in that the more stringent limit applies.
- Corrections to the data have been made where obvious. For example, some samples reported in units of milligrams per litre (mg/L) were obviously measured in micrograms per litre (µg/L). The opposite was also true. If data investigation suggested it was extremely likely that the units should be corrected this was done, but in cases where units could not be validated the samples were omitted from the dataset.
- The preference for the assessment was raw data, but mean averages were used in the case of macroinvertebrate data recorded in the receiving environment management plan (REMP) reports of various mining companies, and were manually extrapolated for inclusion in the Report Card.
- Only data with a spatially defined collection point were used in assessment.

- Laboratory analysed and field-obtained data were consolidated where parameters matched.
- The reporting of ‘average’ was the arithmetic mean, unless otherwise stipulated.

The Program relies on pooling of data from many organisations in the Partnership including state government, resource sector and local government rather than data collected for a specific program. This resulted in over 800,000 sample results being made available in the first year of the Report Card, of which more than 340,000 were used. Even with this number of data points, limitations are apparent in the spatial and temporal coverage of the data.

To account for this in the short term, a site distribution map (Figure 9-4) was developed for each indicator to show the focus of sampling effort and hence the tendency in spatial bias of the data. This allows for transparency of the data limitations and is also useful for identifying gaps in the spatial representativeness of the sample data.

To account for temporal bias (much of which relates to flow in this dataset), all water quality data are weighted by the number of days in low or high flow conditions for each catchment using Equation 2.

Both the Science Panel and Management Committee have repeatedly identified and prioritised the need for investment to additional monitoring to fill data gaps, and as a first step an evaluation of the spatial and temporal bias in the existing monitoring program. A project to evaluate and improve site selection and sampling frequency across the Fitzroy Basin is currently being finalised.

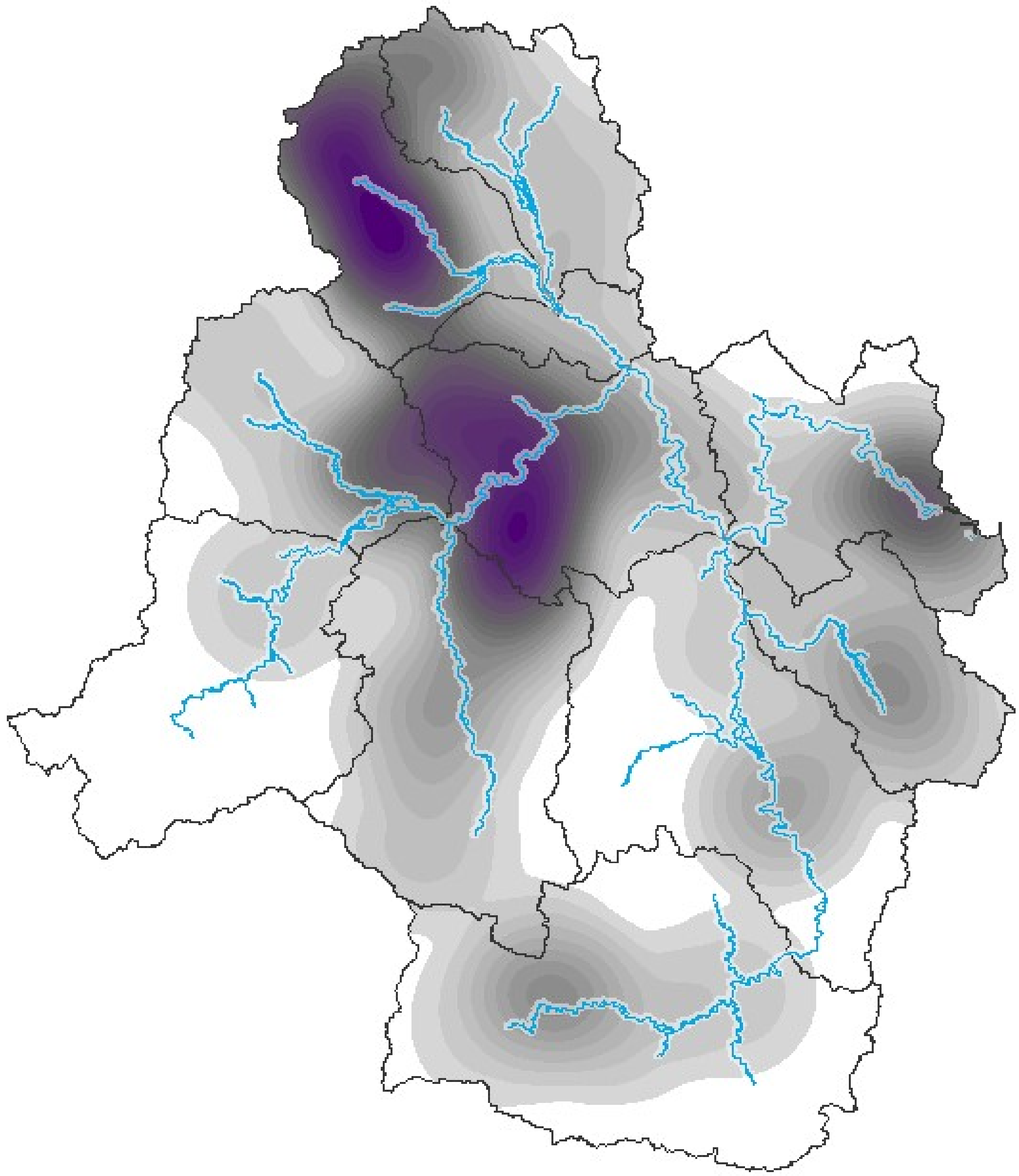


Figure 9-4: Density of available turbidity data across the Fitzroy Basin for the 2010-11 Report Card,illustrating the sampling effort for this indicator

10 Future direction

Both the Science Panel and the Partnership as a whole support a continuing improvement philosophy for the future direction of the Partnership's monitoring and assessment program. It is envisaged that the report card will help shape forthcoming management planning strategies that will embrace better targeted regional plans and water quality improvement plans (Figure 1-1). These plans generally recommend management actions, for example stewardship programs, with objectives to protect or improve components of ecosystem health. Monitoring for relevant effects of these actions is important and will assist future assessment and reporting on indicators of ecosystem health. This future assessment and reporting will then influence management strategies, actions, monitoring and so on in a continual cycle of improvement (Figure 1-1).

This program design is subject to annual reviews and a three-yearly strategic review was also planned. The first strategic review was planned for 2015-16 but will now be completed following the wider strategic review of the Fitzroy Partnership to allow for any changes agreed through that process.The strategic review of the Program Design will benefit from the knowledge and priorities generated by the recent Fitzroy Water Quality Improvement Plan (WQIP:2015) process being managed by FBA and the recommendations arising from the Fitzroy Partnership's recent Monitoring Efficiency Review (Flint et al. 2016).

Many of the future directions described below were identified in 2013 but resourcing constraints mean that they have not been progressed at the time of writing this document.

10.1 The reporting framework

Due to data limitations, Partnership Report Cards currently relate primarily to the state (condition) of the environment and the impacts of that condition, as defined by the DPSIR framework. The 2010 review of the SEQ EHMP found a need to add a "Drivers and Pressures Monitoring Program" to collect information about key drivers and pressures on water quality and ecosystem health at a catchment or waterway scale. The additional monitoring program would also aim to add to interpretation of data and help to inform and prioritise future management actions.

Ideally this EHMP recommendation should also be taken into account in the EHI for the Fitzroy Basin, and indicators of driving forces, pressures and responses incorporated. While the use of the DPSIR framework to select potential indicators provides some indication of causality there remains a need to develop meaningful indicators of driving forces and pressures in the Fitzroy Basin based on causal relationships. The lack of baseline and/or reference data on which to base assumptions about natural variations in ecosystem health within the basin, in combination with the large variety of possible anthropogenic pressures and the diffuse nature of many of these pressures, currently limit the possibility of tracing causality from state and impact indicators back to driving forces and pressures. For this reason the most effective means of assessing causality will be to develop indicators that directly relate to driving forces and pressures in the basin, and upon which assumptions of possible changes to the state of the environment can be based.

The Science Panel recommendsthe inclusion of threats (and emergingpressures) to waterway health through a range of methods including remote sensing and modelling, e.g. land use change, groundcover, riparian and streambank condition, water quality loads and environmental flows.

Such a program will provide the linkage between the cumulative impacts of resource use and management, and waterway health.

Future assessments could focus on the relative threats from major land uses, with analysis utilising spatial imagery, summary data on relevant licenses and modelled outputs. Information on pressures may not be reported as an index, but be presented as part of the Report Card product.

10.2 Stewardship

The Partnership plans to develop a tiered process for stewardship reporting for future Report Cards. Developing a tiered process for waterway management in the Fitzroy Basin could involve the staged development of reporting standards requiring industry groups and scientists to work together to develop good-practice standards.

The development of tiered reporting standards across industries requires a substantial effort. Data collection systems and assessment methods would need to be developed. To avoid confusion, the system would need to align with the GBR reporting. The Science Panel has reiterated the need to move towards an effective measurement of stewardship and concurrent ability to influence management practices. Other report cards in Queensland are currently developing stewardship reporting frameworks which may provide some insight for the Partnership in developing a suitable framework for the Fitzroy Basin.

10.3 Ecosystem health and resilience

Ecosystem resilience is an emerging science in the fields of marine and aquatic ecology. Walker et al. (2011) described resilience as "...the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks." To attempt to address the question of how effectively the ecosystem might recover from stress, the proposed criteria for selecting indicators to include in an EHI for the Fitzroy Basin incorporates a criterion that considers the ability of an indicator to contribute to an assessment of ecosystem health and resilience. For some indicators (e.g. refugia) this will be possible to determine but for others not enough is yet known on this subject to make an accurate assessment.

The Science Panel will review ecosystem health indicators in the strategic program design review in 2016-17, and as part of this review will assess indicator relationships to healthand resilience of aquatic ecosystems.

10.4 Indicators forthe Ecosystem Health Index

The Fitzroy Basin is characterised by a highly variable flow regime with ephemeral streams in its upper reaches (Hart 2008). Periods of drought and seasonal drying are likely equally important as flood events in driving ecosystem function. The prevalence of ephemeral streams in the basin makes application of some aquatic ecosystem health indices (such as SIGNAL scores) problematic. This issue is particularly relevant in relation to biotic indices and biological indicators in general. A research project to develop an AUSRIVAS model and test some biotic (macroinvertebrate) indices that are applicable to the Fitzroy Basin is currently underway at CQU. This project will be available to contribute to future revisions of the EHI.

With the principleof continuous improvement in mind, the Science Panel will review locally relevant macroinvertebrate thresholds for future Fitzroy Partnership assessment and reporting once available.

The Science Panel has reiterated the need to place a high priority on collecting data for Ecology indicators which are currently lacking in the EHI due to insufficient data availability. The Science Panel recommended riparian vegetation (condition, extent, composition and connectivity), instream connectivity, native fish species (observed:expected), exotic fish species (presence, size, distribution), bank condition, freshwater pest plant % cover and flow for development as indicators for the Ecology category in future reporting. In addition, the pesticides: MEMC and ametryn, the herbicides: hexazinone, tebuthiuron, atrazine and diuron; sediment metals, and wetland cover were flagged by the Science Panel for future inclusion and potentially special reporting in years 1-2 of the Report Card.

Both fish assemblage indicators and pesticide indicators have been developed as additional information for 2014-15. These may be suitable for inclusion in the Report Card in the near future. A new PhD project which aims to develop a toolbox of indicators for the assessment of fish habitats and health has also commenced at CQUni, with an expected completion date of April 2017. The results of the project will have implications for the fish indices that are incorporated into the EHI for the freshwater catchment areas.

Dissolved oxygen (DO) saturation in freshwater is not currently evaluated in theReport Card. However, the Science Panel regards DO as an important factor influencing ecosystem health. The DO data that are currently available are mostly from “spot checks” that do not take account of diel DO fluctuations. DO fluctuates with changes to the chemical and biological status of the system during the day. For instance, because of photosynthesis, a spot check measure of DO after midday can be much higher than that recorded in the early morning. Hence, spot data are not representative of the system’s condition. Deploying meters at strategic locations to record ambient DO conditions regularly over a 24 hour period will serve to improve confidence in knowledge of DO.

The Science Panel also recommends a risk assessment of toxicants of potential concernfor the estuarine reporting area to identify future relevant indicators for monitoring and assessment of this area.In particular, agricultural pesticides that have been shown to be ecologically detrimental warrant further monitoring. Pesticide monitoring is expensive and is not regularly undertaken in the Fitzroy Basin (with some recent data exceptions, which have allowed for the reporting of pesticides as additional information for some catchments in 2014-15). This situation that may improve in future as more information becomes available to prioritize monitoring of only the most toxic pesticides in use.

For heavy metals with medium and low reliability trigger values as reference benchmarks the Science Panel recommends future reviews. The trigger values would remain as reference benchmarks in line with the ‘precautionary principal’, but regular reviewsshould be carried out to identify more reliable thresholds. There are currently two PhD projects underway at CQUni that will improve local information on metals in aquatic ecosystems. The projects are due for completion in 2016 and 2017. Another recommendation for metals was that the number of these indicatorsused in reporting could be reduced as more information becomes available. This may be assisted by the findings of the monitoring efficiency review which is currently being finalised.

The Science Panel recommends that the WQOs for the Fitzroy Basin be revised as new data and improved knowledge of ecosystem relationships comes to light. This supports the need for further development of guidelines documented for the Fitzroy Basin (Jones and Moss 2011) to improve the understanding and reporting on indicators of ecosystem health. It is recognised that several WQOs are based on regional guidelines, i.e. the QWQG or the ANZECC guidelines, because local information is lacking. In other instances the range of data available for deriving the current WQOs was limited by very dry conditions as a result of an extended dry climate regime that lasted up to 20 years in some areas. The WQOs for the Fitzroy Basin are currently under review which will have implications for Partnership reporting.

To improve the value of the reporting, the Science Panel also recommends that the location of sampling sites be made available in future reports.

10.4.1 EHI indicators to be considered for the longer term

There are numerous other indicators that the Science Panel and the CQUni project team pre-selected for future monitoring and reporting programs during the initial development of the EHI in 2012/13 (Table 10-1). These are recommended for investigation in terms of relevance for the longer term reporting of ecosystem health in the Fitzroy Basin and estuary.

Table 10-1: The EHI indicators for the longer term - freshwater and estuarine reporting areas

Physical and chemical	Toxicants	Ecology
Freshwaters	**Freshwaters**	**Freshwaters**
DO minimum 24 hour	total BTEX (BTEXN/ BTEXS)	Fitzroy River Turtle Presence/Absence
DO depth profiles Diel DO range	Mussel bioaccumulation	New macroinvertebrate indices that are more relevant to the Fitzroy Basin
Temperature	2,4-D-sodium (CITRUS) Hydrocarbons	Native fish species (observed: expected ratio); Exotic fish species (present/absent), size distribution
Seasonal flow volume	Gramoxine (COTTON)	Macrophyte cover freshwater pest plants (% cover)
Rainfall Residual Mass or a rainfall variability index	Glyphosate (BROAD SPECTRUM)	Instream connectivity (requires data)
	Throttle (BROAD SPECTRUM)	**Estuarine and freshwaters**
Groundwater trends		Fish tissue mercury, pesticides, PCB congeners, PBDE, % moisture and lipid content
	Estuarine Those identified from a risk assessment of toxicants of potential concern	TG1 - Biomass proportion of top predators (trophic group 1); TG2 - Biomass proportion of aquatic invertivores (trophic group 2); TG3 - Biomass proportion of terrestrial insectivores (trophic group 3); TG1/TG4 - Biomass ratio of top predators (TG1): detritivores (TG4)

DO: dissolved oxygen, WCS: worst case scenario, PCB: Polychlorinated Biphenyls, BTEX: benzene, toluene, ethylbenzene, and xylenes, BTEXS: benzene, toluene, ethylbenzene, xylenes and styrene, BTEXN: benzene, toluene, ethylbenzene, xylenes and naphthalene. Source: Jones et al. (2013)

10.5 Weighting of indicators within the Ecosystem Health Index

The weighting of categories and indicators within the EHI and the interaction between indicators needs additional investigation. Possibly, there is also a need to differentiate between stream types, such as ephemeral and permanent, which greatly vary in dynamics. At present this separation requires further investigation and additional data collection.

Could placing more emphasis on certain categories or indicators improve the EHI effectiveness of the Fitzroy Basin? This is a complex question that is hampered by the current lack of knowledge on ecosystem function in the Fitzroy. It is also unaided by natural variability in condition that relate to disparate flows, and seasonal and spatial differences, and how these specifically affect the condition. There is also the interaction between indicators to consider. The correct weighting may be difficult to determine but further research into relationships between indicators, the impacts and conditions in a spatial and temporal context may help to improve weighting methodology for the future.

10.6 Predicting changes in ecosystem health

The Science Panel recommends the use of predictive models to advance ecosystem health assessments of the Fitzroy Basin. These models could be relationships between variables as determined through scientific research. During the EHI development in 2012/13 the CQU team suggested a predictive model of fluctuations in ecosystem health in relation to climate variation would be beneficial. However, very complex models are heavily data reliant, and this has limited model development in the past for the Fitzroy Basin. Further research and data collection would be required to establish reliable predictive models for the Fitzroy Basin.

An ACARP funded project co-led by BMT-WBM and the Partnership commenced in 2015 and is exploring the development of a salinity module for the Source Catchments model for the Fitzroy. The project is due for completion in 2017.

10.7 Reporting and analysing trends in ecosystem health

The effectiveness of management strategies to improve or maintain ecosystem health can only be evaluated through temporal assessment of ecosystem health. The Science Panel has identified trend analysis as an upcoming issue for FPRH reporting. As more data have been analysed and graded there is now enough information to report on trends. This is done both on the Partnership's website for each reporting product and indicator, and for additional information categories such as groundcover and flow. In the next two to three years it is hoped that enough data will be available to enable the formal analysis ofinter-annual trends. This will provide a major advantage to reporting, as it will increase the ability to prioritise management actions in the Fitzroy Basin and to evaluate the effectiveness of past management changes, as well as changes relating to weather and climate.

11 Definitions

Basin	The Fitzroy Basin, including the eleven catchments, estuary and adjacent marine environment.
Catchments	The eleven freshwater catchments shown in Figure 3-2 and consistent with those set down for freshwaters in Schedule 1 of the EPP (Water) Queensland.
Driving forces	Natural and human-induced factors that provide the context for habitats, species and ecosystems that exist in varying environments
Ecosystem health	Defined in terms of assessable characteristics that relate to the physical, chemical and biological processes, vigour (activity or rate of processes), organization (complexity of food webs, wealth of biodiversity) and degree of resilience (or capacity to withstand and recover from disturbance) within the ecological system (Rapport et al. 1998).
Impact	An effect on a living organism or their non-living (abiotic) environment as a result of human activity or natural phenomenon
Mediators	Actions or mechanisms that mitigate environmental impact
Pressures	Human-induced factors that directly or indirectly cause a change in an ecosystem
Reference site	A site whose condition is considered to be a suitable baseline or benchmark for assessment and management of sites in similar water bodies, generally determined by minimal or limited disturbance. The Queensland Water Quality Guidelines set out criteria for determining reference sites (DERM 2009a).
Refugia	Larger river holes that provide permanent aquatic habitat during extended periods of low or no flow (Sheldon et al. 2010). When higher flows restore connectivity in waterways refugia provide a source of aquatic organisms to repopulate waterways
Resilience	The capacity of an ecosystem to respond to a perturbation or disturbance by resisting damage and recovering quickly
Responses	Actions taken by persons, groups or society in terms of an environmental situation
State	A description of the condition of an ecosystem resulting from the interaction of external and internal factors and dynamics
Stressors	Agents, conditions or other stimuli or succession of stimuli that disrupt the equilibrium of an ecosystem
Threats	Possible future events or factors whether intentional or accidental that may directly or indirectly result in an adverse change in an ecosystem
Year	Equates to the Australian fiscal year, i.e. 1 July to 31 June

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Appendix 1: Data Sharing Options Paper

Fitzroy Partnership for River Health Partners Network

Options Paper for Data Sharing **Date: 2012**

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1. **Purpose**
   To outline data sharing arrangements required for partnership activities

2. **Background**
   - Development and public release of a waterway health report for the Fitzroy basin requires a coordinated, cooperative approach to data acquisition, management, processing and reporting
   - Partner's network members can contribute data to the partnership as agreed when signing up for membership
   - Data is currently housed in partner's databases in a variety of formats
   - Prompt data supply will ensure the development of aquatic ecosystem health indices and a report card are delivered within project milestone timeframes
   - Detailed data requirements are provided in the Data Management Plan
   - The preferred formats for data acquisition are those compatible with Microsoft Excel (.csv, .xls, .xslx, .txt, or .dbf)
   - Some data from the resources sector has been provided to DERM and can be released by a letter of authorisation from the company. A template for this letter has been sent to the relevant organisations

3. **Issues**

- Negotiating data agreements will take time. Delays in data supply will impede timely delivery of other partnership project milestones such as development of waterway health indices, and reports
- Agreements are specific for each organisation and will need to be negotiated individually
- In the event that data cannot be supplied additional monitoring is likely to be required to cover data gaps and shortfalls. This has not been accounted for in the current budgeting due to the in principal commitment for in-kind data provision.

4. Options

- Options for data supply are presented for partners network consideration below:

Option 1: Direct provision of data ‘as-is’ with no formal agreement. This data would be treated with creative commons attribution.

Option 2: Data sharing agreement (Draft provided in Attachment 2) for parties requiring a written agreement

Option 3: Restrictive use license (Draft provided in Attachment 3) for parties requiring conditional licensing

5. Actions

Action 1: Resource sector companies who have provided data to DERM to improve model conditions to consider provision of a letter of authorisation for release of the data to FBA as host organisation for the partnership while more complex data sharing arrangements are negotiated

Action 2: Partner’s network members review the data sharing options and decide which option will meet the needs of their organisation. It is important to note that you only have to select one of these options. This is considered a high priority action since subsequent partnership activities depend on timely data collation and processing and internal negotiations may take several months for some organisations

Action 3: The agreements are authorised and returned to the partnership secretariat or further negotiated to a point where they can be authorised. If a data sharing arrangement cannot be reach additional monitoring may be required

Action 3: Resource sector companies who have provided data to DERM to improve model conditions provide a letter of authorisation for release of the data to FBA as host organisation for the partnership

Appendix 2: Fitzroy Partnership for River Health Data Sharing Agreement

Fitzroy Partnership for River Health

Data Sharing Agreement v2.1 Feb 2012

Background

The Fitzroy Partnership for River Health (FPRH) is a collaborative initiative aimed at integrating waterway monitoring and reporting in the Fitzroy Basin (Qld). Under this initiative hosted by the Fitzroy Basin Association Inc (FBA) an aquatic ecosystem health report card and ecosystem health indices will be developed. This will require partner organisations to provide data to the FBA for processing and reporting.

Objective

Data to be provided from the data holder [insert organisation name] to FBA as host for the partnership for the purpose of preparing indices and reporting on aquatic ecosystem health in the Fitzroy region, supporting milestones in the revised project plan.

Scope

Partnership activities will encompass all groundwaters, rivers, off-stream wetlands and estuaries in the Fitzroy Basin, and near-shore coastal and marine environments. Waterway monitoring data from ongoing monitoring programs are required. Data collected in and relevant to, the 2010/11 water year (01 July 2010 to 31 June 2011) for all waterway types will be required.

Only data for natural watercourses are required. Data relevant to point source discharges and off stream storages are not sought because they are not relevant to FPRH objectives.

Data for waterway health parameters required are specified in Table 1. Further details of data requirements and use are available in the Partnership Monitoring Program Design and Data Management Plan.

Use

Indices

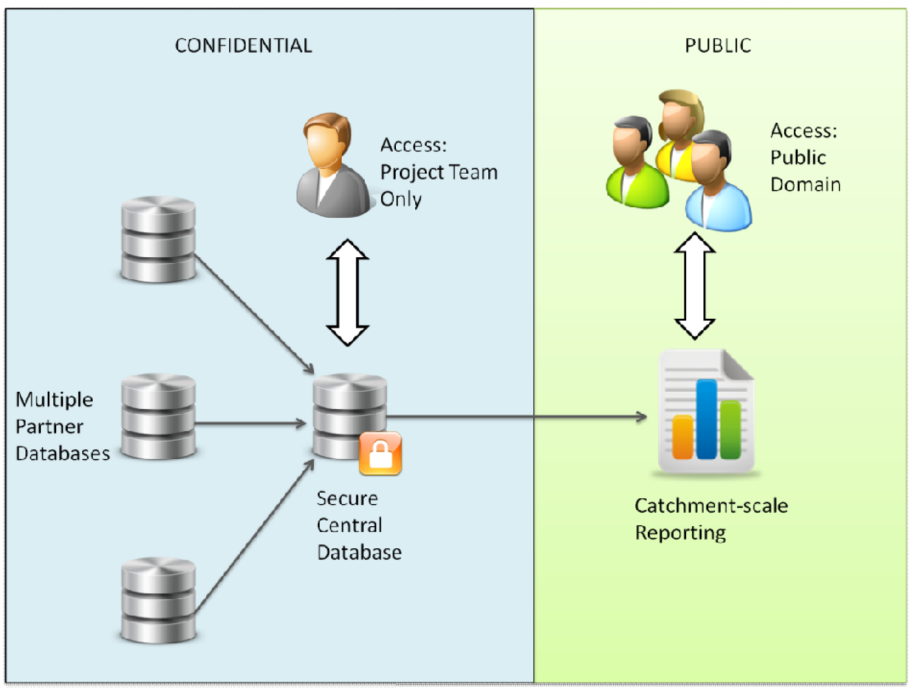
Data will be used to develop ecosystem health indices in order to assess the health of the Fitzroy system.

Reporting

Reporting will involve integrating data into various products for a catchment scale annual report. Importantly, individual data will not be presented in report products - only summary statistical and graphical derivatives of them - ensuring privacy and confidentiality requirements are maintained at all times.

Access and security

All data will be stored in a central database for access by the project team for partnership activities. Raw data (including personal and/or confidential data and metadata) will at no stage in the data management cycle be available to the public or other partners unless otherwise specified in this agreement (see Other Conditions). Processing will be required to normalise data before uploading. User accounts can be established to allow the data contributor to access their own data.



The partnership secretariat will maintain a register of approved users granted access to the partnership database. Only members of the project team identified by the secretariat as requiring access in order to achieve FPRH objectives will be given access. To become authorised users these project members will be required to sign a declaration stating that they understand the terms and conditions of their access and use (Appendix 2).

Indices will be prepared by this authorised team consisting of qualified staff from CQUniversity, DERM and FBA.

The project team will ensure individually identifying or other sensitive data are removed from reporting products. The FPRH management committee will review summary statistics and graphics to ensure privacy concerns are met before approving public release.

Format

The preferred data supply formats for this phase of the project are those compatible with Microsoft Excel (.xls, .xlsx, .csv, .dbf). Other formats can be catered for as needed.

Governance

Ownership of original data remains with the data provider. The partnership host organisation remains custodian of data for the project duration ending July 2013, after which further data acquisition will be negotiated or data will be destroyed. Report products will be licensed by the FPRH to the public domain under a creative commons licence.

Other Conditions

[Details of other conditions for supply and use of data as negotiated, e.g. if the data supplied are already public domain and may be published]

I have read and agree to the terms and conditions detailed in this agreement.

Signature of data provider Date: / /

Signature of customer

Table 1: Data requirements for the Fitzroy Partnership for River Health

Program	Sub-program	Indicator	Units
Reference	Reference	EC	microseimens per centimetre
		ions	milligrams per litre
		NOx, NH4 & FRP	milligrams per litre
		metals	milligrams per litre
Condition Assessment	Riverine monitoring	EC	microseimens per centimetre
		ions	milligrams per litre
		turbidity	nephelometric turbidity units
		NOx, NH4 & FRP	milligrams per litre
		metals	milligrams per litre
		aquatic habitat assessment (riparian & in-stream)	various
		Pest sp., aq. weeds, rip. weeds, pig damage	various
		macroinvertebrates	various
	Refugia monitoring	EC	milligrams per litre
		ions	milligrams per litre
		sedimentation - bathymetry	
		NOx, NH4 & FRP	milligrams per litre
		chlorophyll a	micrograms per litre
		aquatic habitat assessment (riparian & in-stream)	various
		Pest sp., aq. weeds, rip. weeds, pig damage	various
		fish assemblages	various
		Macroinvertebrates	various

	Ground water monitoring	Groundwater levels	metres
	Habitat monitoring	in-stream connectivity (barriers)	various
		riparian extent	various
		wetland extent	various
Estuary & marine	Estuary	Total Phosphorus	milligrams per litre
		Total Nitrogen	milligrams per litre
		NOx, NH4 & FRP	milligrams per litre
		Chlorophyll a	micrograms per litre
		Dissolved Oxygen	% saturation
		Turbidity/TSS	NTU / milligrams per litre
	Marine	Coral survey	various
		Seagrass survey	various
		Chlorophyll	micrograms per litre
		Turbidity	NTU
		Pesticides	micrograms per litre
		Turbidity/TSS	milligrams per litre
		Chlorophyll a	micrograms per litre
		PN, PP	micrograms per litre
Prediction	Flow modelling	Flow measures (tbd)	
	Event modelling	turbidity/TSS	NTU/milligrams per litre
		Nutrients (TN, TDN, Nox, NH4, DON, TP, DOP, FRP)	milligrams per litre
		Pesticides	

Appendix 3: Non-disclosure Agreement

Declaration of agreement

I, of on this, the of 2012, solemnly swear that I have read and do understand the conditions of the data sharing agreement for the Fitzroy partnership for River Health.

I agree to access and use data only as expressed in the agreement and not for any other purposes.

Signature

Witnessed by of

Witness Signature