Queensland Wetland Mapping Method

A Method to Provide Baseline Mapping of Wetland Extent and Changes in Wetland Extent in Queensland

Version 2.0

Queensland Government
Queensland Wetlands Program

Queensland
Wetlands Program

Prepared by: the Queensland Wetlands Program, Department of Environment and Science

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1 Introduction

The Queensland Wetlands Program (QWP) was established by the Australian and Queensland Governments in 2003 to support projects and programs that enhance the wise use and sustainable management of Queensland's wetlands. Having established a clear wetland definition (Environmental Protection Agency 2005; Department of Environment and Resource Management, 2011), one of the first projects undertaken through the QWP was the development of a mapping and classification scheme for wetlands (Environmental Protection Agency 2005) as it was recognised that a consistent, standardised, and repeatable method to comprehensively map and classify wetlands at an appropriate scale was required to facilitate decision making and management activities across the diverse landscapes of Queensland. Knowing where wetlands are and the characteristics (classification) of those wetlands underpins their intrinsic values and the range of services they provide to stakeholders.

Wetlands are critically important ecosystems that support significant biodiversity. Many wetlands process and remove pollutants, support primary industries by providing water, fish and valuable vegetation, many can sequester and store carbon, they can protect coastlines from storm surges, cyclones and the impacts of climate change, they are critically important to First Nations people and provide for many recreation and tourism opportunities. The important of wetlands and the need to protect, manage and rehabilitate them has been recognised in the multiple policy and legislative protection mechanisms in different parts of Queensland. Further information on the legislative and policy drivers for the development of wetland mapping is available through 'Programs, Policy, and Legislation'.

At over 1.7 million square kilometres, with approximately 7,000 kilometres of coastline and containing over 2,000 islands Queensland is a large state with diverse climate, geology, landform, rainfall, hydrological regimes, and ecosystems. It is the most biodiverse state in Australia and contains the greatest diversity of wetlands, the characteristics of which can vary significantly over time in association with factors such as rainfall, hydrological processes, and seasonal variations. Wetlands are transition areas between land and water, comprising a continuum from episodically wet areas to purely aquatic ecosystems and are difficult to map.

The provision of accurate baseline mapping and classification of wetlands in Queensland supports the following outcomes:

- acts as a primary tool to meet Government statutory and policy obligations, including international agreements and conventions (e.g. Ramsar)
- enables protection of wetlands through various management and statutory planning processes
- provides a sound basis for conservation and protected area planning and assessment
- informs scientific and technical assessments
- underpins objectives identified in strategic plans and policies
- underpins reporting on Government environmental targets, regional report cards, state of the environment reporting and other reporting processes
- guides investment in natural resource management
- supports statutory decision making, compliance, and planning processes
- guides research investment
- provides the basis for reporting on change in extent for
- provides the basis for relevant property level management

The initial mapping (v1.0), released in 2006, primarily covered lacustrine, palustrine, riverine, and vegetated estuarine wetlands, above mean sea level, in the catchments of the Great Barrier Reef. The first mapping covering the whole of Queensland (v1.3) for the same wetland systems was released in 2009, based on 2001 extent. The mapping has been updated 4 times (2005, 2009, 2013, 2017 extents) since then based on the EPA 2005 method, with improvements in linework being incorporated over time, greater integration of wetlands into the Regional Ecosystem framework and changes in extent being reported in State of the Environment Report, the Environmental Health Monitoring Program in South East Queensland, the Reef Report Cards, Regional Report Cards.

Methods to map and classify intertidal and subtidal ecosystems were developed in 2017 and 2020 and this was applied to map and classify these wetlands in central Queensland. Methods to map and classify groundwater dependent ecosystems was released in 2015, which provides key information to understanding wetland characteristics.

This document provides a significant update to the original EPA 2005 method, and has been applied to the mapping of lacustrine, palustrine, riverine and vegetated estuarine wetlands above mean sea level. It includes an update to the method used to map wetlands, a change from using estuarine and marine to using intertidal and subtidal, reorganised content to clearly separate the classification (Department of Environment and Science 2023b) and mapping components, updates to references and links, and the incorporation of other updates throughout the document, developed after feedback from users.

1.1 Purpose of this document

This document presents an updated framework for use in conducting baseline mapping of wetlands in Queensland (Section 3) including descriptions of data requirements (Section 4) and methodological steps (Sections 4, 5, 6, 7, 8). The document also includes details on the development and/or updating of primary source data (Section 5). The document does not provide extensive detail on definitions, nor does it provide the detail necessary to operationalise the method including the technical steps, databases, programming scripts, etc. This latter information is retained in related documents (Section 1.2). While previous base wetlands mapping was conducted using EPA 2005, the core method in this document is similar and consequently versions of the mapping will be continued from previous versions. The first version of the mapping undertaken with this revised method will be v6.0 and for mapping of lacustrine, palustrine, riverine, and vegetated estuarine wetlands above mean sea level.

1.2 Version history

Version	Year of Release	Description
1.0	N/A	Draft document for developmental purposes only.
1.1	N/A	Draft document for developmental purposes only.
1.2	2005	Details the methods used by the Queensland Government to classify and map wetlands across Queensland. Environmental Protection Agency (2005) Wetland Mapping and Classification Methodology – Overall Framework – A Method to Provide Baseline Mapping and Classification for Wetlands in Queensland, Version 1.2, Queensland Government, Brisbane. ISBN 0 9757 344 6 6.
	2019	Addendum that provides updates to Table 4 'Local Hydrology/Disturbance Modifiers'. Department of Environment and Science. 2019. Addendum to Wetland Mapping and Classification Methodology – Overall Framework – A Method to Provide Baseline Mapping and Classification for Wetlands in Queensland (Version 1.2). Brisbane: Department of Environment and Science.
2.0	2023	Provides major updates to the previous documents, including methods used to map wetlands, reorganised content to clearly separate the classification and mapping components, updates to references and links, and incorporates other updates throughout the document developed after feedback from users.

2 Background

A variety of methods have been used over time to classify and map different wetlands in Queensland at a range of scales for different purposes. However, since the Queensland Wetlands Mapping has been released in 2009, many policies and programs now refer to this foundational dataset and the content of previous mapping has been incorporated into it. The method described in this document and in the previous document (Environmental Protection Agency 2005) is underpinned by a set of principles, namely that the method must:

1. be consistent, functional, and repeatable throughout Queensland
2. be updatable as more information becomes available
3. use existing information, including remotely sensed and field data, and add value to this information
4. use existing, proven techniques for ecosystem classification and mapping
5. use the significant expertise that exists within Government agencies and held by other key stakeholders
6. be consistent and value add to existing mapping programs such as regional ecosystem, stream mapping etc.
7. include temporal information on the characteristics and distribution of wetlands
8. produce baseline data for use by multiple stakeholders both within and outside Government

2.1 The distinction between classification, typology, and mapping

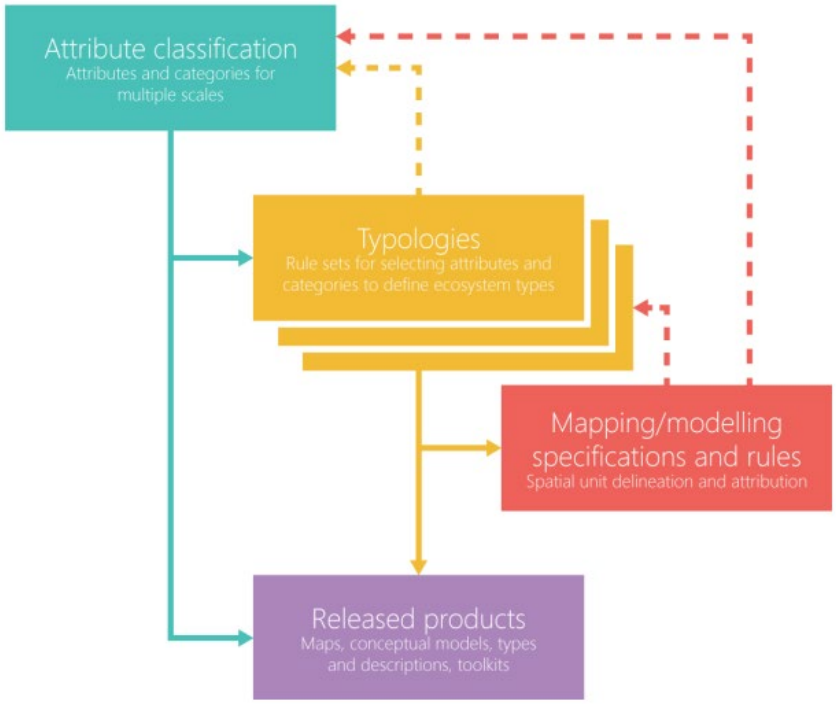

Figure 1 Schematic of the relationship between classification, typology, and mapping products (Department of Environment and Heritage Protection 2017).

Classification

Classification: the process of simplifying complex, and sometimes continuous, data and information and converting it into practical categories to make it more usable. Through classification, attributes can be classified into categories, independent of one another, enabling synthesis of the parts (components) and processes of different ecosystems (Environmental Protection Agency 2005)

Typology

Typology: a set of rules that are applied in a hierarchy to the attribute classification to identify types for a specific purpose. Different typologies can be developed from the same attribute classification to fulfil different purpose (AETG 2012). A typology must have a hierarchy in which the rules are applied based on the purpose of the typology, therefore, not every component or attribute will be required in the application of a specific typology.

Mapping

Mapping is produced by the spatial extension of classification (Neldner et al. 2019) using available spatial data such as aerial photography, satellite imagery, and other spatial data.

2.2 Scale

Scale: the parameter that describes the level of geographic resolution and extent, the context of space and time and helps define the positional accuracy. Scale refers to the relationship between distance on a map and the corresponding distance on the ground. A larger scale has a smaller ratio between the distance on a map and the corresponding distance on the ground and therefore can capture smaller sized features in comparison to a smaller scale. The identified scale also determines the minimum size of wetland and non-wetland features that can be delineated at a site and the positional accuracy of a mapped boundary line (Table 1).

Table 1. Recommended data resolution for various map scales (adapted from Neldner et al. 2019)

	Minimum Size on Map	1:5,000	1:10,000	1:25,000	1:50,000	1:100,000	1:250,000
Area of smallest feature depicted	2 x 2 mm	0.05 ha	0.1 ha	0.25 ha	1 ha	4 ha	25 ha
Minimum width of linear features depicted	1 mm	5 m	10 m	25 m	50 m	100 m	250 m
Precision of line-work	±0.5 mm	5 m	10 m	25 m	50 m	100m	250 m

The scale of the wetland mapping and classification data is determined by the coarsest scale of the primary input data sources (Section 4.1). Therefore, improvements in the scale of primary data sources may improve the scale of the final wetland mapping and classification data. The accompanying metadata specify the scale of the wetland mapping and classification data.

2.3 Currency

This method can be used to develop data for a singular point-in-time or a time-series (e.g., wetland extent as of 2001, 2005, 2009, etc.) of wetland mapping and classification data. The benefit of developing a time-series is the ability to report on trends in the extent, characteristics and distribution of wetlands, and types of wetlands, through time.

Point-in-time data cannot be appropriately compared to other point-in-time data (different versions of the data). This is primarily due to data improvements in the primary source data, such as the use of higher resolution satellite imagery to refine the spatial boundary of identified wetlands, the capture of additional wetlands, user feedback and additional studies. Comparing point-in-time data would conflate trends in actual on-ground change in wetland characteristics and extent with trends in the comprehensiveness and accuracy of source data capture processes. Time-series datasets require the development of several data sets representing different time periods but with all data sets incorporating the same updates and improvements in the primary source data (Figure 2).

The accompanying metadata specify the currency of the wetland mapping and classification data.

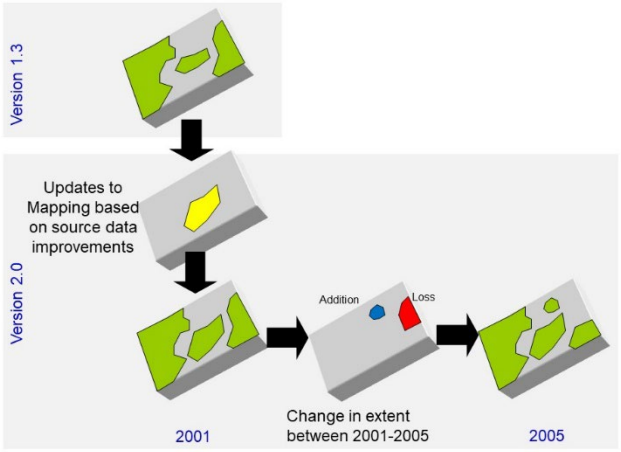

Figure 2. Diagram illustrating the development of time-series wetland extent data including integration of data improvements and on-ground changes.

3 Overview of the Method

This method builds on the Environmental Protection Agency (2005) method, refining the approach to source data, mapping, and quality assurance.

This method follows a logical sequence of six major method steps modified from those originally outlined in Environmental Protection Agency 2005 (Figure 1) that can be broadly grouped into four phases: source data collection and processing ( ), wetland waterbody classification ( ), wetland mapping ( ), and quality assurance ( ).

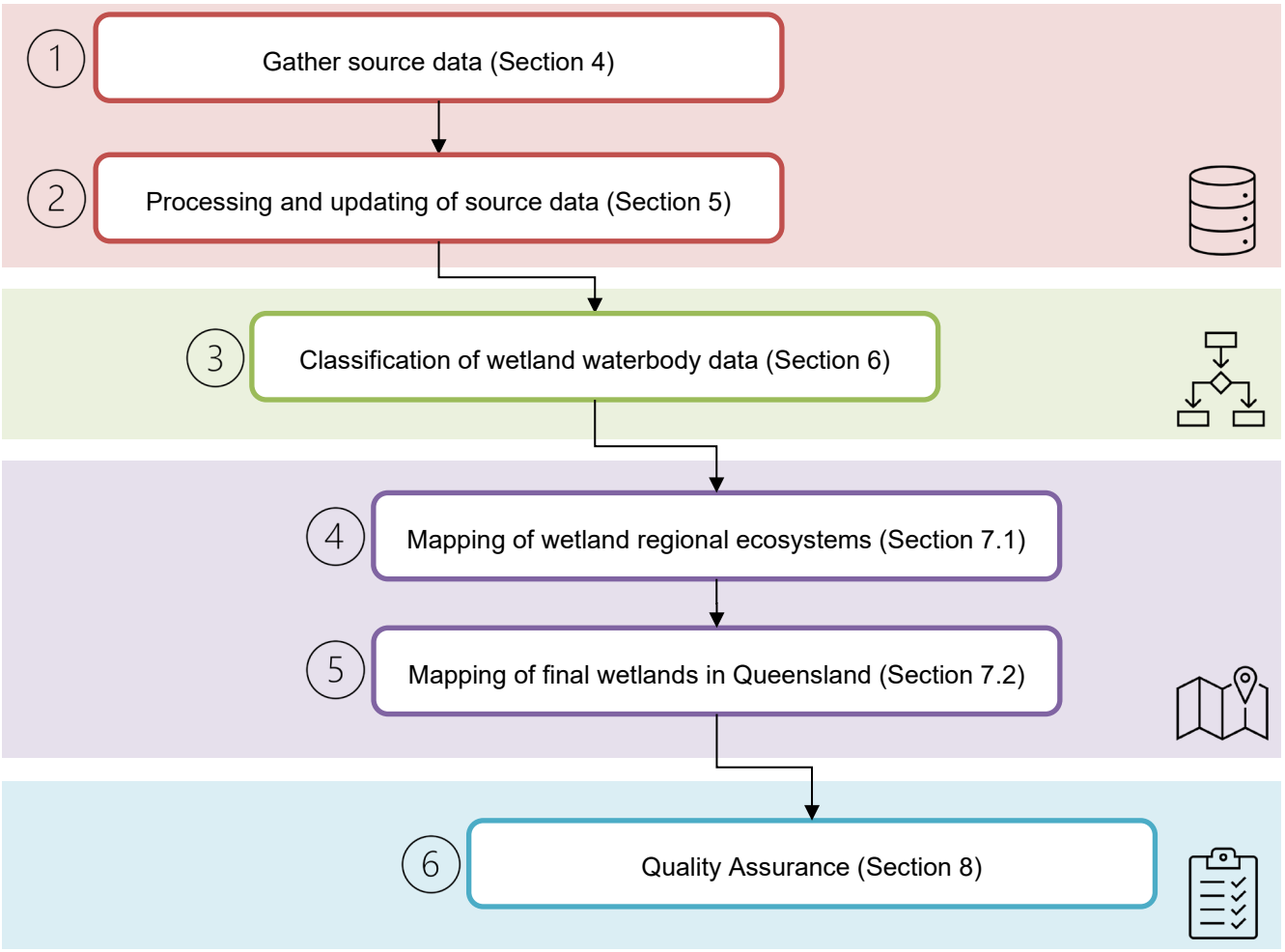

Figure 3 Schematic of the Queensland Wetland Mapping and Classification Method.

The method outlines the collation, processing, updating, and integration of source data to develop wetland mapping data. The use of multiple source data ensures that wetland mapping data represents the maximum wetland extent integral for the development of baseline data. The delineation of maximum wetland extent is the basic unit used for classification and typing. Each major step is detailed in the body of this document and the technical detail necessary to apply the method is provided in the related document 'Queensland Wetland Mapping and Classification Technical Specifications'.

4 Source Data

Primary source data is used to delineate wetlands in Queensland and secondary source data is used in the process of mapping and/or classifying. The primary and secondary source data is acquired from their respective data managers and combined in a geographic information system during analysis. Quality control checks are undertaken prior to the use of source data to ensure its accuracy and currency. The following sections outline the primary (4.1) and secondary (4.2) source data used in mapping and classifying wetlands in Queensland. Other secondary source data may be compiled and used where available to support classifying wetlands (4.3).

For quality control purposes, all source data is acquired directly from the point-of-truth repository (as advised by the relevant data manager) and must be accompanied by metadata recorded in accordance with Australia and New Zealand Land Information Council Metadata Profile Guidelines.

4.1 Primary source data

- Biodiversity of pre-clearing and remnant regional ecosystem data
- Drainage network data
- High Value Regrowth data
- Queensland Springs Database
- Regrowth data
- Hydrographic features data
- Wetland waterbody data[1]
- Woody extent data

4.2 Secondary source data used in the mapping of wetland extent

- 3 Nautical Mile Limit
- Count of detected open water derived from dense Landsat image time series
- Regional Ecosystem Description Database

4.3 Examples of secondary source data used in wetland classification

- Biogeographic Regions data
- Climate data
- Digital Elevation Model data
- Drainage Basin data
- Physiographic Region data
- Regional Ecosystem Description Database
- Wetland Insight Tool (Dunn et al. 2023)

[1] Wetland waterbody data was originally developed based on satellite imagery processing using the Normalised Difference Water Index and Density Slicing techniques. Further detail on these techniques can be found in Environmental Protection Agency (2005).

5 Source Data Processing

The key source data processing steps are described below and include data updates as well as quality control and assurance checks.

5.1 Biodiversity of pre-clearing and remnant regional ecosystem data

Biodiversity of pre-clearing and remnant regional ecosystem data is updated according to the method provided in Neldner et al. (2019). All regional ecosystems in the Biodiversity of pre-clearing and remnant regional ecosystem data are classified in the accompanying Regional Ecosystem Description Database including classification of relevant wetland characteristics consistent with the Queensland Wetland Classification Scheme (Department of Environment and Science 2023b). This includes classification of wetland system (e.g., if the regional ecosystem is a palustrine wetland, etc.). Quality assurance checks of Biodiversity of pre-clearing and remnant regional ecosystem data and the accompanying Regional Ecosystem Description Database are undertaken as per Neldner et al. (2019) including validation of wetland classification.

5.2 High Value Regrowth

High Value Regrowth data is updated as part of the generation of Biodiversity of pre-clearing and remnant regional ecosystem data according to the method provided in Neldner et al. (2019). All regional ecosystems in the High Value Regrowth data are classified in the accompanying Regional Ecosystem Description Database including classification of relevant wetland characteristics consistent with the Queensland Wetland Classification Scheme. Quality assurance checks of High Value Regrowth data and the accompanying Regional Ecosystem Description Database are undertaken as per Neldner et al. (2019) including validation of wetland classification. High Value Regrowth vegetation means native vegetation regrowth greater than 15 years old (Neldner et al. 2019). High Value Regrowth includes high value wetland vegetation regrowth that would not otherwise be captured in other source datasets.

5.3 Regrowth

Regrowth data is updated as part of the generation of Biodiversity of pre-clearing and remnant regional ecosystem data according to the method provided in Neldner et al. (2019). All regional ecosystems in the Regrowth data are classified in the accompanying Regional Ecosystem Description Database including classification of relevant wetland characteristics consistent with the Queensland Wetland Classification Scheme. Quality assurance checks of Regrowth data and the accompanying Regional Ecosystem Description Database are undertaken as per Neldner et al. (2019) including validation of wetland classification. Regrowth vegetation means non-remnant vegetation that has a significant woody component but fails to meet the structural and/or floristic characteristics of remnant vegetation. Includes vegetation that has regrown after clearing or been heavily thinned or logged and may retain significant biodiversity values (Neldner et al. 2019). Regrowth includes wetland vegetation regrowth that would not otherwise be captured in other source datasets.

5.4 Woody Extent

Woody extent data (Statewide Landcover and Trees Study) captures woody vegetation (i.e., vegetation with at least 10% crown cover) at a nominal map scale of 1:10,000 across Queensland. This data is developed using a supervised classification and manual revision and quality assurance.

Woody extent data is used in limited areas of Queensland and therefore the woody extent data is clipped to those areas.

5.5 Wetland waterbody data

Wetland waterbody data was originally developed based on satellite imagery processing using the Normalised Difference Water Index and Density Slicing techniques. Further detail on these techniques can be found in Environmental Protection Agency (2005) and Knight, Tindall & Wilson (2009).

Wetland waterbody data undergoes a series of quality assurance checks including validation of the accuracy and comprehensiveness of data values, geometry, and topology. All identified errors are manually reviewed and corrected. Once errors have been resolved, wetland waterbody data is temporally updated through a two-step process consisting of satellite imagery analysis followed by manual assessment. The detail provided in this section represents the current processing approach, however existing wetland waterbodies in the wetland waterbody source data were developed using other satellite methods. Specifically, advancements in remote sensing have

enabled the use of higher temporal and spatial resolution satellite imagery and improved analysis techniques.

5.5.1 Satellite image processing

Satellite image processing is undertaken to identify the locations of potential open waterbodies. This processing has used different satellite imagery and/or analysis techniques through time since the original wetland waterbodies dataset was developed. Currently, satellite image processing for the purposes of temporal data updates uses the 'Count of detected open water derived from dense Landsat image time series' source data (data custodian: Department of Environment and Science). This source data is a transformation (Danaher and Colllett 2006) of the multi-spectral reflective imagery archive (1987 to present) acquired from the Landsat Thematic Mapper family of satellite-borne instruments (e.g., Landsat-4 TM, Landsat-5 TM, Landsat-7 ETM+) to detect open water for each date of imagery acquisition with consideration made for cloud, cloud shadow, topographic shadow, and atmospheric conditions. The full transformed time series is accumulated into counts of how many occasions the pixel was detected as open water and how many occasions a clear observation was made.

The 'Count of detected open water derived from dense Landsat image time series' detecting open water is reclassified using expert defined threshold(s) for the purpose of identifying potential open waterbodies based on an ecological and hydrological understanding of the landscape. A preliminary, automated assessment is subsequently undertaken in a geographic information system to compare the identified potential open waterbodies and the latest wetland waterbody data eliminating those potential open waterbodies that either overlap existing wetland waterbodies or are too small. The resulting potential open waterbodies are then manually assessed in the subsequent step.

5.5.2 Manual assessment

Manual assessment is undertaken to determine whether the potential open waterbodies (identified in 5.5.1): (1) represents a new or omitted waterbody, and (2) meets the Queensland Wetland Program Wetland Definition (Environmental Protection Agency 2005). Potential open waterbodies that meet both criteria are incorporated into the wetland waterbody source data and manually classified.

Manual classification must include classification of the relevant hydrological modification class and wetland system of the wetland waterbody at each time point (e.g., 2001, 2005, 2009, 2013, 2017, 2019, etc.). Manual classification may also include classification of the regional ecosystem for the wetland waterbody at each time point (e.g., 2001, 2005, 2009, 2013, 2017, 2019, etc.). All manual classification is based on expert interpretation of available data (including aerial and satellite imagery, ecological data, geological data, land survey data, landform data, soils data, vegetation mapping data, and site data) and must be consistent with the Queensland Wetland Classification Scheme.

During the manual assessment process, the following actions may also be undertaken to update the wetland waterbodies source data: re-classification of wetland waterbodies that no longer exist; removal of erroneous features that are not and have never been wetland waterbodies; the addition of new or omitted wetland waterbodies; and refinement to the delineation or classification of wetland waterbodies.

5.5.3 Quality assurance

The updated wetland waterbody source data undergoes a series of quality assurance checks including validation of the accuracy and comprehensiveness of data values, geometry, and topology. All identified errors are manually reviewed and corrected.

5.6 Other data

All other source spatial data (e.g., secondary source data used in wetland classification as described in Section 4.3) undergoes a series of quality assurance checks including validation of geometry and topology. All identified errors are manually reviewed and discussed with the relevant data manager.

6 Classification

This section provides an overview of the classification of core wetland attributes including wetland system, wetland regional ecosystem, and habitat level hydrological modification. Classification of other attributes is described in Section 7.2.2.

6.1 Biodiversity of pre-clearing and remnant regional ecosystem data

All regional ecosystems, including wetland regional ecosystems, are classified with relevant attributes in the accompanying Regional Ecosystem Description Database. This includes classification of wetland characteristics consistent with the Queensland Wetland Classification Scheme. This classification is available for regional ecosystems identified in the Biodiversity of pre-clearing and remnant regional ecosystem, high value regrowth, and regrowth data.

6.2 Wetland waterbody classification

Classification of wetland waterbody system has two components: (1) a manual classification process for wetland system and hydrological modification, and (2) an automated classification process for regional ecosystem. The manual classification process is described in section 5.5.2. The automated classification process is described in this section.

6.2.1 Classifying regional ecosystem(s)

Wetland waterbodies are allocated one or more regional ecosystems based on a spatial intersection with pre-clearing regional ecosystem data (a component of the 'Biodiversity of pre-clearing and remnant regional ecosystems data'). Wetland waterbodies may spatially intersect with one or more polygons in pre-clearing regional ecosystem data and each polygon may be comprised of up to five regional ecosystems.

Wetland waterbodies are allocated one or more regional ecosystems based on a comparison of the wetland waterbody's wetland system determined by a manual assessment (Section 5.5.3) and the wetland systems of each intersecting regional ecosystem as per the Regional Ecosystem Description Database. Where more than one regional ecosystem is allocated to a wetland waterbody, the allocation is undertaken in decreasing proportion of the polygon area.

Subtidal wetland waterbodies and some intertidal wetland waterbodies, below mean sea level, are not included in the regional ecosystem framework underpinning the 'Biodiversity of pre-clearing and remnant regional ecosystems data', and therefore, these wetland waterbodies do not have an accompanying regional ecosystem.

6.2.2 Quality assurance

The classified wetland waterbody data (Section 6.2.1) undergoes a series of quality assurance checks including validation of the combination of regional ecosystem, wetland system, and hydrological modification. All identified errors are manually reviewed and corrected.

7 Mapping

7.1 Wetland regional ecosystem mapping

The extent of wetland regional ecosystems is extracted from the Biodiversity of pre-clearing and remnant regional ecosystem data, High Value Regrowth data, and Regrowth data based on their wetland system classification in the accompanying Regional Ecosystem Description Database, and form intermediate data sets remnant wetland regional ecosystems, wetland high value regrowth, and wetland regrowth respectively.

These intermediate data sets and the woody extent data are compiled into a single data set and undergoes a series of quality assurance checks including ensuring no overlap of extent. All identified errors are reviewed and corrected. The data is compiled based on a hierarchy of source data: remnant wetland regional ecosystems > wetland high value regrowth > wetland regrowth > and woody extent. Where overlap occurs between two or more of the extracted data or woody extent data, the data highest in the hierarchy will take precedence and override all other data.

7.2 Final wetland mapping

There are two components to the wetland mapping and classification data: (1) spatial data providing information on the extent and distribution of wetlands (Section 7.2.1) and (2) attribute data providing information on the characteristics (classification) of wetlands (Section 7.2.2).

7.2.1 Spatial data

Wetland regional ecosystem data (Section 7.1), wetland waterbodies data (Sections 5.1 and 6.2), watercourse lines drainage network data (Section 4.1), wetland points (Section 4.1), and Queensland Springs Data (Section 4.1) are combined by geometry type to generate the final wetland mapping data. Wetland regional ecosystem data and wetland waterbodies data are combined to form Queensland Wetland Data – Areas; watercourse lines drainage network data forms Queensland Wetland Data – Lines; and wetland points and springs data are combined to form Queensland Wetland Data – Points.

The combination of wetland regional ecosystem data and wetland waterbodies data to form Queensland Wetland Data – Areas uses a series of decision rules to determine precedence of data in the case of overlap between two data sets. Decision rules include comparison of classified habitat level hydrological modification and wetland system and are summarised as follows:

- Firstly, precedence is given to wetlands from the wetland waterbodies data where habitat level hydrological modification is not natural.
- Secondly, precedence is given to wetlands from the wetland regional ecosystem data where the overlapping wetlands are both natural, have the same wetland system, and wetland regional ecosystem.
- Thirdly, precedence is given to wetlands from the wetland regional ecosystem data where the overlapping wetlands are both natural and the wetland waterbody has a wetland system of intertidal.
- Fourthly, precedence is given to wetlands from the wetland waterbodies data.

Precedence is assessed for each overlap instance independently.

7.2.2 Attribute data

This method adopts the classification scheme as detailed in Queensland Wetland Classification Scheme (Department of Environment and Science 2023b), including attributes, qualifiers, and categories. A range of secondary source data (Section 4.3) is compiled, processed, analysed, and used, as appropriate, to support wetland classification. Further detail on the use of secondary source data for wetland classification is available on Wetland*Info*.

7.2.3 Quality assurance

Prior to finalisation, wetland mapping requires manual expert review and may require site-based field validation. This review includes generation of wetland extent trend statistics to support identification of classification and/or mapping commission and omission errors (Appendix A).

7.3 Metadata

Wetland data developed using the method outlined in this document must be accompanied by metadata recorded in accordance with Australia and New Zealand Land Information Council Metadata Profile Guidelines.

7.4 Map versions

Queensland Wetland Data developed using this method and by the previous method (Environmental Protection Agency 2005) released as different versions. Data versioning uses a two-level numeric classification (e.g., Version 1.0, Version 2.0) with:

- major updates representing a temporal update (including temporal update to source data), and
- minor updates representing expansion of mapping to previously unmapped areas and/or improvements in source data (excluding temporal updates).

In addition, each version includes a release of all available temporal extent coverages. For example, Version 5.0 included data coverages of wetland extent and characteristics in 2001, 2005, 2009, 2013, and 2017. This enables comparison of wetland extent coverages and associated statistics without confounding changes in extent with changes in source data (as discussed further in Section 2.4).

7.5 Incorporation of mapping from third parties

All mapping acquired from third parties is reviewed by experts prior to its incorporation in one or more of the source data used (Section 4), specifically Biodiversity of pre-clearing and remnant regional ecosystem data and/or wetland waterbody data.

8 Quality Assurance

Numerous quality assurance steps are embedded throughout the method and are summarised below. A strong governance framework is required to ensure continued high quality and high reliability baseline wetland data production. This includes a diverse technical advisory group responsible for, among other activities, the review and endorsement of quality assurance processes undertaken during product development.

- Ensure all source data is acquired from the point-of-truth source with metadata (Section 4)
- Ensure the quality of all source data including validation of the accuracy and comprehensiveness of data values, geometry, and topology (Section 5.1, 5.2, 5.3, 5.4, 5.6)
- Ensure the quality of the temporal update to wetland waterbody data (Section 5.5.4)
- Ensure the quality of wetland waterbody data classification including wetland system, regional ecosystem, and hydrological modification (Section 6.2.2)
- Ensure the quality of developed wetland mapping data:
    - including validation of the accuracy and comprehensiveness of data values, geometry, and topology (Section 7.2.3)
    - including external expert peer review of the accuracy and comprehensiveness of spatial and attribute data
    - including external expert peer review of generated statistics on the temporal trend in wetland extent (Appendix 1)
- Ensure accompanying metadata is consistent with Australia and New Zealand Land Information Council Metadata Profile Guidelines (Section 7.3)

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10 Abbreviations

Acronym or Abbreviation	Acronym or Abbreviation Name
LAT	Lowest Astronomical Tide

11 Units of Measurement

Unit of Measurement	Unit of Measurement Name
%	Percent
ha	Hectares
M	Nautical Mile
ppt	Parts per Thousand

12 Glossary

Term	Definition
Area	Any particular extent of surface; region; tract (Yallop 2005)
Attribute	See Queensland Wetland Classification Scheme
Attribute Data	Tabular or textual data describing the geographic characteristics of features (ESRI n.d.)
Baseline	A basic standard or level, usually regarded as a reference point for comparison (Yallop 2005)
Biodiversity	"Biodiversity (or biological diversity) is the variability among living organisms from all sources including inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species (genetic diversity), between species (species diversity), of ecosystems (ecosystem diversity), and of ecological processes." (Aquatic Ecosystems Task Group 2012)
Category	See Queensland Wetland Classification Scheme
Channel	Linear, generally sinuous open depression, comprising of a bed and banks which is in parts eroded, excavated, or built up by channelled stream flow (Speight 1990)
Classification	"A process of simplifying complex, and sometimes continuous, data and information and converting it into practical categories to make it more usable." (Department of Environment and Science 2020a)
Climate	The composite or generalisation of weather conditions of a region, as temperature, pressure, humidity, precipitation, sunshine, cloudiness, and winds, throughout the year, averaged over a series of years (Yallop 2005)
Component	See Queensland Wetland Classification Scheme
Continuum	A continuous extent, series, or whole (Yallop 2005)
Currency	The fact or state of passing in time (Yallop 2005)
Data	Figures, statistics, etc., known or available; information collected for analysis or reference (Yallop 2005)
Database	Information stored in a computer and organised in categories to facilitate retrieval (Yallop

	2005)
Delineation	To trace the outline of; sketch or trace in outline; represent pictorially (Yallop 2005). In this document, delineation relates to the process of establishing and describing the boundary between wetland and non-wetland ecosystems.
Ecosystem	"An ecosystem is a dynamic combination of plant, animal and micro-organism communities and their non-living environment (e.g., soil, water and the climatic regime) interacting as a functional unit." (Aquatic Ecosystems Task Group 2012)
Embayment	A notch in the shoreline, not restricted to any single form. It may be a lobe of water extending inland as deeply as a firth or fiord, or it may be as shallow as a quarter moon shape. For the purposes of this study this includes a cove, bay, gulf, passage or strait (UN, Division for Ocean Affairs).
Episodic	Dry most of the time with rare and very irregular wet phases (Paijmans et al. 1985).
Estuarine Wetland System	See Queensland Wetland Definition Guideline
Geometry	The shape of a surface or solid (Yallop 2005)
Geographic Information System	A geographic information system (GIS) is a framework for gathering, managing, and analysing data (ESRI n.d. b).
Hierarchy	Any system of persons or things in a graded order, etc. (Yallop 2005)
Intersect	A spatial intersect is where two features cross (ESRI n.d.)
Hydrological Modification	Hydrological modification refers to anthropogenic activities that alter wetland hydrology.
Lacustrine Wetland System	See Queensland Wetland Definition Guideline
Landform	Any of the numerous features which make up the surface of the earth (Yallop 2005)
Landsat Thematic Mapper	Landsat Thematic Mapper is an advanced, multispectral scanning sensor (USGS n.d.).
Landsat-4 TM	Landsat-4 TM is a satellite with Landsat Thematic Mapper sensor onboard launched in 1982 and decommissioned in that orbited from July 1982 to May 2012 (USGS n.d.).
Landsat-5 TM	Landsat-5 TM is a satellite with Landsat Thematic Mapper sensor onboard launched in 1984 and decommissioned in June 2013 (USGS n.d.).
Landsat-7 ETM+	Landsat-7 ETM+ is a satellite with Enhanced Thematic Mapper sensor onboard launched in April 1999 (USGS n.d.).
Lowest Astronomical Tide	Lowest Astronomical Tide is the lowest level that can be predicted to occur under average meteorological conditions and any combination of astronomical conditions (Australian Hydrographic Office n.d.).
Map	Graphic representation that facilitates a spatial understanding of things, concepts, conditions, processes, or events in the human world (Harley and Woodward 1987). See Section 2.1
Mapping	See ‘Map’
Marine Wetland System	See Queensland Wetland Definition Guideline
Metadata	Information about data, especially in relation to its structure and organisation (Yallop 2005)
Mosaic Areas	See Queensland Wetland Definition Guideline
Mosaic Wetland Areas	See Queensland Wetland Definition Guideline

Palustrine Wetland System	See Queensland Wetland Definition Guideline
Perimeter	The circumference, border, or outer boundary of a two-dimensional figure (Yallop 2005)
Quality Assurance	The practices adopted by a business, service provider, etc., to ensure the quality of the products or services provided (Yallop 2005)
Quality Control	A method of ensuring the quality of products, as by sampling the output of an industrial process, based on the theory of probability, with the object of detecting and controlling any variations in quality (Yallop 2005)
Regional Ecosystem	A vegetation community or communities in a bioregion that is consistently associated with a particular combination of geology, landform and soil. (Neldner et al. 2019)
Remote Sensing	The identification of data, usually about features of the earth or other bodies in space, from a satellite, aeroplane, etc. (Yallop 2005)
Resolution	The detail with which a map depicts the location and shape of geographic features (ESRI n.d.)
River Mouth	The point where a stream issues into a larger body of water. For the purposes of this method the larger body of water is the ocean (Environmental Protection Agency 2005).
Riverine Wetland System	See Queensland Wetland Definition Guideline
Salinity	The presence of soluble salts in or on soils or in waters (Department of Natural Resources and Water 1997).
Scale	The parameter that describes the level of geographic resolution and extent, the context of space and time and helps define the positional accuracy (Quattrochi and Goodchild 1997)
Seasonal	Alternatively, wet and dry every year according to season (Paijmans et al. 1985).
Soil	"Pedologic organisation is used to distinguish soil materials. This is a broad concept used to include all changes in soil material resulting from the effect of the physical, chemical and biological processes that are involved in soil formation. Results of these processes include horizonation, colour differences, presence of pedality, texture and/or consistence changes." (Isbell and National Committee on Soil and Terrain 2016).
Source Data	See Section 4
Source Data (Primary)	See Section 4
Source Data (Secondary)	See Section 4
Tidal	"Of or pertaining to tides; caused by tides; having tides; periodically rising and falling, or following and ebbing; as, tidal waters" (Environmental Protection Agency 2005b).
Tidal Salinity	Marine and estuarine wetlands can be described in terms of their salinity structure. The salinity structure of the estuary is determined by its geometry as well as prevailing and antecedent climatic conditions that include (Environmental Protection Agency 2005).: • Fresh water inflow; • Tides, and • Wind.
Topology	Topology is the arrangement for how point, line, and polygon features share geometry (ESRI 2020).
Typing	See ‘Typology’
Typology	See Section 2.1

Waterbody	See Queensland Wetland Definition Guideline
Waterhole	See Queensland Wetland Definition Guideline
Wetland	See Queensland Wetland Definition Guideline
Wetland Regional Ecosystem	A regional ecosystem (see 'Regional Ecosystem') that meets the Queensland Wetland Program Wetland Definition (see 'Wetland').
Wetland System	See Queensland Wetland Definition Guideline
Wetland Waterbody	A waterbody (see 'Waterbody') that meets the Queensland Wetland Program Wetland Definition (see 'Wetland').

Appendix 1 Queensland Wetland System and Type Extent Assessment Method: A Method to Provide Baseline Wetland System and Type Extent Change for Wetlands in Queensland

1 Introduction

Monitoring long-term changes in the distribution, extent and characteristics of wetlands, over time provides critical insights to assist with prioritise investment; inform planning and management activities; evaluate the effectiveness of management activities, legislation, policy and programs; and support environmental reporting (e.g. Environmental Health Monitoring Program, Reef Water Quality Report Card, Regional Report Cards, and State of the Environment Reports). Repeat mapping of wetlands and their characteristics allows Queensland to achieve this monitoring goal.

1.1 Purpose of this Document

The 'Queensland Wetland System and Type Extent Assessment Method: A Method to Provide Baseline Wetland System and Type Extent Change for Wetlands in Queensland' (the Monitoring Method) provides a process for use in state-wide monitoring of wetland distribution, extent, and characteristics. It includes details of data requirements (Section 3.1) and methodological steps (Sections 3.2, 3.3). The document does not detail the definitions adopted for mapping purposes, nor does it provide the detail necessary to operationalise the monitoring method including technical steps, databases, programming scripts.

2 Background

2.1 Definitions

For these guidelines the following definitions apply.

Natural Wetlands

Natural wetlands refer to wetlands where activities that modify wetland hydrology and/or structures associated with these activities cannot be observed from aerial or satellite imagery and are not known from field survey data.

Natural wetlands include those with a habitat hydrological modification qualifier of ‘H1’ in the mapping and classification.

Modified Wetlands

Modified wetlands are existing wetlands which were also former natural wetlands, where activities that modify wetland hydrology and/or structures associated with these activities have been observed from aerial or satellite imagery or from field survey data.

Modified wetlands include those with a habitat hydrological modification qualifier that starts with ‘H2’ in the mapping and classification.

Slightly Modified Wetlands

Slightly modified wetlands are modified wetlands where the hydrological modifications allows the resulting wetland to retain many of their functional and ecological characteristics.

Slightly modified wetlands include those with a habitat hydrological modification qualifier of ‘H2-M1’, ‘H2-M1-a’, ‘H2-M1-b’, ‘H2-M2’, ‘H2-M2-a’, ‘H2-M2-b’, ‘H2-M2-c’, ‘H2-M2-d’, ‘H2-M9’, ‘H2-M9-a’, ‘H2-M9-b’, ‘H2-M9-c’, ‘H2-M10’, ‘H2-M10-a’, ‘H2-M10-c’, ‘H2-M11’, ‘H2-M11-a’, ‘H2-M11-b’, ‘H2-M11-d’, ‘H2-M12’, ‘H2-M12-a’, ‘H2-M12-b’, ‘H2-M12-c’, or ‘H2-M12-d’ in the mapping and classification.

Highly Modified Wetlands

Highly modified wetlands are modified wetlands where the hydrological modifications are considered to significantly degrade the wetland’s functional and ecological characteristics.

Highly modified wetlands include those with a habitat hydrological modification qualifier of ‘H2-M1-e’, ‘H2-M5’, ‘H2-M6’, ‘H2-M6-a’, ‘H2-M6-b’, ‘H2-M6-f’, ‘H2-M7’, ‘H2-M11-c’, or ‘H2-M13’ in the mapping and classification.

Artificial Wetlands

Artificial wetlands refer to anthropogenically constructed wetlands where no natural or modified wetlands existed prior to the commencement of construction.

Artificial wetlands include those with a habitat hydrological modification qualifier that starts with ‘H3’ in the mapping and classification.

Wetland Extent

Wetland extent refers to the maximum areal extent of the wetland.

Baseline Wetland Extent

Baseline wetland extent is a relative term referring to the maximum areal extent of the wetland at the start of a given reporting period.

Pre-clearing Wetland Extent

Pre-clearing wetland extent refers to the maximum areal extent of the wetland prior to clearing (Neldner et al. 2019).

Mosaic wetland areas

Those areas containing a mixture or mosaic of wetland and non-wetland vegetation communities (Department of Environment and Science 2023a).

Reporting Area

Reporting area refers to the geographic area over which changes in wetland extent are calculated.

Reporting Period

Reporting period refers to the time over which changes in wetland extent are calculated. Generally, reporting

periods parallel the temporal resolution of available wetland extent time-series data.

Wetland Loss (Monitoring)

A loss of a wetland for the purposes of monitoring of wetland system and type extent change is defined as wetlands where activities have modified wetland hydrology to such an extent that they no longer meet the definition of a wetland, or where activities have significantly altered the wetland's functional and ecological characteristics (i.e., highly modified wetlands).

Wetland Loss (Quantification)

Wetland loss refers to the difference between wetland extent over a reporting period calculated based on comparable data from two points-in-time, but repeated measures in time can produce multiple results.

2.2 Scope

This Monitoring Method is intended to apply to a single version (Section 7.4) of the time-series of Queensland Wetland Data to ensure appropriate comparison of the extent, wetland system, hydrological modifications, distribution and types of wetlands, through time. The use of a single version of the time-series of Queensland Wetland Data prevents the conflation of trends in on-ground change in wetland characteristics and extent with trends in the comprehensiveness and accuracy of source data capture processes (Section 2.4). Therefore, the results from the application of this Monitoring Method to a newer version of source data will supersede previously published results for all reporting periods. The application of this Monitoring Method is limited by the scale of wetland mapping (Section 2.2) whereby the Monitoring Method can only detect changes in wetland features depicted.

2.3 Limitations

All limitations are considered and quantified, where possible (see 3.3.3).

2.3.1 Pre-clearing Wetland Extent

A proxy data set is required to be used due to the lack of a pre-clearing wetland extent data set. This proxy data set does not comprehensively capture the pre-clearing wetland extent of natural and modified wetlands, therefore introducing a source of error that should be considered (see 3.3.3). Further information on the generation of a proxy data set is available in Section 3.3.1.

2.3.2 Mosaic Wetland Areas

Changes in the extent of mosaic wetland areas are unable to be reliably allocated to a specific vegetation community and this introduces a source of error in calculating overall wetland area changes. This Monitoring Method is therefore only applied to non-mosaic wetland areas and mosaic wetland areas where wetland vegetation communities comprise over 80% of the area to prevent significant over-estimation in results.

3 Monitoring Method

The following sequence of steps that can be broadly grouped into three phases: source data collection and processing (see 3.1, 3.2), analysis and reporting (see 3.3), and quality assurance (see 4). The technical detail necessary to apply the method is provided in the related technical specifications.

3.1 Source Data

Source data is the basic component on which changes in wetland extent are calculated. The source data (listed below) is acquired from their respective data managers and combined per this method in a geographic information system during analysis (detailed in Section 3.2 and 3.3). Quality control checks are undertaken prior to the use of source data to ensure accuracy and currency.

- Queensland Wetland Data
- Biodiversity of pre-clearing and remnant regional ecosystem data
- Wetland waterbodies

For quality control purposes, all source data is acquired directly from the point-of-truth repository (as advised by the relevant data manager) and must be accompanied by metadata recorded in accordance with Australia and New Zealand Land Information Council Metadata Profile Guidelines.

3.2 Source Data Processing

The key source data processing steps are described below and include quality control and assurance checks. Note that source data processing.

3.2.1 Biodiversity of pre-clearing and remnant regional ecosystem data

All wetland regional ecosystems are extracted from the pre-clearing regional ecosystem data (a component of the Biodiversity of pre-clearing and remnant regional ecosystem data) based on their wetland system classification in the accompanying Regional Ecosystem Description Database. This forms the intermediate data set called pre-clearing wetland regional ecosystems.

3.2.2 Wetland waterbody

All wetland waterbodies with no observed hydrological modification (i.e. natural wetland waterbodies) are extracted from the Wetland waterbodies data. This forms the intermediate data set called natural wetland waterbodies.

3.2.3 Identification of Reporting Areas

Spatial data representing the chosen reporting area(s) is identified and processed as required. Example reporting areas include administrative boundaries, biogeographic boundaries, catchment boundaries, etc.

3.3 Data Analysis

3.3.1 Generating an Estimated Pre-Clearing Wetland Extent

The intermediate data sets pre-clearing wetland regional ecosystems (section 3.2.1) and natural wetland waterbodies (section 3.2.2) are combined to generate an estimated pre-clearing wetland extent data. The same decision rules summarised in Section 7.2.1 are applied during this step.

3.3.2 Generating Wetland Extent Change Statistics

The change between pre-clearing and baseline wetland extent can be analysed for all wetlands as a whole or split into statistics groups by any number of characteristics. The choice of relevant characteristics, if any, will depend on the intended purpose of the wetland extent change statistics. For the purposes of state-wide monitoring of wetland system and type extent change, wetland extent change is analysed by reporting area and wetland system. Additionally, state-wide monitoring of wetland system and type extent change only analyses changes in extent to natural or slightly modified wetlands in the reporting area (see the definition of wetland loss in 2.1).

Wetlands in the estimated pre-clearing wetland extent data and the baseline wetland extent data (i.e., Queensland Wetland Data) were processed to retain only the classification information relevant to state-wide monitoring (i.e., wetland system, wetland regional ecosystem, habitat level hydrological modification, wetland percentage, etc.). These datasets, including all time-series data (e.g., 2001, 2005, 2009, 2013, 2017, 2019, etc.), were then

combined to form a single dataset with overlap captured in the data attribute table. All information was retained during the combination step and no decision rules were applied. All wetlands are then allocated to a reporting area based on spatial location. Where wetlands cross multiple reporting areas they were split and allocated to their respective reporting areas. The area (in hectares) was calculated for each wetland polygon.

For each wetland system and reporting year, the following statistics are calculated:

- Extent of natural wetlands (in hectares).
- Extent of natural wetlands as a percentage of estimated pre-clearing wetland extent.
- Extent of natural wetlands as a percentage of the most recent reporting year extent in the time-series.
- Extent of slightly modified wetlands (in hectares).
- Extent of slightly modified wetlands as a percentage of the most recent reporting year extent in the time-series.
- Extent of highly modified and artificial wetlands (in hectares).

For each wetland system and reporting period, the following statistics are calculated:

- Extent of natural wetlands that have been infilled or cleared over the reporting period (in hectares).
- Extent of natural wetlands that have been infilled or cleared over the reporting period as a percentage of the most recent reporting year extent.
- Extent of natural wetlands that have been modified over the reporting period (in hectares).
- Extent of natural wetlands that have been modified over the reporting period as a percentage of the most recent reporting year extent.
- Extent of natural wetlands that have been lost over the reporting period (i.e., cumulative extent of natural wetlands that have been infilled, cleared, or modified) in hectares.
- Extent of natural wetlands that have been lost over the reporting period (i.e., cumulative extent of natural wetlands that have been infilled, cleared, or modified) as a percentage of the most recent reporting year extent.
- Net change in the extent of slightly modified wetlands over the reporting period (in hectares).
- Net change in the extent of slightly modified wetlands over the reporting period as a percentage of the most recent reporting year extent.
- Extent of slightly modified wetlands that have been infilled or cleared over the reporting period (in hectares).
- Extent of slightly modified wetlands that have been infilled or cleared over the reporting period as a percentage of the most recent reporting year extent.
- Extent of slightly modified wetlands that have been modified over the reporting period (in hectares).
- Extent of slightly modified wetlands that have been modified over the reporting period as a percentage of the most recent reporting year extent.
- Extent of slightly modified wetlands that have been gained over the reporting period (in hectares).

3.3.3 Confidence and Error Estimates

Confidence and/or error estimates are required to be generated alongside the outcomes of section 3.3.2. Error estimates must take into consideration identified data limitations (see section 2.3) including the use of a proxy dataset of estimated pre-clearing wetland extent, the exclusion of mosaic wetland areas where wetlands comprise 80% or less of the area, and generation of statistics based on the dominant wetland system where more than one wetland system occurs within the same area.

4 Quality Assurance

External expert peer review of the generated statistics on the temporal trend in wetland extent ensure the quality of developed wetland extent change information. This peer review may refer to spatial data to assist in reviewing and confirming generated statistics. The required depth and rigour of review will depend on the intended usage of the generated statistics.