UPDATED REPORT:

Hornsby Shire Council Risk-based Framework Project – Stage 1

October 2020

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Contents

Figures

Tables

Executive Summary

This report outlines a preliminary risk assessment completed to identify high priority sub-catchments within the Hornsby Local Government Area (LGA) where implementation of catchment management actions could assist with protecting higher value waterways. The adopted preliminary risk assessment approach was based on Step 1 of the *Risk-based framework for considering waterway health outcomes in strategic land use planning decisions* (Dela-Cruz J, et al 2017) (i.e. the 'risk-based framework' or RBF).

Many Councils across NSW currently have limited funding for protection or improvement of waterway conditions within their LGA. To ensure that funding is targeted appropriately, completion of a preliminary risk assessment to evaluate waterway conditions and threats to these conditions from the catchment can assist with prioritising locations where a greater focus can be applied to identifying intervention measures.

The project is being completed over two stages. Stage 1 involved evaluating sub-catchment priorities across the Hornsby LGA based on potential threats in each sub-catchment to identified local community and environmental waterway objectives. Stage 2 of the project will focus on a selected high priority sub-catchment and include refining Step 1 of the RBF and completing Steps 2 to 5 for this sub-catchment. This report documents the process followed to select a high priority sub-catchment for Stage 2.

A goal of this project was to identify an approach that could be applied to prioritise sub-catchments, progressively stepping down in increasingly finer scales from a large basin scale (e.g. Hawkesbury-Nepean catchment), to a major sub-catchment or LGA scale, to a minor sub-catchment scale, and finally to a micro sub-catchment scale.

The Hornsby LGA was initially divided into sub-catchments based on the locations of local creeks. For each sub-catchment, community and environmental waterway objectives were identified along with land uses/activities that potentially threaten these objectives.

The waterway objectives comprise a range of community and environmental uses and values identified from earlier community consultation undertaken for the Local Strategic Planning Statement (LSPS). To enable the data to be mapped clearly, these objectives were divided into community uses and environmental values categories. The mapped community uses included elements where the community interacts actively, passively or spiritually with the waterways (e.g. amenity, contact recreation). Environmental values included elements aligned with the intrinsic natural values of the waterways and supported ecosystems (e.g. riparian condition, macroinvertebrate richness and abundance, high ecological values).

The land uses/activity threats included consideration of effective impervious area, diffuse source runoff quality, point source discharge quality from EPA licensed sites and other sites where indicator concentrations are expected to far exceed those of the surrounding land uses.

The community uses and environmental values were mapped across the LGA and reviewed by a project scoring team. Each sub-catchment was allocated a score between 1 and 5 in a qualitative assessment by each member of the scoring team based on the presence of known community uses and environmental values.

The land use/activity threats were quantified for each sub-catchment considering long-term local water quality monitoring data and observed stream flow volumes. The product of observed water quality indicator concentrations and estimated runoff volumes was calculated for each sub-catchment to provide a quantitative indicator of the potential threat to waterway objectives from the catchment. Point sources were also considered in evaluating and scoring potential land use/activity threats from the sub-catchment.

Sub-catchment priorities (based on the assessed level of risk) were estimated applying the matrix shown in Table 1-1. The consequence component of the risk assessment represents how valuable the waterway reaches are to the community and the extent of high value ecosystems along the waterways. The likelihood component of the risk assessment was based upon the relative threat from the sub-catchment considering the impervious area, diffuse source pollutant concentrations and point sources.

As an example, sub-catchments where waterways are in good physical condition supporting a range of high value ecosystems, but also include land uses where existing or future threats from diffuse and point source pollution are high, were assessed as having a very high priority for intervention.

Table 1-1 *Preliminary risk assessment matrix*

Consequence to waterway objectives	Likelihood of impacts from sub-catchment: Rare	Possible	Likely	Very likely	Almost certain
Minor	low	low	low	low	low
Low	low	low	low	medium	medium
Moderate	low	medium	medium	high	high
High	low	medium	high	high	very high
Very high	medium	high	high	very high	very high

A number of challenges were encountered throughout the project including:

- Identifying useful data from a large number of reports, spreadsheets, numerical models, plans, studies etc prepared across the LGA and confirming the relevance of historical data to current conditions.
- Confirming the relative values of particular community uses across the LGA based on limited data.
- Scoring of the community uses and environmental values was based on limited data in some areas and incomplete knowledge of the scoring team. The project team found it particularly challenging to score differences in community use values between relatively small sub-catchments.
- Translating data from a relatively small number of widely spaced monitoring sites to other locations in the LGA to assist with scoring of environmental values.

The following suggestions are outlined to assist other organisations planning future studies that will include completion of Step 1 of the RBF:

- Prepare a checklist outlining the type of data that would assist with completing Step 1. This would help to focus the data gathering efforts and may reduce the time required to identify and review relevant data.
- Complete targeted community consultation in advance of commencing an RBF project to confirm the range and locations of community uses across the LGA. This consultation should aim to establish the relative value of each use to the community wherever possible.
- Complete more robust scoring of community uses and environmental values of the waterways utilising input from a broader and more extended group of informed community groups/participants, Council officers and industry specialists.
- Complete scoring of community uses and environmental values in a 'live' workshop where data is presented, discussed and scored with all participant present in the same physical or virtual room.
- Revisit the analysis included within the HEV dataset to relate specifically to those attributes that provide data on key ecological attributes. Consider approaches to transfer the gridded data values to waterway reaches/segments.

- Transfer knowledge from this project to other LGAs where Councils may have a significantly less water quality and stream flow data available to assist decision making. Consider developing an approach to apply the concentration ratio method established for this project to other locations when considering relative sub-catchments threats.
- Review the approach applied for this study and determine if it would be possible to simplify the methods (possibly the number of parameters considered) to identify high priority sub-catchments in a more efficient manner.

1 Introduction

1.1 Risk-based framework

The *Marine Estate Management Strategy 2018-28* (MEMS) identified water pollution from litter, oil spills and stormwater runoff as the highest threat to the environmental, social, cultural and economic benefits of the marine estate. The need for a change in business-as-usual approaches to water quality management in NSW was determined by the Marine Estate Management Authority (MEMA), through state-wide community consultation, regional threat and risk assessments and a stakeholder led review of issues with stormwater management.

The Environment, Energy and Science (EES) Group within the Department of Planning, Industry and Environment (DPIE) is leading a water quality initiative to improve the management and co-ordination of urban and rural diffuse source water pollution in NSW, as part of their requirements to implement the Marine Estate Management Strategy 2018-2028 (MEMS). Improving water quality is listed as the first management initiative in the MEMS. This initiative represents an opportunity to improve the coordination and management of diffuse source water pollution at the catchment scale as land use changes are occurring, enabling improvements to water quality and waterway health to be advanced more rapidly than in other degraded catchments where development is progressing at a slower rate.

A key tool for delivering on this initiative is the '*Risk-based framework for considering waterway health outcomes in strategic land use planning decisions*' (Dela-Cruz J, et al 2017) introductory resource (the 'Risk-based Framework) prepared by the former OEH in May 2017. The Risk-based Framework (RBF) is a protocol that decision makers, such as councils, planners and environmental regulators can apply to help manage the impact of land use activities on the health of waterways in NSW.

The RBF is based on the principles outlined in the National Water Quality Management Strategy (NWQMS), which the federal and all state and territory governments have endorsed for managing water quality. The NWQMS aims to assist water resource managers to understand and protect (i.e. maintain or improve) water quality so that it is suitable for the desired community values taking into consideration local conditions. Community values are also known as 'environmental values' and 'beneficial uses' (Australian Government, 2018). These principles are also adopted in the RBF. The RBF comprises 5 key steps, which link management objectives, community environmental values and beneficial uses, and the management or mitigation options needed to achieve them. The RBF is outlined in Figure 1-1.

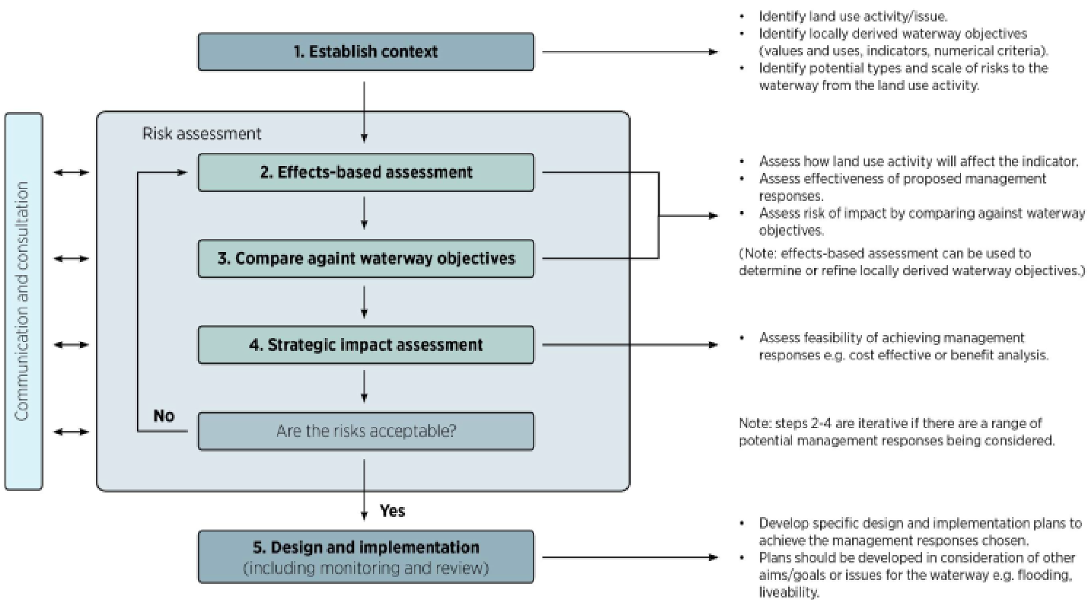

Figure 1-1 *Risk-based framework for considering waterway health outcomes in strategic land use planning decisions (OEH, 2017)*

1.2 Study area and project scope

This project focuses on the application of Step 1 of the RBF to the Hornsby LGA. This step in the RBF process is to establish the context of the study area under consideration and includes consideration of the following elements:

- Confirming community and environmental values and uses of waterways to be protected.
- Identifying measurable indicators that represent the waterway values and uses to be protected.
- Identifying draft locally derived waterway objectives.
- Identifying the existing and future land uses.
- Identifying the types and scale of risks to the waterway from the land uses.

This report outlines a preliminary risk assessment completed with Hornsby Shire Council to identify high priority sub-catchments where implementation of catchment management actions could assist with protecting higher value waterways. The approach followed for this project to prioritise sub-catchments is outlined in Figure 1-2 and described in detail in the following sections.

The Hornsby LGA lies within the broader Hawkesbury-Nepean catchment. The location of the Hornsby LGA in relation to the extents of the Hawkesbury-Nepean catchment is shown on Figure 1-3. Figure 1-3 also shows the results of catchment scale estuary risk mapping of TN loads completed previously by the former OEH.

This project focused on the entire Hornsby LGA, with analysis typically completed at a minor sub-catchment scale. Within urban areas, these sub-catchments up typically less than 5km^2. In rural and bushland areas, the sub-catchments are typically in the 15 to 25km^2 range. The project area extents and adopted minor sub-catchment distribution is shown on Figure 1-4.

This project has been completed based on data that was readily available to Council. No additional data were gathered specifically for this project and consequently there are some limitations in the completed assessments that are discussed below. However, Council was an early adopter of approaches to improve urban, peri-urban and rural catchment management in coastal catchments and had a significant body of past work to draw upon for the purposes of this study.

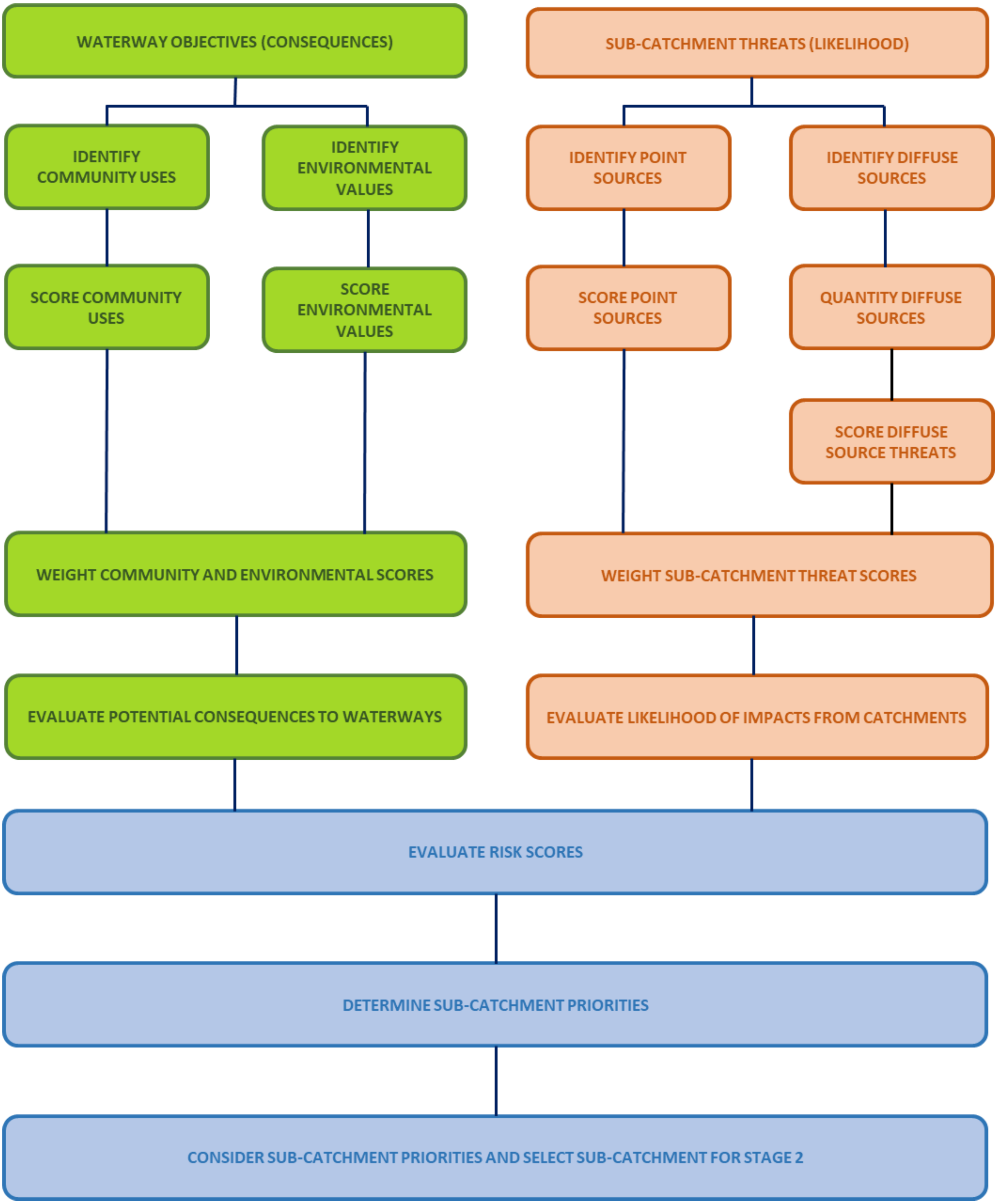

Figure 1-2 *Overview of assessment approach*

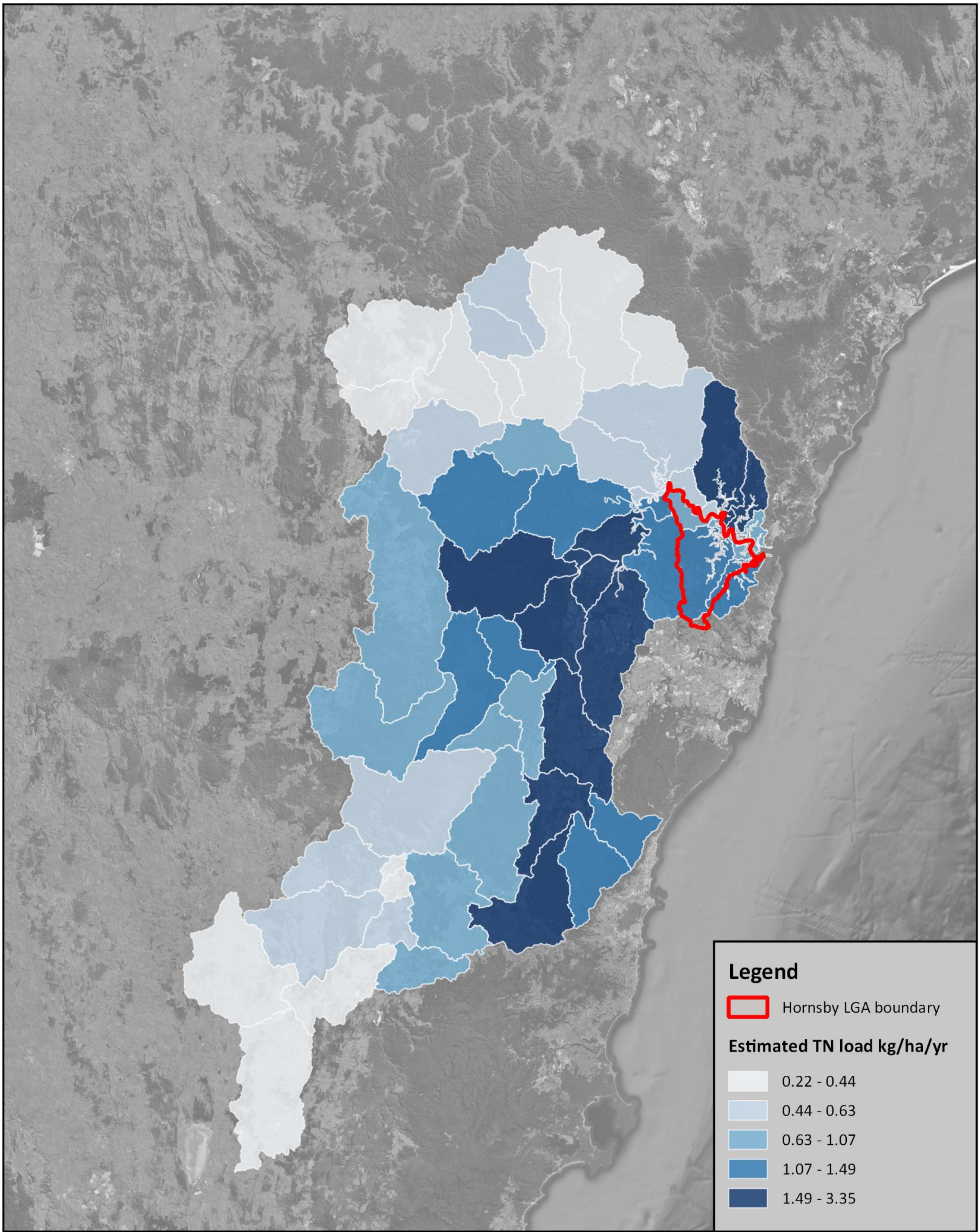

Figure Title:

Estuary Health Risks - Hawkesbury River sub-catchments

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Figure No.:

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0 25 50 km

GDA 1994 MGA Zone 56

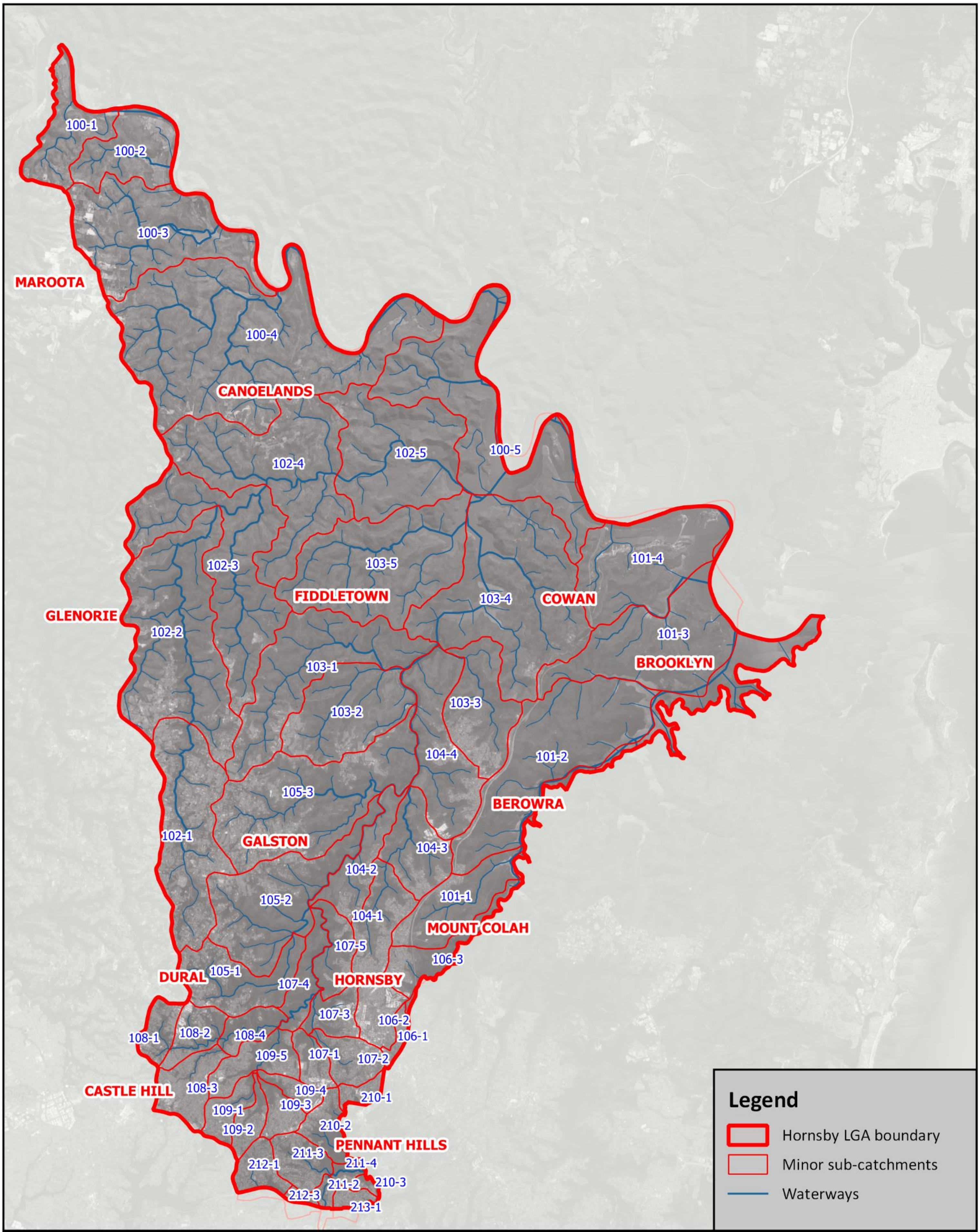

Figure Title:

Hornsby Shire Council LGA minor sub-catchments

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1-4

1.3 Catchment context

Long standing community concerns with poor water quality in Berowra Creek and the limited treatment capacity of the West Hornsby wastewater treatment plant (WHWWTP) led Hornsby Shire Council in 1993 to place a moratorium on any further development that would be connected to the WHWWTP (Hornsby Shire Council, 1997). At that stage, algal blooms were a regular occurrence in the vicinity of Berowra Waters. Evidence of impacts on water quality was clear from water quality sampling for nutrients undertaken by AWT in Berowra Creek over the 1977 to 1981 period.

The moratorium initiated the establishment of a working party comprising representatives from a number of relevant state government authorities to focus on water quality in Berowra Creek. In 1997, a Statement of Joint Intent (SoJI) was signed by the government authorities to work together to achieve the ecologically sustainable development of the Berowra Creek catchment and the recovery of the creek's health. The signed SoJI initiated the preparation of the Berowra Creek Water Quality Management Strategy in 1997 (Berowra Creek WQMS). The SoJI established environmental values that the Berowra Creek WQMS should aim to protect or achieve in the waterway. The environmental values to be protected downstream of Fishponds Waterhole were identified in the SoJI as being primary contact recreation in the short term and modified aquatic ecosystems for fish, crustacea and shellfish in the longer term.

The Berowra Creek WQMS outlined responsibilities for current and future catchment management actions to achieve the established environmental values. The Berowra Creek WQMS strategy established seven key objectives:

- Development of appropriate water quality objectives.
- Increase understanding of aquatic ecosystems and water quality and quantity dynamics.
- Control pollution from point sources.
- Reduce and control diffuse pollution from existing and new urban developments, rural/agricultural properties and degraded sites.
- Improved health of creek and streambanks throughout catchment.
- Increased knowledge and understanding in the community of water quality issues.
- Increase community involvement in improving water quality and in water quality management.

In addition to the objectives, the Berowra Creek WQMS identified specific ecological, social and economic values to be protected that were important to the community, including:

- **Ecological values** - aquatic ecosystem, water associated wildlife, diversity of indigenous aquatic flora and fauna, diversity of indigenous riparian vegetation, native habitat protection.
- **Social values** - canoeing and boating, swimming, recreational fishing, visual amenity, existence value, heritage values, public safety from flood flows.
- **Economic values** - commercial fishing and prawning, commercial oyster farming, property values, stock water, irrigation water, farmstead water, industrial water, groundwater.

These values established in 1997 remain relevant across the catchment in 2020.

As part of the SoJI agreement, Sydney Water Corporation augmented treatment infrastructure to improve the quality of effluent in terms of ammonia, phosphorus and bacterial levels at the West Hornsby and Hornsby Heights WWTPs. Further improvements were completed in a following stage to upgrade each WWTP with an improved lime dosing system and incorporation of ultra-violet (UV) disinfection.

In 1994, Hornsby Shire Council established a Catchment Remediation Rate (CRR) as a Special Rate under Section 495 of the Local Government Act 1993. This rate was initiated at 2% of the Ordinary Rate, initially generating about $600,000 for the purposes of water quality improvement works in the Berowra Creek catchment. In July 1997, this rate was increased to 5% after extensive public consultation and Ministerial approval. The rate generates funds used for implementing structural and non-structural works to improve waterway conditions. The funds are also utilised for progressing sub-catchment stormwater management planning across the LGA.

Since 1994, Council has progressed a program funded by their catchment remediation rate levy and these funds are used to construct, maintain and monitor environmental health in their waterways. This has enabled Council to gather a large amount of data that assists with confirming the existing local waterway conditions. Available data supplied by Council and reviewed by Alluvium for this project includes:

- Waterway health monitoring data including aquatic ecology, sediment quality, water quality and riparian condition data.
- GIS data summarising environmental conditions.
- Community uses and values data.
- Catchment condition and audit reports.
- Catchment management plans and strategies.
- Catchment modelling.
- Future development planning.
- Groundwater characterisation.
- IWCM strategies.

These data were supplemented by additional data sets provided by DPIE including data on high ecological value waterways and remotely sensed impervious area mapping.

2 Land use

2.1 Overview

Key challenges in protecting or improving the community uses and environmental values of waterways are the existing and future land use activities in the catchments draining to the waterways. A key step in the RBF process is to gain an appreciation of the existing and future catchment land use activities that potentially threaten the waterway objectives.

This section focuses on the existing and future land use distribution across the Hornsby Shire Council LGA catchments and provides a picture of the study area in qualitative terms of potential risks to waterways from catchment land uses. The existing land use distribution provides an indication of areas where existing impacts on waterways from diffuse sources are expected to be higher. The future land use distribution provides an indication of areas where impacts on waterways potentially will increase without mitigation. Evaluation of land uses also can assist with identifying areas where existing and future impacts on waterways are expected to be low (e.g. native bushland in pristine natural condition with no planned future development).

2.2 Existing land use

Existing land use provides an indication of how water parameters/pollutants are likely to be impacted in waterways that receive surface runoff and base flow from contributing catchment areas. Comparison of catchment land uses with monitored water quality can provide a relative indication of how particular land uses influence water quality parameters that are indicative of community uses and environmental values of waterways.

Land use across the Hornsby Shire Council LGA was evaluated by Alluvium based on 2016 Australian Land Use and Management (ALUM) classification mapping. The ALUM classification has a three-tiered land use classification structure (primary, secondary and tertiary classes). Primary and secondary classes relate to the main use of the land, whilst the tertiary classification provided more detail on the specific commodities, land management practices or vegetation. Tertiary classification data are particularly valuable in many natural resource planning and management applications and are often expensive to collect.

The 2016 ALUM Classification tertiary classification mapping data were interpreted to derive a simplified map of land uses broadly categorised based on their potential to generate varying concentrations of key water quality indicators that would impact on community uses and environmental values of waterways.

Review of the 2016 ALUM Classification data indicates that the simplified land use categories that cover the majority of the Hornsby Shire LGA area include bushland, urban residential, rural residential, commercial, industrial and agriculture. Land use changes have occurred since 2016 across the LGA, although for the purpose of comparing relative risks between sub-catchments, it is considered that the 2016 mapping provides a reasonable representation of current conditions. The simplified existing land use mapping is provided in Figure 2-1.

Figure 2-1 also shows the locations of water quality monitoring sites where data were reviewed to estimate relative water quality concentrations for different simplified land uses. Further discussion on the approach taken to estimate the relative concentrations is outlined in Section 6.3.

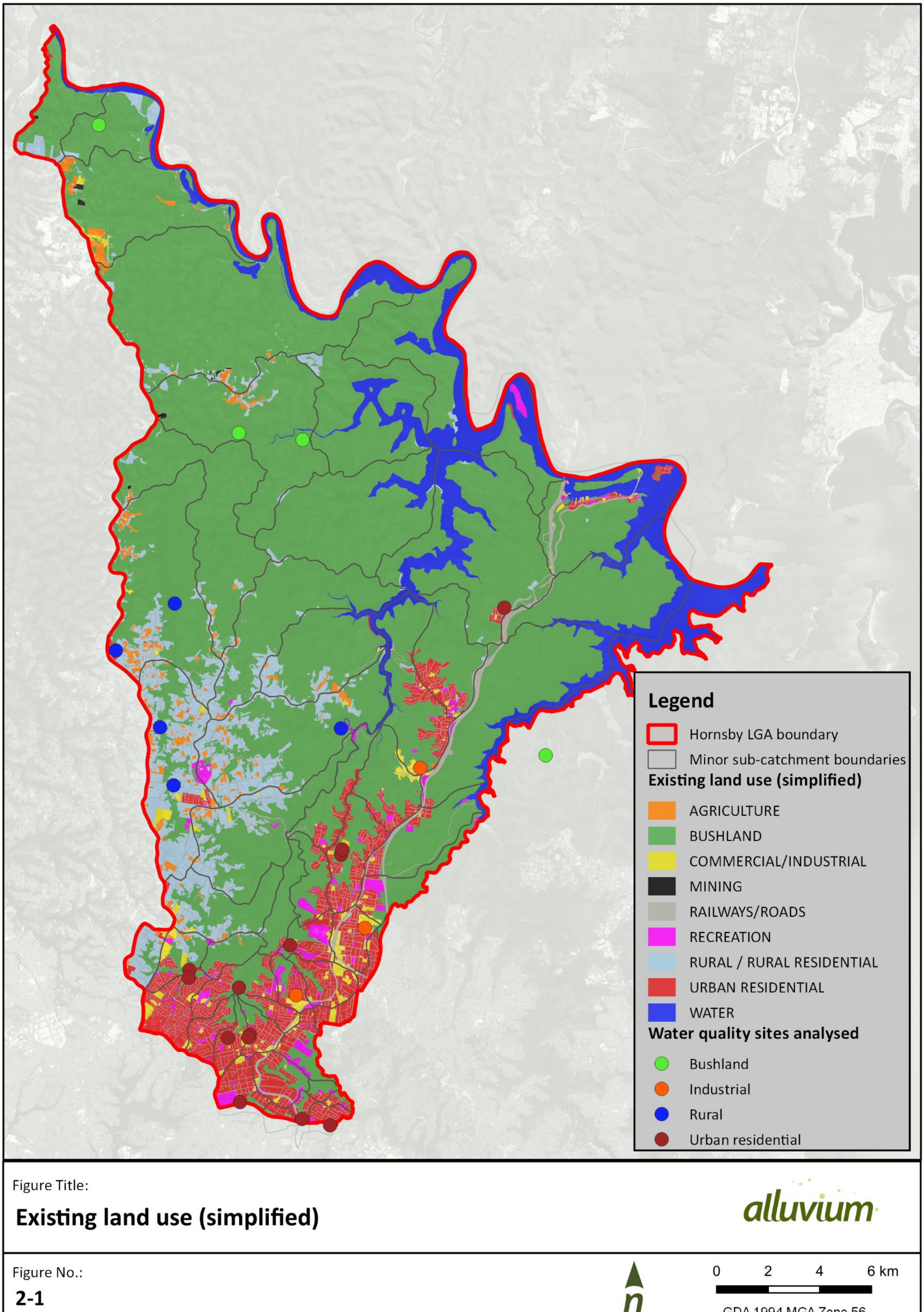

Figure Title:

Existing land use (simplified)

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Figure No.:

2-1

2.3 Future development

Future development mapping assists with predicting where threats to community uses and environmental values of waterways may increase in the near future.

The Hornsby Shire Housing Strategy 2011 (HSC, 2011) identified new areas for medium and high-density development. The Hornsby Shire Housing Strategy 2011 aims to achieve 4,500 new dwellings across Hornsby Shire by 2021. Precincts for new development were selected to focus on areas near public transport and commercial centres, and to avoid environmentally sensitive areas and maintain the character of existing low density suburbs. Housing strategy precincts included provision for up to ten-storey residential buildings in parts of Asquith, Beecroft, Cherrybrook, Hornsby, Mount Colah, Normanhurst, Pennant Hills, Thornleigh, Waitara and West Pennant Hills.

The Environmental Planning and Assessment Act 1979 (EP&A Act) was amended in 2018 to introduce new requirements for councils to prepare and make local strategic planning statements (LSPS). LSPS's outline a 20-year vision for land use in the local area and includes consideration of how growth and change will be managed into the future. Council's LSPS indicates that the Hornsby Shire population is projected to increase by more than 30,000 people between 2016 and 2036 requiring an additional 14,879 dwellings (HSC, 2019). Growth is expected to be highest between 2016 and 2021.

The LSPS projections will approximately require an additional 10,000 dwellings to be provided above that included within the Hornsby Shire Housing Strategy 2011. Areas where additional growth is planned include Hornsby (particularly around the town centre), Asquith and Waitara. The LSPS indicates that Council expects to plan for accommodating increased population growth in these key areas, with limited changes in areas beyond the current urban areas up to 2036.

There is uncertainty with where future development may be concentrated across the LGA. Locations for future development are somewhat beyond the control of Council, with development trends influenced by directives from the NSW government requiring provision for increased population growth and NSW government policies and legislation overriding local planning controls on some matters. A key uncertainty is with the positioning of future seniors living and aged care developments to support a growing need for these type of developments across the Sydney region.

Areas where future land use changes and increased development density are currently planned are shown on Figure 2-2. Within existing urban areas, it is envisaged that the concentration of diffuse source pollutants would be similar to current conditions. With an increase in development density, the imperviousness of these areas will increase resulting in the surface runoff increasing with a related increase in overall loads.

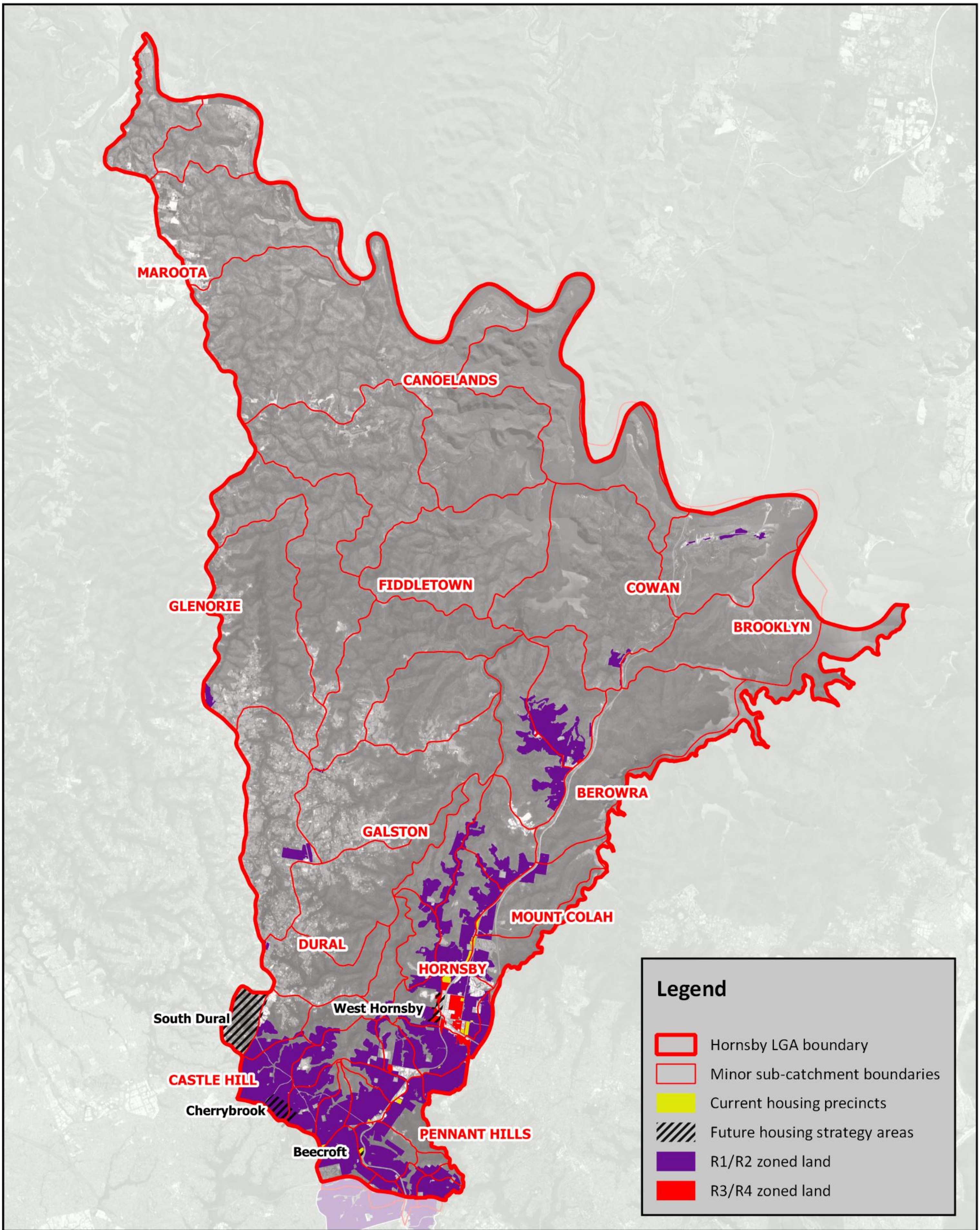

Figure Title:

Future development areas

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0 2 4 6 km

GDA 1994 MGA Zone 56

3 Waterway objectives

3.1 Overview

Establishing the waterway objectives is a fundamental step. At this early stage is it important that the objectives are established in partnership with the community. Identifying the community uses and environmental values of waterways in a study area and establishing the social, and institutional context of the project is crucial for its success and for engaging communities in land use planning and waterway management. Identifying the uses and values assists with confirming priorities for intervention to protect, maintain or rehabilitate waterways. Establishing the community uses and environmental values of waterways also assists with identifying appropriate indicators to monitor to assist with protecting the uses and values to achieve ideal outcomes for the community.

The feasibility of the draft objectives is tested through the following effects-based assessment and economic assessment steps in the RBF. Consideration of the economic implications of the objectives may require modification of the objectives to achieve a feasible outcome that balances the social, environmental and economic impacts.

A more detailed consideration of specific waterway objectives and associated indicators can assist with identifying management objectives for land uses changes, and in particular urban development. It is also considered appropriate to vary the management focus depending on the characteristics of the waterways receiving runoff from differing land uses across the catchment. This would assist in directing investment to management options that are more directly linked to the waterway objectives to be protected.

For this study, community uses and environmental values have been mapped and considered separately. The community uses mapping includes elements where the community interacts actively or passively with the waterways. The mapped community uses include primary contact recreation (whole of body contact), secondary contact recreation (incidental contact) and non-contact recreation (passive/aesthetics uses). The environmental values include those elements that are more aligned with the intrinsic natural values of the waterways and supported ecosystems. Whilst these environmental elements may be valued highly by particular individuals or groups within the community, the importance and function of these elements within a natural ecosystem may not be appreciated by the wider community due to lack of education or interest.

Draft community uses and environmental values for the waterways across the Hornsby LGA have been identified and are included on mapping within the LSPS. For the LSPS, separate draft uses and values have been identified for 14 sub-catchments across the LGA. The draft uses and values mapping included in the LSPS is provided in Figure 3-1.

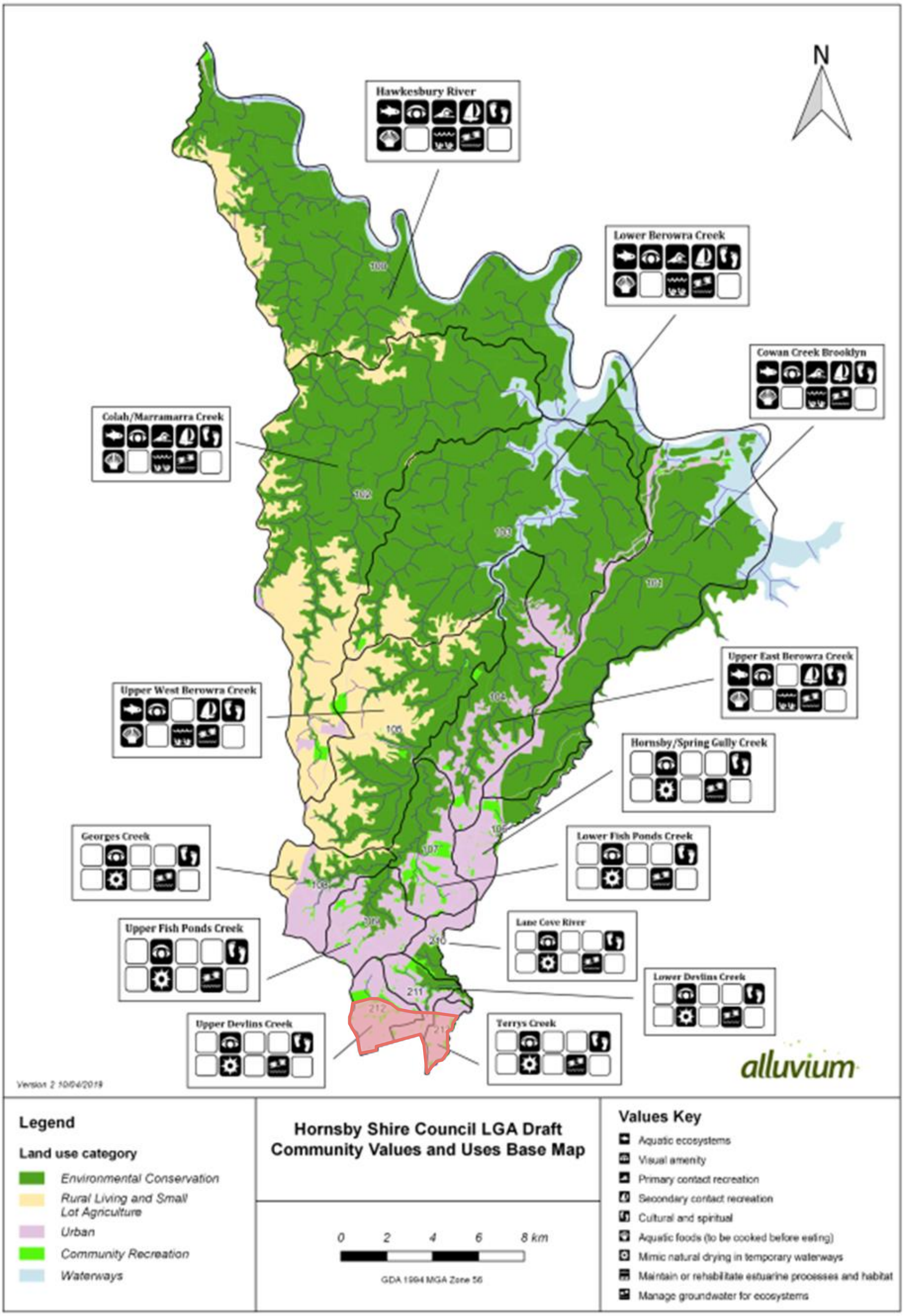

Figure 3-1 *Hornsby Shire Council LGA draft community values and uses (CRC WSC, 2019) (shaded sub-catchment areas in the southern extents are no longer in the Hornsby LGA)*

3.2 Community waterway uses

Figure 3-1 outlines how the draft community values and uses vary between upper, mid and lower catchment areas within the Hornsby LGA. For the purposes of this study, a goal was to explore at a finer scale how these values and uses may vary between individual sub-catchments based on available data. Identified community uses of waterways include:

- Visual amenity
- Primary contact recreation
- Secondary contact recreation
- Cultural and spiritual
- Aquatic foods

Identified primary contact uses across the Hornsby LGA include swimming, water skiing, wading and exploring by children. Secondary contact recreation uses include boating, canoeing, kayaking, rowing, sailing, paddle boarding, adult wading, paddling and jet skiing. Non-contact recreation uses include bushwalking, mountain biking, cycling, running, camping, fishing, yabbying, oyster farming, picnicking, bird watching, nature watching, photography, sightseeing, amenity.

The spatial distribution of community uses across the LGA was evaluated considering data available from sources including:

- GIS data collected by Council.
- Social pinpoint data collected in 2019 to assist Hornsby Shire Council with preparing their Environmental Sustainability Strategy (https://mcnair.mysocialpinpoint.com/hornsby#/).
- Data collected in the CRC for Water Sensitive Cities community workshop held as part of the Shaping Hornsby's Water Sensitive Future project.
- Council staff workshop held as a component of this project on 29 July 2020.

Data gathered from these sources has been spatially mapped where possible and this is shown on Figure 3-2. Data that the community identified as being relevant to environmental values of the waterways has been included on Figure 3-3.

Available data on community values is primarily focused on mainstream values. We understand that Council currently has limited spatial data available on aboriginal cultural values across the LGA. Whilst a number of aboriginal cultural values are likely to align with high environmental value areas, other cultural watering sites potentially will be associated with ephemeral waterways in the catchments. We understand that Council is about to commence an Aboriginal Heritage Study where known aboriginal sites are to be reviewed and sensitivity maps prepared. When this data becomes available it is recommended that the community value mapping and assessments be updated to include consideration of this data.

3.3 Environmental waterway values

Environmental waterway values include elements that are intrinsic to the ecological health of the waterways. The environmental waterway values include:

- Aquatic ecosystems.
- Mimic natural drying in temporary waterways.
- Maintain or rehabilitate estuarine processes and habitat.
- Manage groundwater for ecosystems.

For the Hornsby LGA, data provided by DPIE on high ecological value (HEV) waterways were utilised to evaluate the existing conditions of waterways. Mapping of HEV waterways across the entire LGA was completed by DPIE based on available datasets. Whilst the data was not ground-truthed, it is particularly useful where other local field collected data or observations are unavailable. The HEV mapping was supplemented by data gathered by Council that is not included in the HEV data sets utilised by DPIE.

Across the Hornsby LGA, Council has gathered field data for a number of indicators that reflect the environmental conditions of the waterways. In particular, riparian condition data and macroinvertebrate data gathered as a component of Council's EcoHealth monitoring program provides an indication of the medium to longer term condition of the waterways. Other spatial data provided by Council identifies the extents of biobanking sites, conservation sites, wildlife refuges that are additional areas of high environmental value. These data sources were used to assess the current environmental waterway values across the LGA. Further discussion on keys data sets considered is outlined below.

High ecological value (HEV) waterways and water dependent ecosystem mapping
High ecological value waterways and water dependent ecosystems for the Hornsby LGA were mapped by the Science Division of DPIE with support from the former NSW DPI Fisheries and DPI Crown Lands and Water. Water dependent ecosystems are defined as wetlands, and flora and fauna that rely on water sources (including groundwater). The map for the Hornsby LGA includes 22 of 39 indicators being used by the State Government to define high ecological values for waterways. The high ecological value waterway mapping includes consideration of the presence, extent and condition of the following indicators:

- Freshwater fish community status.
- Waterways located in National Parks.
- Creek/river condition – RiverStyles Framework (https://riverstyles.com).
- Macrophyte habitat.
- Aquaculture leases.
- Groundwater dependent ecosystems.
- Water dependent migratory birds.
- Water dependent flora and fauna.
- Riparian lands and watercourses.
- Coastal wetlands and other water dependent Endangered Ecological Communities.

The mapping shows areas where waterways and water dependent ecosystems are defined as having high ecological values based on definitions, guidelines and policies under the Environment Protection and Biodiversity Conservation Act 1999, Biodiversity Conservation Act 2016, Fisheries Management Act 1994 and Water Management Act 2000.

The purpose of the mapping is to identify strategic planning priorities for protecting and improving the health of high value waterways and water dependent ecosystems across the LGA. The priorities can be used (amongst other considerations) as a basis for setting management targets and/or identifying land use planning controls that would protect or improve the health of waterways and water dependent ecosystems. The mapping was specifically developed for consideration during preparation of the LSPS.

The mapping was created from a 1 ha hexagon cell grid placed over the entire LGA. Each hexagon cell was attributed with the area, length and/or frequency of occurrence of high value water dependent ecosystems. The number of high value water dependent ecosystem attributes present in each cell was summed by the Science Division of DPIE and this data provides a relative indicator of the ecological value of each 1 ha cell.

DPIE has combined the presence of the indicators into a 'Tvalue' for each of the 1 ha hexagon grid cells. These Tvalues have been mapped on Figure 3-3. Grid cells with a higher mapped Tvalue indicate the presence of a greater number of high ecological value indicators. The individual indicators have not been ground-truthed and DPIE has recommended that field assessments and/or comparative local mapping be completed prior to decisions being made based on the mapping.

Riparian conditions

As a component of the EcoHealth monitoring program, the University of New England (UNE) has assessed the riparian conditions at each of the 33 monitoring sites. The assessment included scoring a range of riparian condition sub-indicators at each site including:

- Habitat – channel width, proximity to native vegetation, connectivity to native vegetation through vegetated banks, diversity of habitat layers, presence of large native and hollow bearing trees.
- Native species – presence of native canopy, midstorey, understorey, graminoid and macrophyte species.
- Riparian cover – coverage by canopy, midstorey, understorey, graminoid and macrophyte species.
- Debris – presence, size and coverage by leaf litter, dead trees/logs and fringing vegetation.
- Management - tree clearing activity, fencing, animal impacts, canopy health, exposed roots, woody regeneration.

Summary scores for each of the five main indices listed above are totalled and combined to provide a riparian condition grading varying between A and C. The riparian condition gradings are mapped on Figure 3-3. These riparian condition gradings provide a recent ground-truthed indicator of environmental conditions at each monitoring site.

Macroinvertebrates

The EcoHealth monitoring program includes sampling of macroinvertebrates at the monitoring sites. In the spring of 2017 and autumn of 2018, UNE sampled macroinvertebrates within edge habitats at the monitoring sites. Macroinvertebrates were sampled adopting the standard protocols developed for the EcoHealth monitoring program. The assessment included scoring a range of macroinvertebrate sub-indicators at each site including:

- Total abundance
- Total richness
- Mean weighted SIGNAL2
- Nativeness
- EPT richness and abundance.

Best-available scores (BAS) were calculated for the catchment using the entire dataset available for reference sites, including available historic data. Sites were assigned a sub-indicator score calculated against the BAS and these were summed to give a site score. Scores were then graded between A+ and D- using the standard EcoHealth grading approach. The macroinvertebrate gradings are mapped on Figure 3-3.

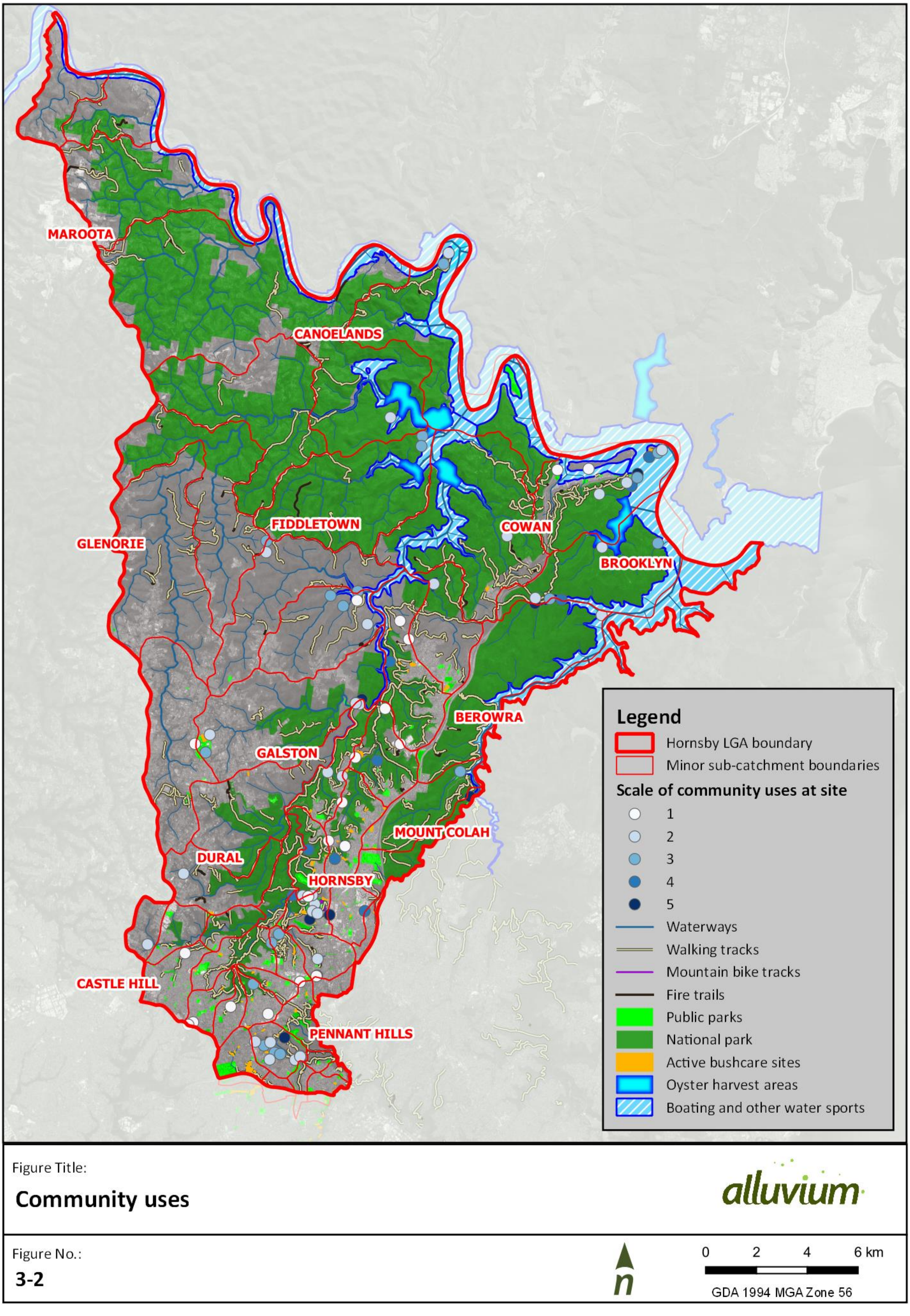

Figure Title:

Community uses

alluvium

Figure No.:

3-2

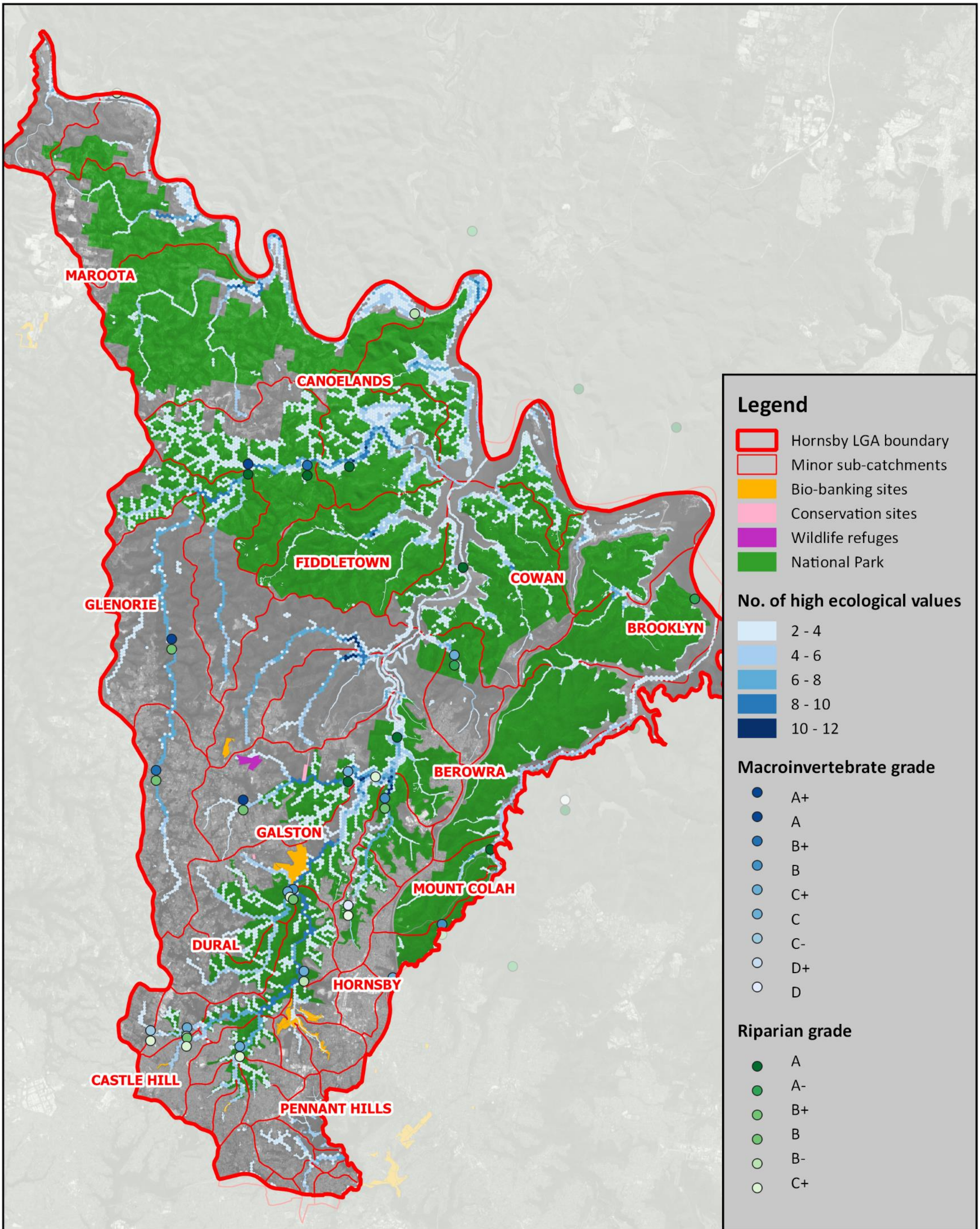

Figure Title:

Environmental values

alluvium

Figure No.:

3-3

4 Waterway objectives indicators

4.1 Overview

A key component of Step 1 of the RBF is to identify indicators that are representative of the community uses and environmental values of the waterways. Consideration of the waterway uses and values alongside the existing and future land uses assists with selecting indicators that can be measured over time to monitor waterway conditions as land use changes occur progressively across the catchment. In addition to considering existing land uses, it is important to evaluate how existing waterways may change following future land use activities when selecting appropriate indicators.

It is preferable to identify indicators where there is some history of sampling as a component of current or past monitoring programs. For Hornsby, selection of indicators that have been monitored as a component of Council's historical 20-year water quality monitoring program and current EcoHealth monitoring program would be preferable where these align with the waterway objectives.

4.2 Hornsby water quality monitoring program

Council has sampled water quality at over 150 sites across the LGA for over 20 years. Over 500 individual samples for specific indicators have been collected at some sites. Council's long term water quality monitoring data cover a range of physical, chemical and biological indicators including:

- Physical - temperature, pH, dissolved oxygen, electrical conductivity, salinity, turbidity, suspended solids.
- Chemical - ammonia-nitrogen, oxidised nitrogen, total nitrogen, total phosphorus, soluble reactive phosphorus, chlorophyll-a.
- Biological - faecal coliforms, enterococci, E coli.

Council's water quality monitoring program includes a number of long term sites that provide an indication of water quality from sub-catchments that include predominant urban residential, industrial, rural or bushland uses. Specific sites also provide an indication of water quality in tributaries influenced by wastewater treatment plan effluent and historical land fill leachate. The water quality monitoring data were reviewed in detail within the Waterway Health Review (HSC, 2019) recently completed by Council.

4.3 EcoHealth monitoring program

Council has recently implemented a catchment-based Ecosystem Health Monitoring Program (EcoHealth) developed by the University of New England (UNE). EcoHealth is a comprehensive monitoring program developed to assist with reporting on the health of estuarine and freshwater waterways across the LGA to a range of stakeholders. The monitoring program provides a greater focus on 33 key sites (21 freshwater and 12 estuarine) that are currently monitored for water quality across the LGA. These sites were selected to best represent catchment reaches. Previous sites were primarily selected to monitor water quality from specific land uses. The locations of the EcoHealth monitoring sites are shown on Figure 4-1.

The EcoHealth program involves monitoring of a range of physical, chemical and biological indicators to identify short-term, intermediate term and long-term responses to environmental change. The program expands on Council's water quality monitoring program to include monitoring of additional indicators including riparian conditions and estuarine habitat extents. The program aims to assist Council with identifying and prioritising management actions to protect, maintain and improve waterway health.

The EcoHealth monitoring program includes sampling/evaluation of the following indicators:

- Physical - temperature, pH, dissolved oxygen, electrical conductivity, turbidity, suspended solids.
- Chemical - total nitrogen, oxidised nitrogen, ammonia-nitrogen, total phosphorus, soluble reactive phosphorus, chlorophyll-a, major ions.

- Biological –macroinvertebrates, riparian condition index, geomorphic condition index.

4.4 Objective zones

HSC has previously delineated 14 major sub-catchments across the LGA and these major sub-catchments have formed the basis for developing draft community uses and environmental values objectives across the LGA. HSC has also delineated 55 minor sub-catchments across the major sub-catchments. Whilst LGA boundary changes have occurred recently, these minor and major sub-catchments still provide a useful basis for strategic water planning purposes and have been adopted for this study to maintain consistency with previous planning.

The Hornsby LGA includes particular areas where steep terrain, major waterways and existing land use patterns divide the LGA into distinct zones. Key topographical features including a ridgeline aligned with the old Pacific Highway, Berowra Creek and the incised Galson Gorge form distinct separation lines between adjacent areas. The extent of land disturbance caused by human settlement, and current development characteristics also assists with separating the LGA into zones that can be considered separately for the purpose of establishing objectives. Considering the existing terrain and land use patterns, the following 'objective zones' have been delineated as a basis for this study:

- Zone A – Urban sub-catchments draining to the Lane Cove River
- Zone B – Urban sub-catchments on the eastern side of Berowra Creek
- Zone C – Rural sub-catchments on the western side of Berowra Creek
- Zone D – Partial National Park and rural sub-catchments north of Zone C
- Zone E – Primarily National Park sub-catchments draining into the Hawkesbury River or the estuarine reaches of Berowra Creek and Cowan Creek

Each zone incorporates multiple minor sub-catchments that have previously been defined by Council. The objective zones are shown on Figure 4-2.

A key focus of the RBF is to identify objectives for different sub-catchments, areas or zones in a study area where the community uses and environmental values to be protected are likely to require different management responses. Defining objectives for individual minor sub-catchments typically will require more detailed investigations of the local context. For higher level planning, delineating larger objective zones with similar land use characteristics (and related similar threats to waterway health) can assist.

4.5 Recommended indicators

Considering the identified community and environmental uses and values across the Hornsby LGA, and the current EcoHealth monitoring program parameters, the indicators summarised in Table 4-1 and Table 4-2 are recommended to be considered in the effects-based assessment.

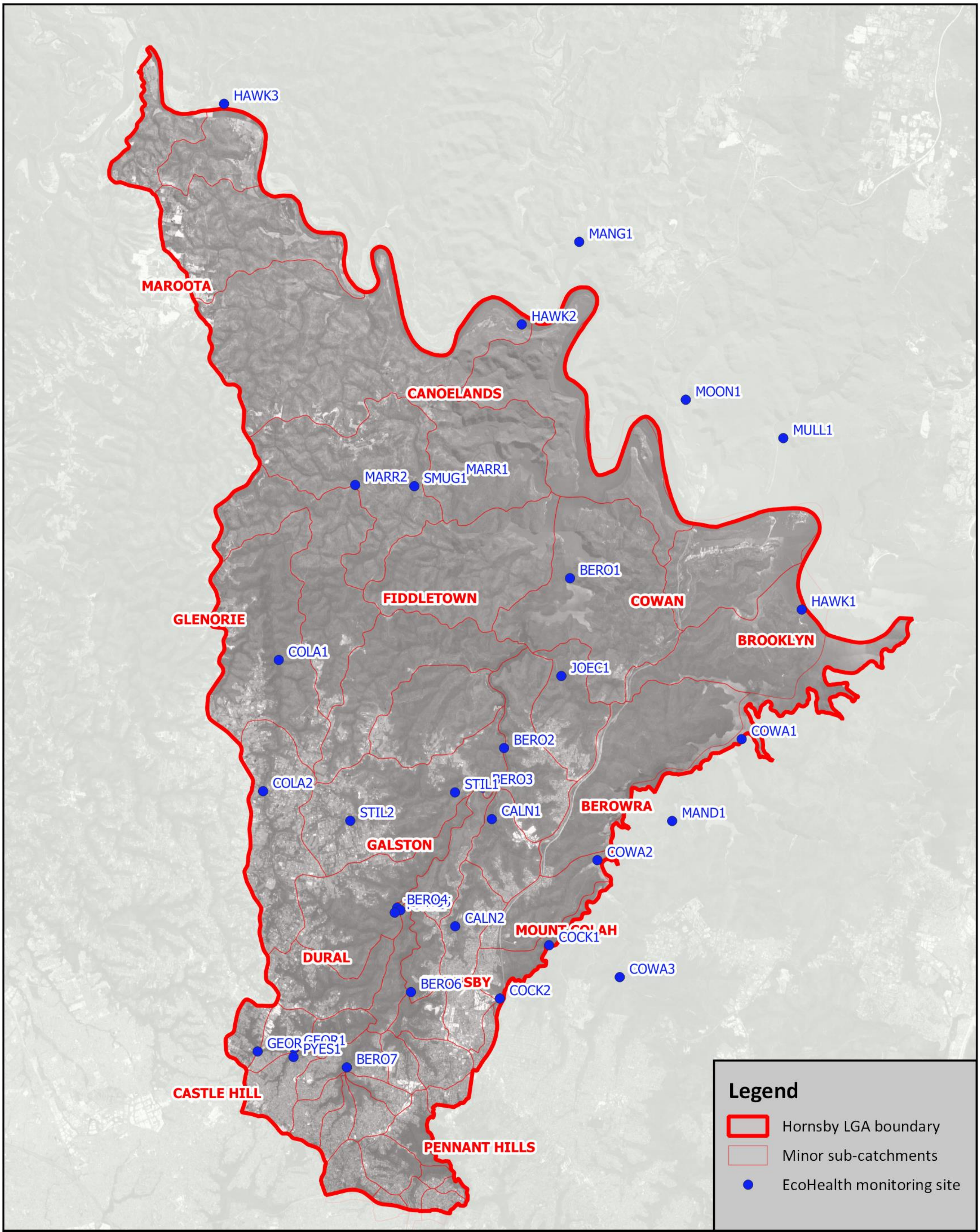

Figure Title:

EcoHealth monitoring sites

alluvium

Figure No.:

4-1

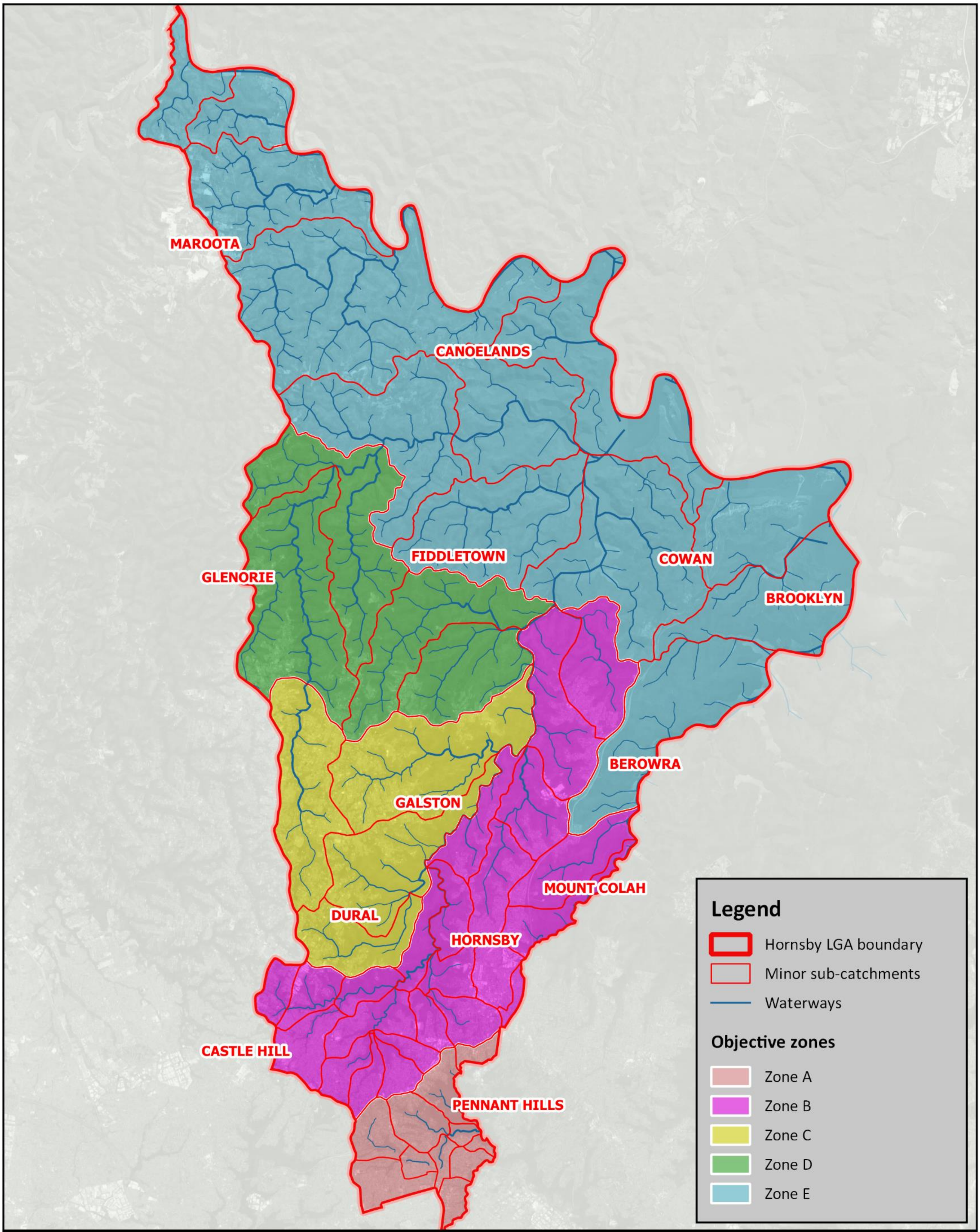

Figure Title:

Waterway objective zones

alluvium

Figure No.:

4-2

n

0 2 4 6 km

GDA 1994 MGA Zone 56

Table 4-1 *Community uses - objectives and indicators*

Symbol	Community uses	Definition	Objective Zones	Current relevant monitored indicators	Suggested additional indicators
	Non-contact recreation / visual amenity	Maintain or improve aesthetic qualities of waters.	A, B, C, D, E	Turbidity, riparian condition index, geomorphic condition index.	Litter – include within the riparian condition index monitoring.
	Primary contact recreation	Maintain or improve water quality for activities such as swimming where there is a high probability of water being swallowed.	B, E	Turbidity, enterococci. Ch-a	
	Secondary contact recreation	Maintain or improve water quality for activities such as boating and wading, where there is a low probability of water being swallowed.	B, E	Turbidity, enterococci	
	Cultural and spiritual	Maintain or improve cultural and spiritual values of water relating to a range of uses including spiritual relationships, significant sites in the landscape, customary use, aquatic plants and animals, drinking water or recreation.	To be confirmed	Not currently monitored. Council is about to commence an Aboriginal Heritage Study where known aboriginal sites are to be reviewed and sensitivity maps prepared.	Regular surveys and targeted consultation with the local community.
	Aquatic foods	Refers to protecting water quality so that it is suitable for the production of aquatic foods for human consumption (e.g. recreational fishermen) and aquaculture activities.	E	Turbidity, faecal coliforms, E. coli, enterococci	Litter – include within the riparian condition index monitoring.

Table 4-2 *Environmental values - objectives and indicators*

Symbol	Environmental values	Definition	Objective Zones	Current relevant monitored indicators	Suggested additional indicators
	Aquatic ecosystems	Maintaining or improving the ecological condition of waterbodies and their riparian zones over the long term.	A, B, C, D, E	DO, turbidity, TN, TP, chlorophyll-a, , macroinvertebrates, , riparian condition index, geomorphic condition index.	
	Mimic natural drying in temporary waterways	Mimic the natural frequency, duration and seasonal nature of drying periods in naturally temporary waterways.	A, B, C, D, E	Not current monitored.	Manually sampled water depths or automatic water level recorder.
	Maintain or rehabilitate estuarine processes and habitat	Maintain or rehabilitate estuarine processes and habitats. Estuaries often change in response to storms or tides. Catchment runoff affect estuarine processes and habitat through transport of nutrients, organic matter and sediments. Reduced freshes and flooding deplete food sources for estuarine species.	E	Mangrove/seagrass/saltmarsh coverage, riparian condition index, geomorphic condition index.	
	Manage groundwater for ecosystems	Maintain groundwater within natural levels and variability, critical to surface flows and ecosystems.	E	Not currently monitored.	Manual or automatically sampled groundwater bore water depths.

5 Waterway threats

5.1 Existing diffuse pollution sources

Typical diffuse source pollutant concentrations are primarily associated with the land use characteristics. Although, events such as bushfires can also significantly alter the typical diffuse source pollutant concentrations from bushland areas for an extended period whilst the catchment restabilises. The existing diffuse pollution sources are shown on Figure 5-1.

Diffuse source pollutant loads include consideration of a combination of the concentration of particular indicators/parameters and the volume of runoff generated within the catchment. Runoff volumes are significantly influenced by imperviousness and other physical catchment characteristics (e.g. soils and terrain). Variation in effective impervious area between sub-catchments is likely to be the primary catchment variable influencing runoff volumes.

Sub-catchments including land uses that typically produce runoff with higher pollutant concentrations and have higher effective impervious areas have a greater likelihood of impacting on the waterway objectives.

Monitoring of water quality in creeks in the Hornsby LGA that drain sub-catchments with a particular dominant land use indicates how the concentration of water quality indicators varies distinctly between sub-catchments. Comparison of developed catchments with water quality monitored in natural bushland catchments demonstrates that water quality concentrations are many multiples higher for different land uses. Comparison of the differences in monitored water quality for sub-catchments with different land use across the LGA is provided in Section 6.3.

5.2 Existing point pollution sources

Point sources are hotspot locations within the Hornsby LGA where the pollutants generated by a land use activity are potentially (or known to be) proportionally much higher than generated by the surrounding diffuse land uses. Point sources of pollutants across the Hornsby LGA have been identified considering data from a number of sources including:

- The Protection of Environment Operations Act 1997 public register of licensed activities;
- Review of existing land use mapping and LEP zoning;
- GIS data supplied by Council and Sydney Water Corporation;
- Council reports and studies;
- Social pinpoint data collected in 2019 to assist Hornsby Shire Council with preparing their Environmental Sustainability Strategy (https://mcnair.mysocialpinpoint.com/hornsby#/);
- Data collected in the CRC for Water Sensitive Cities community workshop held as part of the Shaping Hornsby's Water Sensitive Future project;
- Council staff workshop held as a component of this project on 29 July 2020.

Existing known or potential point pollution sources are shown on Figure 5-2 and Figure 5-3.

5.3 Effective impervious area

DPIE provided mapping of impervious roof areas and public road pavement across the entire Hornsby Shire Council LGA. This mapping included consideration of remotely sensed data that captured a high proportion of the roof areas within the LGA. DPIE supplemented this data with estimates of road pavement extents from available cadastral mapping. The data provided by DPIE was reviewed and was observed to identify the majority of potential effective impervious areas within the LGA. It was noted that the provided data was limited in capturing some impervious surfaces including private carparking areas, driveway accesses and some building roofs.

The data supplied by DPIE was interrogated by Alluvium to estimate impervious areas for each minor sub-catchment in the LGA. The estimated effective impervious areas based on the mapping by DPIE were increased proportionally by 10% to account for the noted limitations in the remotely sensed data.

The estimated existing effective impervious areas are shown on Figure 5-4.

5.4 Future point and diffuse sources

The Hornsby Shire Housing Strategy 2011 (HSC, 2011) identified new areas for future medium and high-density residential development across the LGA for the period up to 2021. GIS data were provided by Council showing sites where future (and recent) development is planned under this strategy. The LSPS provides an indication of where additional development between 2021 and 2036 is likely to be accommodated across the LGA, with Hornsby (particularly around the town centre), Asquith and Waitara being key areas where population growth is planned to be accommodated.

Current planning indicates that future population growth and related development is planned to be concentrated in existing urban areas. Within these areas, the concentration of pollutants generated from these areas is likely to be similar in characteristics to current conditions. It is likely that the impervious area in these urban areas will increase to accommodate a higher density of residential development. This increase in impervious area is likely to be the most significant contributor to increased diffuse source pollutant loads from these areas.

Precinct scale greenfields or re-development is currently ongoing or being planned in areas of Beecroft, Cherrybrook and South Dural. Development of this scale in these areas will potentially result in a significant localised increase in point source loads impacting on runoff within the relevant sub-catchments and external downstream sub-catchments in the vicinity of the development.

Limited data is available on where future additional point sources of pollution will occur. Many of these sites would be privately owned and licensed under the Protection of Environment Operations Act 1997 where discharge to waters are proposed. Increased discharges from the West Hornsby and Hornsby Heights WWTP is expected in the future in response to the increased population and connection of currently unsewered properties.

Currently known future sources of pollution would primarily be associated with locations where future urban development is planned and these areas are shown on Figure 2-2.

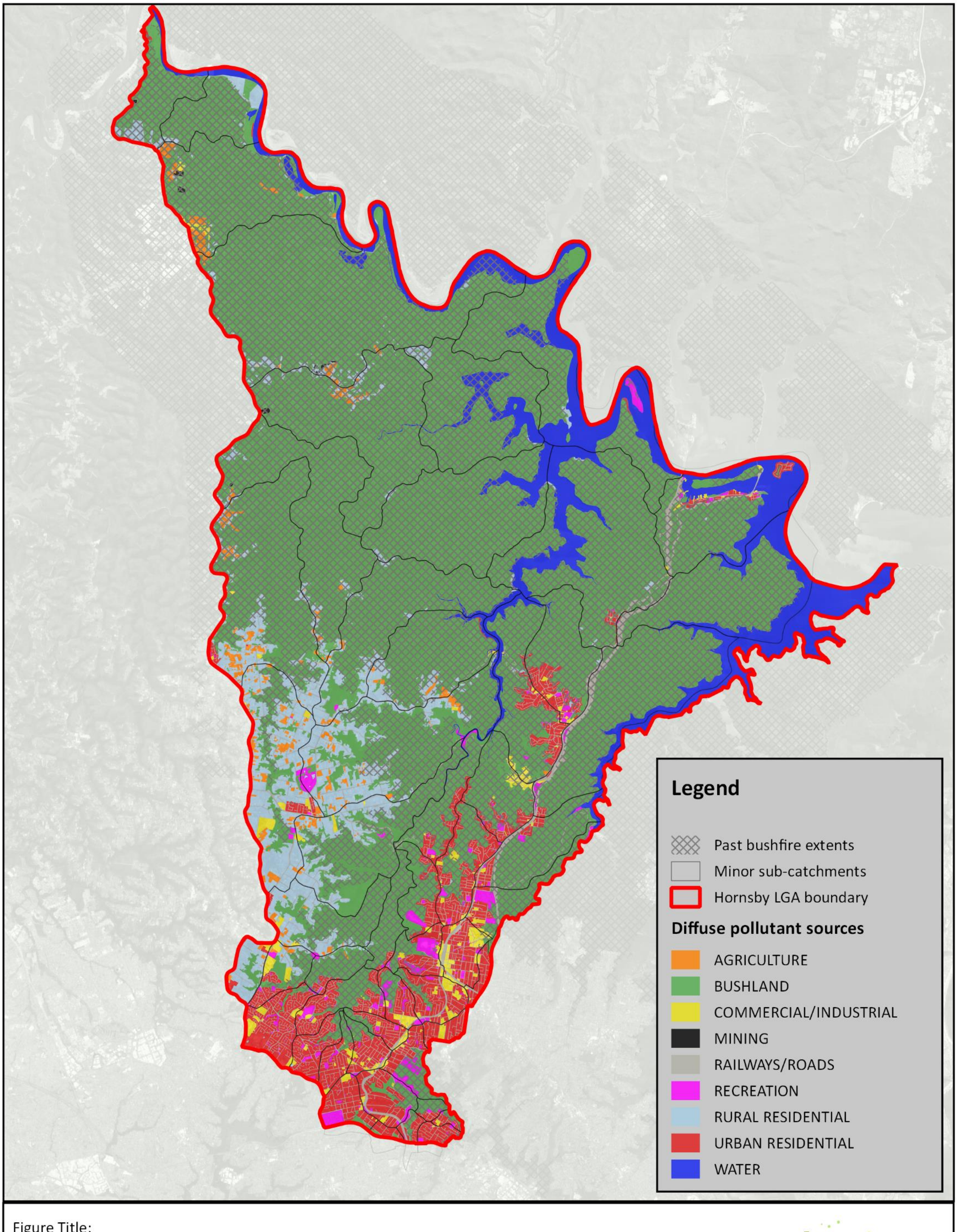

Figure Title:

Existing diffuse pollutant sources

alluvium

Figure No.:

5-1

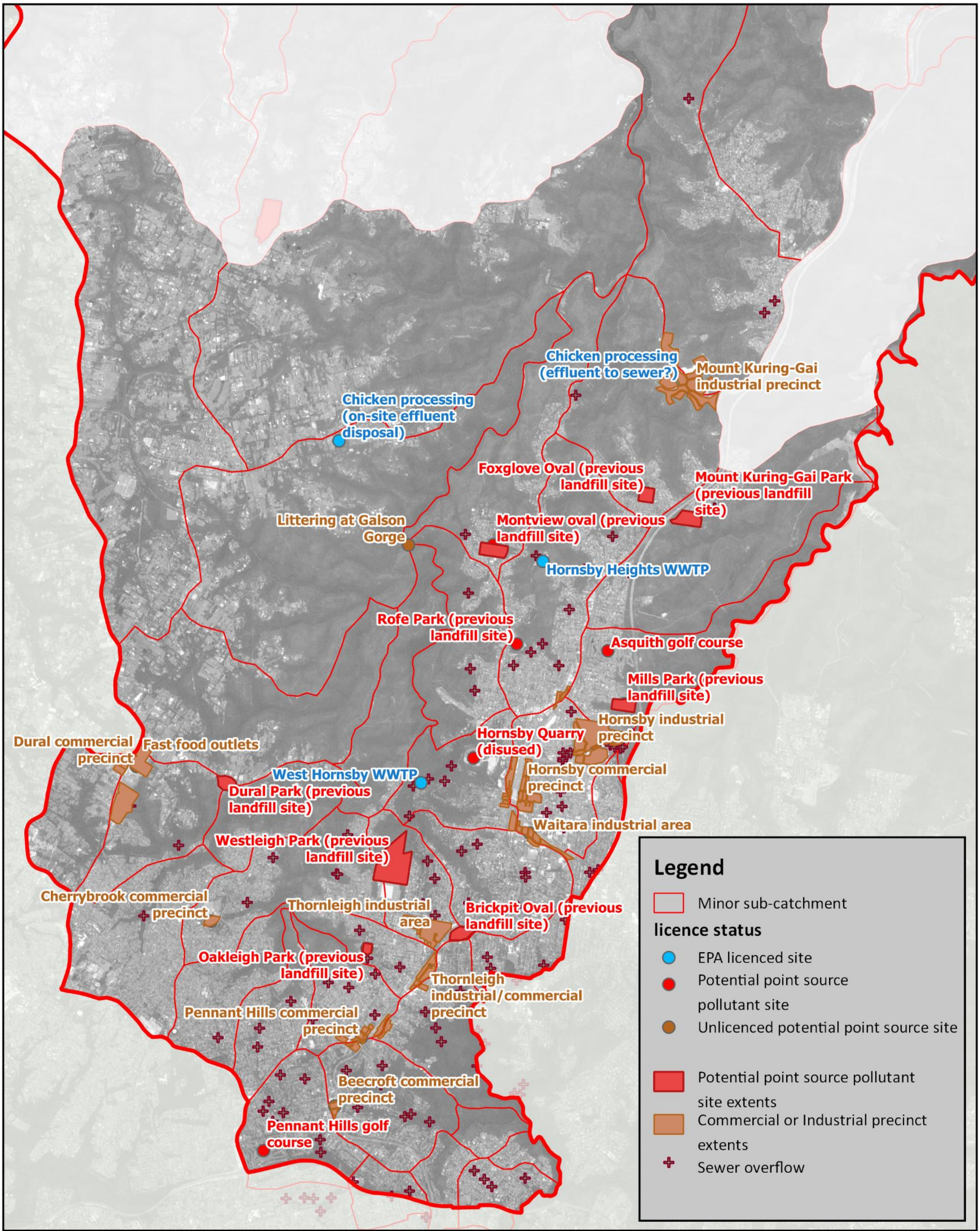

Figure Title:

Existing potential point source pollutant sites (south)

alluvium

Figure No.:

5-2

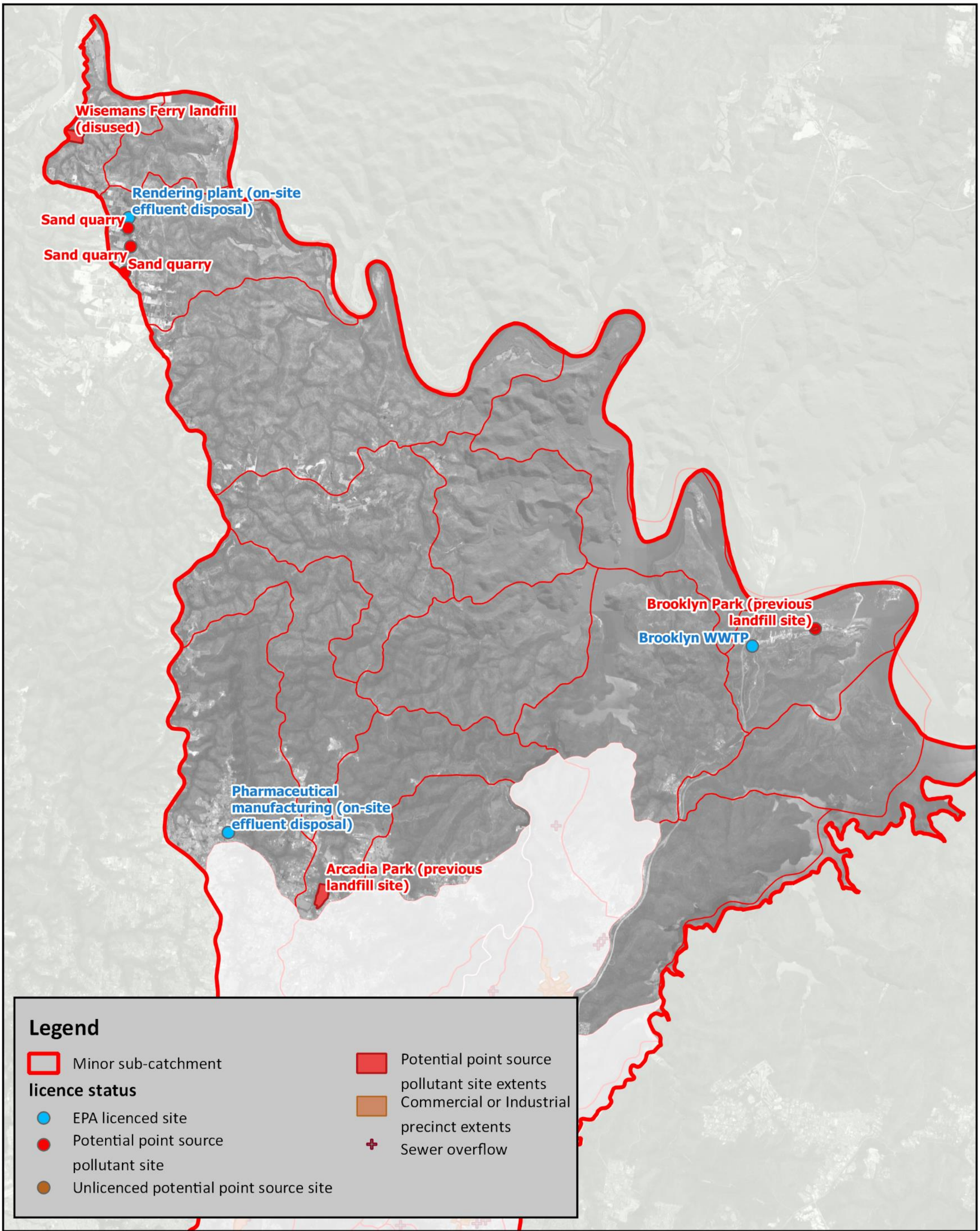

Figure Title:

Existing potential point source pollutant sites (north)

alluvium

Figure No.:

5-3

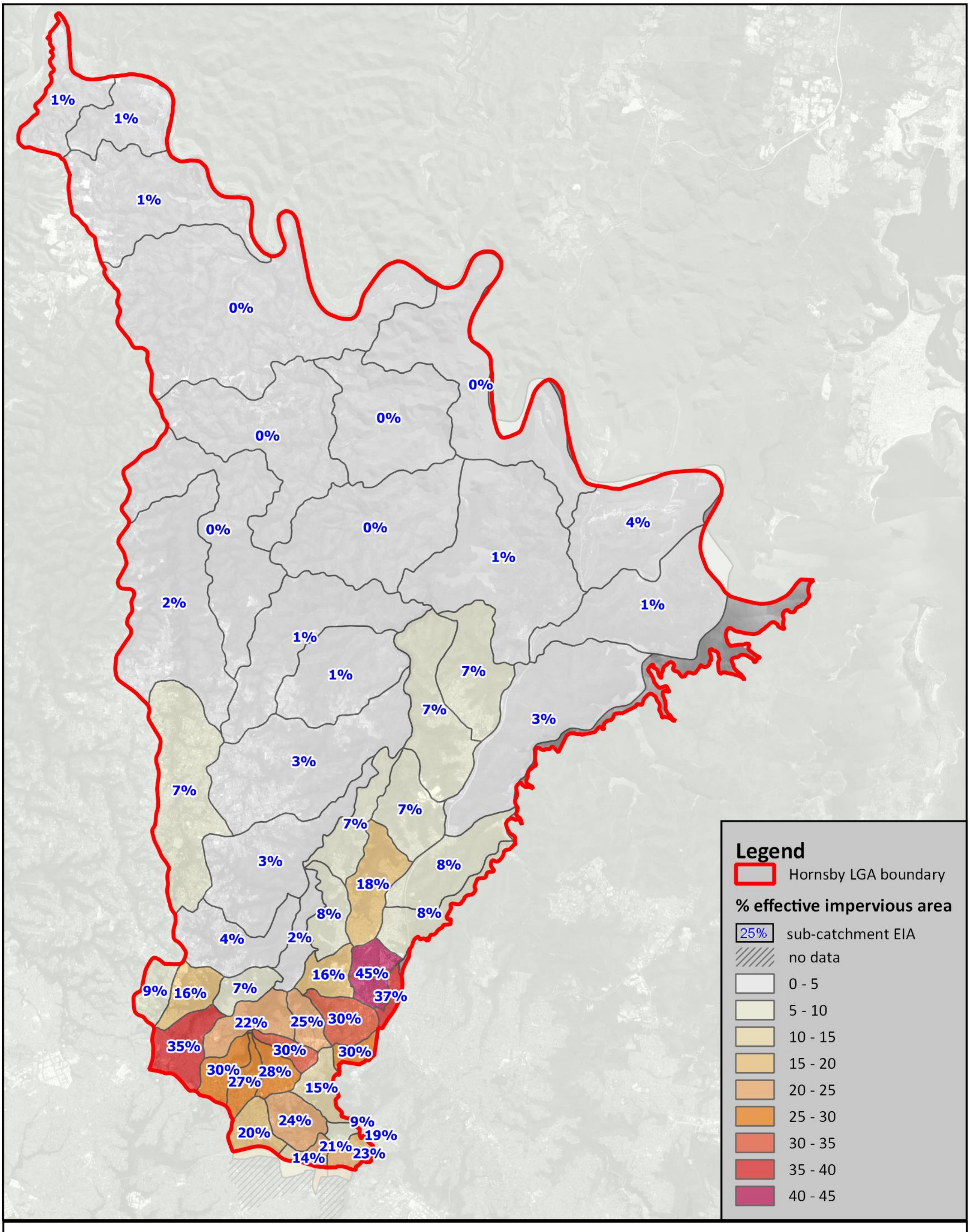

Figure Title:

Existing effective impervious areas

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Figure No.:

5-4

6 Preliminary assessment of existing risks

6.1 Assessment approach

A preliminary risk assessment was completed for each sub-catchment to identify priorities for management actions. The preliminary risk assessment was based upon the following relationship:

Risk = Likelihood x Consequence

The likelihood represents the land use pressure on waterways. The consequence represents the potential impact on community uses and environmental values associated with waterways.

The **likelihood of impacts on waterway objectives** was evaluated based on the **level of exposure to potential threats** from existing diffuse sources, existing point sources, effective impervious areas and future pollutant sources. Sub-catchments with a higher level of potential threats were considered to have an increased likelihood of impacts on waterway objectives.

The **consequences to waterway objectives** was evaluated considering the **level of community uses and environmental values** within the sub-catchment. Consequences for sub-catchments with a high level of community uses and environmental values were considered to be higher than for sub-catchments with less identified community uses and lower environmental value waterways.

The sub-catchment priorities for intervention were evaluated in line with the risk matrix presented in Table 6-1.

Table 6-1 *Sub-catchment priority risk matrix*

		Likelihood of impacts from sub-catchment				
		Rare	Possible	Likely	Very likely	Almost certain
Consequence to waterway objectives	Minor	low	low	low	low	low
	Low	low	low	low	medium	medium
	Moderate	low	medium	medium	high	high
	High	low	medium	high	high	very high
	Very high	medium	high	high	very high	very high

The purpose of this preliminary risk assessment is to assist with identifying high priority sub-catchments for management actions to reduce threats to the community uses and environmental values. Step 2 of the RBF process involves completion of a more detailed effect-based assessment that would include the following tasks:

- Assessing how land uses affect the measurable indicators.
- Developing a management strategy that responds to waterway health threats
- Assessing the effectiveness of the planned management responses
- Assessing the risk of impacts by comparing the effectiveness of the planned management responses with the draft locally derived waterway objectives.

- Comparing effects-based assessment (EBA) outcomes with objectives.
- Reviewing the draft objectives to confirm their practicality and feasibility and refine if necessary (potentially considering 'optimum' solutions).

6.2 Consequences for community uses and environmental values

Community use scores
The community uses map shown in Figure 3-2 was provided to members of the project team for qualitative evaluation. The project team members have a good appreciation of the waterway uses, with a spread of knowledge on community uses between the urban waterways and other estuarine waterways close to the Hawkesbury River. Each sub-catchment was allocated a score between 1 and 5 separately by each project team member based on the number of identified community uses associated with waterways in each sub-catchment. A score of 1 is representative of sub-catchments with a small number of community uses, whilst a score of 5 is representative of a sub-catchment with a large number of community uses. The individual scores allocated for each site were combined into an average score and these scores are mapped on Figure 6-1.

The scoring was based primarily on the number of identified uses at each site and the project team's local appreciation of the areas. A limitation of the data is specific knowledge on the numbers of community members who use each site, and the frequency of use that could be used to confirm how important each site is from a community use perspective. Further community consultation or sourcing of location data through mobility tracking services (e.g. Google, STRAVA) could assist with more closely quantifying community site usage patterns.

Environmental value scores
Similarly to the community uses scoring, the environmental values mapping shown in Figure 3-3 was provided to the project team for qualitative evaluation. Each sub-catchment was allocated a score between 1 and 5 by each project team member based on the identified environmental values associated with waterways. A score of 1 is representative of a sub-catchment with lower environmental values associated with waterways, whilst a score of 5 is representative of a sub-catchment with high environmental values associated with waterways. The individual scores allocated for each site were combined into an average score and these scores are mapped on Figure 6-2.

The community use and environmental value scores were weighted (in this case 50% each) to calculate a combined consequence score for each sub-catchment. These potential consequence scores are mapped on Figure 6-3.

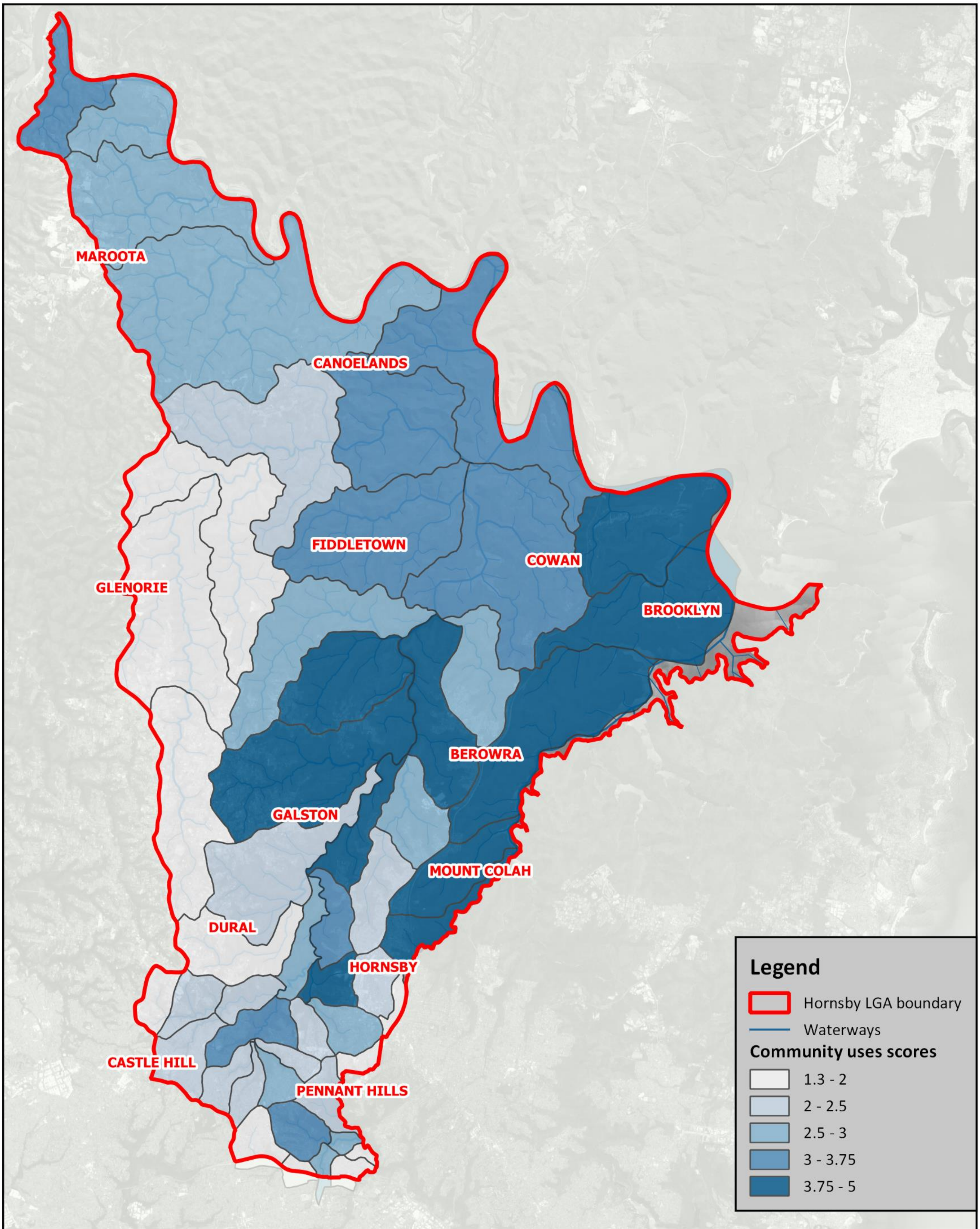

Figure Title:

Community waterway uses scores

alluvium

Figure No.:

6-1

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0 2 4 6 km

GDA 1994 MGA Zone 56

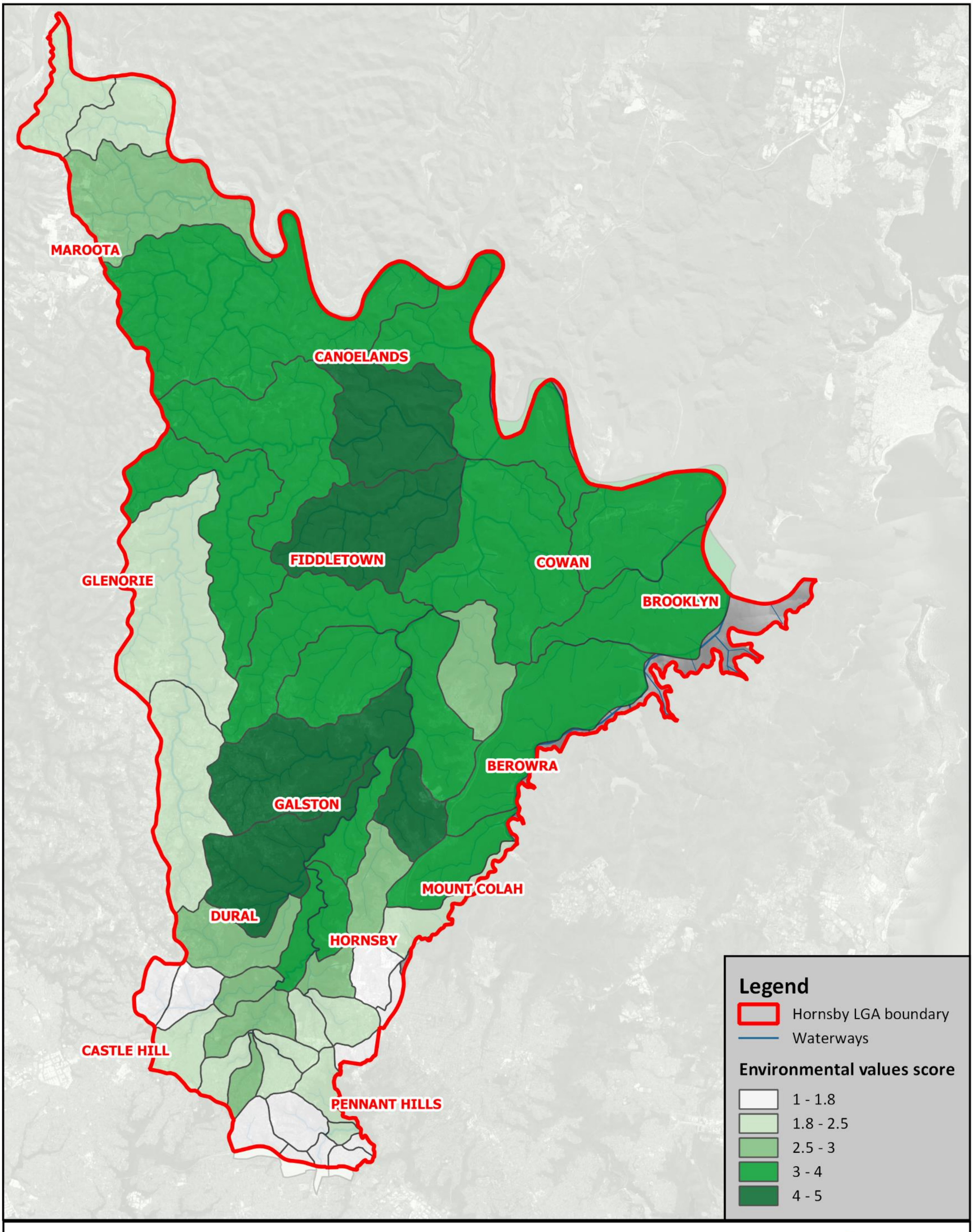

Figure Title:

Environmental values of waterways scores

alluvium

Figure No.:

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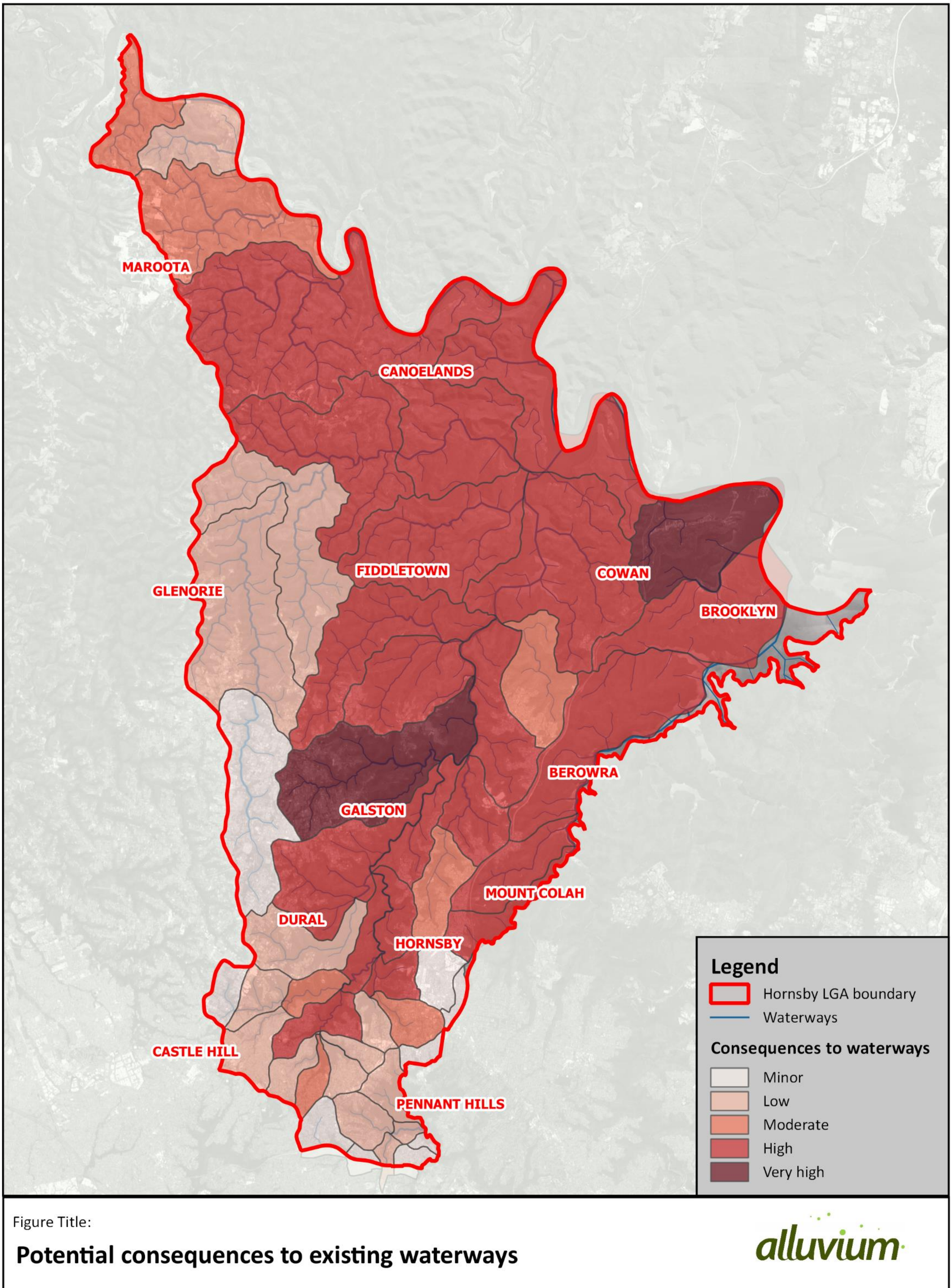

Figure Title:

Potential consequences to existing waterways

alluvium

Figure No.:

6-3

6.3 Likelihood of impacts

Existing diffuse source concentration ratios

Summary statistical water quality monitoring data were provided by Council for water quality sampling sites located across the LGA. The data were provided for a number of active sampling sites included in the current EcoHealth monitoring program, and non-active sampling sites that were monitored as part of earlier water quality monitoring programs.

The available water quality data provides the evidence of the land use activity impacts across a catchment, and particularly when this data is collected from multiple sites over a long term period. The water quality monitoring data is preferable to use over modelling when evaluating existing conditions as the data reflects real observed conditions and will typically differ (sometimes considerably) from modelled scenarios that require assumptions on water quality derived from external monitored catchments that are quite often unrepresentative of the catchment under consideration.

Council's data were reviewed, and sites located immediately downstream of sub-catchment with a predominant existing land use were identified. These sites were reviewed to confirm that water quality was not impacted by regular point source discharges (e.g. wastewater) and that the site had a sufficient number of sampling events (minimum 100). The sampling sites adopted as representative of key simplified land uses in the LGA are summarised in Table 6-2 and the locations of these sites are shown on Figure 4-1.

Table 6-2 *Representative sampling sites for simplified land uses*

Upstream land use	Active sampling sites	Non-active sampling sites
Urban residential	BERO7, PYES1, GEOR1, 008, 023, 062	050, 007, 046, 020, CALN2, 057, 051, 147
Industrial	010, 012, 013	
Rural/rural residential	COLA2, STIL2, COLA1, 064, 080	
Bushland	MAND1, SMUG1	149, 054

The water quality data for the sites summarised in Table 6-2 were analysed considering selected indicators included turbidity, nutrients (total nitrogen, total phosphorus) and enterococci indicators that are broadly representative of water quality constituents relevant to a range of identified community uses and environmental values. Weighted mean values (based on the number of samples at each site) were calculated for each combination of predominant upstream land use and indicator. Mean values for each simplified upstream land use category were then compared to the bushland mean values and ratios calculated (refer Table 6-3). The calculated ratios provide a broad indication of the proportional difference in mean concentration observed from different land uses when compared to a natural bushland catchment.

Table 6-3 *Mean concentration ratios relative to bushland land use*

	Turbidity	Total Nitrogen	Total Phosphorus	Enterococci
Urban residential	7.0	4.8	3.6	8.2
Industrial	15.5	11.9	31.8	29.2
Rural/rural residential	5.8	6.7	7.0	14.8
Bushland	1.0	1.0	1.0	1.0
Near WWTP outlet	3.5	41.0	5.9	4.4

The ratios outlined in Table 6-3 provide a relative indicator of monitored mean concentrations from particular land uses. These ratios were adopted to estimate sub-catchment averaged concentrations based on the area of each simplified land use in each sub-catchment (refer Figure 2-1). The sub-catchment averaged diffuse source concentration ratios are shown on Figure 6-4.

Existing diffuse source runoff volume ratios
The sub-catchment averaged diffuse source concentration ratios outlined above provide an indication of the average concentration of particular indicators from each sub-catchment over a long term range of dry and wet weather conditions. To estimate relative diffuse source loads from each sub-catchment, an estimate of the relative runoff volume from each sub-catchment is required.

Daily stream flows have been recorded at Stream Gauge 212294 Berowra Creek at Galston Gorge since 1987. This gauge receives runoff from a 57.7km^2 catchment that includes a large proportion of the urban areas in the Hornsby LGA. Flows to this stream gauge include discharges from Sydney Water's West Hornsby Wastewater Treatment Plant. Monitored flow discharges from the West Hornsby WWTP were also available for the period since 1987.

Flow data from the West Hornsby WWTP were utilised to estimate the net flow observed at Stream Gauge 212294 that is attributable to runoff from the catchment (assuming leaks from the reticulated water mains and sewerage systems represent a minor proportion of the observed flow). It was estimated that the West Hornsby WWTP discharges contributed approximately 25% of the total flow volume observed at the stream gauge over the 1987 to 2019 period. The wastewater discharge estimates exclude the contribution of stormwater runoff to increased wastewater discharges resulting from infiltration into the sewerage system during wet weather.

Concurrent flow and rainfall data for the 1987 to 2019 period were reviewed to estimate the mean annual volumetric runoff co-efficient. Based on the rainfall and stream flow data for years in the 1987 to 2019 period (where complete or near complete rainfall and flow records were available) it was estimated that the average annual volumetric runoff co-efficient for the 57.7km^2 catchment draining to the gauge is 0.28 (i.e. 28% of rainfall becomes runoff). DPIE provided remote sensed data indicating that the directly connected impervious area of the catchment draining to the gauge is currently approximately 14%.

Considering the available stream flow and impervious area data, it is estimated that surface runoff from impervious and pervious urban surfaces is approximately 8.8 ML/yr/ha and 2.3 ML/yr/ha respectively. Assuming that runoff from pervious rural and bushland areas would be similar to that estimated for urban pervious surfaces (i.e. Volumetric runoff co-efficient (Cv) = 0.21), estimated diffuse source runoff volume ratios for each sub-catchment (relative to 100% pervious bushland areas) are shown in Figure 6-5.

Existing diffuse source threat scores
The sub-catchment average diffuse source concentration ratios shown in Figure 6-4 were multiplied by the sub-catchment averaged diffuse source runoff volume ratios shown in Figure 6-5 to determine an existing diffuse source threat score relative to bushland areas that have threat score of 1. These combined diffuse source threat scores are shown on Figure 6-6.

Existing point source threat scores
Existing known or potential point pollutant sources are shown on Figure 5-2 and Figure 5-3. These point pollutant sources were reviewed considering the potential for each to impact on the indicators representative of the identified community uses and environmental values. The point pollutant scores are summarised on Figure 6-7.

It is expected that the influence of point sources on water quality for most sub-catchments would be reflected in the water quality monitoring results adopted for evaluating diffuse source threats from different land uses. The exception to this is the West Hornsby and Hornsby Heights WWTPs discharges which far exceed the nitrogen contributions from all other land uses (refer Table 6-3). Considering that the West Hornsby WWTP discharges are estimated to represent approximately 25% of the total flow observed at Galson Gorge, the contribution of the WWTP discharges to TN loads is likely to far exceed the contribution from the total catchment areas draining to Galston Gorge. For this reason, threats to community uses and environmental values susceptible to high nutrient loads will be significantly higher in sub-catchments where WWTP discharges occur. To avoid double counting the influence of point sources on monitored water quality that was used to evaluate diffuse source threats, only the diffuse source scores and WWTP point sources were considered in estimating a combined likelihood score for each sub-catchment. These likelihood of impacts to waterways scores are mapped on Figure 6-8.

6.4 Sub-catchment priorities

The potential consequences to the community uses and environmental values shown on Figure 6-3 were overlaid with the likelihood of impacts from existing sub-catchments shown on Figure 6-8. The paired consequence and likelihood values were then compared with the risk matrix shown in Table 6-1 to confirm a priority for each sub-catchment to be considered in the following Step 2 effects-based assessment and later steps in the RBF process. These sub-catchment priorities are shown on Figure 6-9.

Figure 6-9 also highlights sub-catchments where it is considered that planned future development is likely to pose a significant additional risk to waterways in these sub-catchments (and waterways in adjacent downstream sub-catchments) without mitigations actions. The assessment of the impacts of future planned development in the LGA is outlined in Section 7.

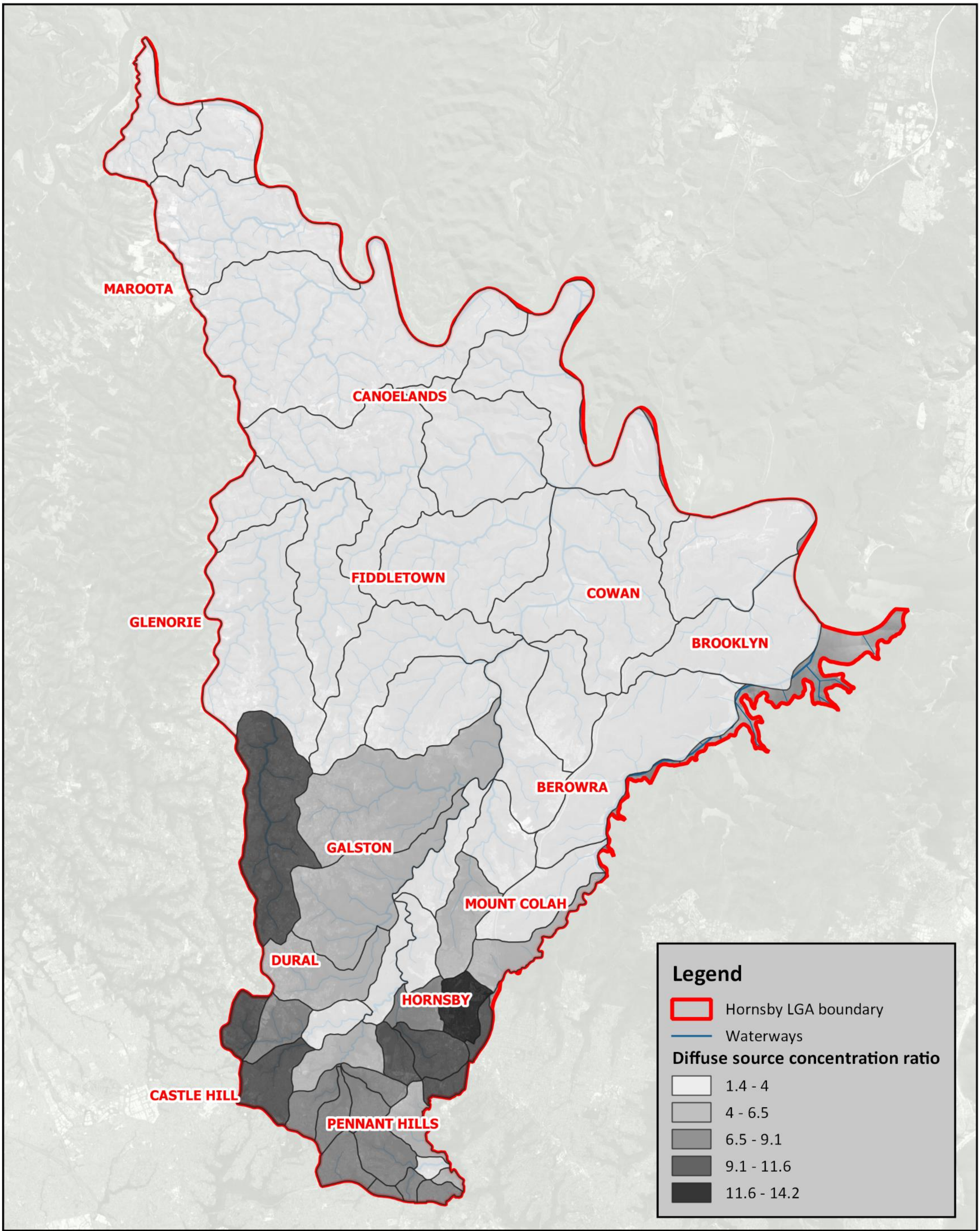

Figure Title:

Diffuse source concentration ratio

alluvium

Figure No.:

6-4

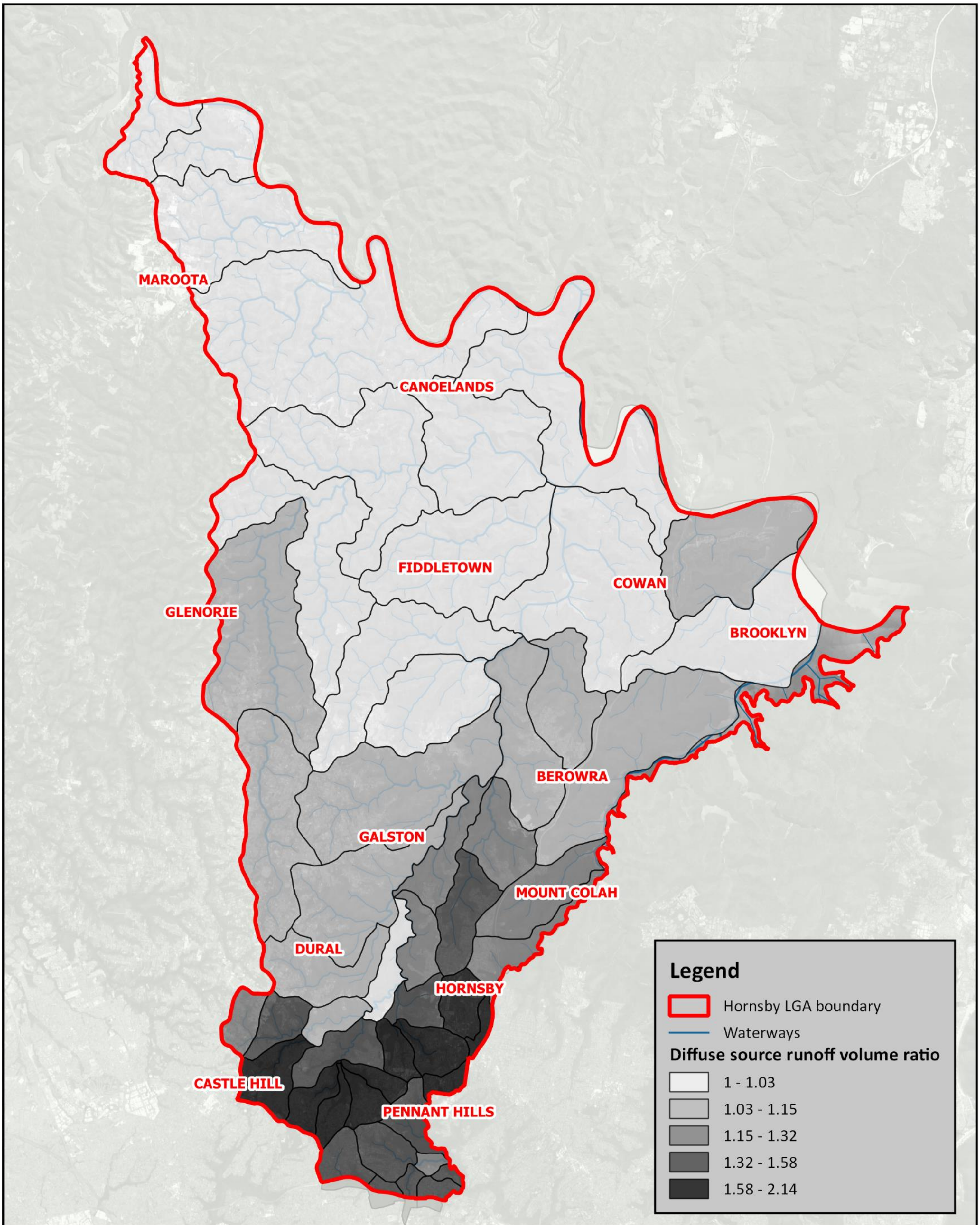

Figure Title:

Diffuse source runoff volume ratio

alluvium

Figure No.:

6-5

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0 2 4 6 km

GDA 1994 MGA Zone 56

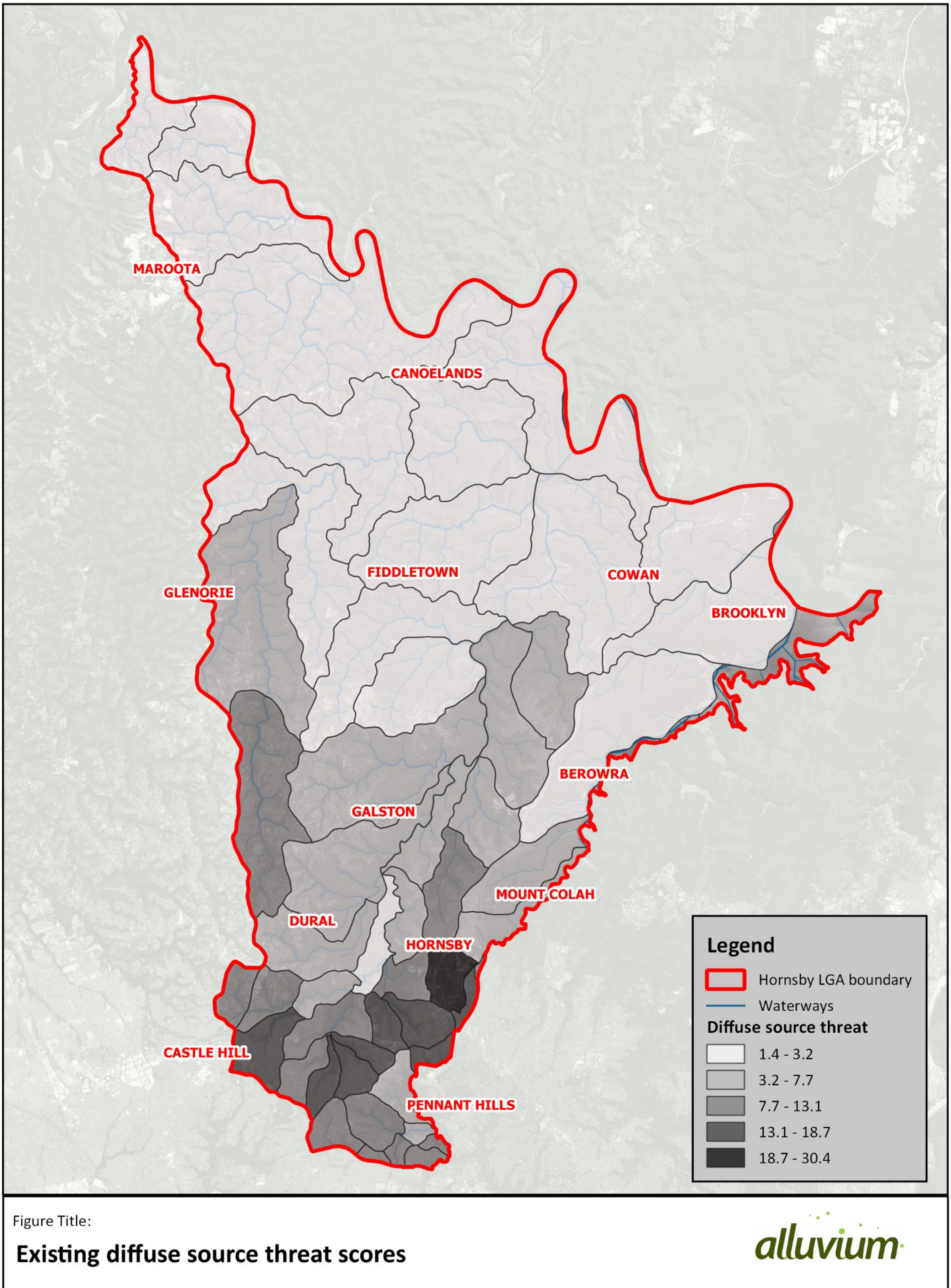

Figure Title:

Existing diffuse source threat scores

alluvium

Figure No.:

6-6

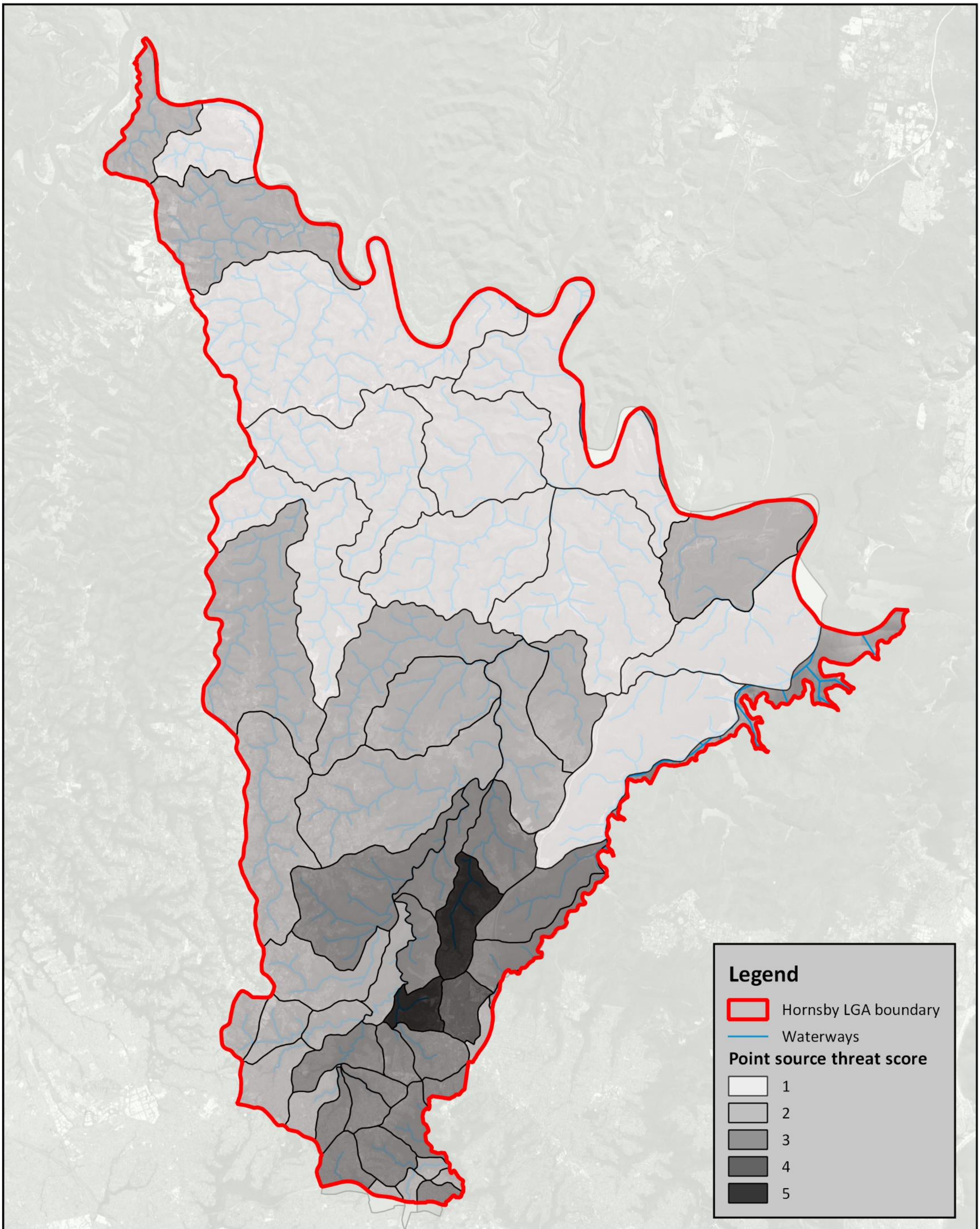

Figure Title:

Existing point source threat scores

alluvium

Figure No.:

6-7

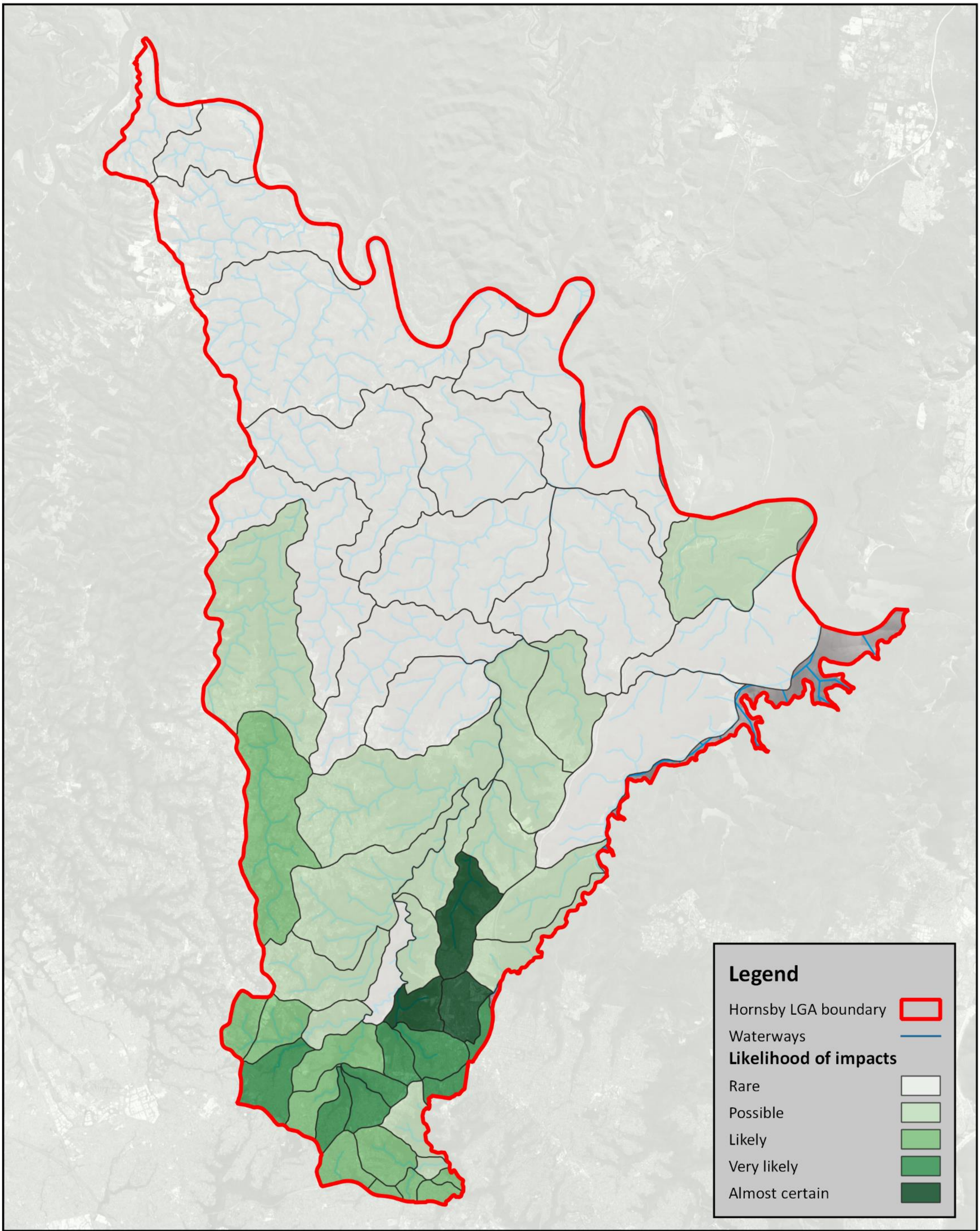

Figure Title:

Likelihood of impacts from existing sub-catchments

alluvium

Figure No.:

6-8

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0 2 4 6 km

GDA 1994 MGA Zone 56

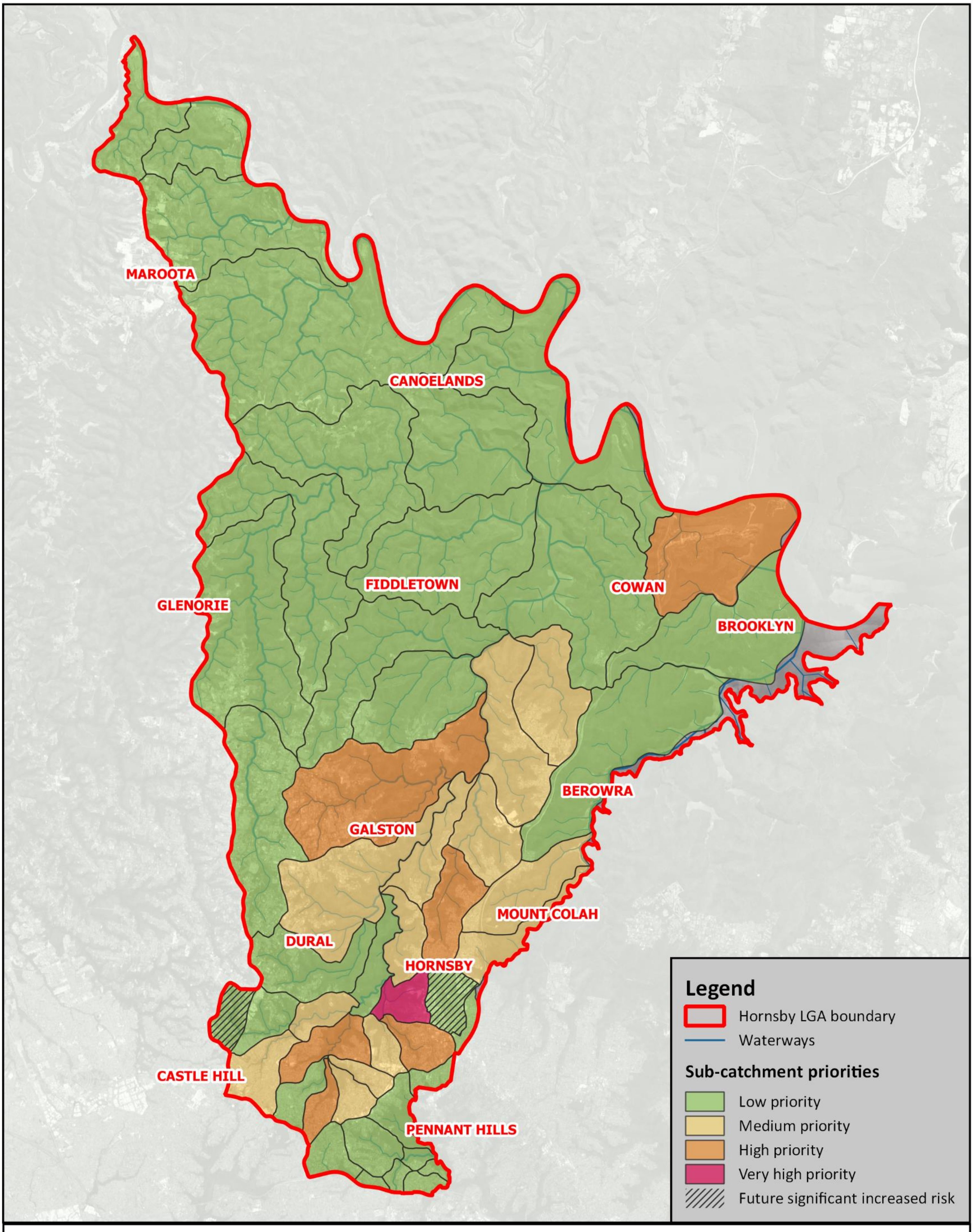

Figure Title:

Sub-catchment priorities

alluvium

Figure No.:

6-9

7 Assessment of future waterway condition trajectory

The preliminary risk assessment outlined in Section 6 provided an indication of the existing risks to waterway objectives across the Hornsby LGA sub-catchments from existing land uses. This section focuses on the potential increase in risks to particular waterways associated with planned future land use activities.

At this stage, the assessment focuses on the planned future land use activities that would result in increased development density in current urban areas and new greenfields development in existing urban and rural areas. The assessment focuses on the land use changes and currently does not include consideration of the influence of other factors including climate change (e.g. impacts on hydrology and increased fires), changes to point source discharges (e.g. treated wastewater) and catchment management activities.

The future planned developed extents shown on Figure 2-2 were considered in evaluating the potential additional diffuse source risks to waterways. The majority of planned future development coincides with the existing urban footprint and will primarily involve increasing densities and associated imperviousness in these areas. The existing diffuse risks were factored considering the estimated increase in imperviousness of each sub-catchment associated with the future development.

Indicatively it was assumed that redevelopment of existing residential areas would occur at the rate of approximately 1% of properties each year. Adopting a 20 year planning horizon, it is therefore assumed that approximately 20% of current residential areas would be redeveloped to a higher density over this period.

It was assumed that 50% of the South Dural investigation area would be developed. This development is likely to significantly increase threats to the waterways within the sub-catchment and the immediate downstream sub-catchment (i.e. minor sub-catchments 108-1 and 108-2).

A qualitative assessment of the future additional diffuse source threat associated with increased development is shown in Figure 7-1. Areas where existing threats are expected to be significantly increased are indicated on Figure 6-9.

Recommended considerations for selecting an appropriate sub-catchment for Stage 2 of this project (i.e. Steps 2 to 5 in the RBF) are discussed in Section 9.

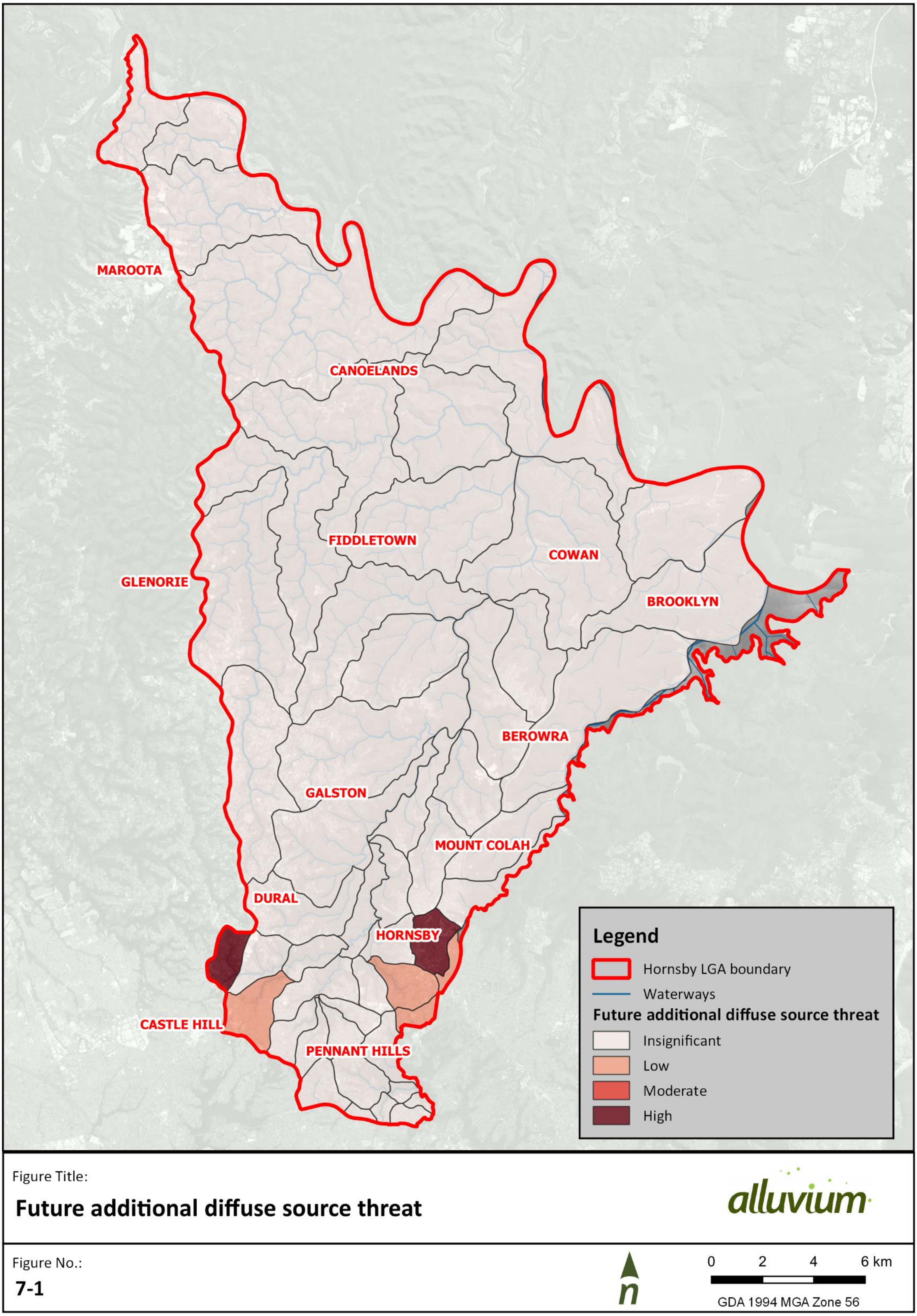

Figure Title:

Future additional diffuse source threat

alluvium

Figure No.:

7-1

8 Sensitivity risk assessment

A sensitivity risk assessment was completed including only the environmental values for each sub-catchment in the evaluating the consequences component of the risk assessment. The re-evaluated consequences mapping is shown in Figure 8-1. The risks were re-evaluated based on the modified risk matrix shown in Table 8-1.

Table 8-1 *Modified risk matrix*

Consequence to environmental values	Likelihood of impacts from sub-catchment				
	Rare	Possible	Likely	Very likely	Almost certain
Minor	Low	low	low	low	low
Low	Low	low	low	medium	medium
Moderate	Low	medium	medium	high	high
High	Low	medium	high	high	very high
Very high	medium	high	high	very high	very high

The re-evaluated sub-catchment priorities based on the environmental values only are shown on Figure 8-2.

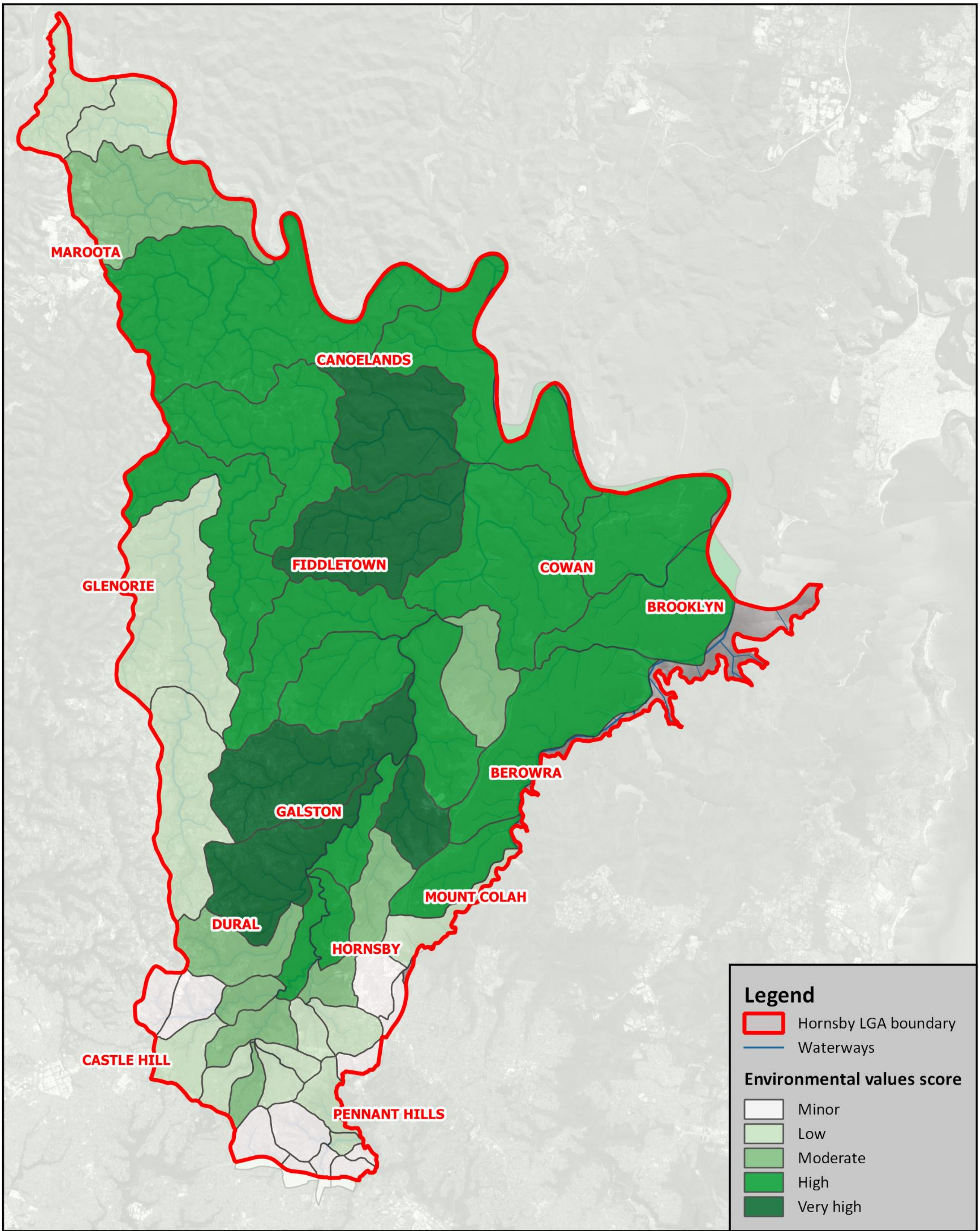

Figure Title:

Potential consequences to environmental values of waterways

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Figure No.:

8-1

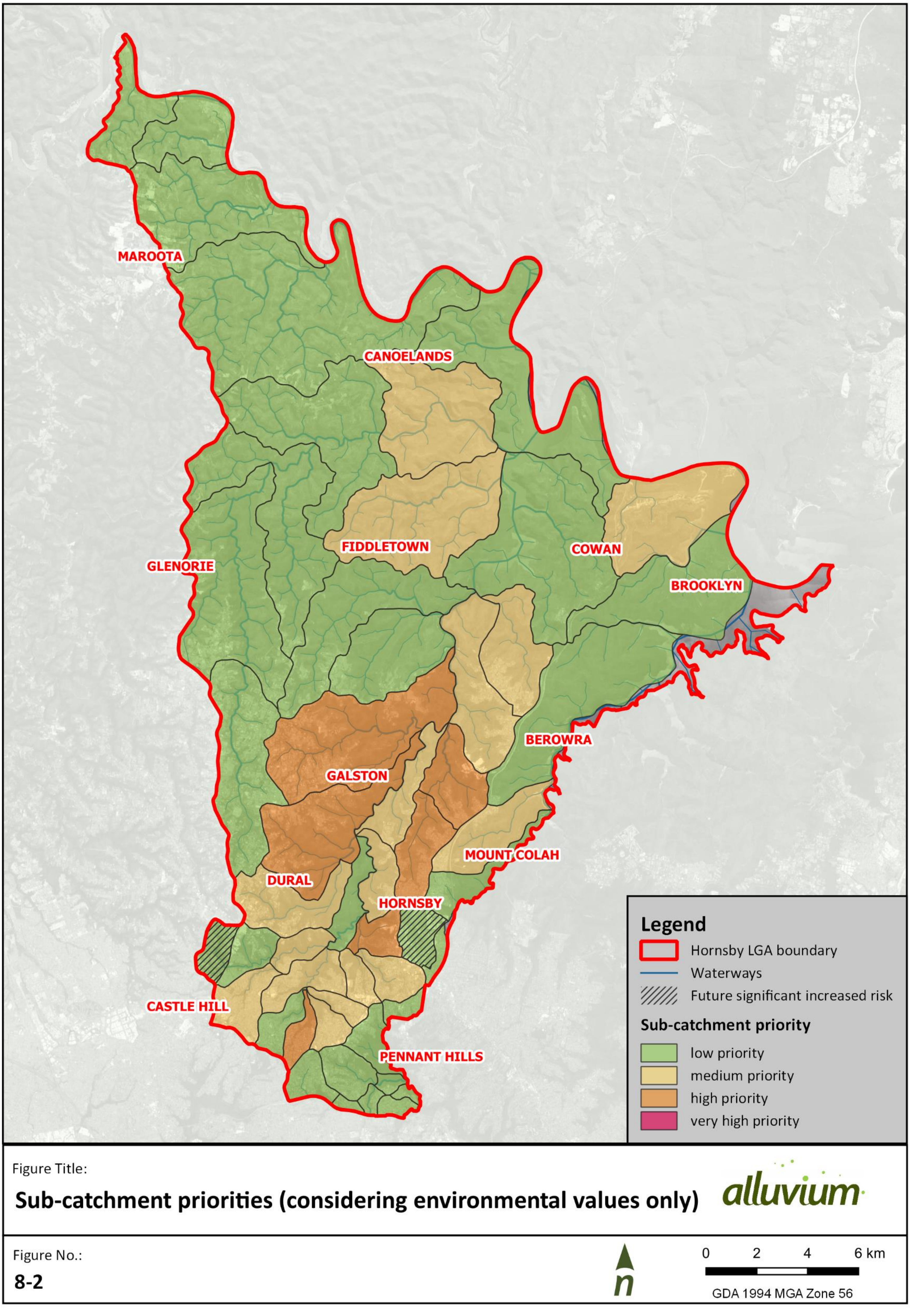

Figure Title:

Sub-catchment priorities (considering environmental values only)

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Figure No.:

8-2

9 Conclusions and recommendations

9.1 Stage 1

This stage of the project focused on the application of Step 1 (Establishing the context) of the RBF to the Hornsby LGA. Step 1 was completed with a key focus being to identify sub-catchments across the LGA where existing and future threats from diffuse and point sources potentially will continue to impact on waterway reaches with high community use and environmental values. Council's intention is to complete Stage 2 of this project focusing on Steps 2 to 5 of the RBF process for a selected higher priority sub-catchment. The sub-catchment will be confirmed following Council's consideration of the outcomes of Stage 1 provided in this report.

Comparison of the risk assessment mapping for circumstances where community uses and environmental values were considered equally, and environmental values separately is provided in Figure 9-1. This comparison indicates that the priorities are similar. Although, the assessed priority of some sub-catchments either increases or decreases slightly depending on whether community uses are considered in the assessment.

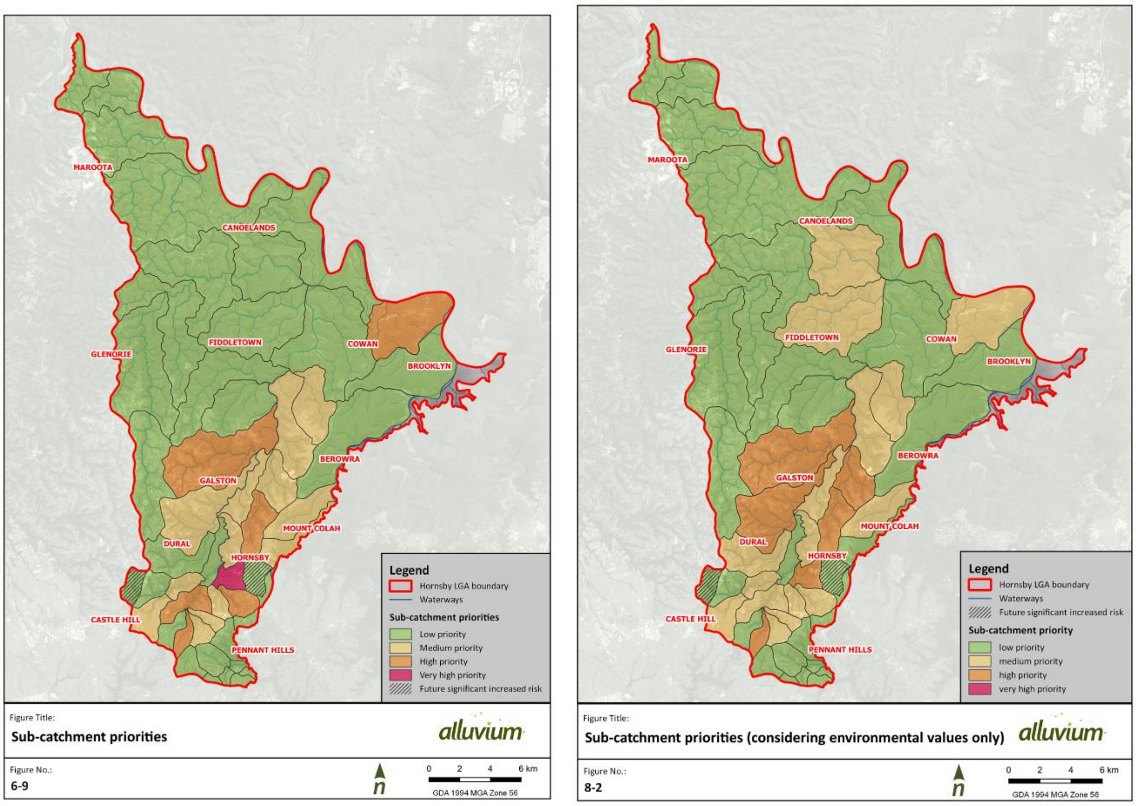

Figure 9-1 *Comparison of risk assessment mapping including consideration of community and environmental objectives (LHS) and environmental objectives only (RHS)*

To achieve Council's objective to prioritise sub-catchments to enable a high priority sub-catchment to be selected for further work required the community uses and environmental values to be evaluated for 52 separate sub-catchments. Some of the main challenges encountered throughout this project are discussed below with recommendations for consideration that may assist progressing Step 1 of the RBF for future studies.

Confirming community uses of waterways at sub-catchment scale was challenging for this project. No additional focused community consultation was able to be undertaken within the scope of this project to confirm how community uses/values may vary spatially across the LGA. This data would be useful for assisting with prioritising waterway reaches that have similar environmental values. The project therefore relied on the outcomes of recent community consultation completed for other studies with different objectives. This was quite challenging and time consuming for Council as it required filtering of a large number of comments provided by the community to extract data relating specifically to community uses near waterways.

The spatial distribution of community uses (primarily recreational) was estimated from the recent community consultation that included data on activities aligned with waterways. This was supplemented by GIS data showing the locations of key waterway related community infrastructure and community recreational uses. Whilst many locations where community uses occur close to waterways were able to be identified, the available data was insufficient to confirm the extent and frequency of use by the community. The evaluation of community uses was therefore based primarily on the known presence of a particular community use at a location and not how widespread or popular the use is at that location. The assessments were therefore qualitative and limited to consideration of the sourced data (that is likely to be incomplete).

Early targeted community consultation to confirm the range of community uses and locations across the LGA would assist other projects. In addition, gathering data through surveys (and review of tracking data) on the extent and frequency of community uses would assist with establishing how valuable particular sites are for particular uses.

It is recommended that Councils looking to undertake similar projects be provided with a check list of the types of data (and locations of freely available data where applicable) that would assist with confirming community uses and environmental values at the sub-catchment scale. If DPIE could prepare a list of state-wide data sets that can be accessed for a study, that is also likely to assist with confirming and sourcing appropriate data. This would enable Councils to gather data, identify data gaps (and seek to fill gaps) and review data for its suitability prior to commencing Step 1 of an RBF project. This could also potentially save a significant amount of time.

The community use scores were estimated from a qualitative assessment completed by members of the project team with varying levels of knowledge of the identified community uses across the LGA. The scores determined applying this approach are therefore quite subjective and somewhat limited in reliability by the size and experience of the scoring team. It is recommended that similar assessments be completed including input from a range of informed community groups/participants, Council officers and industry specialists based on known uses and the extent of use derived from surveys and other sources. An effective way to complete this assessment could be through a 'scoring workshop' involving the broad range of informed participants indicated above.

Evaluation of environmental values associated with waterways relied heavily on available mapping of high ecological value (HEV) waterways and the estimated 'Tvalue' for each cell in the supplied grid. The limitation of this data is that it provides a summary estimate of the potential presence of ecological values in each grid cell. Similar to the available community values data, the HEV data does not include information on the condition or quality of the ecosystems at each location. Whilst the data includes individual attributes indicating the estimated length or area of particular ecological values at each location, further processing of the data would be required to quantify the ecological values in each data cell. It is recommended that the HEV data be reviewed further to identify and quantify the key ecological attributes in the grid. Potential transferring the gridded data to unit values for waterway reach lengths (i.e. m^2 of an EEC habitat per km of waterway length) may be helpful for completing Step 1 of the RBF.

In addition to the DPIE HEV mapping, additional environmental data collected by Council were available at specific sites near waterways throughout the LGA. The data included mapped locations of biobanking sites, conservation sites, wildlife refuge sites and National Park in catchment areas adjacent to waterways. Council also provided recent EcoHealth monitoring data including riparian and macroinvertebrate gradings within the waterway extents at specific locations. A limitation of this data is that it only represents waterway conditions in the immediate vicinity of the sites. This requires assumptions to be made about how the environmental values in other reaches and waterways would align with particular sites when scoring the environmental values. Council also holds additional riparian condition data that was collected around 15 years ago. No additional riparian condition data appears to have been collected in these reaches recently. Additional historical macroinvertebrate data were also available. The challenge with using this data is that it may be unrepresentative of current conditions. Guidance is likely to be required for other Councils on appropriate approaches for considering historical data and also on transferring waterway condition data from monitored waterway reaches to unmonitored waterway reaches.

Similar to the community uses scoring, the environmental values scoring approach undertaken for this study was subjective and influenced by the specific knowledge of each team member, and their spatial experience across the LGA. Some of the scorers had a good knowledge of the estuarine waterways, and others were more familiar with the urban waterways. Although, for most of the sub-catchments, scores were observed to be within one point across all scorers. In some circumstances, the local knowledge of a scorer indicated that higher environmental values were observed to be present than indicated by the available data. This highlights the need to include a range of expertise and experienced people when completing subjective scoring where data may be limited. It is recommended that consideration be given to scoring being completed in a workshop format using best available technologies to gather scores.

Council has long-term water quality data and gauged stream flow data available across the LGA. It is envisaged that interpretation of this data, and other water quality data sets available in other LGA's could assist with refining the relative mean concentration of key water quality indicators for particular land uses. In advance of completing more detailed numerical modelling as a component of the effects based assessment (if required), these relative mean concentrations in combination with runoff volume estimates are expected to provide a reasonable indication of the relative contribution of individual sub-catchments to diffuse source pollution. It is envisaged that most Councils will not have access to the same amount of water quality data and flow gauging data that is available in Hornsby. Deriving appropriate data sets using Council's data (and data from other sources) could form a useful resource for other Councils in circumstances where limited local data is available.

The existing land use distribution across the LGA was evaluated based on 2016 ALUM classification data that was simplified for this project into key land use categories aligned with typical diffuse source pollutant concentration categories. Whilst land use changes would have occurred at some locations between 2016 and 2020, it is likely these would be insignificant for the purposes of Stage 1 of this project. It may assist future projects for other Councils if more recent land use mapping could be analysed by DPIE on a state-wide basis (if not already done so) to prepare consistent simplified land use category mapping that could be adopted for evaluating diffuse source pollutant risks. Evaluation of effective impervious areas based on remotely sensed data and suitable classification algorithms is also likely to be highly beneficial for estimating runoff volumes from urban catchments.

It is suggested that an additional component to consider incorporating into Step 1 or Step 2 of the RBF is a review of existing management actions within the study area and their effectiveness at mitigating impacts on the community uses and environmental values of the waterways from the land uses in the catchment. Although, prior to progressing the effects-based assessment, it may be challenging to confirm the contribution of existing management actions until the modelling approach (or other assessment method) is established.

9.2 Stage 2 recommendations

There are a number of existing high priority sub-catchments that could potentially be selected for Stage 2 of this project. In addition, there are other waterways that will come under increasing pressure due to land use changes in the sub-catchment or immediately adjacent sub-catchment.

The assessment outcomes indicates that the highest priority sub-catchments for managing diffuse and point sources to improve conditions for community uses and protect environmental values would be sub-catchments 104-1 and 107-3 (refer Figure 6-9). These two sub-catchments include point source discharges from the West Hornsby and Hornsby Heights WWTPs. Achieving measurable improvements in these two sub-catchments will require close collaboration with Sydney Water to identify feasible options. We understand that Sydney Water are committed to a program of gradual improvements for discharges from these WWTPs.

Considering the risk assessment outcomes for the existing sub-catchments shown in Figure 6-9, and the future threats shown in Figure 7-1, it is recommended that Council consider adopting either of Sub-catchments 101-4, 105-3, 107-2, 108-2, 109-2 or 109-5 for progressing Stage 2 of this project.

Suggested tasks to refine RBF Step 1 for the selected sub-catchment are:

- Sub-catchments – Divide the sub-catchment into smaller 'micro' sub-catchments considering constructed stormwater drainage lines and first-order stream locations.
- Existing land use – Complete a closer analysis of the sub-catchment identifying individual businesses, parks, bushland areas, areas with different residential density, proposed/future development lots.
- Sub-catchment audit - Complete an audit of the sub-catchment to identify specific local issues relevant to community uses and environmental values.
- Community uses – Review available data and mapping to identify draft community uses within this sub-catchment linked to the waterways.
- Environmental values – Review available data to confirm draft environmental values for the individual waterways including assessments of existing riparian conditions and current macroinvertebrate grades.
- Threats to community uses and environmental values – Confirm existing and future threats to the uses and values.
- Community consultation – Undertake targeted consultation with the local community to test and confirm the draft community uses and environmental values. Identify community members interested in assisting with scoring of the uses and values for each micro-sub-catchment.
- Scoring workshop – Hold a scoring workshop including participants from Council, the community and other experts (if necessary) to score community uses and environmental values for individual waterways / waterway reaches.

Following completion of this refined Step 1 of the RBF for the selected sub-catchment, it is recommended that Council select a high priority micro sub-catchment within the selected sub-catchment to progress Steps 2 to 5 of the RBF. This may involve selecting a specific waterway reach to focus on.