

# COASTAL QUATERNARY GEOLOGY MAPPING: FILLING THE NEWCASTLE TO WOLLONGONG GAP

Alexa Troedson  
Geological Survey of New South Wales  
NSW Trade & Investment, Maitland, NSW

## Abstract

Detailed (1:25 000 scale or better) digital geological mapping of surficial coastal Quaternary geology of the Newcastle to Wollongong region has recently been completed on behalf of the Geological Survey of New South Wales. This project has filled in the mapping gap that remained after completion of the Coastal Quaternary Geology Mapping Project undertaken for the Comprehensive Coastal Assessment (CCA) (Troedson & Hashimoto, 2008; Troedson, 2013).

The new geological mapping extends from the southern bank of the Hunter River in the north, to northern Lake Illawarra in the south. Inland coverage varies but typically extends to the heads of coastal creeks. The mapping is based on geological interpretation of remotely sensed LiDAR digital elevation model (DEM) and DEM-derived hillshade imagery, aerial imagery, soils data, geological records from the NSW water bores database and other existing geological information. Very limited field checking was carried out.

Compared to previously available mapping, the new mapping features:

- greatly improved accuracy of Quaternary–bedrock boundaries;
- consistent and detailed classification of Quaternary deposits;
- seamless boundaries with the adjoining CCA Quaternary geology.

This paper presents some examples of the new mapping for key areas and discusses limitations and potential applications. The new mapping will be incorporated into the statewide NSW Seamless Geology Project database being compiled by the GSNSW and will be publicly available through its online data delivery systems.

## Introduction

Whether your professional interest in the coastal environment is management, planning, engineering or basic science, geological mapping is one of the key data sets that can contribute to an understanding of that environment. Most geological maps for NSW are produced by the Geological Survey of New South Wales (GSNSW). Traditionally, such mapping has been compiled at 1:250 000 or 1:100 000 and published as hard copy map sheets. Such map sheets, dating from the 1960s to the 2000s, exist for all regions of coastal NSW. While these maps are appropriate for regional studies, they have significant limitations for applications such as environmental management, land use assessment, natural hazards assessment and geotechnical engineering. Issues include relatively imprecise geological boundaries at local scales, lack of edge-matching and inconsistent classification schemes between map sheets. In many cases there is minimal detail for the unconsolidated Quaternary sedimentary deposits of alluvial, estuarine and coastal barrier origin which occur extensively in coastal regions.

In response to the need for more detailed and consistent geological mapping of NSW coastal regions, from 2002 to 2004 a team from the GSNSW undertook the Coastal Quaternary Geology Mapping Project enabled by funding from the Comprehensive Coastal Assessment (CCA). This project involved production of new 1:25 000 seamless maps of the Quaternary coastal geology of NSW regional areas. This mapping was released on DVD as a digital GIS data set along with simplified bedrock geology data and associated data, reports and metadata (Troedson & Hashimoto, 2005) and on the CCA Toolkit double DVD set (NSW Department of Planning & Environment, 2007). Subsequently, two series of hard copy maps for the north and south coasts of NSW respectively were created based on the Quaternary geology digital data, and the report was released as a GSNSW Bulletin with DVD insert (Troedson & Hashimoto, 2008).

After completion of the Coastal Quaternary Geology Mapping Project, a gap in map coverage remained over the greater metropolitan areas of Newcastle, Sydney and Wollongong, which were outside the CCA study area. A project has recently been undertaken on behalf of the GSNSW to map the surficial Quaternary geology of these regions in order that a seamless coverage of coastal NSW may be created. This paper explains and provides some examples of the new data set.

## **Coastal Quaternary geology classification**

The mapping approach is underpinned by research findings on the nature and evolution of NSW coastal Quaternary deposits by Roy, Thom and others (see for example, Roy & Thom, 1981; Roy, 1984, 1994; Roy et al., 2001; Thom, 1984; Roy & Boyd, 1996). A summary of the key concepts is provided in the CCA report (Troedson & Hashimoto, 2008) and greater detail can be found in the literature cited above.

The Quaternary is the most recent period of the geologic timescale and extends from approximately 1.8 million years ago to the present. It is subdivided into the Pleistocene (1.8 million years to 10 000 years ago) and Holocene (10 000 years ago to the present day). Within the project area, most surficial Quaternary deposits are inferred to date from the late Quaternary (approximately the last 125 000 years), in particular the periods of high relative sea level that occurred during the late Pleistocene and from the mid-Holocene to the present. Surficial Pleistocene deposits typically exhibit a greater degree of physical and chemical weathering than Holocene deposits and may be recognised based on geomorphological expression. For example, higher elevation of equivalent deposits are associated with the late Pleistocene sea level highstand that was up to 5 m higher than the mid to late Holocene highstand which continues to the present day.

Three broad depositional environments are recognised in NSW coastal Quaternary deposits, namely coastal barrier, estuarine plain and alluvial plain. These differ in terms of dominant sedimentary processes and sediment sources. *Coastal barrier* deposits occupy the seaward edge of the coastal plain. For the purposes of the mapping, coastal barrier deposits include beaches, coastal dunes, beach-ridge plains, back-barrier flats and related deposits composed mainly of highly reworked quartzose marine sand, and for which the dominant depositional processes are ocean waves and currents, and wind. *Estuarine plain* deposits are those deposited within and at the margins of estuaries and occur in between alluvial and coastal barrier/oceanic depositional environments. They include tidal delta, estuarine basin and fluvial (river) delta deposits. The main processes are tidal currents and locally generated wind waves. Near fluvial inputs, fluvial flow may also be significant. Estuarine plain sediments may include contributions from fluvial and marine sediment sources. *Alluvial plain* deposits occur in the landward parts of the coastal plain, extending upstream from

tidal estuarine reaches of rivers to non-tidal reaches. They consist of fluvial deposits with local contributions from colluvial processes. In coastal NSW, alluvial deposits occur as superficial cover deposits on estuarine deposits in areas where estuaries have been or are being infilled. Further upstream in non-estuarine reaches alluvial deposits form valley-fill deposits.

Local human impacts on natural Quaternary deposits are considerable in some parts of the mapping area. Development on coastal Quaternary deposits commonly involves deposition of fill particularly in areas that were originally swampy. Land reclamation around estuarine shorelines has been common, and excavation and remodelling associated with sand mining has occurred on many of the dune systems within the mapping area. Anthropogenic map units have been used where some combination of the following criteria applies:

- the original identity of Quaternary deposits cannot be recognised due to anthropogenic interference;
- Quaternary deposits are overlain by thick fill;
- extensive excavation of Quaternary deposits has occurred.

The CCA coastal Quaternary classification scheme was used for the new mapping with the addition of six newly-defined units. The Quaternary deposits are classified using codes of three to six letters on the basis of inferred geological age (Holocene, Pleistocene, undifferentiated Quaternary, modern), depositional environment (alluvial, estuarine, coastal barrier, anthropogenic), and mapping unit. The latter is defined on the basis of geomorphological character, depositional process and sediment properties. Some examples are shown in Table 1.

<b>Unit code</b>	<b>Age</b>	<b>Depositional system</b>	<b>Unit name</b>	<b>Lithologies</b>
<b>Qhem</b>	Holocene	Estuarine Plain	Estuarine basin and bay	Clay, silt, shell, fluvial or marine sand
<b>Qhbb</b>	Holocene	Coastal Barrier	Sandy beach	Marine sand, shell, gravel
<b>Qpat</b>	Pleistocene	Alluvial Plain	Terrace	Silt, clay, fluvial sand, gravel
<b>Qmxe</b>	Modern	Anthropogenic	Reclaimed estuarine areas	Fill

**Table 1. Examples of Quaternary geology units used in mapping**

## **Mapping extent**

The area covered by the new Quaternary mapping is illustrated in Figure 1. The project area extended from the southern bank of the Hunter River in the north to northern Lake Illawarra in the south, in order to adjoin the boundaries of the existing north and south coast CCA Quaternary mapping. In most areas, the inland extent of mapping is to the heads of coastal valleys. The Hunter and Hawkesbury–Nepean river systems are exceptions. For the Hunter, the mapping terminates within the lower parts of the fully alluvial (i.e. non-estuarine-influenced) tracts of the main channel and tributaries. For the Hawkesbury–Nepean, detailed mapping extends to the vicinity of Pitt Town, with more generalised mapping extending to the Penrith area. Both subaerial and subaqueous deposits were mapped albeit to different levels of detail and certainty. Offshore sediments have not been mapped. The shoreline boundary was taken from

the Smartline mapping, which is based mostly on best available NSW Maritime data sets (Sharples et al., 2009).

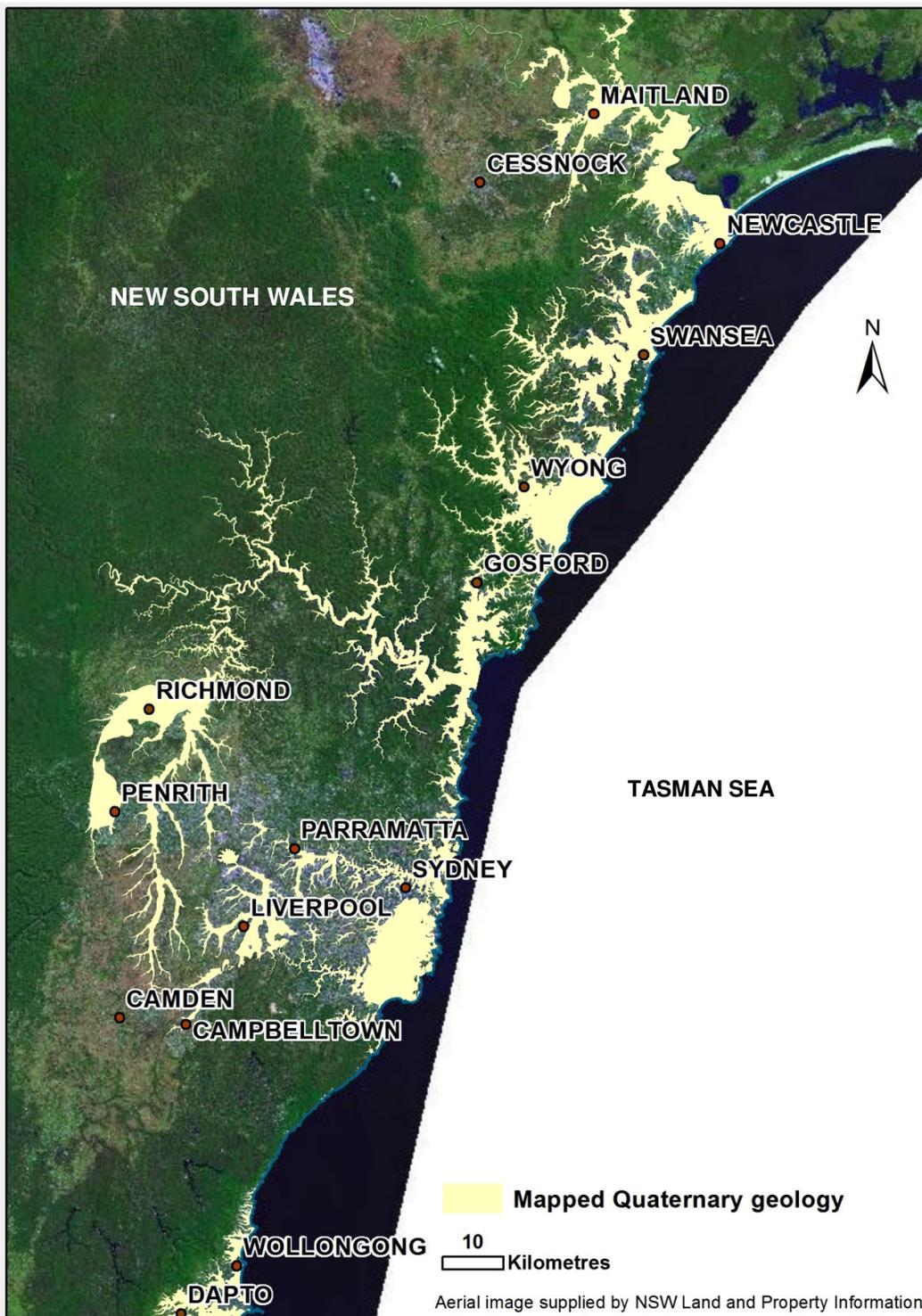


Figure 1. Extent of coastal Quaternary geology mapping

## **Mapping methodology**

The mapping is based on geomorphological and geological interpretation of remotely sensed LiDAR digital elevation model (DEM) data and derived hillshade imagery supplied by NSW Land and Property Information and Maitland City Council, aerial imagery, soils data, geological records from the NSW water bores database supplied by the NSW Office of Water, and other existing geological information and literature. Due to time and budget constraints, very limited field checking was done. The mapping was created in ArcGIS software using a digitising tablet and pen.

## **Quaternary geology of NSW central coast**

Significant features of the Quaternary geology of the project area include the following:

- Wide regional variations in the nature and extent of Holocene coastal barrier development
- Minimal surface exposure of Pleistocene coastal barrier deposits (unlike the extensive surficial Pleistocene coastal barrier deposits of northern NSW)
- Twenty-one distinct estuarine water bodies of varying type and degree of maturity in terms of Holocene depositional infilling
- Three large barrier lake systems (Lake Macquarie, Tuggerah Lakes and Lake Illawarra) in which medium-scale coastal creeks terminate
- Two estuaries associated with very large alluvial systems — the Hawkesbury–Nepean River and the Hunter River, the only mature (largely infilled) riverine estuary in the study area
- Inferred widespread surface to near-surface Pleistocene estuarine and alluvial deposits on the margins of the Hunter estuarine–deltaic plain, in the southern Tuggerah Lake to Gosford area, in the northern beaches of Sydney, western Sydney and the Wollongong area.

## **Mapping examples and applications**

Four examples of the new Quaternary geology mapping are discussed below. In each case a comparison is made with previously available mapping to illustrate the improved mapping accuracy and detail provided by the new data. These examples also demonstrate some of the limitations of the data including the difficulty of interpretative mapping in areas where the surface expression of natural deposits has been disrupted by development. The mapping is shown draped with partially transparent hillshade imagery derived from LiDAR DEM data to emphasise the geomorphology. The underlying aerial photograph shows through in areas mapped as bedrock.

### ***Example 1 – Newcastle area***

The first example is from the urban Newcastle area. The Quaternary geology depicted on the Newcastle Coalfield Geology 1:100 000 sheet is shown in Figure 2, with new Quaternary geology mapping for the same area shown in Figure 3.



mapping, the Quaternary–bedrock boundary was relatively imprecise and the Quaternary geology was differentiated into only two unit types — alluvium (pale orange) and coastal sand (yellow). Based largely on elevation (mainly 4.5–6.5 m above sea level) and geomorphic expression, most of these deposits are inferred to be Pleistocene in age. Lower elevation areas (mostly <2 m above sea level) adjacent to the Hunter River are dominantly Holocene tidal delta sand deposits covered by thick filling. Despite the plethora of borehole information in the area, the extent of development across the region renders more detailed interpretation problematic.

The new geological mapping of this area is useful for understanding environmental and geotechnical constraints to development, including the distribution of potential acid sulphate soils, for which the greatest risk is associated with Holocene estuarine deposits. The new mapping also has use in earthquake risk modelling, as a greater seismic risk to infrastructure areas is associated with areas underlain by unconsolidated (Quaternary) deposits rather than bedrock.

### ***Example 2 – Wyong area***

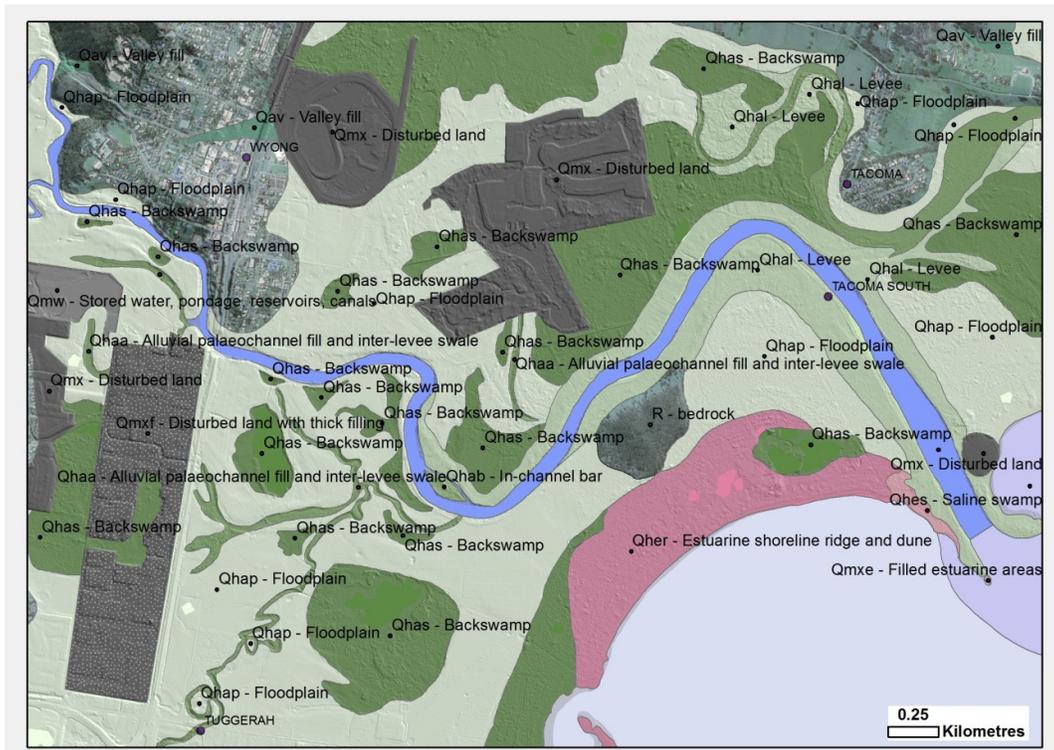
The second example is from the Tuggerah Lakes area near Wyong. In this area, the best available previous mapping is from the Gosford–Lake Macquarie 1:100 000 geology sheet, provisional edition, in which Quaternary deposits are differentiated mainly on the basis of sediment type. In Figure 4, this mapping shows the Quaternary geology differentiated into three units, Qa (gravel and sand), Ql (subaqueous lithic sand), and Qm (subaqueous mud and sandy mud).



**Figure 4. Wyong area, 1:100 000 Quaternary geology**

In the new mapping the alluvial plain of the Wyong River is differentiated into many discrete units indicating areas of backswamp, levee, palaeochannel and floodplain

deposits. Surficial areas of the alluvial plain that have undergone significant disturbance and filling are mapped. Potential applications might include riverbank erosion studies, soils investigations and geotechnical investigations.



**Figure 5. Wyong area, new Quaternary geology**

***Example 3 – Narrabeen area***

The third example is from the Narrabeen area on the northern beaches of Sydney. Previous mapping in this area is from the Sydney 1:100 000 geology sheet which did not show subaqueous deposits (Figure 6). The new mapping depicts the approximate distribution of tidal delta, estuarine basin and fluvial delta deposits in the lake, and provides more detail of surrounding terrestrial Quaternary deposits.

Subaqueous sediment bodies were mapped based on their visibility on aerial imagery and from information in published documents, particularly the work of Peter Roy and co-workers who documented the approximate extents of marine tidal delta sands, estuarine basin mud deposits, and fluvial delta sands for many of the major waterways within the project area. This information can contribute to estuary management due to the links between deposit type, estuarine processes and ecology.



Figure 6. Narrabeen area, 1:100 000 Quaternary geology

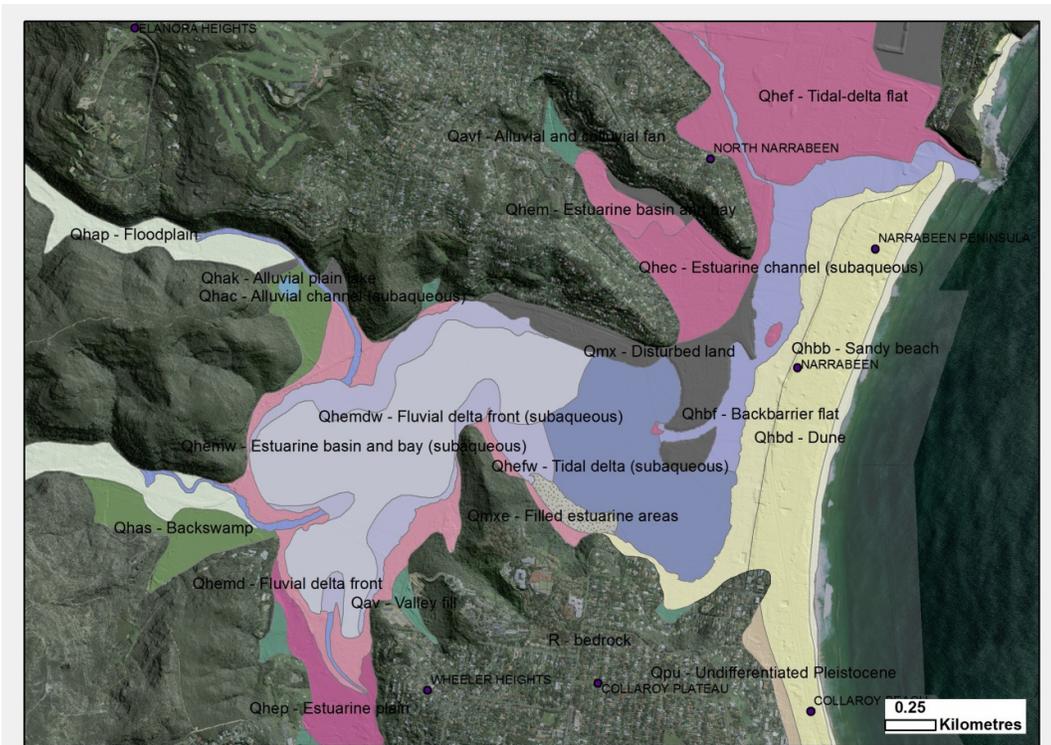


Figure 7. Narrabeen area, new Quaternary geology

### Example 4 – Lake Illawarra

The final example is from northern Lake Illawarra area, near Wollongong.

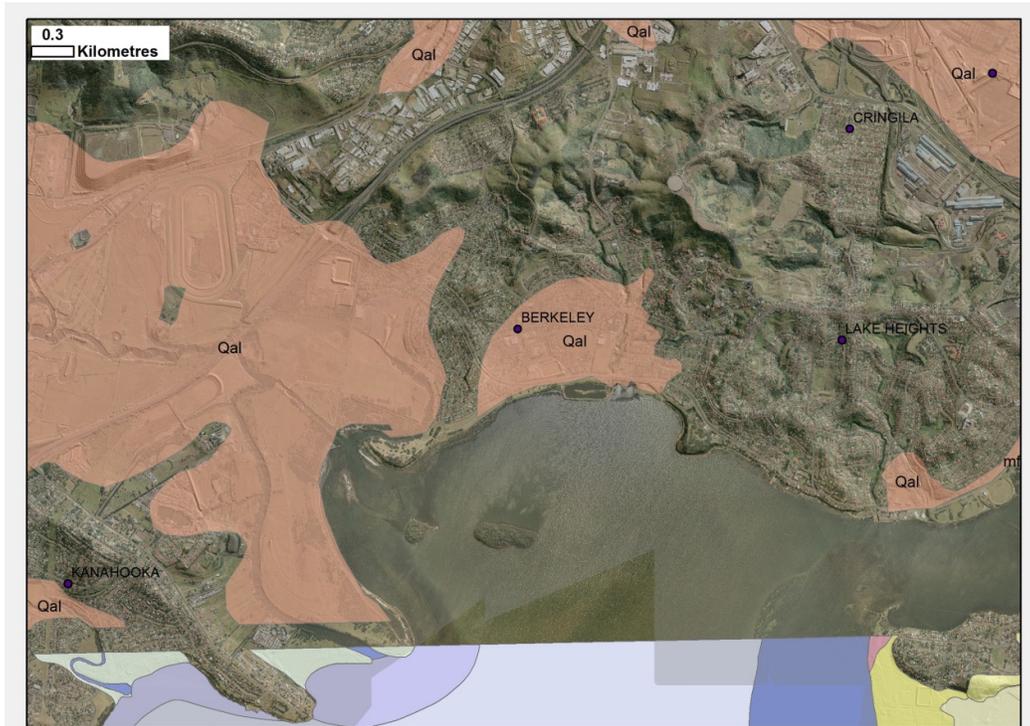


Figure 8. Northern Lake Illawarra area, 1:100 000 Quaternary geology

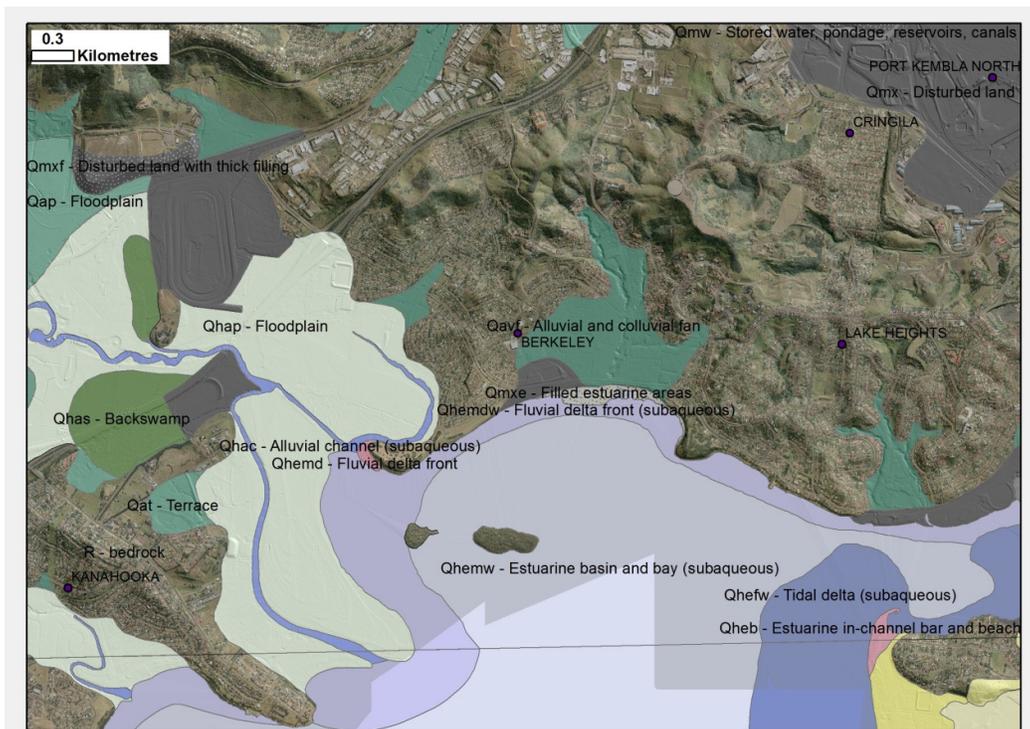


Figure 9. Northern Lake Illawarra area, new Quaternary geology

The Wollongong–Port Hacking 1:100 000 geology sheet depicts the Quaternary deposits in this region as undifferentiated alluvium (Qal) (Figure 8). The new data shows subaqueous estuarine and alluvial plain detail, and more accurate Quaternary–bedrock boundaries (Figure 9). The northern border of the south coast CCA Quaternary mapping is also shown in both figures, illustrating in Figure 9 the seamless boundary with the new Quaternary geology data.

## Data access

The new mapping is to be integrated with the CCA coastal Quaternary geology mapping and incorporated into the statewide NSW Seamless Geology Project database being compiled by the GSNSW. This database, along with seamless bedrock geology layers, will be made publicly available through an online data delivery system.

The CCA digital Quaternary geology data is available for purchase from the GSNSW as a DVD data package and report. The GIS data files provided in that package enable flexibility with data display, processing and integration with other data. Double-sided paper maps displaying the CCA mapping and based approximately on LGA areas are also available for individual purchase. It is hoped that the new coastal Quaternary geology mapping will be integrated with the CCA mapping and made available as a single statewide coastal geology GIS data set in the future.

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