

FROM CATCHMENT TO INNER SHELF: INSIGHTS INTO NSW COASTAL COMPARTMENTS

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Abstract

This paper addresses the coastal compartments of the eastern coast by analysing characteristics of the seven biggest catchments in NSW (Shoalhaven, Hawkesbury, Hunter, Manning, Macleay, Clarence and Richmond) and coastal landforms such as estuaries, sand barriers, beaches, headlands, nearshore and inner shelf, providing a framework for estimating sediment budgets by delineating compartment boundaries and defining management units. It sheds light on the sediment dispersal by rivers and longshore drift by reviewing literature, using available information/data, and modelling waves and sediment dispersal. Compartments were delineated based on physical characteristics through interpretation of hydrologic, geomorphic, geophysical, sedimentological, oceanographic factors and remote sensing. Results include identification of 36 primary compartments along the NSW coast, 80 secondary compartments on the South and Central coast, and 5 tertiary compartments for the Shoalhaven sector.

Introduction

This paper looks at the coastal compartments of the eastern coast of NSW by delineating boundaries and defining management units, providing a framework for estimating sediment budgets.

Compartments are subdivisions of the coastal zone for management and planning, separated by major obstacles, such as headlands, which stop longshore transport of sediment. Compartmentalisation identifies boundaries within which to consider the implications of engineering works and management strategies especially at the state and local government levels to reduce risks and protect coastal assets and values.

There is a need to look at coastal systems in terms of the existence of a wide range of possible transport conditions (Davies, 1974) as compartments are leaky to some extent (Woodroffe, 2002). Often some subaerial and/or subaqueous leakage occurs under storm conditions, but it is still profitable to think in terms of compartments even where it is known that sediment is entering or leaving by longshore (Davies, 1974) or other movements.

Compartments occupy a threefold hierarchy of scales based on sediment flows. The primary level is based on the influence of large landforms and offshore processes; the secondary level on medium landforms and regional sediment processes and the tertiary level is based on individual beaches (Thom, 2014).

Compartment boundaries at primary scales are defined by several features. Headlands, large engineered structures and, in some cases, estuaries mark the longshore limit of primary compartments. The landward limit is set by the back of the barrier or dune

system, whereas the offshore limit is commonly placed at the 30 m isobath. Examples of case studies down to the tertiary scale in Australia include Swan (Stul et al. 2012) and Pilbara regions (Stul et al. 2014) in Western Australia, Avoca (Mariani et al. 2013), Cabarita (Mariani et al. 2013) and Shoalhaven (Carvalho and Woodroffe, 2014) beaches in NSW.

The NSW coast extends for about 1600 km comprising approximately 750 beach deposits of up to 30 km in length in the north, to pocket beaches in the south (Short, 2006). The coastal geology consists of five provinces: i) Hard Silurian Metamorphic rocks north of the Clarence River; ii) Soft Mesozoic Sedimentary and Tertiary basalts of the Clarence-Moreton Basin; iii) Hard–Moderately hard Palaeozoic Metamorphic rocks of New England Fold Belt; iv) Soft Triassic/Permian sedimentary rocks and Jointed hard Hawkesbury sandstone of the Sydney Basin; and v) Hard Palaeozoic Metamorphic and Igneous rocks of the Lachlan Fold Belt in the south.

The wave dominated microtidal coastal zone east of the Great Dividing Range (Fig. 1) has a continental shelf that is generally less than 50 km wide and break of slope around 150 m depth contour. Seven major catchments (max. elevation < 1600 m and area > 6000 km²) cover ~77% of the coastal zone, discharging sediments into seven of the biggest estuarine systems of NSW. The general average monthly catchment rainfall decreases from north to south. Storm waves recorded by offshore buoys and summarised by Shand et al. (2010) last longer in the north and are more frequent in the Sydney area, where it also reaches the highest offshore mean and maximum wave heights. Longshore drift follows the main swell direction from southeast to north.

Vast quantities of quartzose sand occur on the inner continental shelf of NSW between 20 and 70 m depth. Its occurrence is associated with two types of deposits: thin inner shelf sand sheets composed of iron-stained coarser sand grains; and linear shore-parallel 20-30 m thick shelf sand bodies made of fine-medium grains (Roy and Stephens, 1980; Roy, 2001; Whitehouse, 2007).

Methods

Compartments were delineated based on physical characteristics through reviewing the literature and interpreting hydrologic, geomorphic, geophysical, sedimentological, oceanographic and remote sensing data.

The identification of compartment boundaries along the NSW coast at primary level had as a starting point the preliminary assessment of compartmentalisation and littoral bypassing by Chapman et al. (1982). Boundary limits were set to the 30 m contour depth for the offshore; landward limit of Holocene systems for the onshore; and Headlands and engineered structures, tide-dominated estuaries and embayments, in between compartments.

South and Central coast secondary level compartments were defined by subdividing primary compartments into smaller ones, having as a starting point sediment data collected by Davies (1979). 176 sample points were digitised and interpolated for sediment grain sizes. Wave refraction modelling was applied to provide information about wave height and direction incidence on the Central and South coast. Secondary compartment limits were set to the 15 m depth contour for offshore, while landward limit

was kept the same as the primary compartments. Boundaries between secondary compartments were based on smaller headlands and engineered structures, tide-dominated estuaries and embayments, sediment type and wave refraction.

The Shoalhaven tertiary compartment was delineated based on the sediment results by Carvalho and Woodroffe (2015), wave refraction and unpublished bathymetric surveys and side scan imaging. Boundary limits were set to the 15 m contour depth for the offshore; and the foredune for the onshore

Results and discussion

36 primary compartments were identified along the NSW coast (Fig.2). The mean length of compartments was 30.4 km. The smallest (3.7 km) primary compartment is located between Pretty Point and Burrewarra Point (no. 28), on the South coast. Due to the rocky, embayed nature and orientation of the Central and South coast, long primary compartments are found only in between Birubi Point and Tudibaring Heads (no. 7; 97.8 km) and Burrewarra Point and Tathra Head (no. 29; 101 km), respectively. On the other hand, three long compartments are found north of Seal Rocks: in between Tweed River and Yamba Heads (no. 1; 142.6 km), Yamba Heads and Bare Bluff (no. 2; 81.3 km) and the longest NSW primary compartment, between South West Rocks and Seal Rocks (no. 5; 180.8 km). Despite the long extent of these compartments, some experience partially long-term loss of nearshore sand to deep water sinks offshore, as in Cape Byron (no. 1) and in between Foster and Seal Rocks (no. 5), as pointed out by Roy and Stephens (1980) and Chapman et al. (1982).

Apart from the Shoalhaven River, the large NSW coastal rivers are thought to supply insignificant quantities of sand to the coast, at present time (Chapman et al. 1982). However a study by Kidd (1978) has revealed that the smaller catchment of the Bega River (1945 km²), on the south coast, does deliver sediment to the coast (no. 29), as shown by the mixing of fluvial and marine sand. Anthropogenic changes in tidal regimes also contribute to delivery of sand to the coast, as happened after the Wallis Lake (no. 5) entrance training works construction, at Forster, where the tidal range increased and scour of the entrance channel occurred (Nielsen and Gordon, 1980).

The Central and South coast of NSW is depicted on Fig. 3. The majority of the shelf is dominated by fine and medium sand. Silt deposits are mainly found in the mid shelf between south of Port Stephens and Gosford, adjacent to primary compartments no. 7 and 8, whereas very coarse sand is found off Ulladulla, Long Reef and Newcastle Bight, the latter one related to an old drainage system of the Hunter River (Roy and Stephens, 1980).

Broadly speaking, average wave conditions (1.6m/9.5s/135°) cause northwards drift from Cape Howe until south of Batemans Bay, where the orientation of the coastline changes and beaches become swash-aligned with little or no drift occurring all the way until Bate Bay. Obviously, features such as Green Cape acts as a sand trap and the north and south vertical headlands flanking Jervis Bay impose changes in the coastal orientation and drift to inner and outer adjacent embayments. The rugged coastline between Bate Bay and the Hawkesbury River is filled with tide-dominated estuaries, which act as sediment sinks in their flood tide deposits. Not much longshore drift is expected with the average wave incidence there. From Gosford to Newcastle the coastline changes its

orientation and drift-aligned beaches with little longshore transport are found. The broad Newcastle Bight is also oriented normal to the predominant wave regime and a large gross, but no net littoral drift occurs. A deficit budget is actually found there due to the loss of sand from the beach to the dune system (Roy and Stephens, 1980).

80 secondary compartments were created subdividing the 30 primary compartments that compose the Central and South coast (Fig. 4). The mean length of secondary compartments is 7.8 km. The smallest (1.1 km) secondary compartment is located between North Head and Three Islet Reef (no. 28a), just north of Batemans Bay, on the South coast, and the longest (34.9 km) between (south of) Port Hacking Point and Sandon Point (no. 14b; Table 2). The most subdivided primary compartment was the 101 km long one that extends from Burrewarra Point to Tathra Head (no. 29; Table 1). This primary compartment was divided into 11 secondary compartments.

There is a need for management of compartments whose boundaries were created as a result of engineering like Coffs Harbour (between no. 3 and 4), halting northward littoral drift from prograded Holocene deposits in the south to embayed pocket beaches with narrow backed barriers. Joint management of secondary compartments especially at numbers 7b, 7d, 7f, 8c and 16a by different councils is also needed, as changes to landforms within sediment compartments operate regardless of administrative boundaries (Stul et al. 2012).

An online GIS platform (<http://cdb.io/1PEzQyj>) has been set up depicting the primary and secondary compartments so that regional and local specialists can provide their feedback.

Five tertiary compartments (Fig. 5) comprise the Shoalhaven coast (from Black Head at Gerroa to Beecroft Peninsula). One secondary compartment remained undivided while two others (17a and 17c) were subdivided into four tertiary compartments based on sediment characteristics and transport. The secondary compartment from Black Head to Crookhaven Heads (17a) was divided at Shoalhaven Heads, and the one from Penguin Head to Beecroft Peninsula (17c) was segmented at Hammerhead Point.

The Shoalhaven Heads opening dynamics and sediment dispersal as pointed out by Wright (1970) and Carvalho and Woodroffe (2015) were responsible for the subdivision into N/S tertiary compartments. Grain size and sorting decrease from Shoalhaven Heads towards both north and south ends. A very distinct sediment type is found at Culburra with iron-coated quartz grains all over the embayment. Granulometry increases from Penguin Heads (south) to Crookheaven Heads (north) where well-sorted sediments are found. At Hammerhead Point an extensive submerged reef platform extends offshore isolating the subaqueous sediments from the mid-northern part of the embayment. South of Hammerhead Point, sediment is very different from the iron-coated quartz found to the north. Grainsize increases and sorting improves towards Warrain.

The Shoalhaven coastal compartment can be considered a closed compartment. The southern part of the Shoalhaven coastal sector is bordered by Jervis Bay which imposes a barrier for transport of sand northwards. The 25m thick linear shelf sand body deposit (Ferland, 1987) around Beecroft Head is blocked by the Sir John Young Banks. On the northern end, longshore transport of sediment to the north finds the underwater extension of the Black Head platform difficult to transpose. Recent bathymetric survey and side scan imaging has shown the prolongation of the rock platform for at least 2 km

offshore and the existence of a small discontinuity of the reef around 19 m depth and 750 m to the south west of the subaerial platform, making northwards drift difficult. However, during flood events like the ones that happened in June/2013 and August/2015, the compartment can become leaky. The artificial breaching of Shoalhaven Heads by Shoalhaven council, transported fine sediments out of the primary compartment as depicted on fig. 6.

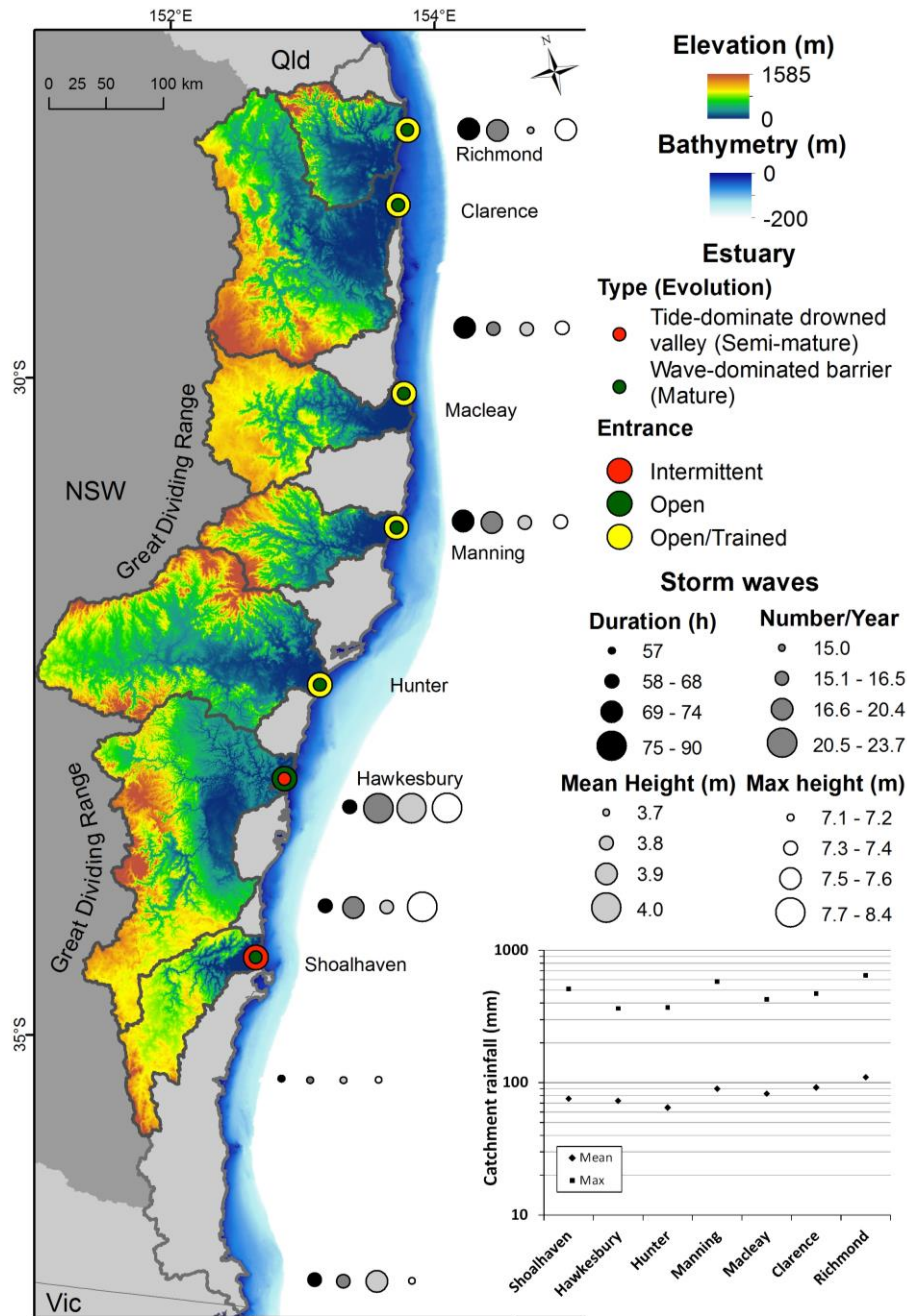


Fig. 1: Physical characteristics of the NSW coastal zone. Storm data retrieved from Shand et al. (2010). Catchment rainfall derived from information retrieved from BoM's gridded data.

Table 1: NSW Primary compartments.

Primary Compartment	Length* (km)	Start (N)	End (S)
1	142.6	Tweed River	Yamba Heads
2	81.3	Yamba Heads	Bare Bluff
3	17.6	Bare Bluff	Corambirra Point
4	63.5	Corambirra Point	South West Rocks
5	180.8	South West Rocks	Seal Rocks
6	57.3	Seal Rocks	Birubi Point
7	97.8	Birubi Point	Tudibaring Heads
8	30.7	Tudibaring Heads	Long Reef
9	9.1	Long Reef	North Head
10	7.8	North Head	Ben Buckler Headland
11	8.6	Ben Buckler Headland	Malabar Headland
12	4.1	Malabar Headland	Cape Banks
13	6.3	Cape Banks	Kurnell P. (Merries Reef)
14	56.3	Kurnell P. (Merries Reef)	Red Point (Hill 60)
15	11.8	Red Point (Hill 60)	Bass Point
16	21.6	Bass Point	Black Head
17	25.7	Black Head	Beecroft Penin. (North)
18	9.8	Beecroft Penin. (North)	Point Perpendicular
19	11.4	Point Perpendicular	Steamer Head
20	4.2	Steamer Head	St. Georges Head
21	23.5	St. Georges Head	Bannisters Point
22	4.7	Bannisters Point	Warden Head
23	23.6	Warden Head	O'Hara Head
24	10	O'Hara Head	Point Upright
25	5.5	Point Upright	Flat Rock Point
26	4.8	Flat Rock Point	North Head
27	9.8	North Head	Pretty Point
28	3.7	Pretty Point	Burrewarra Point
29	101	Burrewarra Point	Tathra Head
30	14.9	Tathra Head	Tura Head
31	5.4	Tura Head	Merimbula Point
32	5.3	Merimbula Point	Haycock Head
33	11.8	Haycock Head	Worang Point
34	5.1	Worang Point	Red Point
35	20.1	Red Point	Green Cape
36	27.7	Green Cape	Cape Howe

*Distance in a straight line between the start and end points (landward/nearshore interface) of compartments

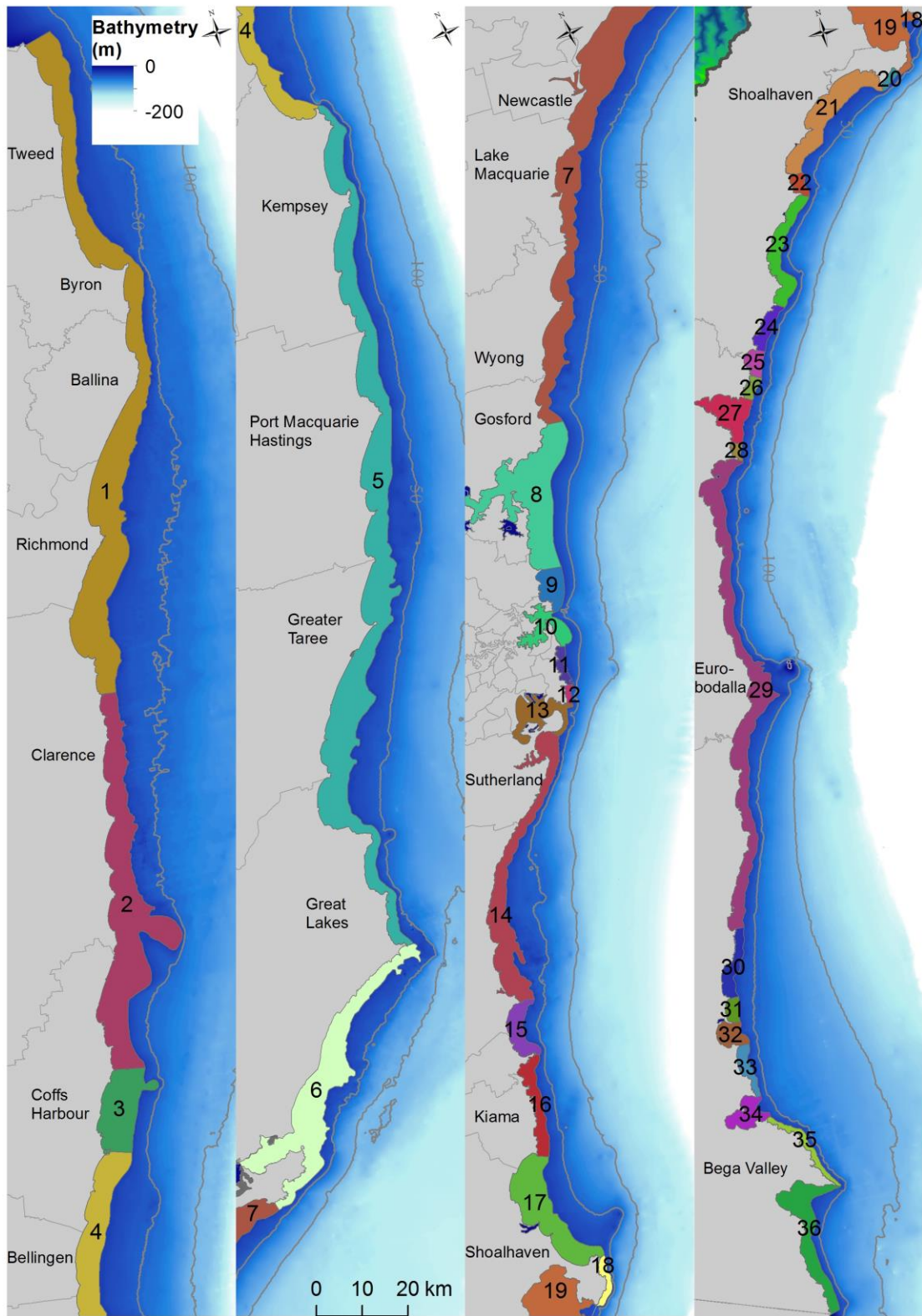


Fig. 2: 36 primary compartments along the NSW coast

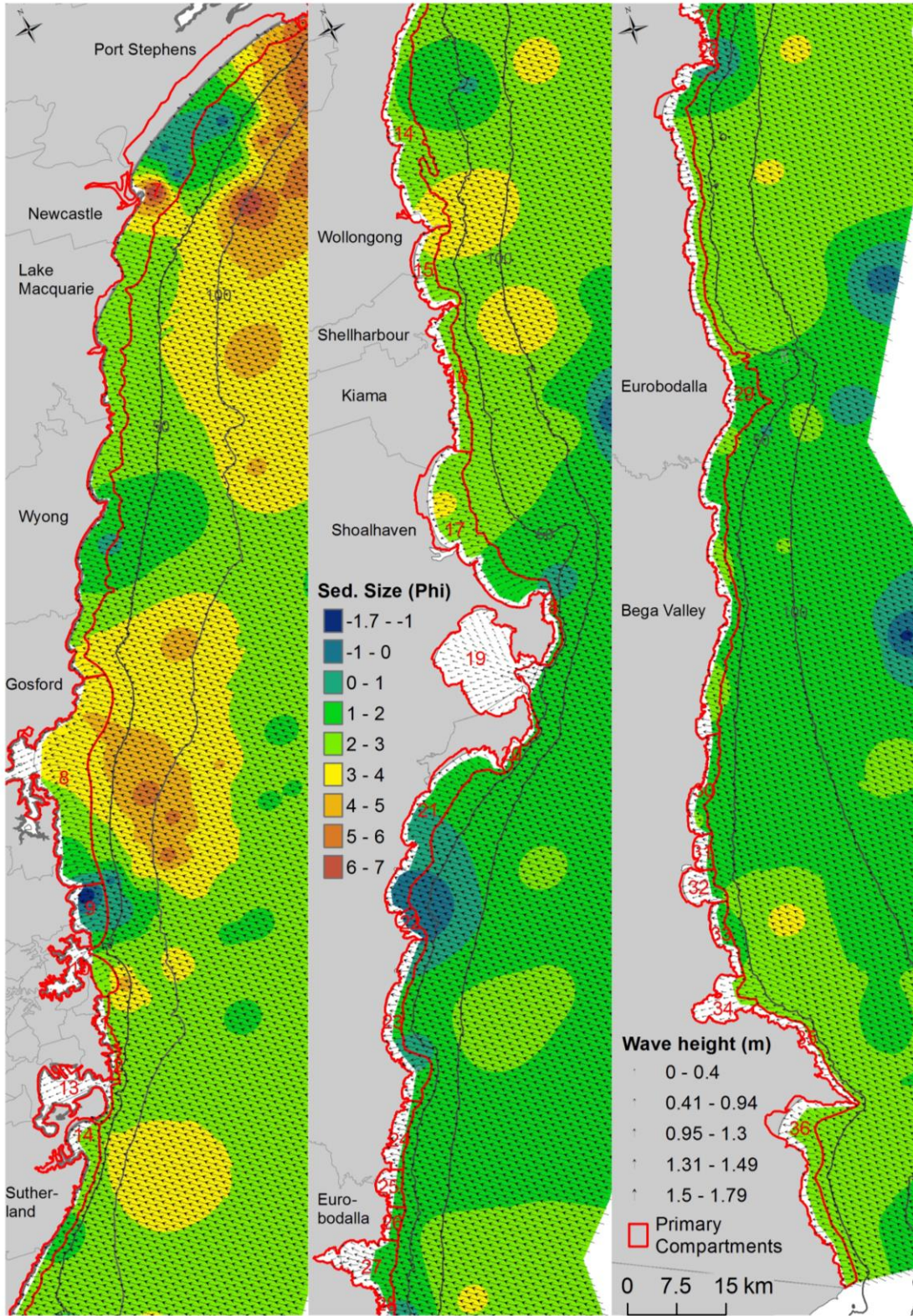


Fig. 3: Surficial sediment distribution after Davies (1979), wave height and direction on the Central and South Shelves of NSW. Wave results are based on modelled propagation of average wave conditions (1.6m/9.5s/135°)

Table 2: Secondary compartments of the Central and South coast of NSW.

Secondary Compartment	Length* (km)	Start (N)	End (S)
7a	31.3	Birubi Point	Nobbys Head
7b	11	Nobbys Head	Redhead Point
7c	14.9	Redhead Point	Spoon Rocks breakwall
7d	8.8	Spoon Rocks breakwall	Wybong Head
7e	10.3	Wybong Head	Norah Head
7f	25.9	Norah Head	Tudibaring Heads
8a	11.5	Tudibaring Heads	Box Head
8b	4.1	Box Head	Barrenjoey Head
8c	17.9	Barrenjoey Head	Long Reef
9a	9.1	Long Reef	North Head
10a	2.9	North Head	Middle Head
10b	1.3	Middle Head	South Head
10c	6.7	South Head	Ben Buckler Headland
11a	2.8	Ben Buckler Headland	Shark Point
11b	5.9	Shark Point	Malabar Headland
12a	4.1	Malabar Headland	Cape Banks
13a	1.9	Cape Banks	Botany Bay NP
13b	4.4	Botany Bay NP	Kurnell P. (Merries Reef)
14a	5.8	Kurnell P. (Merries Reef)	South of Port Hacking P.
14b	34.9	South of Port Hacking P.	Sandon Point
14c	4.1	Sandon Point	Bellambi Point
14d	6.3	Bellambi Point	Flagstaff Point
14e	5.8	Flagstaff Point	Port Kembla Breakwall (S)
14f	2.3	Port Kembla Breakwall (S)	Red Point (Hill 60)
15a	8.7	Red Point (Hill 60)	Barrack Point
15b	2.1	Barrack Point	Shellharbour B.T.P. Platform
15c	3.1	Shellharbour B.T.P. Platform	Bass Point
16a	8.7	Bass Point	Kiama Blowhole
16b	12.9	Kiama Blowhole	Black Head
17a	13.8	Black Head	Crookhaven Heads
17b	3.8	Crookhaven Heads	Penguin Head
17c	10.9	Penguin Head	Beecroft Peninsula (N)
18a	4.1	Beecroft Peninsula (N)	Drum & Drumsticks
18b	6.3	Drum & Drumsticks	Point Perpendicular
19a	3	Point Perpendicular	Dart Point
19b	7.1	Dart Point	Plantation Point
19c	8.5	Plantation Point	Governor Head
19d	6.7	Governor Head	Steamer Head
20a	4.1	Steamer Head	St. Georges Head

21a	14.8	St. Georges Head	Red Head (Bendalong)
21b	10	Red Head (Bendalong)	Bannisters Point
22a	3.1	Bannisters Point	Ulladulla North Headland
22b	1.7	Ulladulla North Headland	Warden Head
23a	6.4	Warden Head	Dolphin Point
23b	13.7	Dolphin Point	Murramarang Point
23c	4	Murramarang Point	O'Hara Head
24a	6	O'Hara Head	Clear Point
24b	4.2	Clear Point	Point Upright
25a	3.8	Point Upright	Wasp Head
25b	1.9	Wasp Head	Flat Rock Point
26a	1.4	Flat Rock Point	Richmond B. Headland
26b	3.4	Richmond B. Headland	North Head
27a	1.1	North Head	Three Islet Reef
27b	5.9	Three Islet Reef	Lilli Pilli Head
27c	3.4	Lilli Pilli Head	Pretty Point
28a	1.8	Pretty Point	Rosedale Headland
28b	2.1	Rosedale Headland	Burrewarra Point
29a	2.2	Burrewarra Point	Long Nose Point
29b	3.2	Long Nose Point	Broulee Island
29c	6	Broulee Island	Moruya Heads
29d	11.6	Moruya Heads	Bingie Bingie Point
29e	9.3	Bingie Bingie Point	Potato Point
29f	19	Potato Point	Bogola Head
29g	19	Bogola Head	Bermagui Point
29h	13.8	Bermagui Point	Goalen Head
29i	3.5	Goalen Head	Bunga Head
29j	12.5	Bunga Head	Baronda Head
29k	4.5	Baronda Head	Tathra Head
30a	7.7	Tathra Head	Turingal Head
30b	7.3	Turingal Head	Tura Head
31a	3.5	Tura Head	Short Point
31b	2	Short Point	Merimbula Point
32a	5.3	Merimbula Point	Haycock Head
33a	7.6	Haycock Head	Lennards Island
33b	4.2	Lennards Island	Worang Point
34a	3.2	Worang Point	Eden Lookout Point
34b	4.5	Eden Lookout Point	Red Point
35a	20	Red Point	Green Cape
36a	10.1	Green Cape	1 km (N) of Jane Spiers B.
36b	19.6	1 km (N) of Jane Spiers B.	Cape Howe

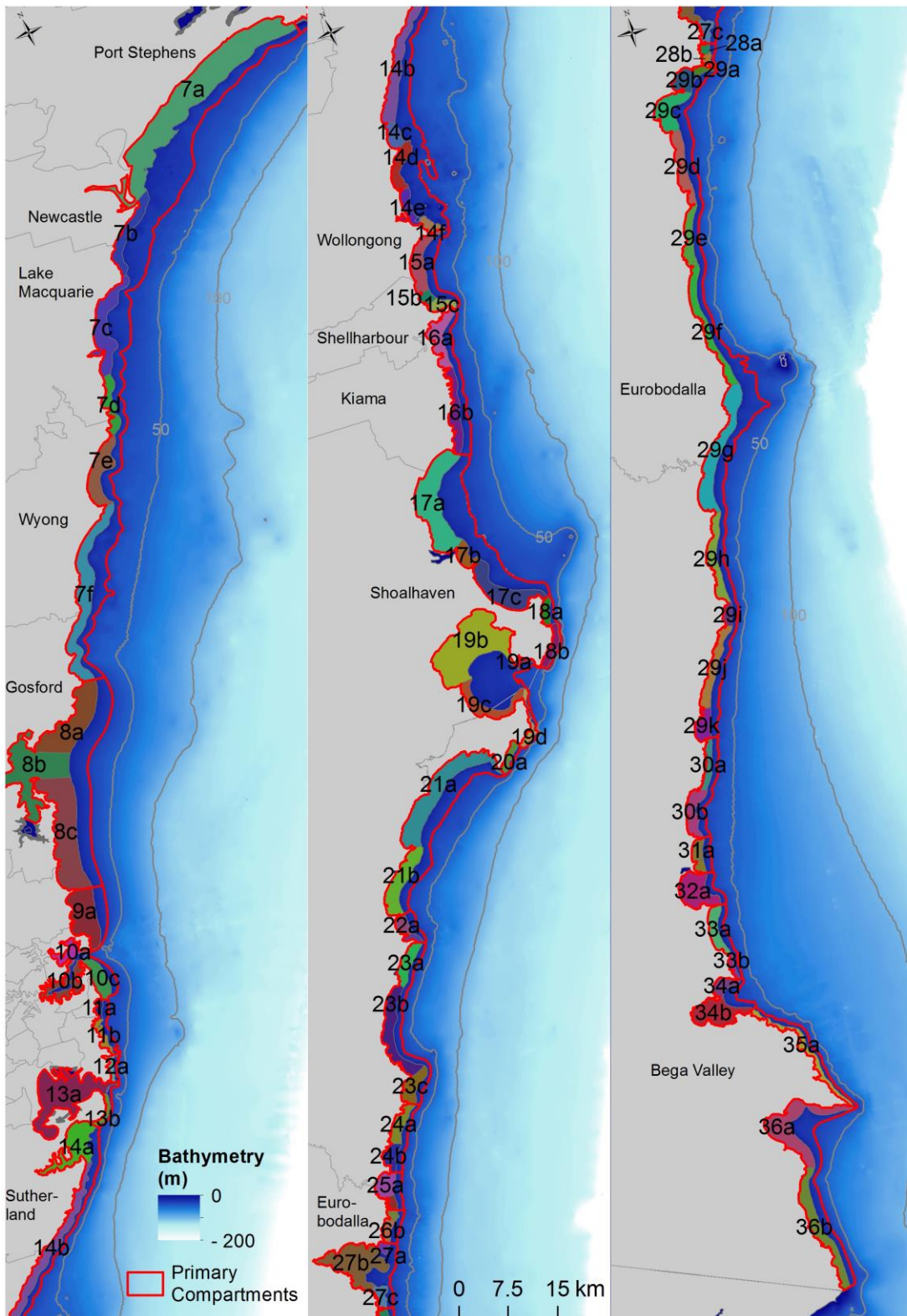


Fig. 4: 80 secondary compartments along the south and central coast of NSW

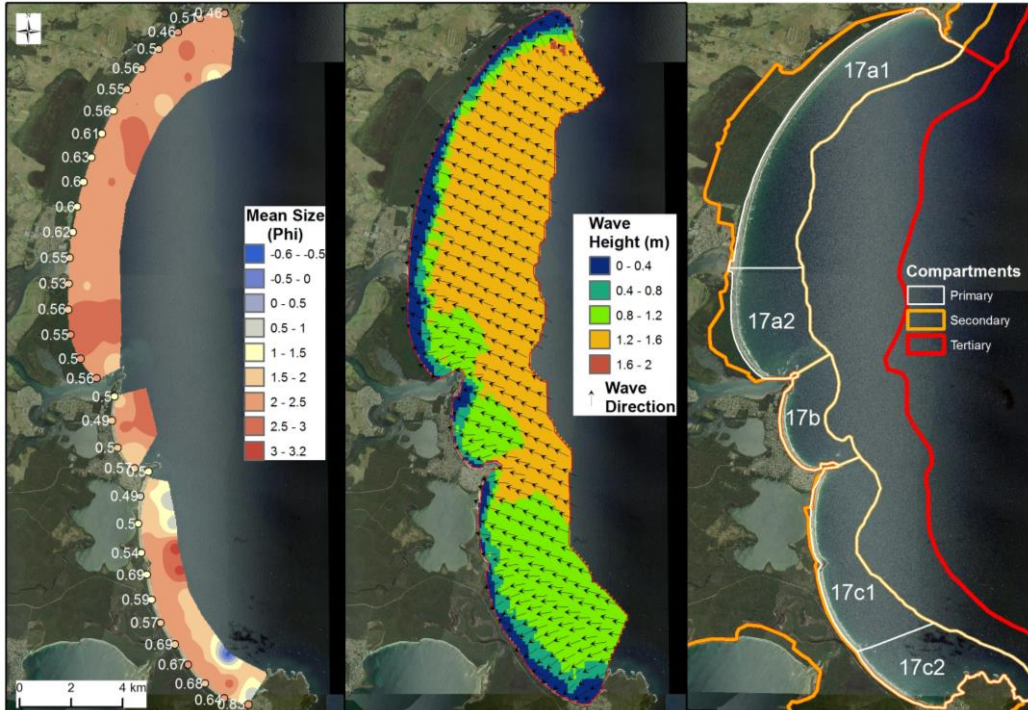


Fig. 5: The Shoalhaven coastal compartment. Mean grain size distribution with labelled sorting values for beach samples (left). Wave height and direction modelled results for average wave conditions (middle). Tertiary compartments subdivisions (right).



Fig. 6: 30/06/2013 Landsat 8 false colour composite showing breached Shoalhaven Heads transporting fine material out of the primary compartment, towards both north and south directions.

Conclusion

36 primary compartments were identified for the coast of NSW. 30 primary compartments in the Central and South coast of NSW (From Birubi Point to Cape Howe) were subdivided into 80 secondary compartments. Five compartments at tertiary level were defined for the Shoalhaven coastal sector (From Black Head at Gerroa to Beecroft Peninsula).

This exercise has allowed the identification of coastal sectors with closed compartments and also secondary compartments where joint management is required by adjacent local coastal managers. An online GIS platform (<http://cdb.io/1PEzQyj>) has been created too, so that different stakeholders can provide comments on the subdivisions that *per se* could change as detailed terrestrial and marine elevation are incorporated, as well as geophysical data.

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