Department of Transport

Coastal Sediment Cells for the Mid-West Coast

Between the Moore River and Glenfield Beach, Western Australia

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Photographs used are from WACoast[30].

The Department of Transport acknowledges Bob Gozzard from Geological Survey of Western Australia for providing the images.

Geological Survey of Western Australia

Seashore Engineering

Executive summary

The aim of this report is to identify a hierarchy of sediment cells to assist planning, management, engineering, science and governance of the Mid-West coast.

Sediment cells are spatially discrete areas of the coast within which marine and terrestrial landforms are likely to be connected through processes of sediment exchange, often described using *sediment budgets*. They include areas of sediment supply (sources), sediment loss (sinks), and the sediment transport processes linking them (pathways). Sediment transport pathways include both alongshore and cross-shore processes, and therefore cells are best represented in two-dimensions. They are natural management units with a physical basis and commonly cross jurisdictional boundaries.

Sediment cells provide a summary of coastal data in a simple format and can be used to:

1. Identify the spatial context for coastal evaluations;
2. Provide a visual framework for communicating about the coast with people of any background;
3. Support coastal management decision-making;
4. Support a range of technical uses largely relating to coastal stability assessment, such as interpreting historic trends, understanding contemporary processes and basis for projection of potential future coastal change; and
5. Reduce problems caused by selection of arbitrary or jurisdictional boundaries.

Boundaries of sediment cells have been identified for the Mid-West coast between the Moore River (Guilderton) and Glenfield Beach (north of Geraldton) in Western Australia. Six primary cells, 15 secondary cells and 41 tertiary cells were identified between the Moore River and Glenfield Beach. The cell hierarchy for the Mid-West coast is presented as maps and tables in this report, and in electronic datasets available from the Department of Transport. They were defined in three steps through selection of:

1. Points along the shoreline (beachface);
2. Offshore and onshore boundaries; and
3. Alongshore boundaries connecting the beachface points to the offshore and onshore boundaries.

This focuses on boundary definition at the beachface where the highest rates of sediment transport are likely to occur.

The cells have been mapped as a hierarchy of primary, secondary and tertiary levels to incorporate three space and time (spatio-temporal) scales. This hierarchical representation of cells gives a basis for implementation of integrated planning and management at a number of scales, from small-scale engineering works, through to large-scale natural resource management.

- Primary cells are related to large landforms, and are most relevant to potential change in large landform assemblages or land systems over longer coastal management timescales of more than 50 years.
- Secondary cells incorporate contemporary sediment movement on the shoreface and potential landform responses to inter-decadal changes in coastal processes.
- Tertiary cells are defined by the reworking and movement of sediment in the nearshore and are most relevant for seasonal to inter-annual changes to the beachface. Mapping of tertiary cells was limited to the beachface point because of insufficient resolution of the available datasets.

Common use of cells is intended to facilitate better integration of coastal management decision-making between governance, science and engineering at a regional and local level.

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Introduction

This report presents a hierarchy of sediment cells along the Mid-West Coast for application in engineering, science, planning, management and governance of the region.

Sediment cell boundaries were mapped and identified at three spatio-temporal scales, along approximately 350km of the Western Australian coast between the Moore River and Glenfield Beach. The area includes the inner continental shelf and coastal lands of the Mid-West Region in the northern Swan Coastal Plain (Figure 1; Figure 2; Appendix A). The three scales range from small, local landforms and the day-to-day processes affecting them to large coastal systems changing over millennia in response to global processes. At each scale the cells identify boundaries within which to consider the potential implications of proposed coastal engineering works as well as for assessment of coastal planning and management practices.

The hierarchy of cells facilitates understanding of contemporary sediment movement, encourages projection of future coastal change at a conceptual level, and establishes a context for qualitative investigations. Additionally, the hierarchy is intended to assist identification of differences in the processes driving coastal change at each scale.

Cells within this report are labelled according to a system described in *Cell labels*.

What are sediment cells?

Sediment cells are spatially discrete areas of the coast within which marine and terrestrial landforms are likely to be connected through processes of sediment exchange, often described using *sediment budgets*. Each includes areas of sediment supply (sources), loss (sinks), and areas through which sediment is moved between sources and sinks (pathways)[1]. These components are illustrated in Figure 3 for all levels in the hierarchy. Cells are natural management units with a physical basis and commonly cross jurisdictional boundaries.

Box 1: Literature on sediment cells

Sediment cells are spatially discrete areas of the coast within which marine and terrestrial landforms are likely to be connected through processes of sediment exchange, often described using *sediment budgets*. Extensive global literature related to coastal sediment cells and sediment budgets is available and has previously been reviewed[2,3,4,5,6,7,8]. The literature includes a number of terms similar in meaning to coastal sediment cell, with slight disparities in their use, although the broad concepts underpinning cell identification and sediment budget estimation are well established[6].

Alternative terms for coastal sediment cell at varied spatial scales are littoral cell[1,9], coastal compartment[10], coastal sector[11], beach compartment or coastal segment[12], sediment cell with smaller coastal process units or sub-cells[13], coastal cell[14], process defined management unit or coastal management unit[15,4], coastal tract[5] and three nested systems of coastal behaviour systems, shoreline behaviour units and geomorphic units[16]. The term sediment cell is used in this report for the Mid-West Region.

Sediment cells are commonly identified as self-contained where little or no sediment movement occurs across cell boundaries[16,8]. This concept is most applicable at a broad scale, such as when defining the scale and limits of coastal investigations[5]. Restriction of sediment movement is not a fundamental characteristic of cells at a fine scale or those not markedly compartmentalised by extensive rocky headlands. The cell approach retains meaning for these coasts, although their cells may have substantial sediment exchange across their boundaries[2,17].

Constraints to sediment transport vary over time for different spatial scales and types of cell boundaries. For example, some rocky headlands are bypassed under infrequent high-energy conditions, but are a major constraint to sediment transport on a seasonal basis. Similarly, on sandy coasts cell boundaries may correspond to ephemeral areas of sediment transport convergence which indicate zones of reduced transport[18,19]. This variability in sediment bypassing at boundaries prompts the incorporation of time-dependence between levels within a cell hierarchy[10], with the boundaries of the larger (primary) cells being related to longer-term processes.

Cell boundaries defined in this document extend landward from points on the shoreline to include terrestrial landforms, and seaward to encompass the nearshore marine environment in which waves and currents are most active. The offshore and onshore boundaries of cells should be determined by the scale of sediment transport processes operating within a cell, as well as by topographic features.

Why use sediment cells?

Sediment cells define natural units with each cell encompassing adjoining marine and terrestrial environments. The cells thereby provide a base for integrated coastal management in which the components of each cell is considered holistically as an interactive system. In this context sediment cells aid interpretation of historic trends, add to an understanding of contemporary processes and provide an important basis for projection of future coastal change. The objectives of determining a three-scale hierarchy of cells were to:

- Identify sediment cells which are recognisable as natural management units for regional, sub-regional and local scale coastal studies;
- Establish a framework for linking marine and terrestrial projects that is founded on the connectivity of subaqueous and submarine coastal landforms, and which supports integrated coastal planning and management;
- Identify areas of coast where sediment budget estimates may provide a useful tool for coastal planning and management based on landforms at varying time and space scales[20,21,22]; and
- Avoid clashes of policy and practice where coastal management is required by neighbouring coastal agencies, particularly local government authorities, within single or adjacent cells.

Characteristics of the sediment cell approach which make it a fundamental tool for assessment of hazards to land use caused by coastal change are that[23]:

- There is a plausible connectivity of geology, landform and hydrodynamics for coastal evolution and change that can be established and used in identification of the cells[24];
- It focuses on the integration of coastal and marine processes with landform responses to them rather than more static, quasi-equilibrium approaches such as those forming the basis for numerical models of beach profile change; and
- The consistent methodology applied to identifying the cell hierarchy facilitates up-scaling and down-scaling in assessments of coastal change, a capability recommended in the assessment of coastal vulnerability to meteorologic and oceanographic change[25].

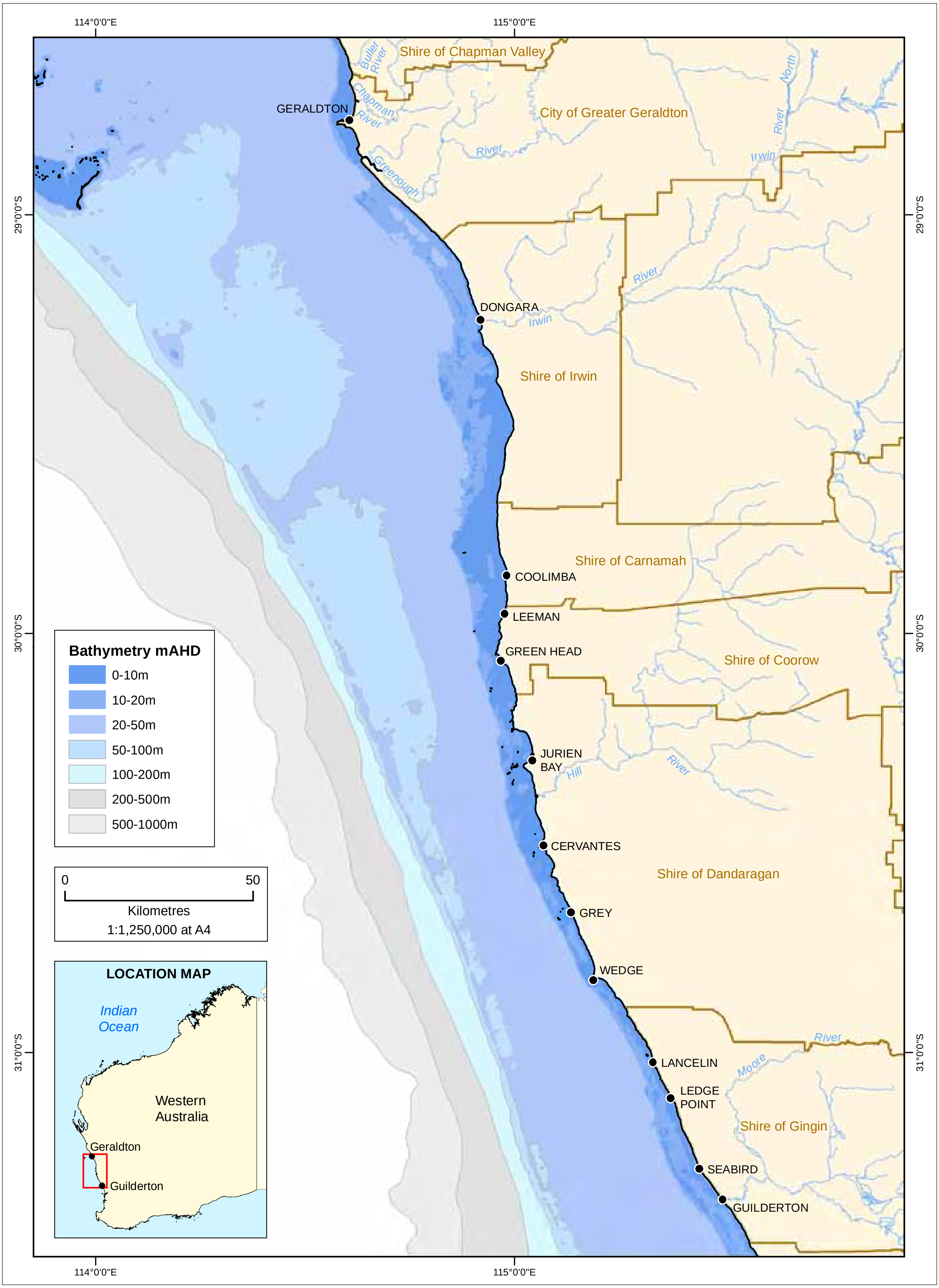


Figure 1: Mid-West Region coast from Moore River to Glenfield

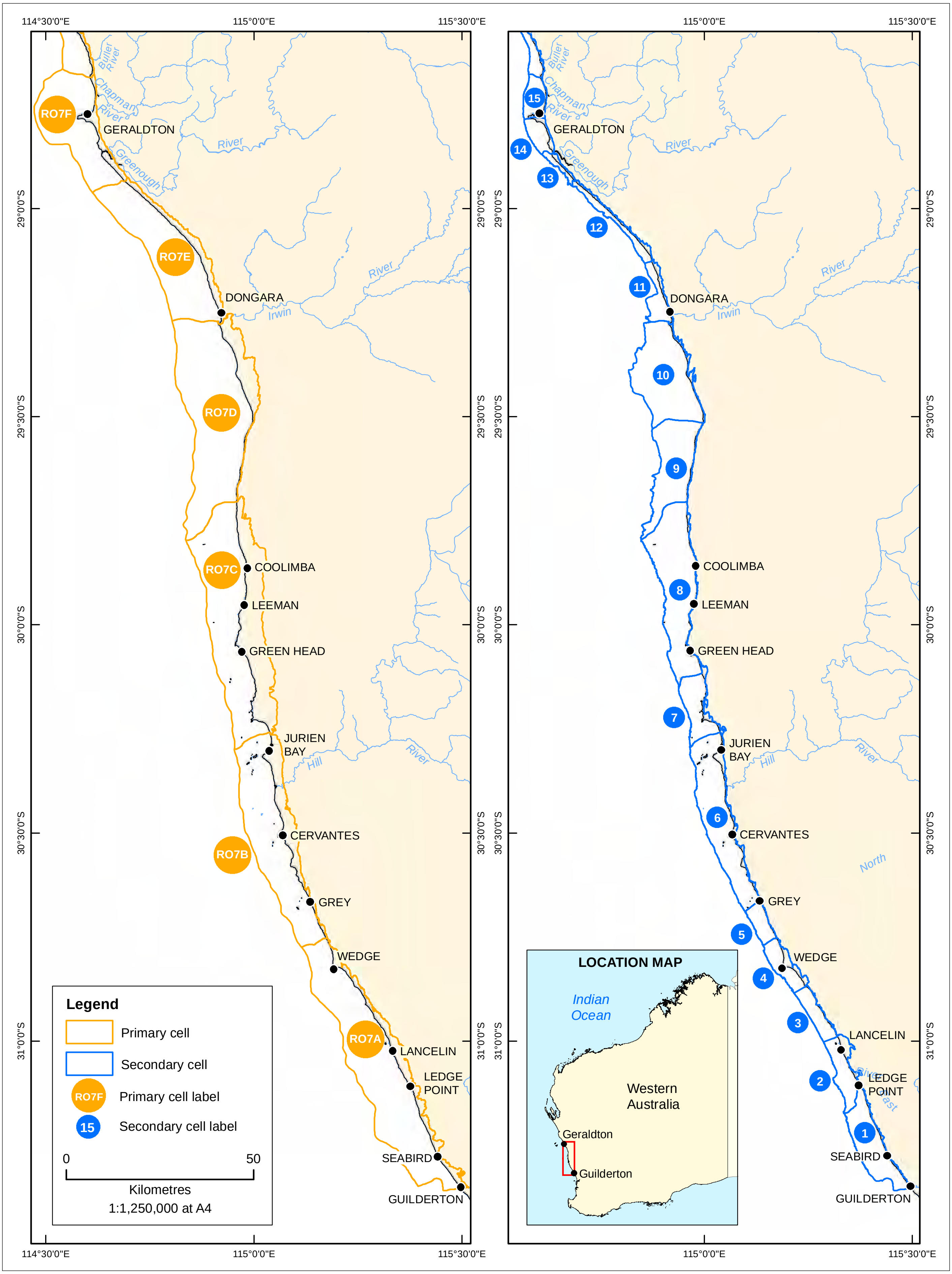


Figure 2: Primary and secondary cells of the Mid-West Region

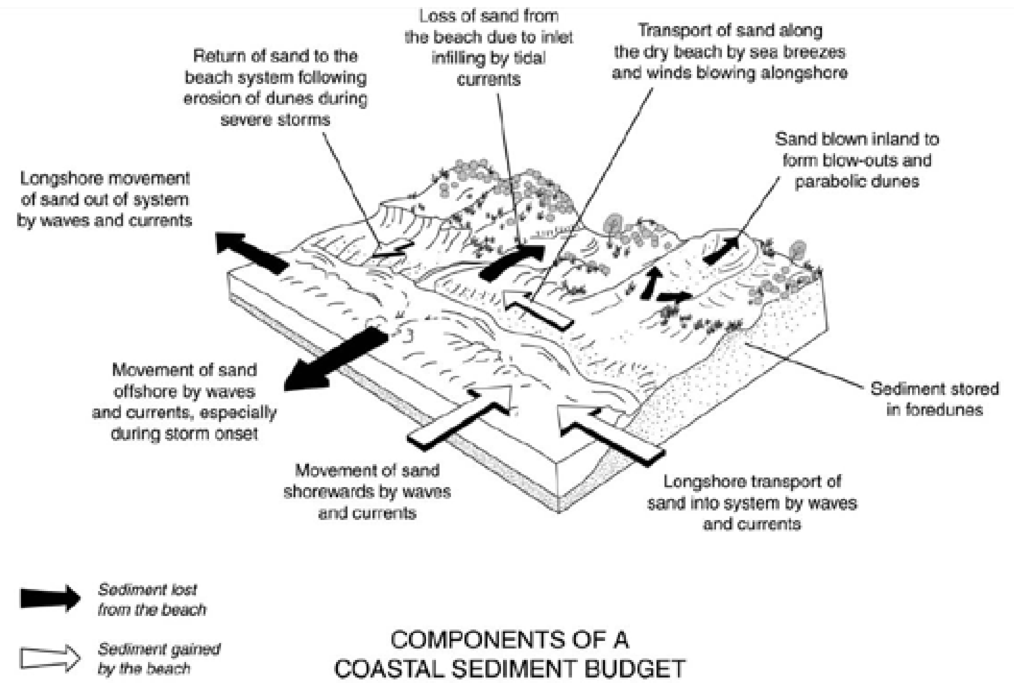


Figure 3A: Components of a coastal sediment cell (WAPC 2003)

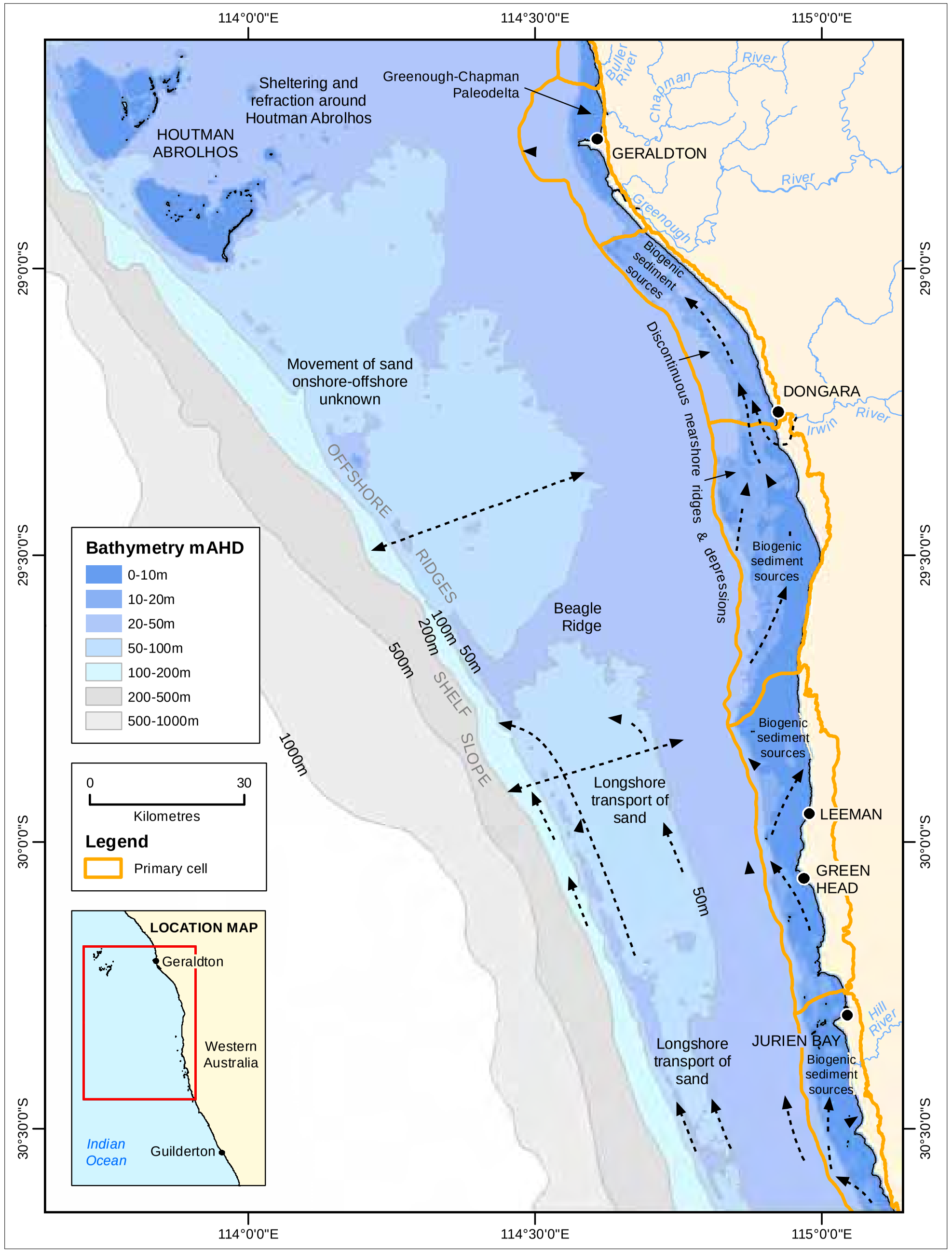
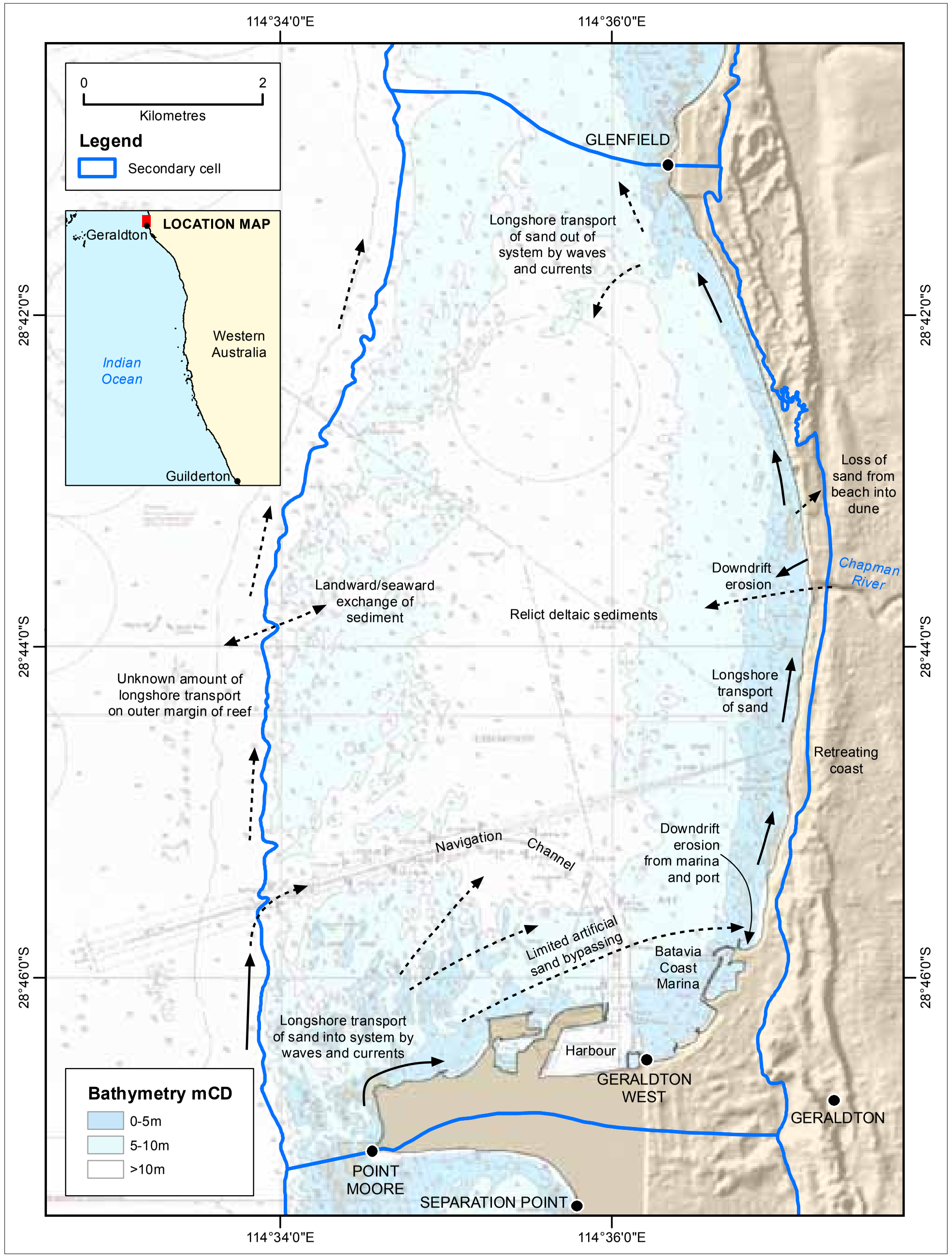


Figure 3B: Example primary cells (R07B to R07F)



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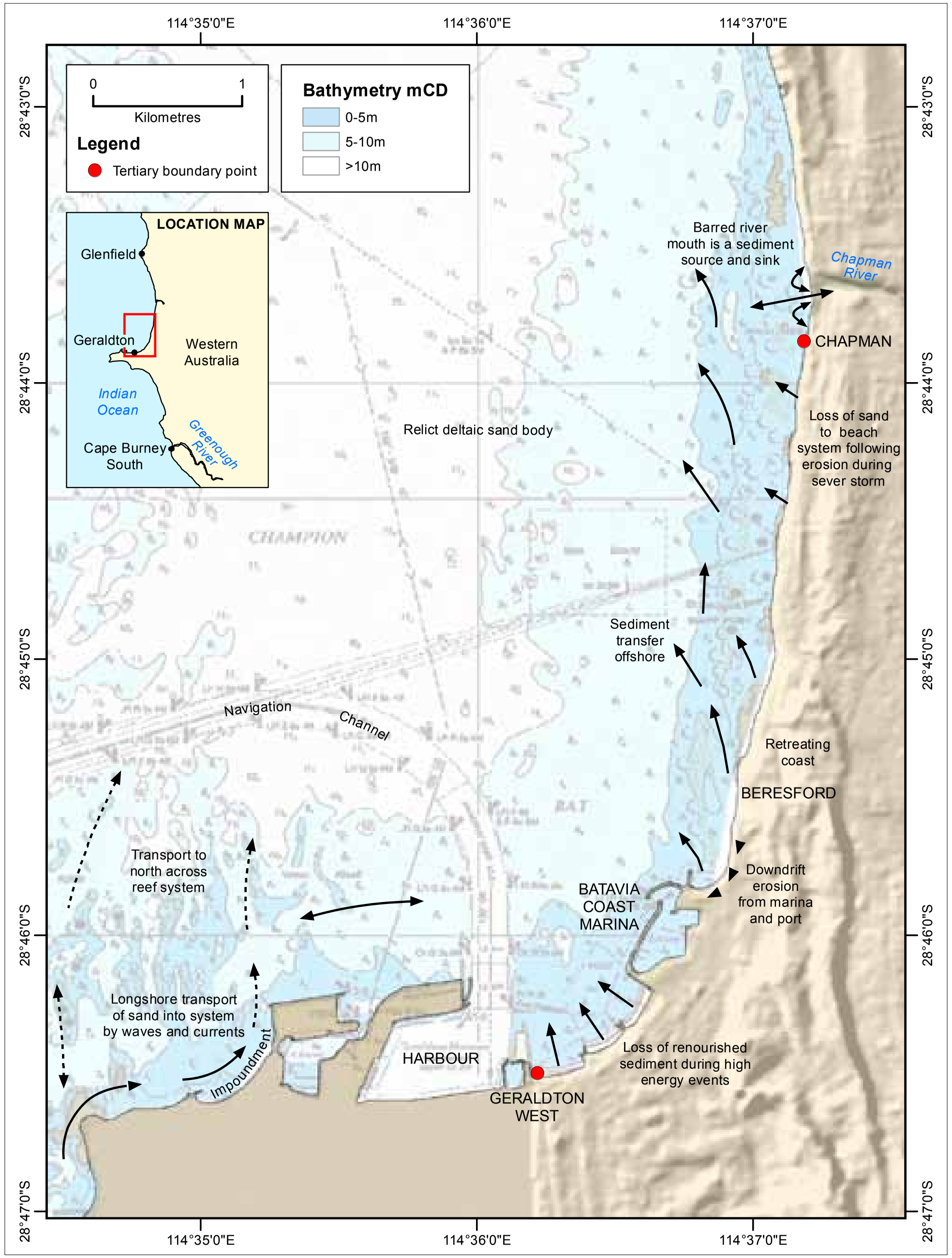


Figure 3D: Example tertiary cell (R07F15b)

The Mid-West coast

Coastal landform development on the microtidal Mid-West coast, with low present day supply of sediment is subject to substantial control by the geologic framework. Control occurs through interaction of the fixed rocky topography, comprising the framework, with coastal processes and available sediments. The framework for the Mid-West has been described at a variety of scales as part of a series of large-scale coastal compartments identified for the whole Western Australian coast[26].

Modern Holocene sediments and inherited, remnant landforms abut and overlay the geologic framework. Both are reworked by present-day processes, although typically less for remnant landforms. The partly repetitive patterns of reworking define sediment transport behaviour at all scales. Landforms of the Mid-West region include:

1. Sand flats, sediment lobes, sand banks and shoals between reef gaps;
2. Flats, subtidal terraces and sand banks spilling into nearshore basins in the inshore waters; and
3. Tombolos, spits, cuspate forelands and coastal dune barriers along the coast[27,28].

These landforms provide an indication of the source areas, transport pathways and sinks; although they need to be established in relation to the processes driving coastal change.

The spatial distribution of alongshore sediment supply is affected by the degree of bypassing at rocky coastal features. This varies with shoreline aspect and may therefore be subject to decadal-scale fluctuations. Further offshore, discontinuous reef ridges and inshore reef chains provide a leaky constraint to onshore and offshore sediment movement. Shoreward exchange of sediment typically occurs through gaps in the reef chains and may result in pulses of sediment transport to landward. More commonly, material is moved offshore through reef gaps and is lost from the nearshore system. At the shore, the geologic framework in the form of cliffs and bluffs may constrain sediment transport to landward.

The geologic framework provides a context for identification and description of sediment cells. However, transition from the fixed-structural, broad-scale geologic framework of the compartments to the functionally highly-variable, fine-scale sediment cells commonly includes a change in the balance of processes affecting the shore. For example, offshore currents driven by tides or winds may be significant to coastal evolution at a broad scale but not at a local scale where waves are likely to be dominant. This implies there is potential for process-landform interactions to generate errors at a broader or finer scale than a specific scale under investigation. The broader scale interactions commonly are apparent as trends whereas finer scale interactions contribute to the variability of the system being investigated.

Further information on geology, geomorphology, landforms, meteorological and oceanographic processes for the Mid-West Region is included in two recent vulnerability reports[27,28]. Additional geology and geomorphology information is included in the WACoast[29,30] database and from a country-scale study of Australian beaches[31]. Information on terminology used in this report is contained in previous reports[27,28,26,32] and global publications. A glossary relevant to landforms in the Mid-West is included in Appendix B of the landform vulnerability reports[27,28].

Methods for the definition of sediment cells

Coastal sediment cells and sectors have previously been investigated along large sections of the Mid-West Region[11,34,36,17,37,27,28]. These are commonly identified as points along the coast. They provided a starting point for the cells identified in 2012[27,28], which are refined in the present report. In the present analysis, established techniques[38], with some modification of terminology, have been applied to map sediment cell boundaries. Notably, some adaptation of the technique used to identify and map sediment cells in the Vlamingh Region[38] was required for the Mid-West Region, with the expectation that further revision of the criteria used (Figure 4; Table 1; Table 2; Appendix C) will be required for application to other parts of the WA coast or elsewhere.

A threefold hierarchy of cells was defined by the type and shape of landforms present as well as the frequency of coastal processes and potential landform responses relevant to each scale. Each larger primary cell is related to a functional coastal land system, whereas the smaller secondary and tertiary cells identify specific coastal landforms and landform components at increasingly detailed scales. Further offshore, larger cells may extend to a continental shelf feature well offshore, whereas a smaller cell may capture seasonal to decadal nearshore processes. At each scale cells are likely to vary in area based on the dimensions of the geologic framework containing the coastal landforms or landform elements being considered, together with meteorologic and oceanographic processes driving coastal change.

Tasks undertaken were based on available data, and involved:

1. Review of available literature to determine prevailing regional and local processes driving geomorphic change[27,28], including their temporal and spatial attributes;
2. Identification of the geologic framework and environmental context in which processes operate;
3. Establishment of criteria to identify cell boundaries at each level in the hierarchy of spatial scales indicated in Task 1;
4. Application of the criteria along the Mid-West coast between the Moore River and Glenfield Beach to identify sediment cells;
5. Preparation of digital datasets and maps showing the cells at primary and secondary levels in the hierarchy, and points along the shoreline at the tertiary level; and
6. Comparison of potential differences in the morphodynamic processes active at each level in the cell hierarchy.

Information used to define the cells

Points along the shoreline that separate sediment cells were derived using the existing knowledge base of the coast, remotely sensed datasets and landform digital datasets (Table B.1 in Appendix B). Datasets used were:

1. Landgate Mean High Water Mark (MHWM) shoreline compiled to 2006;
2. Department of Transport nautical charts and isobaths; along with Australian Navy hydrographic charts and isobaths;
3. Onshore geology and geomorphology (including landforms) from Geological Survey of Western Australia[29,30];
4. A shaded relief model from the Geological Survey of Western Australia;
5. Aerial orthophotography from Landgate; and
6. High-angle oblique aerial photography from Geological Survey of Western Australia[29,30].

These datasets cover most of the Mid-West Region but vary with respect to time, spatial scale of capture and level of resolution. These factors limit use of the project datasets which may be reviewed as more detailed information becomes available. Information from which the secondary cell onshore boundaries were determined also included recent oblique aerial photography, the shaded relief model, 2011 field surveys and landform mapping at various scales using 2006 aerial orthophoto mosaics[29,30]. Nautical charts, hydrographic charts, isobaths and 2006 aerial orthophoto mosaics were used for delineation of the offshore boundaries and marine sections of the alongshore boundaries at both primary and secondary cell levels.

Additional information, particularly at a local scale, may facilitate refinement of the cell boundaries and provide sufficient data to map the tertiary cell boundaries. In no particular order the extra information could include:

1. Local seismic surveys to determine rock coverage and depth of sediments;
2. Landform mapping of foredunes and frontal dunes for onshore boundaries of tertiary cells;
3. Sediment distributions;
4. Long-term analysis of aerial photographs for dune activity;
5. Benthic habitat information;
6. Collection of LiDAR bathymetry; and
7. Contemporary and projected local variations in water levels, waves, currents and winds.

For example, detailed assessment of sediment characteristics and processes contributing to their distribution is useful for boundary verification[39] (see *Detailed evaluation of coastal behaviour*). An ongoing review process, say every 10 years, may allow the implications of observed coastal change to be incorporated.

Cell boundaries

A threefold hierarchy of cells is considered for the Mid-West coast with each cell represented as two-dimensions because sediment transport pathways include both alongshore and cross-shore processes. Each cell may be thought of holistically as a collection of marine and terrestrial landforms, inter-related by sediment exchange between the landforms.

In this study, points along the shoreline separating the cells have first been identified (Table 1), followed by offshore and onshore boundaries (Figure 4; Table 2). Offshore and onshore boundaries are connected by mapping through the beachface points at the shoreline (Table 1). This sequence provides a focus on the alongshore boundary definition at the shoreline, and therefore on beachface processes, while being aware that significantly higher rates of sediment transport occur in this zone. Only points were identified for tertiary cells as the available data were inadequate for accurate mapping of the onshore and offshore boundaries.

Alongshore cell boundaries (beachface points) are principally determined by one or several geologic, geomorphic or engineered features at the shoreline (Table 1). Each alongshore boundary has marine and terrestrial sections that connect the offshore and onshore cell boundaries through the beachface point (Figure 4). Distinctions between morphology and processes at each sediment cell scale are incorporated in criteria used to identify the beachface points and cell boundaries. Separate criteria are described for each level in the hierarchy (see *Primary cells, Secondary cells and Tertiary cells*). Sediment cells with cliffed coasts may have alongshore boundaries with no terrestrial section where the beachface point is coincident with the Landgate MHWM to 2006.

A list of features used to determine the alongshore boundary lines for marine and terrestrial sections is included in Table 1. Those identifying the marine section of the alongshore boundaries provide some restriction to sediment transport at varying timescales: from greater than 100 years for primary cells to inter-decadal and higher frequency timescales for tertiary cells. The terrestrial section of alongshore boundaries is the limit of, or discontinuities in, the relative coastal land system or coastal landform between adjacent cells at the scale of interest. Relevant Holocene coastal land systems are used at a primary cell scale, with foredune plains and parabolic dunes at a secondary scale and frontal dunes or foredunes at a tertiary scale. Exceptions occur on engineered coasts and cliffed coasts where there is no terrestrial section of the alongshore boundary. In places where there is no variation in the land system or landform landward of the beachface point, a *notional* boundary is mapped as a landward extension of the marine boundary line through the beachface point to the onshore boundary along a similar trajectory or orthogonal to the coast (e.g. North Break Reef in Figure A.3 in Appendix A).

Points along the shore separating the cells are characterised according to the restriction of sediment transport (open or closed); the extent of the restriction (point or zone) and the potential for migration (fixed or ambulatory). For example the apex of a rocky headland is defined as a fixed point whereas a salient sustained by wave convergence behind a large area of reef is recognised as a fuzzy boundary or zone, although it is geographically fixed. Ambulatory features may be points (e.g. large spits) or zones (e.g. deltas). By definition, an alongshore boundary cannot be ambulatory and closed.

Method overview

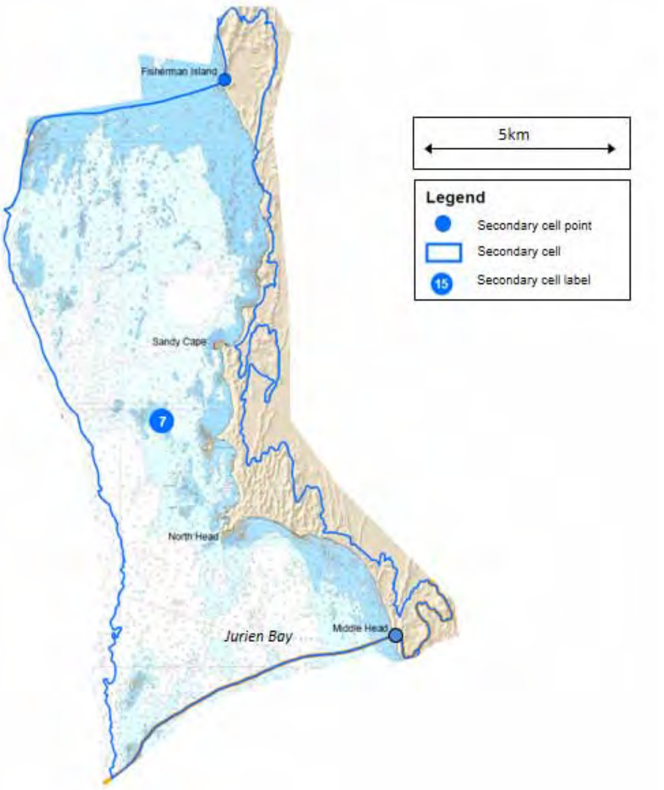
1) Identify points at the beachface.

2) Identify offshore and onshore boundaries.

3) Map alongshore boundaries that connect onshore and offshore boundaries through the beachface point.

Each alongshore boundary has a marine and a terrestrial section.

4) Process is iterative and is checked between cell scales.



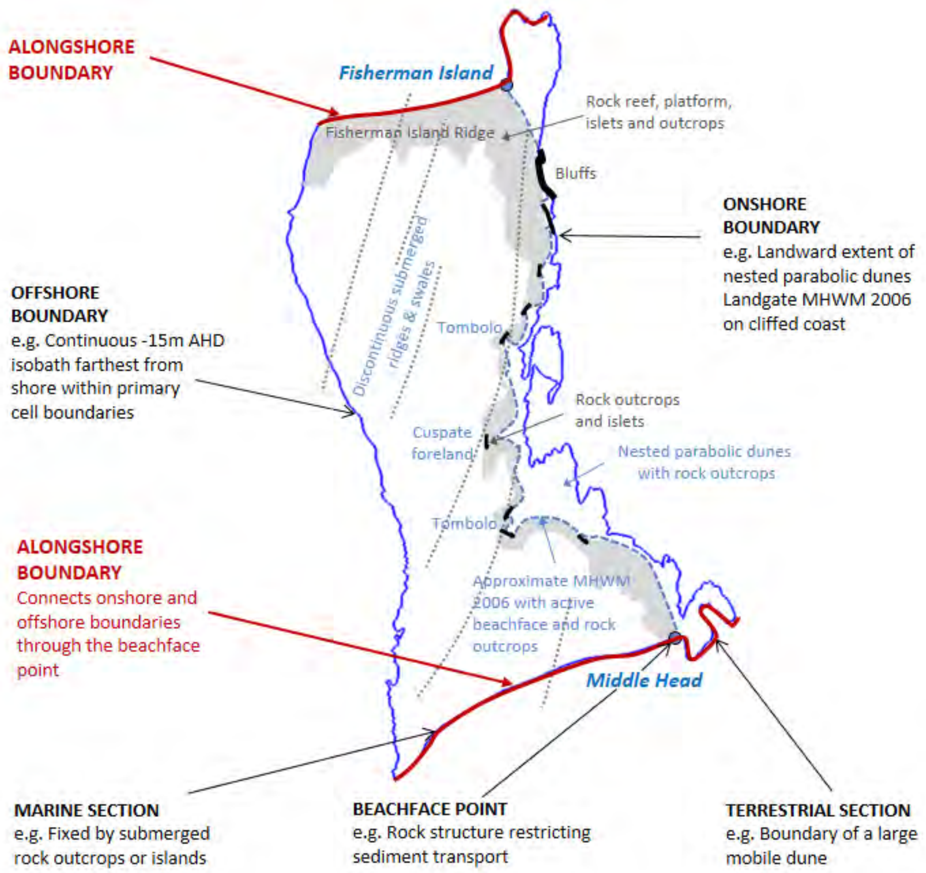


Figure 4: Cell boundaries - example for R07C7

Data Source: Bathymetry by Department of Transport and shaded relief model supplied by Geological Survey of WA, Department of Mines and Petroleum.

Table 1: Criteria for mapping alongshore boundaries in the Mid-West Region

Variation of criteria will be required when applied to other coastal regions

	Primary cell	Secondary cell	Tertiary cell
Alongshore Boundary	**Marine Section** (i) Fixed by a submerged ridge with rock outcrops or islands, then, a marine extension from the edge of the outermost rock outcrop to the offshore boundary (perpendicular to bathymetric contours where possible)[1] (ii) Deepest point of depression or contour reentrant (if depth < -30m AHD)[2] (iii) Broad area of sediment transport convergence (e.g. reefs, banks, change in aspect) (iv) Boundary is drawn orthogonal to coast because of a lack of bathymetric information	**Marine Section** (i) Fixed by submerged rock outcrops or islands (ii) Area of sediment transport convergence on banks or reefs (iii) A marine extension of the beachface point to the offshore boundary (perpendicular to bathymetric contours where possible) (iv) Deepest point of depression or contour reentrant (if depth < -15m AHD)[2]	**Marine Section** (i) Fixed by rock outcrops or islands (ii) Focal point of sediment transport convergence on banks or reefs (iii) Engineered structures or dredged areas (iv) A marine extension of the beachface point to the offshore boundary (perpendicular to bathymetric contours where possible)
	Beachface Point (May be multiple reasons for selection of position) (i) Rock structures restricting sediment transport at a decadal scale (ii) Geomorphic feature (land system or landform) (iii) Adjacent cells have a different shoreline aspect restricting sediment transport at a decadal scale (iv) Engineered structure (e.g. port) or shipping channel	**Beachface Point** (May be multiple reasons for selection of position) (i) Rock structures restricting sediment transport at an annual scale (ii) Geomorphic feature (landform) (iii) Adjacent cells have a different shoreline aspect restricting sediment transport at an annual scale (iv) Engineered structure (e.g. large marina) or dredged channel	**Beachface Point** (May be multiple reasons for selection of position) (i) Rock structures restricting sediment transport at a seasonal scale (ii) Geomorphic feature (landform or landform element) (iii) Adjacent cells have a different shoreline aspect restricting sediment transport at a seasonal scale (iv) Engineered structure (e.g. small harbour) or dredged channel
	Terrestrial Section (i) Boundary of, or discontinuity in, a Holocene land system (ii) An extension of marine section and beachface point directly to the onshore boundary if there is no change in land system between adjacent cells (iii) Centre line of engineered structure or feature (iv) No terrestrial section (e.g. cliffs)	**Terrestrial Section** (i) Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune (ii) An extension of marine section and beachface point directly to the onshore boundary if there is no change in foredune plains, parabolic dunes or frontal dunes between adjacent cells (iii) Centreline of engineered structure or feature (iv) No terrestrial section (e.g. cliffs)	**Terrestrial Section** (i) Boundary of, or discontinuity in, the foredune (ii) Boundary of frontal dune if the foredune is eroded or absent (iii) An extension of marine section and beachface point directly to the onshore boundary if there is no change in foredune or frontal dune morphology between adjacent cells (iv) Centreline of engineered structure or feature (v) No terrestrial section (e.g. cliffs)

Note: 1. In some locations the ridge may need connection to the beachface
2. Isobaths were mapped to the vertical datum of Australian Height Datum (AHD).

Table 2: Criteria for mapping onshore and offshore boundaries in the Mid-West Region

Variation of criteria will be required when applied to other coastal regions.

	Primary cell	Secondary cell	Tertiary cell
Offshore Boundary	(i) -30m AHD[1] isobath farthest from shore	(i) Continuous -15m AHD[1] isobath farthest from shore within primary cell boundaries	(i) -5m AHD isobath[1] closest to shore
Onshore Boundary	(i) Landward extent of Holocene land system, except for a transgressive dune system overlying older and higher land surfaces (ii) Landward extent of a coast-linked transgressive dune system overlying older and higher land surfaces (iii) Late Holocene dunes abutting rocky topography to landward (e.g. foot slopes, bluffs and cliffs) (iv) Landgate MHWM to 2006 on cliffed coast without dunes	Landward extent of: (i) foredune plain (e.g. Cervantes) (ii) large mobile dune (e.g. Southgate dune) (iii) narrow dune barrier (iv) small parabolic dunes (v) frontal dunes (vi) Landgate MHWM to 2006 on cliffed coast without dunes	(i) Landward extent of foredunes (ii) Landward extent of the frontal dune if the foredune is eroded or absent (e.g. Sunset Beach) (iii) Landgate MHWM to 2006 on cliffed coasts without dunes (iv) Landgate MHWM to 2006 on engineered coasts with shore parallel structures without dunes to landward

Note: 1. Isobaths were mapped to the vertical datum of Australian Height Datum (AHD).

Primary cells evolve over centuries and millennia. They are linked to coastal land systems[40,41,42,43,44] and broad marine systems[11,35]. Secondary cells are based on large coastal landforms[29,30] subject to inter-decadal change. Tertiary cells are based on coastal landforms subject to change on an inter-annual scale, as well as beachface features restricting sediment transport at a seasonal scale.

Primary cells: geologic framework and long-term change in morphology

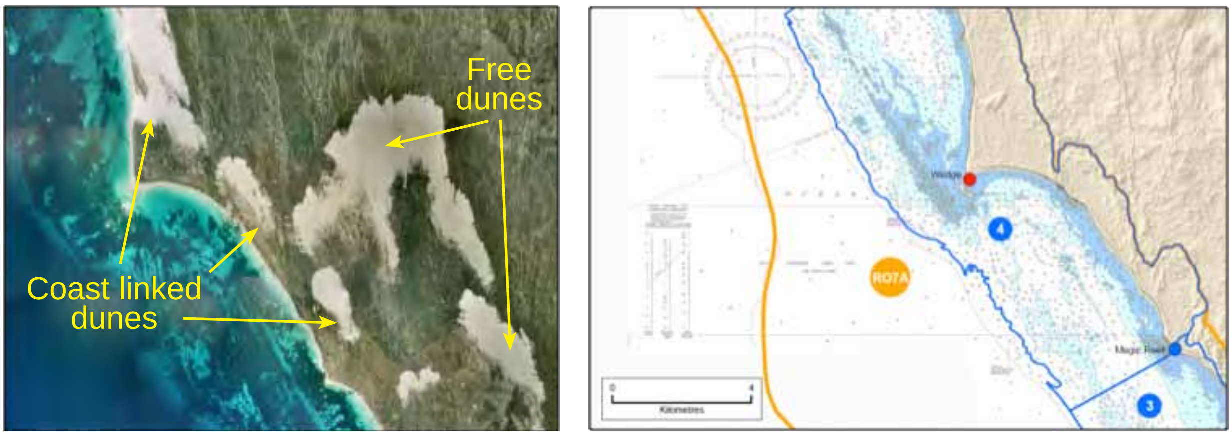
Primary cells (Figure 2) encompass the geologic framework controlling long-term evolution of the coastal land systems, such as coastal barriers, cuspate forelands and river deltas. Although substantial changes to these large land systems occur at time scales longer than 100 years, the changes are general trends when considered over coastal management time scales.

At the shoreline, boundaries of primary cells are defined by one, or a combination of, rocky structures, large accretionary landforms, changes in coastal aspect and large engineered structures that restrict sediment transport at a decadal scale. In the Mid-West, all alongshore cell boundaries of primary cells, other than North Wedge (Cell R07A), are defined by a rock structure. The structures include rocky salients at Moore River (Cell R07A1a) and Phillips Road coast (Cells R07E12). Leander Point (Cell R07D) is the only alongshore boundary controlled by an engineered structure and this is constructed on a rocky headland.

Accretionary landforms include cuspate forelands, such as North Wedge (Cells R07A and R07B); broad foredune plains, such as the Cervantes-Jurien foredune plain (R07B); and remnants of paleo-deltas, such as the Greenough-Chapman paleo-delta (R07F). The beachface point on the alongshore boundary for an accretionary landform is located at the northern extent of the landform to encompass the whole sediment sink. For example, the northern extent of the Cervantes-Jurien foredune plain is located at the limestone foreland of Middle Head (R07B6f), rather than at the tip of the cuspate foreland at Island Point (R07B6e).

The offshore boundary of primary cells is the -30m AHD isobath or depth contour. It is located on the inner continental shelf and seaward of offshore reef ridges impounding inshore lagoons and basins. Selecting this depth includes the outer margin of the discontinuous shore-parallel ridge of limestone reefs within the cell and provides separation between large-scale ocean currents and the complex inshore circulation patterns. Hydrographic charts and aerial photography reveal migratory bedforms across sand banks and reefs and suggest a considerable volume of sediment transport presently occurs along the outer margin of the discontinuous ridge and spills landward. This may be primarily related to the Holocene rise in sea level[45,46,47] but it also currently occurs as pulsational migration of sand waves and shoals.

The onshore boundary of primary cells is the landward extent of Holocene accretionary land systems, including the foredune plains, transgressive dune systems and dunes abutting rocky topography to landward[29,30]. Exceptions to this are cliffed coasts without dunes to landward and when broad transgressive dune systems overlay older and higher land surfaces (Table 2). The Landgate MHWM to 2006 has been used for cliffed coasts (Appendix B). All sections of coast with Landgate MHWM to 2006 as the onshore boundaries require further investigation at a more detailed scale. For example, there may be small pocket beaches or sections with lower elevation rock or engineered structures that have sediment exchange to landward. In the case of broad transgressive dune systems overlying older and higher land surfaces only the dunes with direct link to the coast were included in the primary cell. For example, in the primary cell from North Wedge to Middle Head (R07B) the dunes landward of the onshore cell boundary are considered free dunes, without a direct connection to the coast (Figure 5).



At a primary cell scale for transgressive dune systems overlying older and higher land surfaces, there is separation of free dunes and dunes with a coastal connection. Free dunes have no direct shore connection while coast-linked dunes have a direct shore connection or may have a future shore connection through dune reactivation

Figure 5: Free dunes and coast-linked dunes overlying older and higher land surfaces

Data Source: Aerial Photograph is Landgate 2008, bathymetry by Department of Transport and shaded relief model supplied by Geological Survey of WA, Department of Mines and Petroleum.

Secondary cells: regional-scale processes and morphology

Secondary cells contain the broad patterns of contemporary (inter-annual to decadal) sediment movement on the inner continental shelf (Figure 2).

The beachface points on the alongshore boundaries may be fixed or ambulatory (Table 1; Table 7). Fixed boundaries include rocky outcrops restricting sediment transport at an annual scale such as at Fisherman Islands (R07C7) and Nine Mile Beach (R07E11), as well as the large engineered structures at Leander Point (R07D10). Ambulatory boundaries are associated with areas of convergence of sediment transport which occur on, or at the northern extent, of many of the accretionary landforms such as forelands and salients; for example Point Moore tombolo in Geraldton (R07F14) and the tombolo at Ledge Point (R07A1). The northern extent of accretionary landforms was selected as the beachface point on the alongshore boundary to encompass the extent of the sediment sink at an inter-decadal scale. At the secondary cell scale, the main ambulatory boundary that has been stabilised using engineering structures is Leander Point (R07D10) being associated with Port Denison Boat Harbour.

The offshore boundary of secondary cells follows the continuous -15m AHD isobath farthest from shore and within the offshore boundaries of primary cells. This depth is near the seaward margin of discontinuous shore-parallel limestone ridges close to shore. Selecting this depth encompasses contemporary sediment transport by nearshore wave[48] and current processes within the cell, including dispersal of locally derived biogenic material[49,36,39].

Onshore boundaries of secondary cells include potential landform activity at an inter-decadal scale. The onshore boundary corresponds to the landward extent of the foredune plain, large mobile dune systems (such as Southgate dune in cell R07F14), narrow parabolic dune barriers, small parabolic dunes or frontal dunes. As noted above, an exception to this is cliffed coast without dunes, where the Landgate MHWM to 2006 is used as the onshore boundary (Table 2). Sediment activity could extend beyond the onshore boundaries of secondary cells in some circumstances.

Tertiary cells: local-scale, short-term processes and morphology

Tertiary cells incorporate the reworking and movement of sediment near the shore and associated potential seasonal to inter-annual landform response (Figure A series in Appendix A). Tertiary cells perform similar functions to those of secondary cells, often on a finer scale. Their alongshore boundaries coincide in some places. Beachface points on the alongshore boundaries of tertiary cells (mapped; Table 1), along with onshore and offshore boundaries (not mapped; technique could follow Table 2) are highly subject to change. They may be transgressed by extreme events and modified by low frequency coastal processes.

Tertiary sediment cells were identified for the Mid-West coast, excluding islands and with only the beachface points on the alongshore boundaries mapped.

Beachface points on the alongshore boundaries of tertiary cells restrict sediment transport at a seasonal to inter-annual scale. Fixed boundaries include rocky headlands, such as at North Head (R07C7a), north of Jurien Bay. They also include engineered structures, such as marinas and harbours, which restrict sediment transport in depths shallower than the -5m AHD isobaths. The installation of engineered structures potentially may change the alongshore boundaries of tertiary cells and lead to development of new cells. Ambulatory boundaries are associated with zones of convergence or divergence associated with local wave refraction and diffraction patterns[19,17]. Ambulatory boundaries at a tertiary cell scale may be located at the tip of accretionary landforms, such as at Wedge Island (R07A4a) or Island Point (R07B6e), as the change in aspect and wave sheltering restrict sediment transport at a seasonal to inter-annual scale.

The offshore boundaries of tertiary cells would have been mapped to the -5m AHD isobath (Table 2). This approximately corresponds with the toe of reef platforms and large sand shoals flanking the shore. It is applicable as the Mid-West coast is sheltered by offshore reefs and islands to the extent locally generated wind-waves and partially-attenuated swell are prevailing components of the wave regime.

When mapped, the onshore boundary of tertiary cells should indicate the landward extent of average seasonal processes. Onshore boundaries would be the alongshore swales between the foredunes and the frontal dunes or the landward toe of the frontal dunes if foredunes are eroded or absent (Table 2). Exceptions to the landward extents of landforms as onshore boundaries would be cliffed coasts or engineered coasts with extensive shore parallel structures (e.g. seawalls) without dunes to landward. The onshore boundary of tertiary cells would not be indicative of the landward extent required for engineering, planning and management investigations. It represents the landward extent of average seasonal processes which may be superseded annually. However, it may be used as a marker to establish higher frequency changes at the shore.

Rivers

Onshore boundaries for rivers in the Mid-West Region have been represented in datasets and the figures in this report as a truncation between the dune and alluvial landforms on opposite banks of the rivers. In this respect the onshore boundary does not comprehensively represent the onshore extent of estuarine processes within each river. Further investigation of landforms and sediment budgets adjacent to rivers should include:

- All alluvial landforms with connection to the coast;
- The potential for alluvial landforms to become estuarine with changing climatic conditions;
- The capacity for flooding;
- Sediment transport along the river; and
- Sediment transport fluxes associated with opening and closing of sand bars across river mouths.

The main estuarine systems of the area are the Moore River, Hill River, Irwin River, Greenough River and Chapman River (Figure 1), all of which have barred mouths that are breached and flow intermittently.

Marine sections of the alongshore cell boundaries may follow the submarine paleo-channels of rivers, which are likely to trap sediment and divert sediment movement. For the Mid-West coast the marine sections of primary and secondary cell alongshore boundaries at the Moore River (Guilderton) follow the Moore River paleo-channel (R07A) and the marine section of the secondary cell alongshore boundary at Cape Burney South follows the Greenough River paleo-channel (R07F13).

Cell labels

The cell labelling convention follows the direction of prevailing littoral drift according to:

1. Region – increasing order of R01, R02 to R13 from the South Australia border[26]. The Mid-West is region R07;
2. Primary cell – upper case letter resetting for each region;
3. Secondary cell – number resetting for each region;
4. Tertiary cell – lower case letter resetting for each secondary cell with letters increasing in the direction of littoral drift or clockwise around islands, for example 14a; and
5. Quaternary cell – Roman numeral resetting for each tertiary cell, for example 14ai. Quaternary cells were not applicable in this investigation.

Mid-West cells are labelled to the tertiary cell, for example R07A1a, from south to north following the direction of prevailing littoral drift.

Sediment cell results along the Mid-West coast

Six primary cells, 15 secondary cells and 41 tertiary cells were identified along the Mid-West coast between the Moore River and Glenfield Beach. The hierarchy of cells is presented as maps, tables and electronic datasets available from the Department of Transport (Table 3).

Table 3: Location of cell results for the Mid-West Region

Item	Further information included	Location in report
Beachface points on the alongshore boundaries[1]	Information on the beachface point on alongshore boundaries at all three sediment cell scales. This includes features that define the beachface point, coordinates and character of the boundary	Tables in Appendix E (separate document)
Alongshore boundaries[1]	Information on the features that define the marine and terrestrial sections of the alongshore boundaries for cells at the primary and secondary scales	
Onshore and offshore boundaries[1]	Information on the features that define the onshore and offshore boundaries for cells at the primary and secondary scales	
Cell names	Hierarchy of cell names including cell labels	Table 4
Maps of cells	Primary and secondary cells at 1:1,250,000 scale at A4 size	Figure 2
	Secondary and tertiary cells at 1:100,000 scale at A4 size	Figures A.1-A.16 in Appendix A
Coincidence of cell boundaries	Boundary names and coincidence at different levels in the hierarchy	Table 5
Comparison to previous study	Comparison with previously defined sediment cell boundaries[27,28] in landform vulnerability reports.	Tables D.1-D.2 in Appendix D

Note: 1. Electronic datasets of boundaries and beachface points available from Department of Transport in ESRI shapefile format or as Google Earth KMZ files. The kmz filename is 'R07 Mid-West Cells.kmz'. The shapefile filenames are Primary_Cells.shp and Secondary_Cells.shp and are available upon request from the Department of Transport officers.

Cell boundaries

The alongshore spatial scale of cells in the Mid-West Region varies with wave exposure, geologic framework, sediment availability and aspect. Further information on these parameters is provided in landform vulnerability reports[27,28], but should be updated at an appropriate scale in any analysis of sediment budgets. The mean length of cells was 57km (37-78km), 23km (9-52km) and 8km (2-22km) for primary, secondary and tertiary cells respectively (Table 6). Larger cells in the size ranges are present on coasts with reduced reef sheltering and large rock outcrops, with smaller cells in the size ranges on coasts with increased geological control, such as coasts with tombolos and large cuspate forelands. Secondary and tertiary cell boundaries may be coincident for coasts that are open or have inherited features.

There is some consistency in scale with littoral cells reported from elsewhere, overseas and on the WA coast. Spatial scales of primary cells (37-78km) are smaller than the littoral cells in England, Wales and Scotland (50 -300km)[13,14] and the Pilbara Region (100-300km)[50], and at a similar scale to cells in the Vlamingh Region (13-87km)[38] in Western Australia; California (10-95km)[20] and Hawkes Bay, New Zealand (20-60km)[51]. The Mid-West had fewer smaller primary cells than the Vlamingh Region[38] because there were no large islands within the primary cell boundaries and the offshore ridges are more discontinuous. The local primary and secondary cell scales correspond with sub-cell scales in the United Kingdom. The comparison across the hierarchy of cells provides confidence in linking cell dimensions to the geologic framework, sediment availability and different metocean processes driving shoreline change at each scale.

Primary cell boundaries are also secondary and tertiary cell boundaries, with the only exception being the barred river mouth at Guilderton (Table 5). Fifteen (94%) secondary cell boundaries are also tertiary cell boundaries, with 27 (64%) unique tertiary cell boundaries.

The cell hierarchy and boundary character classification (Table 4; Table 7) reveal the complexity of the coastal system of the region which has varied rock control and inherited features. The majority (≈90%) of boundaries are open at all three scales with varying degrees of sediment transport leakage. Notably, sediment flow directions may be reversed with changes in meteorological and oceanographic conditions, with some boundaries effectively closed for one sediment transport direction.

Table 4: Primary, secondary and tertiary sediment cells of the Mid-West Region

Region	Primary	Secondary	Tertiary
R08. Northampton Region	Beyond Study Area	Beyond Study Area	Beyond Study Area
R07. Mid-West Region from Moore River to Glenfield	F. Phillips Road Coast to Glenfield	15. Point Moore to Glenfield	c. Chapman to Glenfield
			b. Geraldton West to Chapman
			a. Point Moore to Geraldton West
		14. Cape Burney South to Point Moore	b. Separation Point to Point Moore
			a. Cape Burney South to Separation Point
		13. Phillips Road Coast to Cape Burney South	a. Phillips Road Coast to Cape Burney South
	E. Leander Point to Phillips Road Coast	12. Nine Mile Beach to Phillips Road Coast	b. Headbutts to Phillips Road Coast
			a. Nine Mile Beach to Headbutts
		11. Leander Point to Nine Mile Beach	c. Seven Mile Beach to Nine Mile Beach
			b. Harleys Hole to Seven Mile Beach
			a. Leander Point to Harleys Hole
	D. South Illawong to Leander Point	10. Cliff Head to Leander Point	b. White Point to Leander Point
			a. Cliff Head to White Point
		9. South Illawong to Cliff Head	a. South Illawong to Cliff Head
	C. Middle Head to South Illawong	8. Fisherman Islands to South Illawong	d. Coolimba to South Illawong
			c. Leeman to Coolimba
			b. Point Louise to Leeman
			a. Fisherman Islands to Point Louise
		7. Middle Head to Fisherman Islands	c. Sandy Cape to Fisherman Islands
			b. North Head to Sandy Cape
			a. Middle Head to North Head
	B. North Wedge to Middle Head	6. Grey to Middle Head	f. Island Point to Middle Head
			e. South Booka Valley to Island Point
			d. Black Point to South Booka Valley
			c. Thirsty Point to Black Point
			b. Kangaroo Point to Thirsty Point
			a. Grey to Kangaroo Point
		5. North Wedge to Grey	b. Kearn Reef to Grey
			a. North Wedge to Kearn Reef
	A. Moore River to North Wedge	4. Magic Reef to North Wedge	b. Wedge to North Wedge
			a. Magic Reef to Wedge
		3. North Break Reef to Magic Reef	c. Narrow Neck to Magic Reef
			b. Dide Point to Narrow Neck
			a. North Break Reef to Dide Point
		2. Ledge to North Break Reef	c. Edward Island to North Break Reef
			b. Fence Reef to Edward Island
			a. Ledge to Fence Reef
		1. Moore River to Ledge	c. South First Bluff to Ledge
			b. Seabird to South First Bluff
			a. Guilderton N to Seabird
R06. Vlamingh Region	Beyond Study Area	Beyond Study Area	32d. Guilderton S to Guilderton N

Table 5: Sediment cell alongshore boundaries of the Mid-West Region

Coordinates, alongshore boundary character, onshore and offshore boundaries, along with marine and terrestrial sections of the alongshore boundary are in the KMZ file, shapefile and Appendix E.

Cell alongshore boundary name	Cell boundaries
Glenfield	1°, 2°, 3°
Chapman	3°
Geraldton West	3°
Point Moore	2°, 3°
Separation Point	3°
Cape Burney South	2°, 3°
Phillips Road Coast	1°, 2°, 3°
Headbutts	3°
Nine Mile Beach	2°, 3°
Seven Mile Beach	3°
Harleys Hole	3°
Leander Point	1°, 2°, 3°
White Point	3°
Cliff Head	2°, 3°
South Illawong	1°, 2°, 3°
Coolimba	3°
Leeman	3°
Point Louise	3°
Fisherman Islands	2°, 3°
Sandy Cape	3°
North Head	3°
Middle Head	1°, 2°, 3°

Cell alongshore boundary name	Cell boundaries
Island Point	3°
South Booka Valley	3°
Black Point	3°
Thirsty Point	3°
Kangaroo Point	3°
Grey	2°, 3°
Kearn Reef	3°
North Wedge	1°, 2°, 3°
Wedge	3°
Magic Reef	2°, 3°
Narrow Neck	3°
Dide Point	3°
North Break Reef	2°, 3°
Edward Island	3°
Fence Reef	3°
Ledge	2°, 3°
South First Bluff	3°
Seabird	3°
Guilderton N	3°
Moore River	1°, 2°
Guilderton S	3°

Table 6: Alongshore length of cells of the Mid-West Region

Cell level	Minimum length (km)	Maximum length (km)	Mean length (km)	Median length (km)
1°	37	78	57	56
2°	9	52	23	18
3°	2	22	8	8

Table 7: Alongshore boundary characteristics of cells of the Mid-West Region

Alongshore boundary characteristics for each cell are in the KMZ file, shapefile and Appendix E.

	Alongshore boundaries					
	Primary		Secondary		Tertiary	
	Count	%	Count	%	Count	%
Point	4	57%	8	50%	24	57%
Zone	3	43%	8	50%	18	43%
Fixed	5	71%	11	69%	29	69%
Ambulatory	2	29%	5	31%	13	31%
Open	1	14%	1	6%	6	14%
Closed	6	86%	15	94%	36	86%

Boundaries are ambulatory (≈30%) where rock control is on the sub-tidal part of the shoreface and may be defined as a zone where there is limited to no rock control on the beachface. At all scales, half of all cell boundaries are points and half are zones with 30% ambulatory boundaries. Landforms adjacent to tertiary cell boundaries are susceptible to variation as a result of both sub-tidal and inter-tidal rock control.

Along coast variation of sediment cells

Geographic differences in geology, sediments and processes cause alongshore variation in the characteristics of sediment cells over both regional and sub-regional scales. These differences change the relative influence of the criteria used to define sediment cells boundaries. They identify which attributes best define the sediment cells and at what scale.

Intra-regional variation in sediment cells of the Mid-West is described according to primary cells, linked to the seafloor terrain, onshore sedimentary landforms and coastal processes. The Mid-West Region comprises offshore reefs; inshore lagoons and basins, submarine rocky pavement, mobile sand sheets, sea grass meadows, shore platforms, cliffs and bluffs; and the several types of barrier dunes along the shore[27,28]. The barriers include cuspate forelands and tombolos, as well as foredune plains and ridges of overlapping parabolic dunes. The distribution of these landforms changes with distance northward from the Moore River.

The southern part of the region (Cells R07A and R07B) has extensive reef running parallel to the shore, with inshore lagoonal basins formed by cuspate forelands and tombolos where the reefs are close to the coast as at Wedge Island and Cervantes. Foredune plains, such as that landward of Island Point at Jurien Bay, and ridges of parabolic dunes are common features between the Moore River and North Head. In the central part of the region (Cells R07C to R07E) the reefs extend both parallel and transversally to the shore, commonly outcropping as rock platforms and bluffs. Long-walled parabolic dunes are tied to sandy beaches between rocky headlands on this part of the coast. Further north (Cell R07F), reefs form an arcuate feature in the offshore between Cape Burney South and Glenfield Beach. The arc closes with the coast to form an extensive tombolo landward of Point Moore (Cell R07F14). Changes in the plan form of the reefs, their position of outcropping along the shore, and the development of large sedimentary landforms contribute to local variation in coastal aspect and exposure, hence variation in the relative intensity of meteorological and oceanographic processes affecting the coast.

Inter-regional variation in sediment cells is summarised by comparing the criteria for mapping cells for the four regions of Vlamingh, Mid-West, Northampton and Pilbara. Criteria for defining sediment cells for the Mid-West Region were the same as the Northampton Region[52], but differ from those used in the Vlamingh and Pilbara Regions[38,53]. Despite the differences, a consistent approach has been used to determine the beachface point on the alongshore boundaries and follows the procedure described in the coastal compartments report[26]. Differences in criteria between the Vlamingh Region and Mid-West Region is related to engineering modifications and the presence of near continuous ridges formed by elongate reefs, large islands and basins in the Vlamingh Region (Appendix C). Differences in criteria between the Pilbara Region and Mid-West Region is related to a shift in dominant forcing from waves in the southern regions to tidal reworking, extreme waves and increased river activity in the Pilbara (Appendix C).

Differences to landform vulnerability assessments

The cells defined in this report may differ from those described within the recent landform vulnerability reports prepared by the same authors[27,28]. Previous cell descriptions and vulnerability assessments[27,28] should not be aggregated into the revised cell hierarchy presented here without reassessing the main landforms within each cell appropriate to the scale of interest. The hierarchy of cells presented here should be used in preference to those previously defined for the Moore River to Kalbarri[27,28].

Cells reported in 2012[27,28] were non-hierarchical, comprising a set of points along the coast. They were used for a landform-based coastal vulnerability assessment and were therefore mapped to a high resolution (small-scale cells). They correspond to tertiary or quaternary cell scales in the present hierarchy. The two-dimensional mapping of cells in this present report captures interactions between marine and terrestrial environments at comparable scales along the coast. It also facilitates interpretation of the interactions between and within scales.

Comparison of the cell hierarchy with previous cell definitions[27,28] is demonstrated in Tables D.1 and D.2 in Appendix D for the two separate reports. The 29 cells of the Shires of Gingin and Dandaragan report[27] are mapped as three primary, seven secondary and 21 tertiary cells (Table D.1 in Appendix D). The 46 cells of the Shires of Coorow to Northampton report[28] within the Mid-West Region are mapped as four primary, nine secondary and 20 tertiary cells (Table D.2 in Appendix D).

Applications

In this report, sediment cells are areas in which there is strong connectivity between marine and terrestrial landforms. Hence, they are natural management units, presented in a simple spatial format. Applications of sediment cells include identification of spatial context for coastal evaluations; a common framework for dialogue about the coast; support to coastal management decision-making and a range of technical uses largely relating to coastal stability assessment. Some uses of sediment cells are listed in Table 8 and briefly described below.

Table 8: Applications of sediment cells

Context	• Identification of area to be evaluated • May be used for problem scaling
Communication	• Cross-jurisdictional co-operation • Spatial basis readily comprehended by non-technical audience • Common framework for discussion between disciplines
Decision-Making	• Screening destabilising actions from high coastal amenity • Recognition of stabilisation trade-offs
Technical Use	• Improved coastal erosion assessment • Sediment budget development • Upscaling and downscaling of coastal information • Identification of key coastal processes • Landform vulnerability assessment

Context

As defined in this report, sediment cells provide an indication of a spatial area within which marine and terrestrial landforms are likely to be connected through processes of sediment exchange. This implies that either natural or imposed changes at any point in the cell may affect any other part, recognising such relationships are strongly bound by proximity. A fundamental use of sediment cells is therefore one of ***context***, to identify an area that should be considered in a coastal study. Specifically, questions that should be considered are:

- How may an imposed action, such as installation of a groyne, affect the wider coast through changes to the sediment budget?
- Have changes to the wider area influenced locally observed response?

Note that this does not mean that sediment cells must be used to define a study area or model area. These are typically smaller due to data or budget limitations.

A qualitative assessment within the sediment cells context is often valuable for problem scaling when dealing with coastal instability. Considering whether an observed issue is prevalent within a cell or adjacent cells may provide guidance on the type of management solutions available, and therefore suggest the form of technical advice most likely to be useful (Figure 6). For example (labelling corresponds to panels in Figure 6):

A. If there is a balance of erosion and accretion within a sediment cell, there is potential opportunity to manage the problem through coastal stabilisation works, which transfer stresses along the coast;
B. For a coastal stability issue that is affecting the majority of a sediment cell, it is appropriate to improve coastal resilience, including techniques that improve the transfer of sand from the nearshore to the beach and dune system;
C. If erosion and accretion occur differently between cells, it is possible that the stress can be more evenly distributed, including artificial interventions such as bypassing. However, limited natural sediment transfer at cell boundaries determine that balancing erosion and accretion requires long-term management;
D. If erosion or accretion is prevalent across multiple cells, the issue is likely to be dominant in the long term. This typically requires a decision about where to focus the problem, such as through identification of sacrificial coastal nodes.

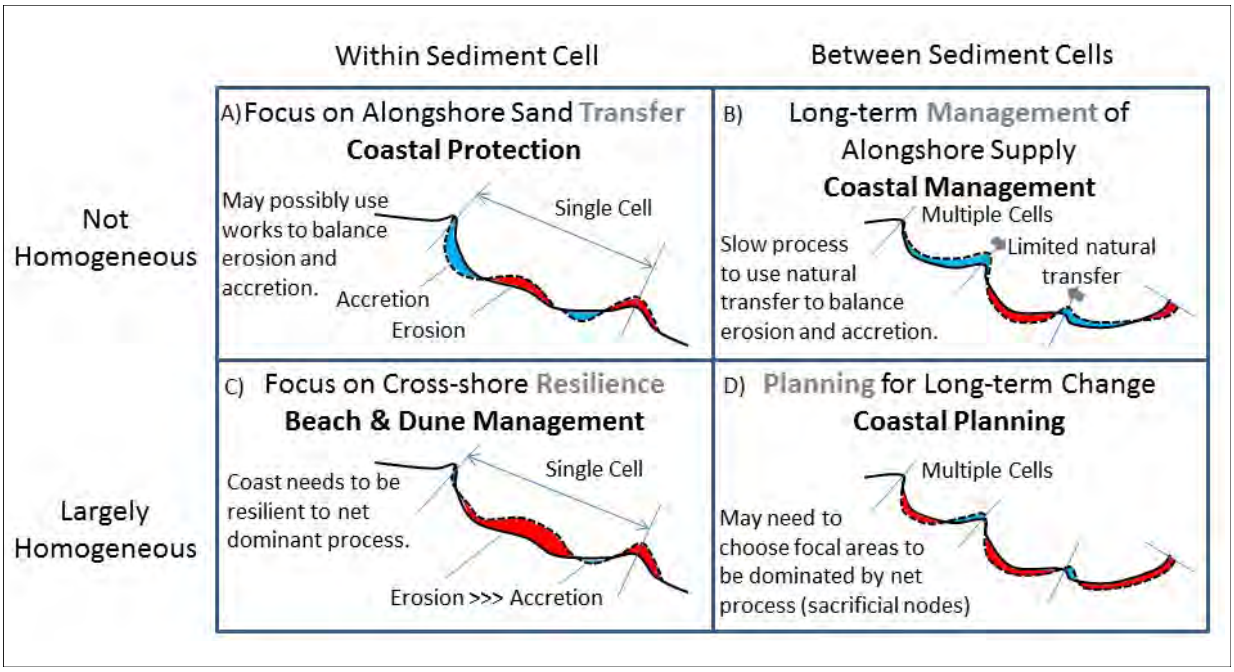


Figure 6: Use of sediment cells for problem scaling

Communication

A key feature of the sediment cell framework is its development from physical attributes rather than a jurisdictional basis. This highlights situations where communication between coastal managers may be necessary, and supports formation of strategic planning groups such as the Peron-Naturaliste Partnership or Cockburn Sound Coastal Alliance in the Vlamingh Region.

The relatively simple spatial representation of sediment cells may be a valuable tool for communication between technical agencies and the general public. Recent application of coastal process connectivity mapping[24] has highlighted the value of simple spatial tools to help explain the basis for coastal management decisions to a non-technical audience.

The value of communicating through a common spatial framework may also enhance dialogue between technical staff involved in different disciplines. The framework of sediment cells and coastal compartments are designed to be of use for coastal management across multiple scales, from engineering through to strategic planning[26]. However, the strong relationship between habitats and morphology[54], includes links between catchments areas and sediment cells. This more broadly suggests that sediment cells may have value as natural management units when considering natural resource management or coastal ecosystem services.

Decision-making

Recognition of the inter-connected nature of marine and terrestrial landforms within a sediment cell may support simplified decision-making by coastal managers, including local and State government agencies.

For agencies managing large areas, sediment cells can be used for low-cost geographic screening, particularly when combined with the direction of net alongshore sediment transport. As the cells provide preliminary guidance regarding the possible extent of development impacts, the cells framework may be used to guide the distribution of infrastructure. For example, destabilising infrastructure may be preferentially excluded from a cell containing sensitive or high amenity coastal areas. Alternately, a largely isolated single cell may be identified as a strategic coastal node, with focused coastal protection works and interventions creating a minimised coastal footprint.

An objective of the sediment cells definition is to focus coastal managers' attention upon the connected nature of marine and terrestrial landforms. This is intended to disrupt expectation that the whole coast under management can be made stable. For every effort toward stabilisation, the consequent trade-off should be clearly identified and understood. This way of thinking reduces the likelihood of tail-chasing through successive coastal stabilisation works.

Technical use

A major technical use for sediment cells is to improve erosion hazard assessments by better integrating regional and local coastal change. Regional changes may include the effects of climate or sea level fluctuations and the consequent variations in sand supply. Local changes include storm responses and coastal interactions with natural and artificial structures. Improved knowledge of how local changes may have broader impact is essential to good coastal planning[20,21,22,55,56,57]. Equally, refined understanding of how regional change influences local response can improve setback assessment[58] and structural design[59].

Sediment cells evaluated for regional processes should be identified based on the relative magnitude of local coastal change and the proximity to cell boundaries. Large-scale engineering works, such as ports and harbours, should be considered over the full hierarchy of primary, secondary and tertiary sediment cells to ensure adequate identification of possible effects. However, most planning and engineering investigations require consideration at a secondary cell scale as this incorporates broad sediment transport processes over inter-decadal timescales. If proposed works are unlikely to restrict sediment transport on an inter-annual scale, assessment may occur at tertiary cell scale. In all cases, proximity to a cell boundary may suggest the need to consider adjacent cells.

Landform information used to develop the sediment cells, including indications of sediment transport pathways and sinks, is equally important to the development of quantitative sediment budgets. Consequently, the sediment cells framework provides a useful spatial basis for the development of sediment budgets[1,2,6]. Detailed application of a sediment budget-based coastal assessment has recently been conducted in the Geraldton area[39] (Cell R07F). The effect of timescale on sediment budget variability is acknowledged along the Midwest coast, with ocean-estuary exchange and pulses of sand supply contributing to these fluctuations.

Definition of sediment cells (and coastal compartments[26]) over multiple spatial scales supports the processes of upscaling and downscaling, where information collected or applicable at one particular scale is made meaningful at another larger or smaller spatial scale. Upscaling involves the aggregation of information from a finer scale, often sparse across the wider area. Downscaling involves interpretation of coarse scale information at a finer scale, usually through the use of additional information. The concepts of upscaling and downscaling are important tools for combining regional and local coastal change assessments, often using a sediment budget approach.

Connectivity of marine and terrestrial landforms is used as a basis for sediment cell definition. The identified landforms and pathways for transport may also suggest the key active coastal process and therefore indicate appropriate conceptual models for coastal dynamics. Mapping of coastal morphology in the Mid-West Region has been described as part of the WACoast series[29,30] and landform vulnerability reports[27,28].

Sediment cells have previously been used as a spatial framework for landform-based coastal vulnerability assessment in the Mid-West Region[27,28]. This assessment involved coastal classification based on landform characteristics considering both present-day mobility and the potential sensitivity to disturbance of existing conditions.

Modification of cell boundaries

Although the cell boundaries have been presented as a spatial framework, they are based upon interpretation of geomorphic information. Therefore boundaries may require variation according to either the intended application or due to further relevant information being obtained. Common reasons to update the database describing the cells may include:

- Large-scale change that will affect cell connectivity;
- Coastal change near a cell boundary;
- Modification due to engineering works; or
- More detailed evaluation of active coastal behaviour.

Sediment cell connectivity

Determination of the number and scale of sediment cells used for coastal assessment should involve consideration of the magnitude and timescale of coastal change as well as the relative connectivity between sediment cells. It is appropriate to consider multiple sediment cells when evaluating larger or more sustained coastal change, or when assessing cells with moderate or high connectivity. Cell connectivity is indicated by the nature of the coastal boundary, with higher connectivity occurring where:

- The boundary is open or ambulatory; for example, sediment transfer occurring across boundaries on salients and cuspate forelands;
- Reversal of littoral drift direction is known to occur;
- There is an onshore feed of sediment;
- A boundary is located on a sediment source or sink; or
- Boundaries providing headland control of estuary entrances to coastal lowlands.

Investigation of coastal processes should recognise the potential role of connectivity between cells, including the relative significance of prevailing and extreme events in driving linkage of adjacent cells.

In situations where coastal change is substantial, such as coastal adjustment subsequent to mass deposition from a river system, or the potential impact of sea level rise over the next hundred years, there is potential for change to affect even rock boundaries. Users of the cell framework on mixed rock and sand coasts, such as the Mid-West coast, should consider:

1. Sections of coast which have occasional outcrops of rock and are progressively eroding will potentially reach points where either the rock has reduced influence on the coast, or a newly exposed area of rock starts to control the coastal configuration. These changes of coastal state may effectively alter sediment cell boundaries.
2. The influence of rock features that control the coast through sheltering may change with sediment supply. The resulting sandy features, salients or cuspate forelands, may migrate under changing meteorological, oceanographic or sediment supply conditions. This can occur following a loss of offshore reef control, as has been reported for a calcarenite coast[60], or if there is a reduction in sediment supply such as caused by Geraldton Port breakwaters.

Proximity to cell boundaries

As the influence of a local coastal change is strongest in its immediate vicinity, it is possible for the effect of a moderate change to be transferred across a cell boundary. In such a situation, adjacent sediment cells should be assessed simultaneously.

Modification due to engineering works

Engineering works may modify the nature of sediment cell boundaries and in some instances, might create new boundaries. An example of modifying the cell boundary has occurred at Geraldton Port, where the influence of the partly mobile salient has been overtaken by the extensive rock breakwaters.

Detailed evaluation of coastal behaviour

Detailed coastal assessment, including sediment analysis, sediment transport assessment or higher frequency evaluation of coastal configuration may provide better representation of how the sediment cell boundary operates. Cell boundaries may need to be reviewed following such investigations.

Recent work provides an example of how sediment analysis may be used to verify and resolve cell boundaries[39]. It is also an example of how previous knowledge of sediment cells can inform and have a bearing on a study of sediment transport. Processes affecting the distribution of sediments and variability in sediment supply from nearshore sources were investigated to help develop sediment budgets for the Tarcoola and Champion Bay embayments, north and south of Point Moore (R07F14 and R07F15). Study[39] outcomes relevant to the definition of sediment cells included:

- At a primary cell scale the study improved understanding of sediment sources and sinks over a long time scale. The presence of heavy mineral and garnet sands in beach sediments indicates river processes have played a major geologic role in sediment supply north of the Greenough River. This supports the selection of the primary cell Phillips Road Coast to Glenfield primary cell (R07F) incorporating the Greenough-Chapman paleo-delta.
- Separation of secondary cells at Point Moore was supported by differences in contemporary sources of sediment north and south of the Point Moore tombolo, with higher biogenic components derived from seagrass meadows to the south and higher components of reworked marine and terrestrial components to the north.

Possible studies to further resolve cell boundaries requires consideration of how the cells are to be applied, the time and space scales and the range of landforms within the domain of interest. For example, when assessing over an extended time scale for climate change adaptation assessment, there may be sensitivity to buried rock. A program of seismic surveys could therefore refine the onshore boundary. A second example is where coastal dunes define the onshore boundary of secondary cells, as the degree of dune mobility and the time scale of change will directly affect the area of interest. In this situation, active dune movement may be identified through aerial photograph interpretation or sediment analysis.

Further work to increase the resolution of cell boundaries may involve:

1. Ensuring the temporal and spatial resolution of data are consistent between datasets and fit for purpose at the scale at which they are being applied;
2. Extension of the criteria used to identify the cell boundaries to include criteria describing sediment characteristics and the limits to their distribution;
3. Identification of the potential for change of ambulatory boundaries at a local scale related to projected variation in climate and ocean processes, along with more detailed information of underlying rock structures;
4. Verification of sediment cells through determination of sediment character, composition, depth and distribution;
5. Determination of the contribution of barred estuaries to cell functions; and
6. Revision of cell boundaries in the event of large-scale engineering works, such as ports or harbours, restrict sediment transport at relevant time and space scales.

In the future, the beachface points identifying the alongshore boundaries of tertiary cells in the Mid-West Region should be extended to include their marine and terrestrial sections and link them with onshore and offshore boundaries, according to the recommended criteria in Table 1 and Table 2. This work could be conducted when datasets of sufficient resolution are available, such as LiDAR imagery of the nearshore (see *Information used to define the cells*).

Proposed modification of cell boundaries should be presented to the dataset custodian, the Western Australian Department of Transport. The modifications should be presented in either ESRI Shapefile format or as Google Earth KMZ files with metadata and supporting documentation.

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Coastal Sediment Cells for the Mid-West Coast

Appendices A to E

Appendix A
Secondary and Tertiary Cells

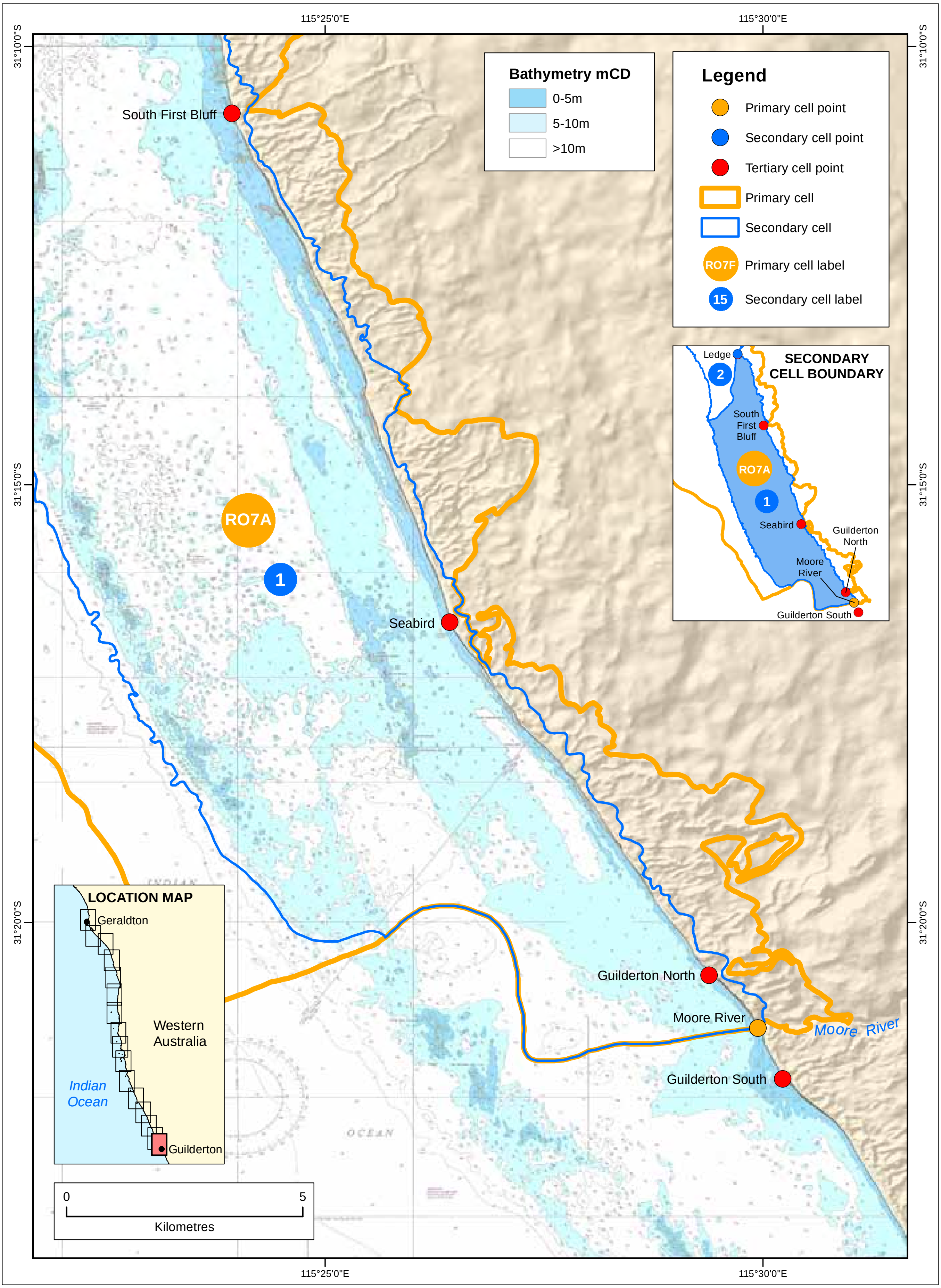

Figure A.1: Secondary cells and tertiary cell points of the Mid-West Region

Figure is at scale of 1:100,000 at A4. For all cells other than Moore River, a primary cell point is also a secondary and tertiary cell point. A secondary cell point is also a tertiary cell point. Moore River is only a primary and secondary point. This map should not be used for navigation purposes. Bathymetry information supplied by Department of Transport. Shaded relief model supplied by Geological Survey of WA, Department of Mines and Petroleum.

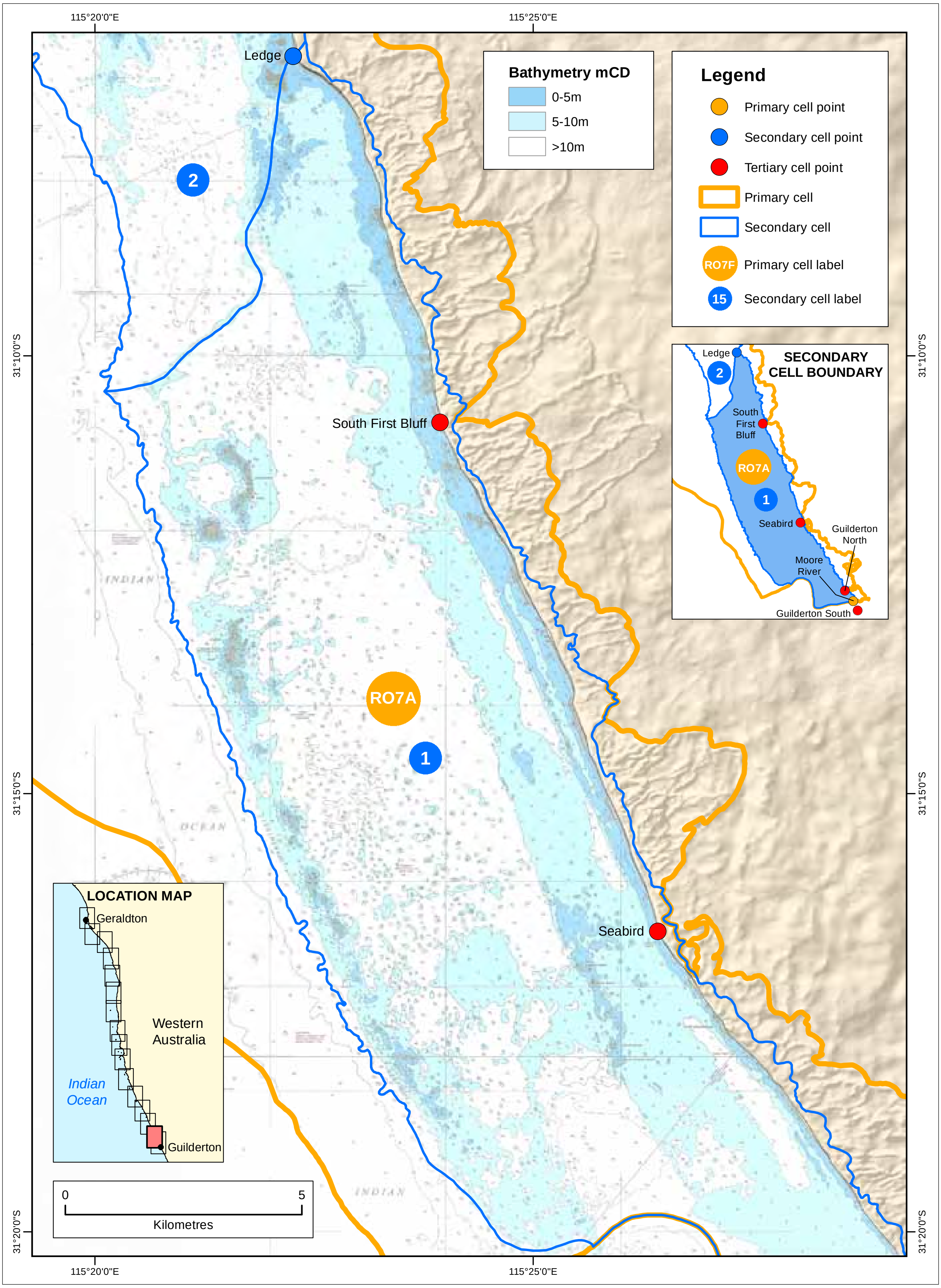

Figure A.2: Secondary cells and tertiary cell points of the Mid-West Region

Figure is at scale of 1:100,000 at A4. A primary cell point is also a secondary and tertiary cell point. A secondary cell point is also a tertiary cell point. This map should not be used for navigation purposes. Bathymetry information supplied by Department of Transport. Shaded relief model supplied by Geological Survey of WA, Department of Mines and Petroleum.

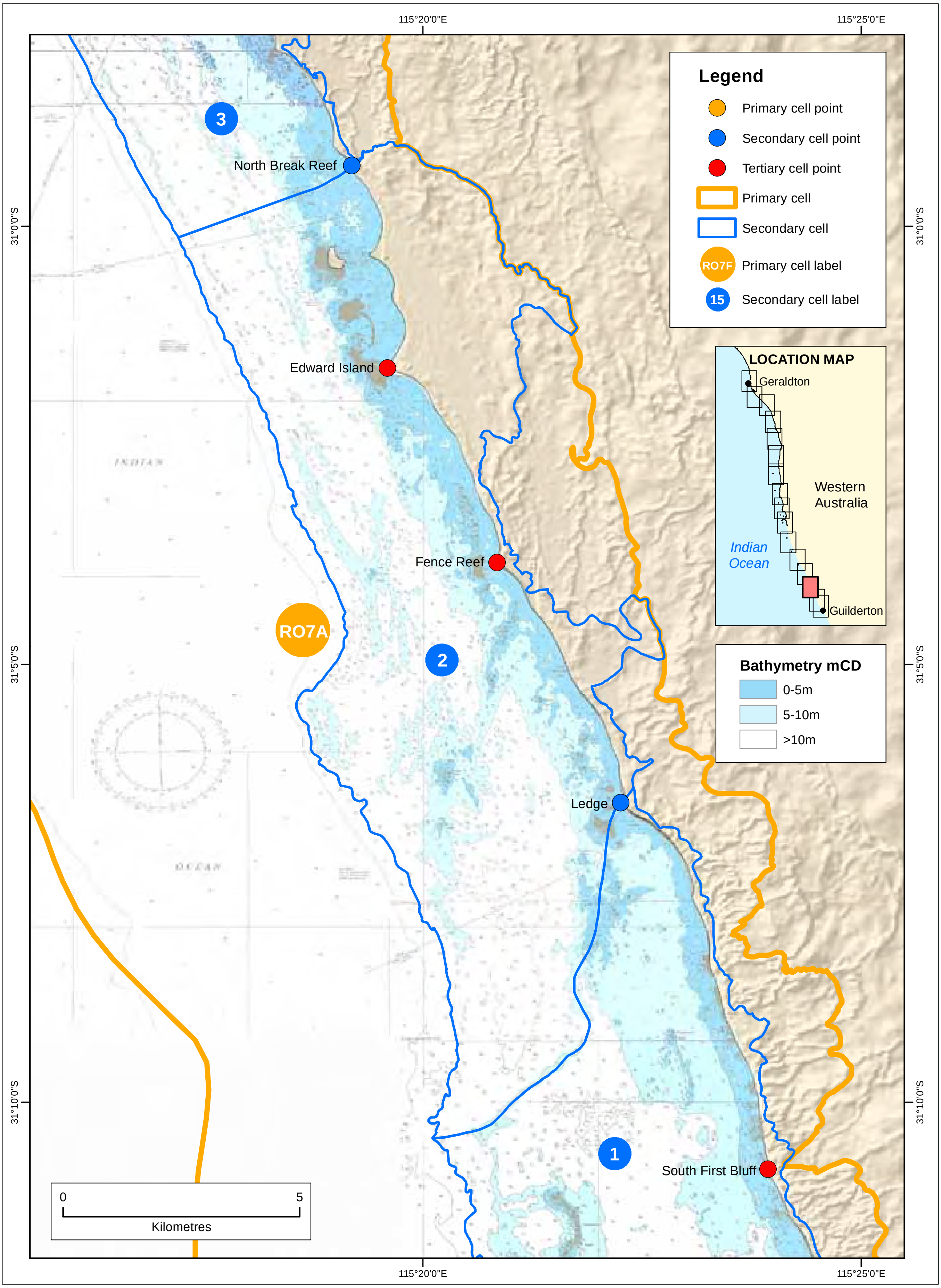

Figure A.3: Secondary cells and tertiary cell points of the Mid-West Region

Figure is at scale of 1:100,000 at A4. A primary cell point is also a secondary and tertiary cell point. A secondary cell point is also a tertiary cell point. This map should not be used for navigation purposes. Bathymetry information supplied by Department of Transport. Shaded relief model supplied by Geological Survey of WA, Department of Mines and Petroleum.

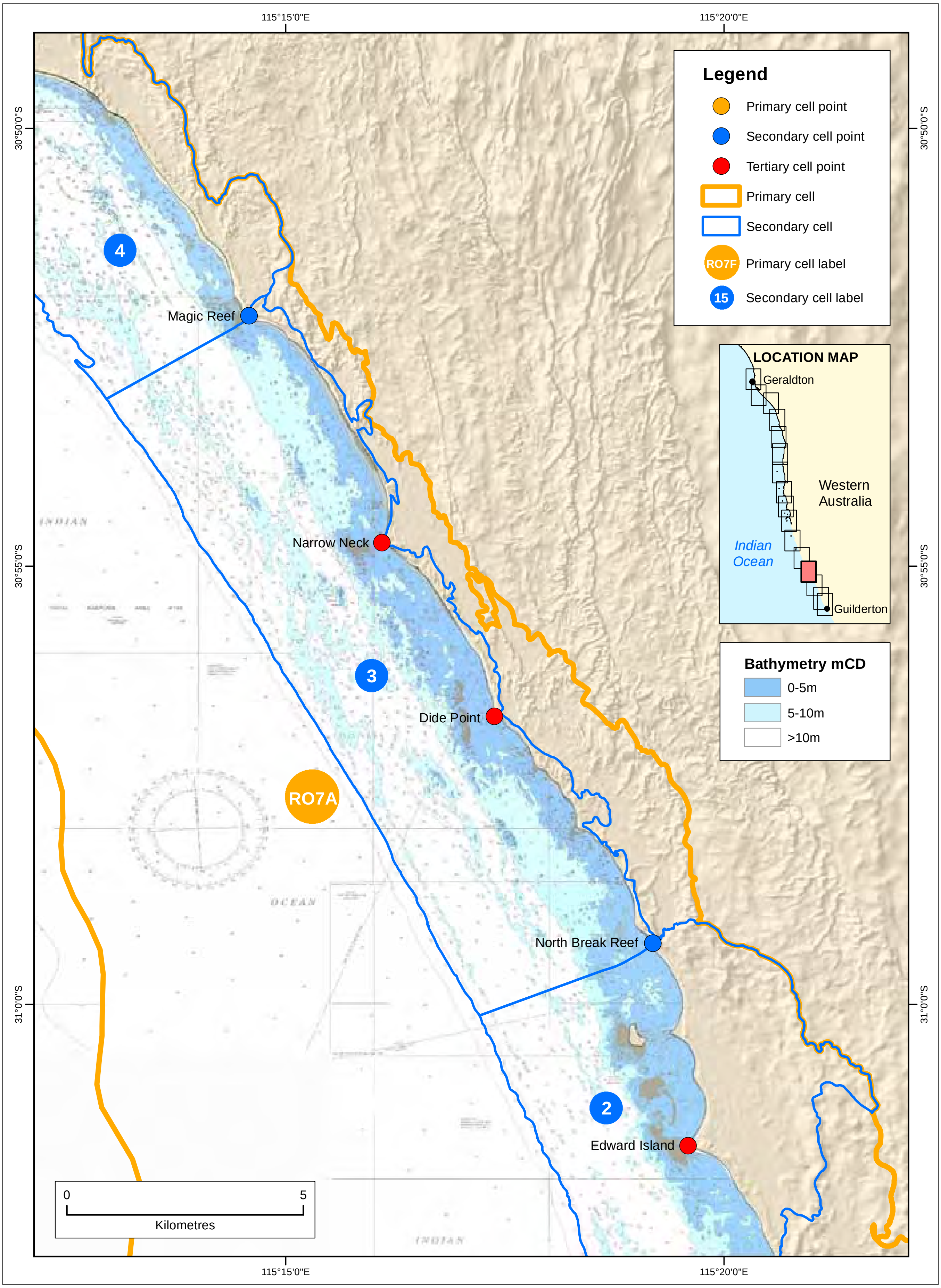

Figure A.4: Secondary cells and tertiary cell points of the Mid-West Region

Figure is at scale of 1:100,000 at A4. A primary cell point is also a secondary and tertiary cell point. A secondary cell point is also a tertiary cell point. This map should not be used for navigation purposes. Bathymetry information supplied by Department of Transport. Shaded relief model supplied by Geological Survey of WA, Department of Mines and Petroleum.

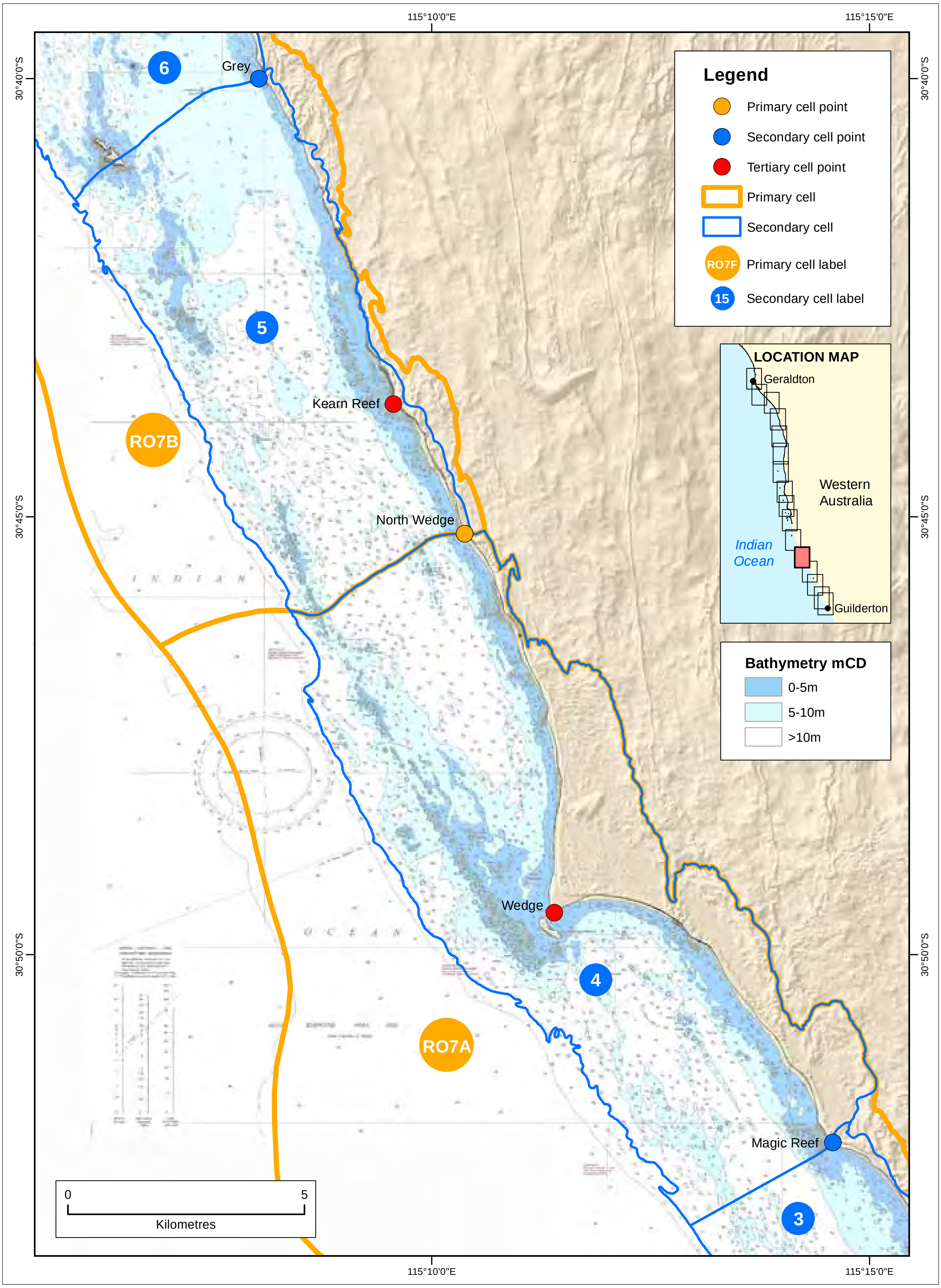

Figure A.5: Secondary cells and tertiary cell points of the Mid-West Region

Figure is at scale of 1:100,000 at A4. A primary cell point is also a secondary and tertiary cell point. A secondary cell point is also a tertiary cell point. This map should not be used for navigation purposes. Bathymetry information supplied by Department of Transport. Shaded relief model supplied by Geological Survey of WA, Department of Mines and Petroleum.

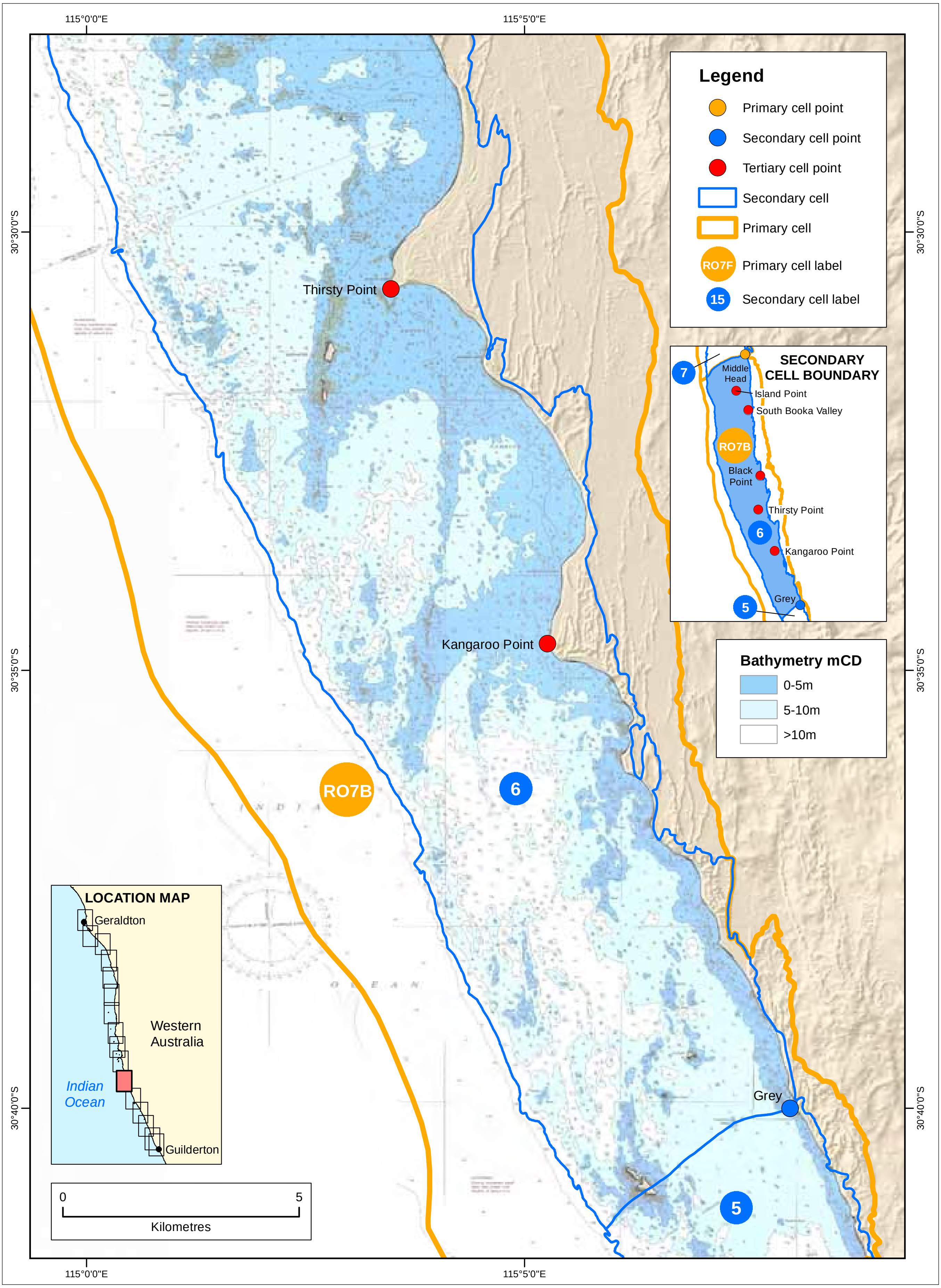

Figure A.6: Secondary cells and tertiary cell points of the Mid-West Region

Figure is at scale of 1:100,000 at A4. A primary cell point is also a secondary and tertiary cell point. A secondary cell point is also a tertiary cell point. This map should not be used for navigation purposes. Bathymetry information supplied by Department of Transport. Shaded relief model supplied by Geological Survey of WA, Department of Mines and Petroleum.

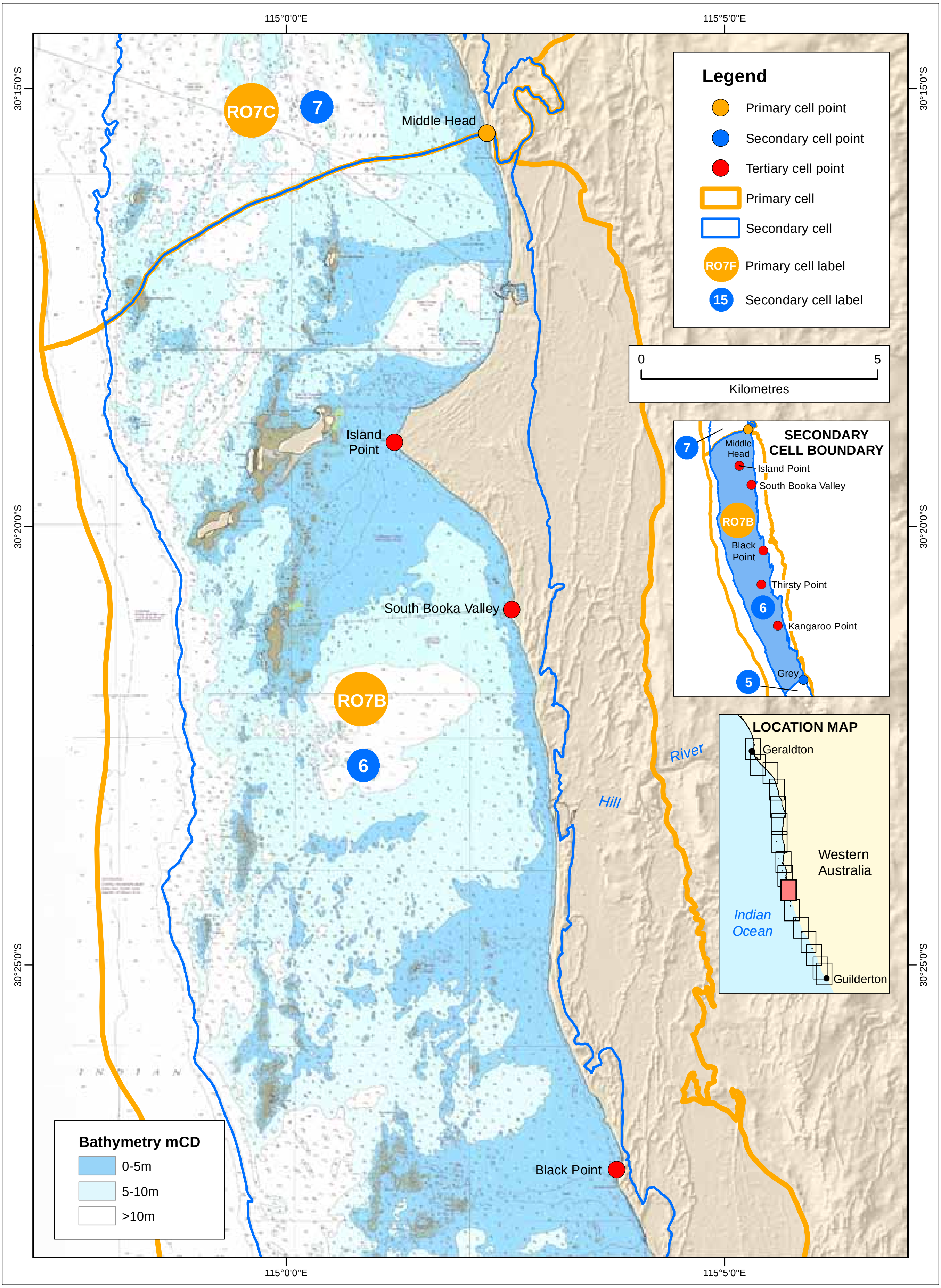

Figure A.7: Secondary cells and tertiary cell points of the Mid-West Region

Figure is at scale of 1:100,000 at A4. A primary cell point is also a secondary and tertiary cell point. A secondary cell point is also a tertiary cell point. This map should not be used for navigation purposes. Bathymetry information supplied by Department of Transport. Shaded relief model supplied by Geological Survey of WA, Department of Mines and Petroleum.

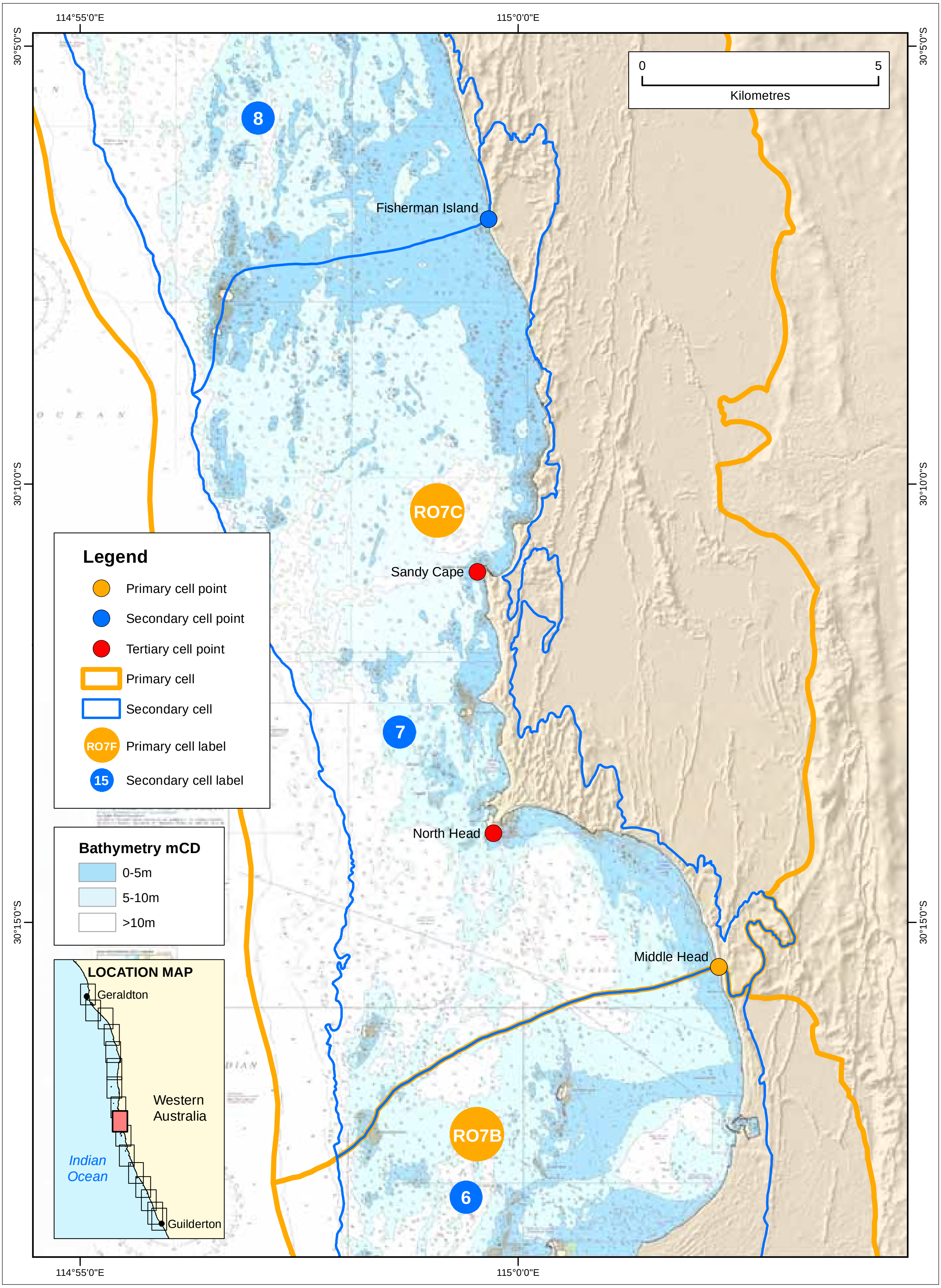

Figure A.8: Secondary cells and tertiary cell points of the Mid-West Region

Figure is at scale of 1:100,000 at A4. A primary cell point is also a secondary and tertiary cell point. A secondary cell point is also a tertiary cell point. This map should not be used for navigation purposes. Bathymetry information supplied by Department of Transport. Shaded relief model supplied by Geological Survey of WA, Department of Mines and Petroleum.

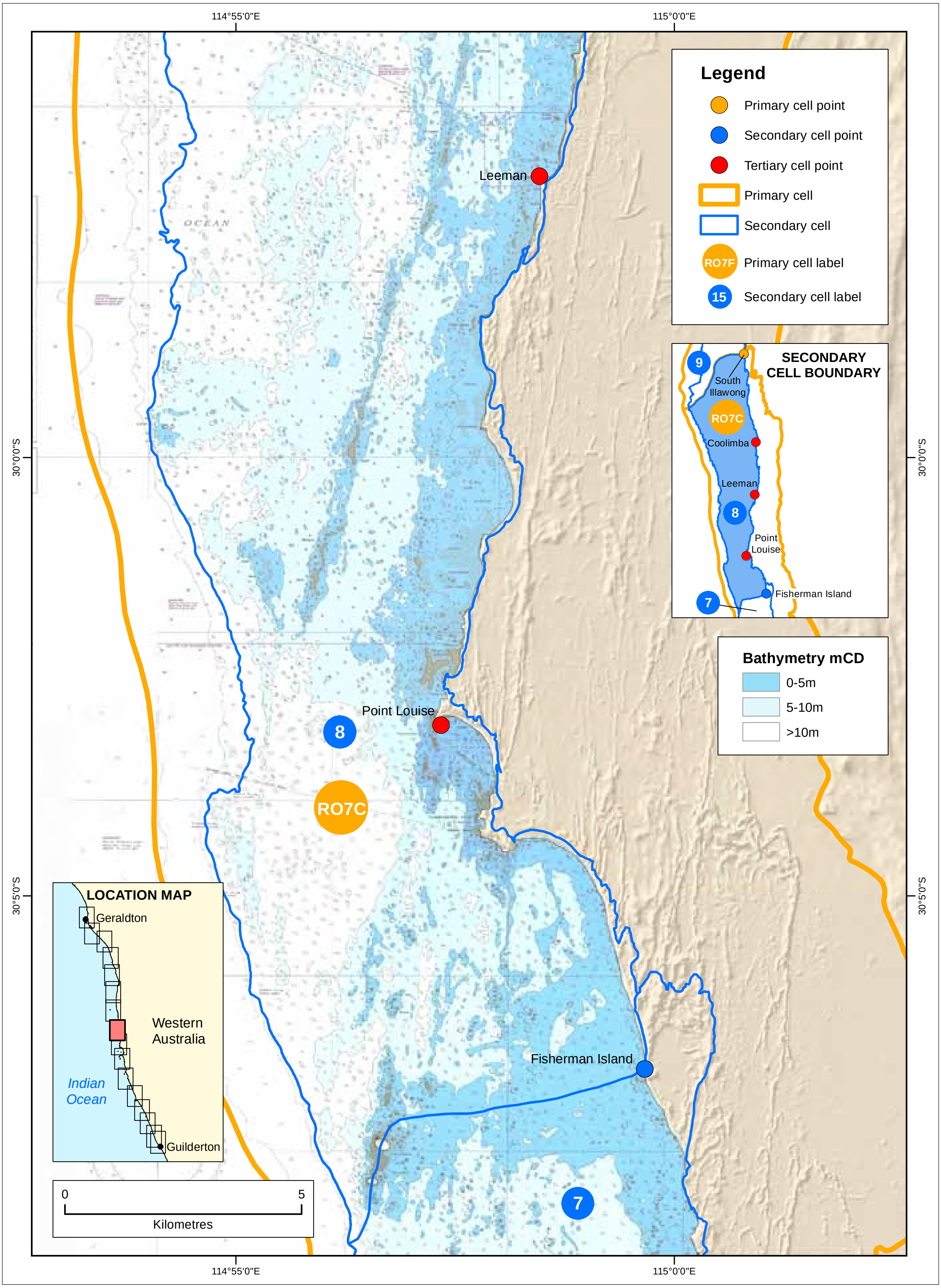

Figure A.9: Secondary cells and tertiary cell points of the Mid-West Region

Figure is at scale of 1:100,000 at A4. A primary cell point is also a secondary and tertiary cell point. A secondary cell point is also a tertiary cell point. This map should not be used for navigation purposes. Bathymetry information supplied by Department of Transport. Shaded relief model supplied by Geological Survey of WA, Department of Mines and Petroleum.

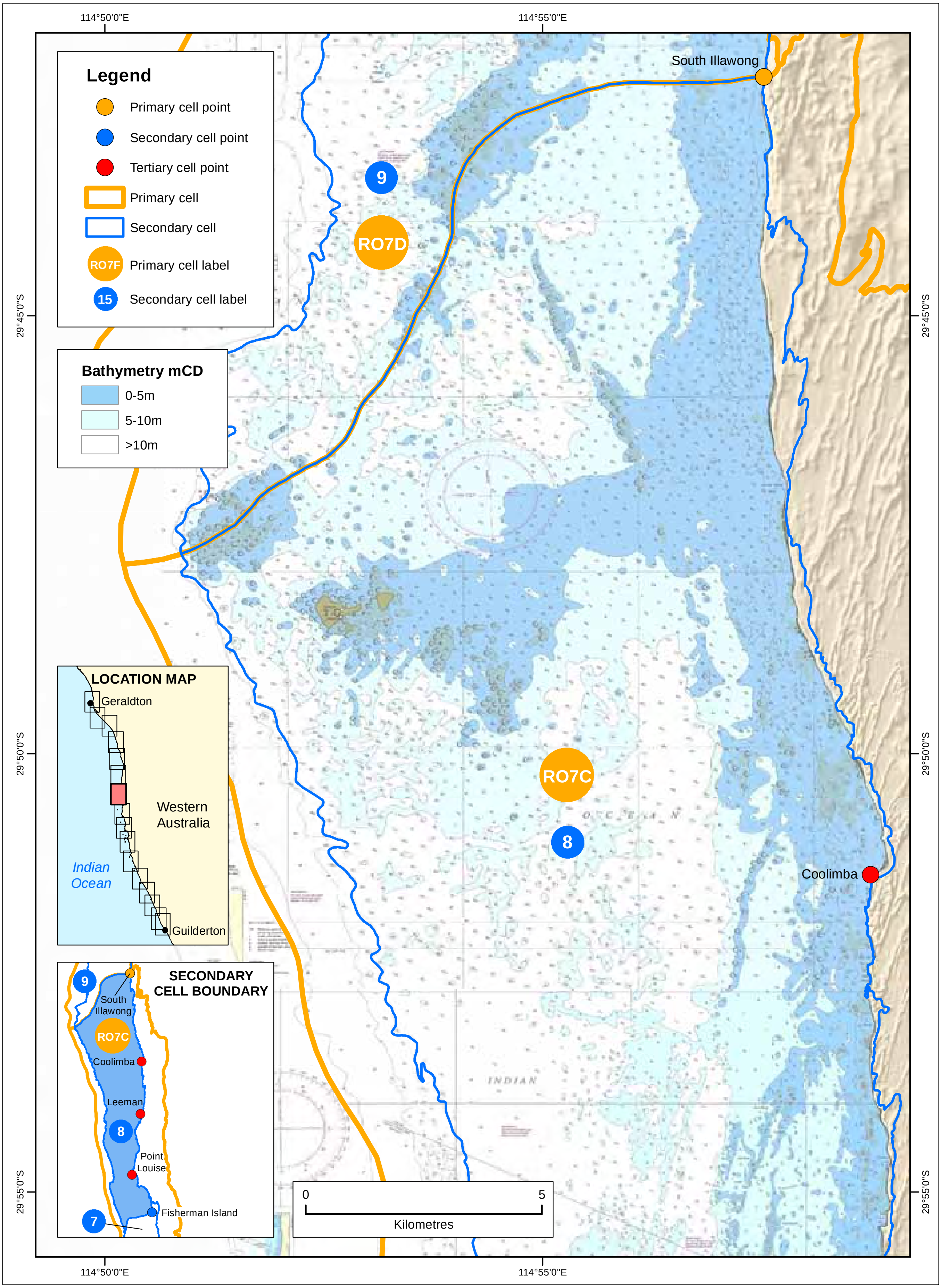

Figure A.10: Secondary cells and tertiary cell points of the Mid-West Region

Figure is at scale of 1:100,000 at A4. A primary cell point is also a secondary and tertiary cell point. A secondary cell point is also a tertiary cell point. This map should not be used for navigation purposes. Bathymetry information supplied by Department of Transport. Shaded relief model supplied by Geological Survey of WA, Department of Mines and Petroleum.

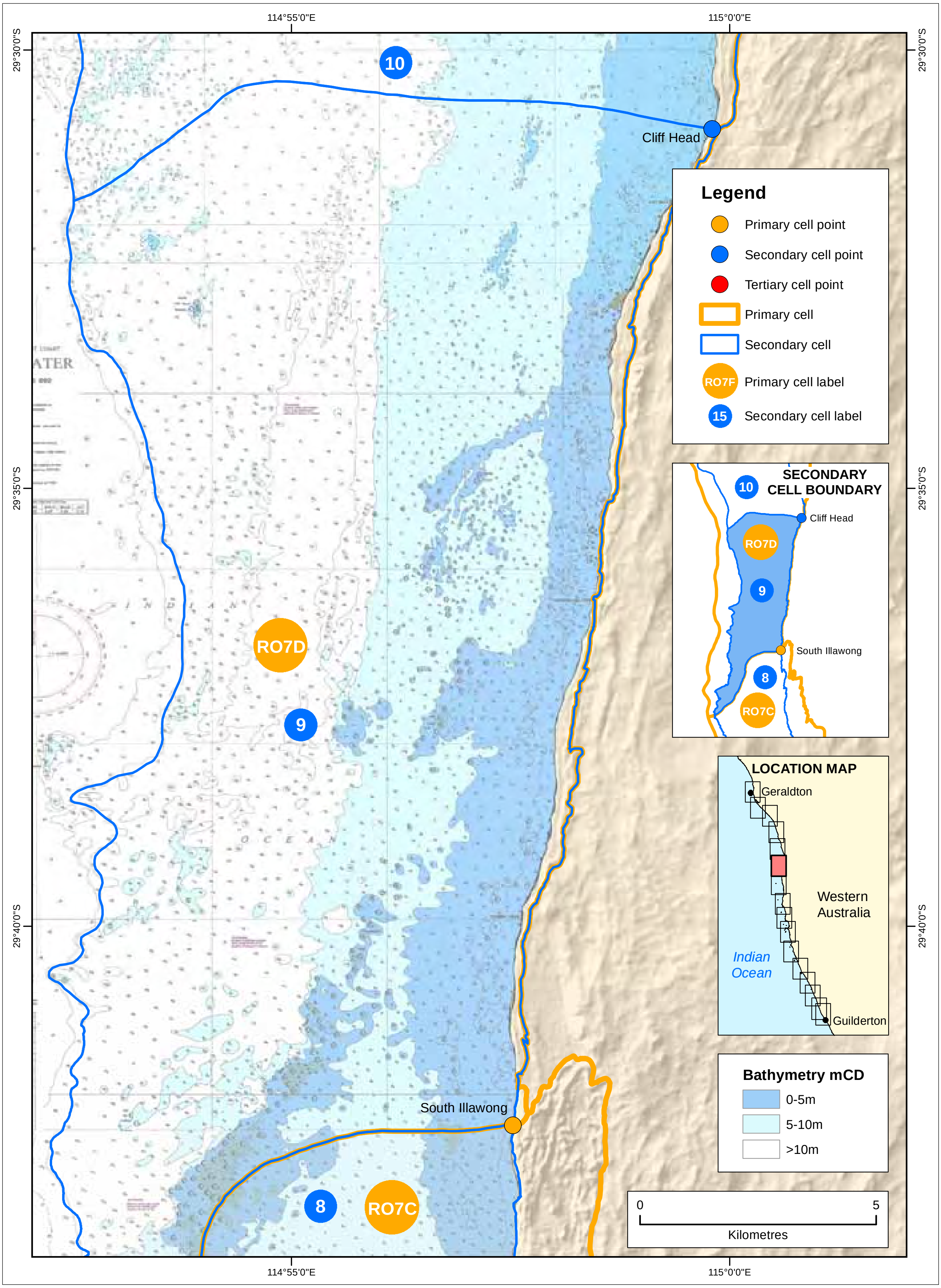

Figure A.11: Secondary cells and tertiary cell points of the Mid-West Region

Figure is at scale of 1:100,000 at A4. A primary cell point is also a secondary and tertiary cell point. A secondary cell point is also a tertiary cell point. This map should not be used for navigation purposes. Bathymetry information supplied by Department of Transport. Shaded relief model supplied by Geological Survey of WA, Department of Mines and Petroleum.

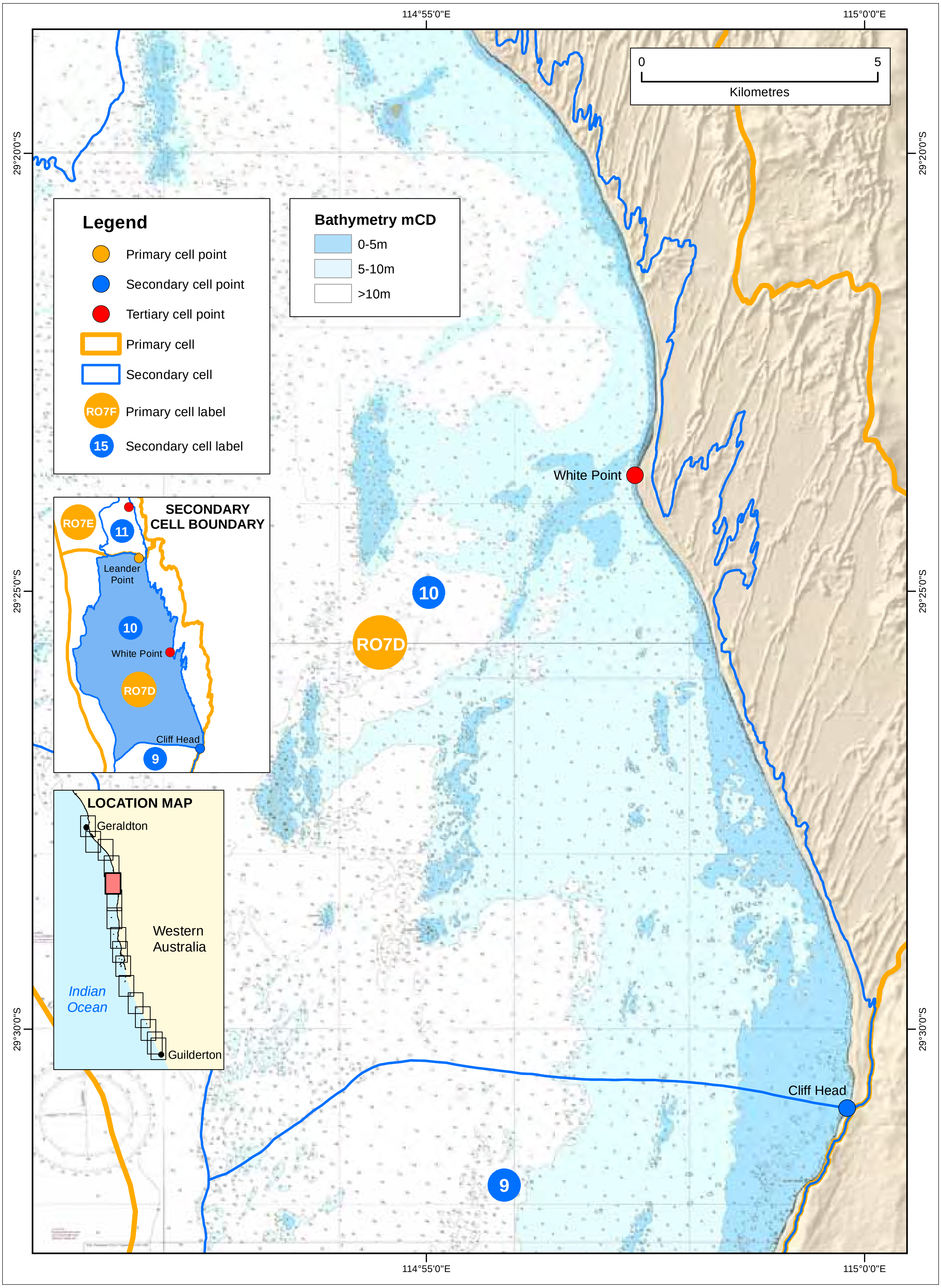

Figure A.12: Secondary cells and tertiary cell points of the Mid-West Region

Figure is at scale of 1:100,000 at A4. A primary cell point is also a secondary and tertiary cell point. A secondary cell point is also a tertiary cell point. This map should not be used for navigation purposes. Bathymetry information supplied by Department of Transport. Shaded relief model supplied by Geological Survey of WA, Department of Mines and Petroleum.

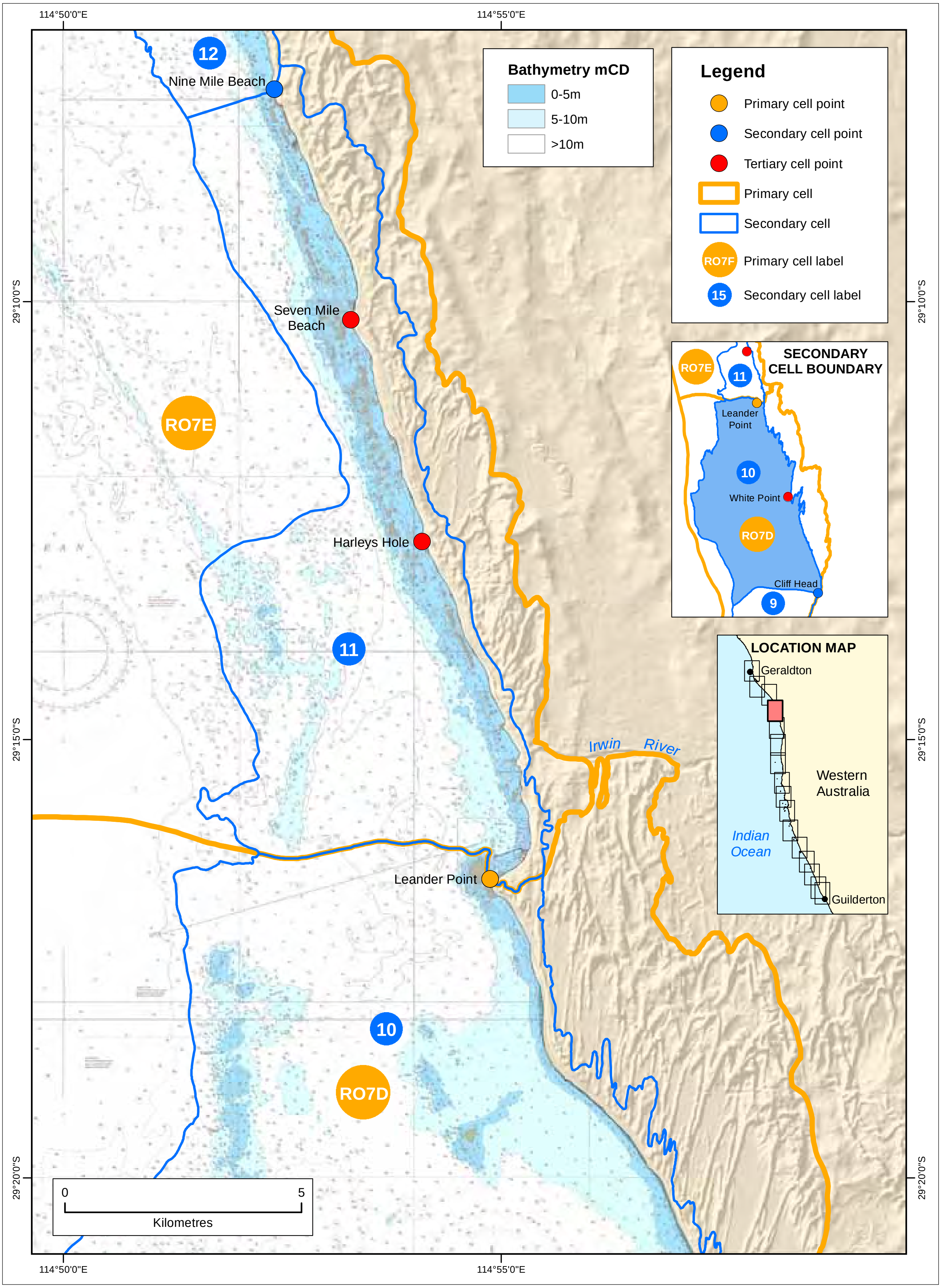

Figure A.13: Secondary cells and tertiary cell points of the Mid-West Region

Figure is at scale of 1:100,000 at A4. A primary cell point is also a secondary and tertiary cell point. A secondary cell point is also a tertiary cell point. This map should not be used for navigation purposes. Bathymetry information supplied by Department of Transport. Shaded relief model supplied by Geological Survey of WA, Department of Mines and Petroleum.

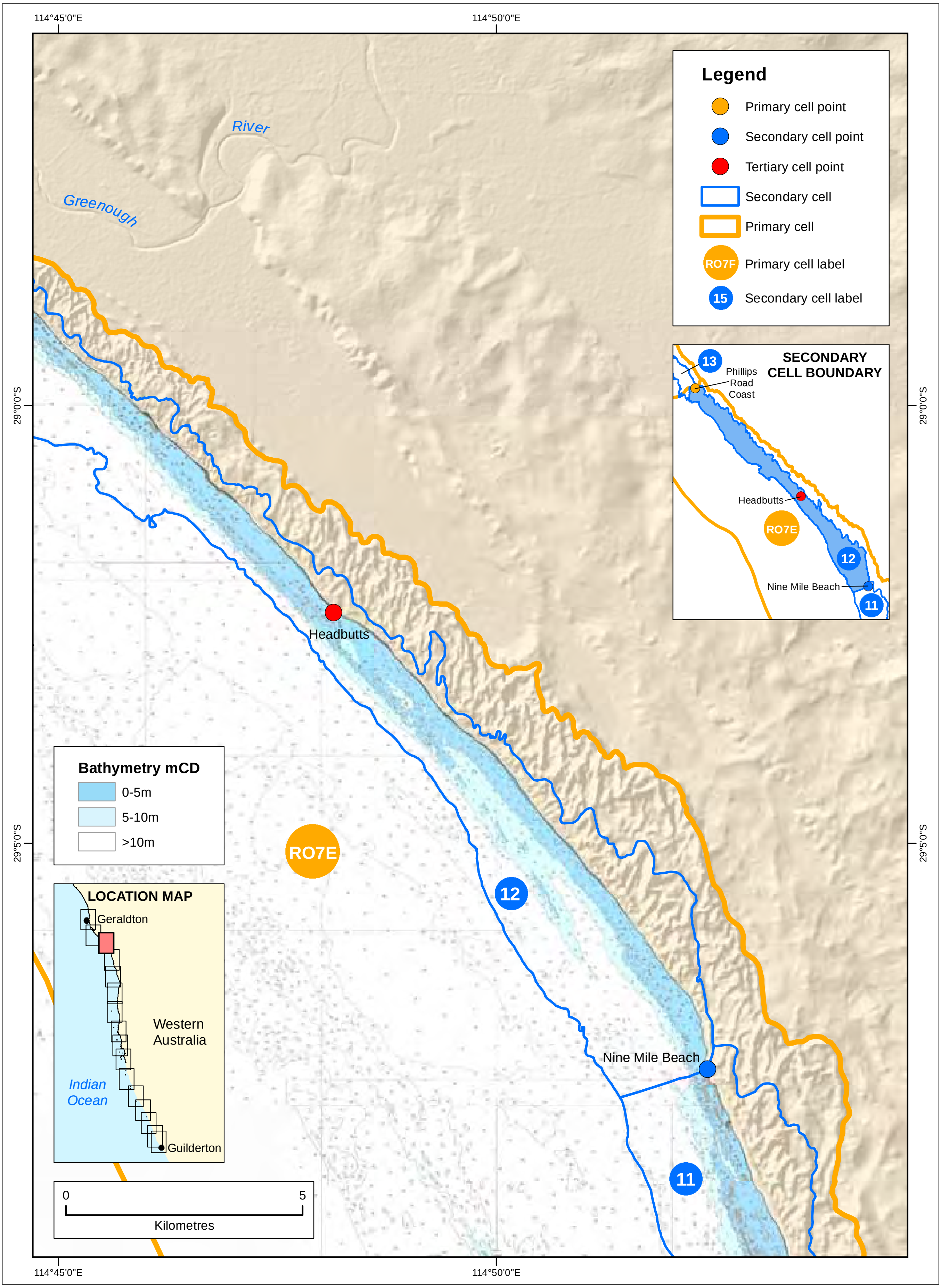

Figure A.14: Secondary cells and tertiary cell points of the Mid-West Region

Figure is at scale of 1:100,000 at A4. A primary cell point is also a secondary and tertiary cell point. A secondary cell point is also a tertiary cell point. This map should not be used for navigation purposes. Bathymetry information supplied by Department of Transport. Shaded relief model supplied by Geological Survey of WA, Department of Mines and Petroleum.

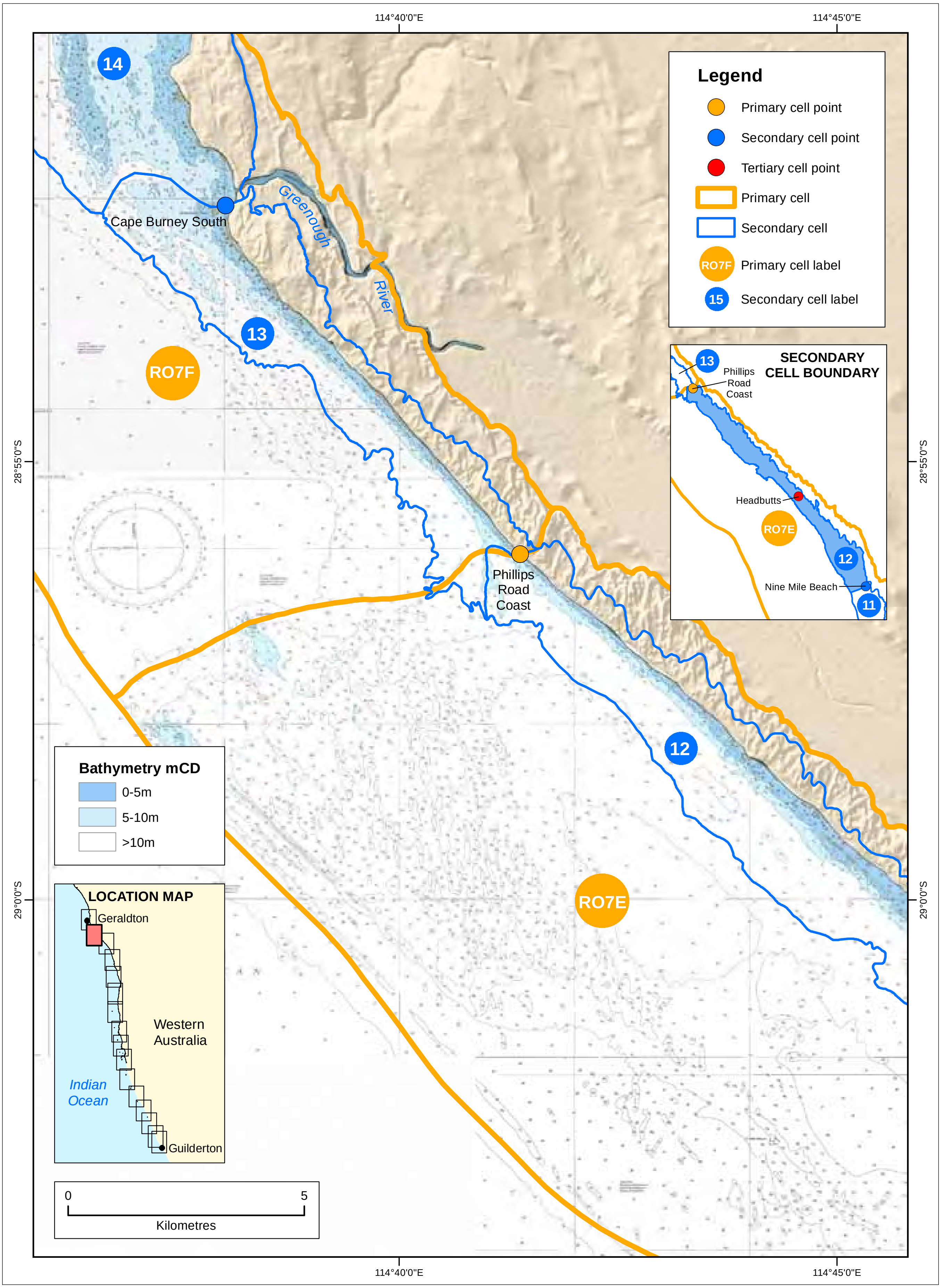

Figure A.15: Secondary cells and tertiary cell points of the Mid-West Region

Figure is at scale of 1:100,000 at A4. A primary cell point is also a secondary and tertiary cell point. A secondary cell point is also a tertiary cell point. This map should not be used for navigation purposes. Bathymetry information supplied by Department of Transport. Shaded relief model supplied by Geological Survey of WA, Department of Mines and Petroleum.

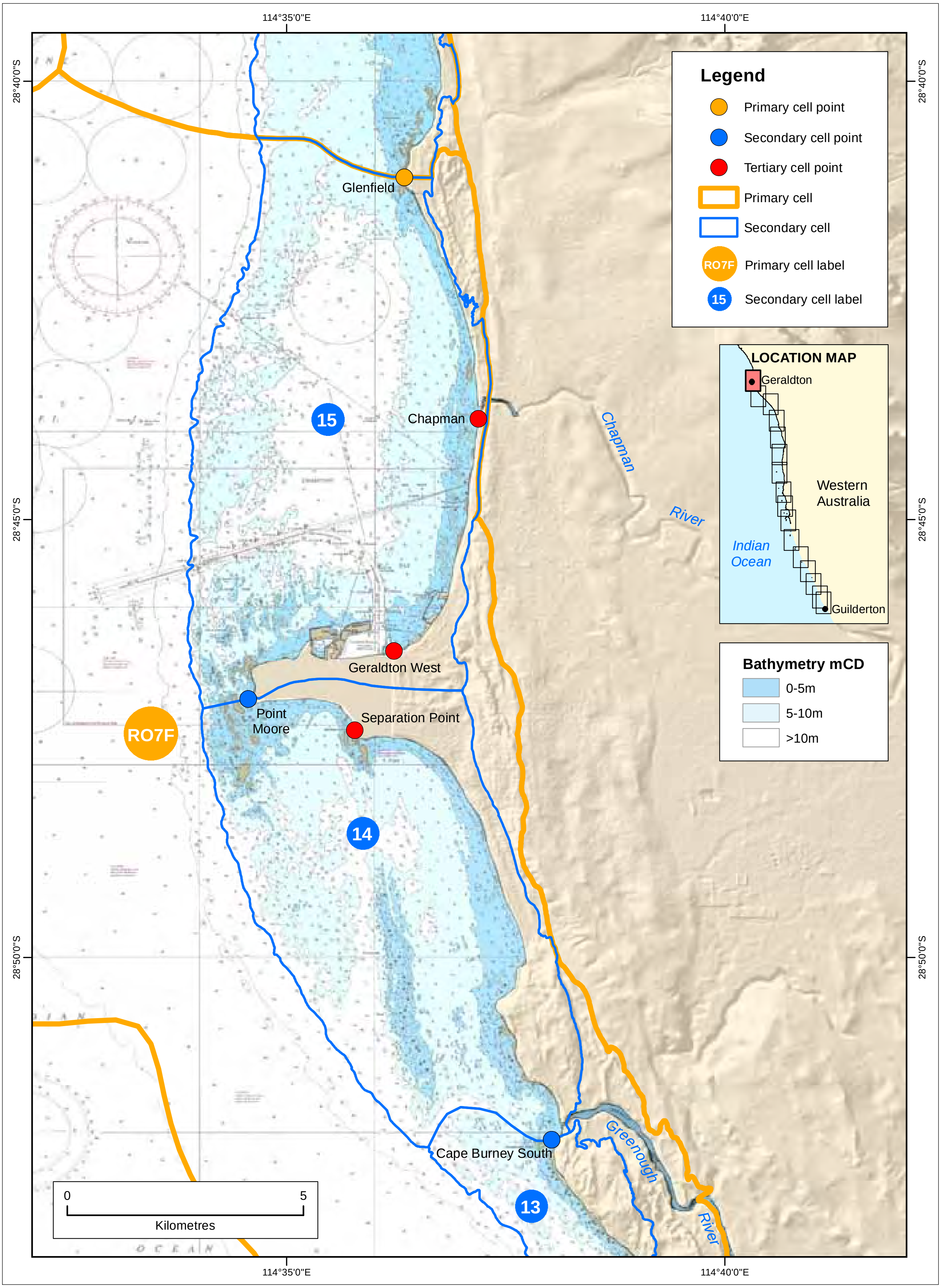

Figure A.16: Secondary cells and tertiary cell points of the Mid-West Region

Figure is at scale of 1:100,000 at A4. A primary cell point is also a secondary and tertiary cell point. A secondary cell point is also a tertiary cell point. This map should not be used for navigation purposes. Bathymetry information supplied by Department of Transport. Shaded relief model supplied by Geological Survey of WA, Department of Mines and Petroleum.

Appendix B
Data sets

Table B.1: Data Sources used for determining cell boundaries in the Mid-West Region

Source	Dataset
Context	• Geological and geomorphological information and photographs contained in the WACoast[1] database.
	• Sediment information, with some examples provided in cited references[2] .
Remotely sensed datasets	• *Bathymetry*: The preferred bathymetric data source for mapping sediment cells is nearshore and inshore LiDAR, with none available for this project. Datasets used were the Department of Transport (previously Department of Marine and Harbours) nautical charts and nautical isobaths; and Department of Planning polygons derived from Department of Transport nautical charts. All depths use the vertical datum of Australian Height Datum (AHD). Alternative information could have been used, however it was generally of a larger spatial resolution than needed, with reduced spatial accuracy. These datasets include the Australian Navy hydrographic charts, Geoscience Australia bathymetry, General Bathymetric Chart of the Oceans (GEBCO) bathymetry.
	• *Topography*: Geological Survey of Western Australia shaded relief model derived from the Landgate high-resolution digital elevation model. Alternative sources include Landgate topographic contours and spot heights; and recent onshore LiDAR collected by Northern Agricultural Catchments Council, made available after mapping was completed for this project.
	• *Vertical aerial imagery*: Landgate orthophotography from 1999-2012. Satellite imagery could be an alternative information source, but is generally of reduced spatial resolution and accuracy.
	• *Historic coastal change*: Historic aerial imagery provided context for coastal change, including recent changes identified in the time-series available in NearMap or GoogleEarth. There were limited Department of Transport shoreline movement plots for this coast[3], including plan books DPI5, DPI377 and DPI565. • *Shoreline*: The shoreline used as the basis for mapping is the Mean High Water Mark (MHWM) to 2006 prepared by Landgate and used by the Department of Environment and Conservation as the basis for the coastal compartment mapping[4]. This dataset is based on a combination of the cadastral and topographic coasts and is updated in areas as required based on government priority. It is unlikely to represent the location of the MHWM in 2006.
	• *Rivers*: 1:1M and 1:250k scale rivers by the Department of Water.
Landform mapping	• Digital dataset of the Holocene dunes and other landforms at 1:20,000 scale to 3km inland of Landgate MHWM to 2006 as part of WACoast datasets[1]. Land system information also in Department of Agriculture and Food Western Australia land resources series map and reports.
	• Heads up digitising (not photogrammetric) of frontal dunes from orthophotographs at various scales.
	• 1:100k geology maps (GSWA) show the Holocene extent for primary cell onshore boundaries.
Naming conventions	• AUSLIG. (1993) Topographic Series, 1:100 000 Map Sheets for Western Australia. Commonwealth Government, Canberra.
	• Geological Survey of Western Australia. (2007) Atlas of 1:250 000 Geological Series Map Images.
	• Department of Transport nautical charts and Australian Navy hydrographic charts.

(Footnotes)

1 Gozzard JR. (2011a) *WACoast – Cape Naturaliste to Lancelin*. Geological Survey of Western Australia digital dataset.
Gozzard JR. (2011b) *WACoast – Lancelin to Kalbarri*. Geological Survey of Western Australia digital dataset.

2 Collins LB. (1988) Sediments and history of the Rottnest Shelf, southwestern Australia: a swell dominated, non-tropical carbonate margin. *Sedimentary Petrology*, 60: 15–29.
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3 Public Works Department: PWD. (1983) *Coastline Movements: Leander Point to Moore River-Coolimba*. Coastline Movements Map Series, Public Works Department, Western Australia. 566-601.

4 Eliot I, Nutt C, Gozzard B, Higgins M, Buckley E and Bowyer J. (2011) *Coastal Compartments of Western Australia: A Physical Framework for Marine and Coastal Planning*. Report 80-02. Damara WA Pty Ltd. Report to the Departments of Environment and Conservation, Planning and Transport. Environmental Protection Authority.

Appendix C
Regional variation in criteria

Table C.1: Comparison of cell criteria for the Mid-West, Vlamingh and Pilbara Regions

The same criteria apply for Mid-West and Northampton Regions

	Vlamingh Region compared to Mid-West Region	Pilbara Region compared to Mid-West Region
Beachface point	Same criteria used.	Cells in the Pilbara Region are frequently defined to include areas with likely sediment supply by individual river systems, incorporating whole deltas within broader cells. Rivers in the Mid-West discharge smaller volumes of sediment, with cells more frequently defined based on changes in barrier land systems.
Offshore boundaries and marine section of the alongshore boundary	Continuous ridgelines of elongate reefs, large offshore islands within the primary cell offshore boundaries, large sediment banks and basins are prominent features in the Vlamingh Region. The offshore boundaries and the marine section of alongshore boundaries in the Vlamingh Region take into account the presence of these features as well as sheltering of wave energy by the larger islands. *Offshore boundaries* are simplified for the Mid-West Region to one criterion per cell level corresponding to a depth of -30m AHD for primary cells, -15m AHD for secondary cells and -5m AHD for tertiary cells.	*Offshore boundaries* of cells in the Pilbara Region are related to tidal reworking of sediment and waves, whereas waves are the primary process for the Mid-West Region. One consequence of this difference is offshore boundaries generally occur at shallower depths for the Pilbara Region in areas where tidal reworking and extreme waves provide the dominant environmental forcing.
	Marine sections of the alongshore boundaries were mapped as orthogonal to the coast in the Mid-West Region where limited bathymetric information was available. Mapping the toe of Holocene sediment banks in the Vlamingh Region is not included for the Mid-West Region.	*Marine sections* of the alongshore boundaries cannot be easily resolved due to extensive tidal reworking of sediments from multiple rivers across the broad nearshore area in the Pilbara Region, combined with limited bathymetric information. Marine sections were often not orthogonal to the coast, but were skewed in the direction of the dominant current or wave forcing following high points in the bathymetry or ridge lines of islands.
Onshore boundaries and terrestrial section of the alongshore boundary	The Vlamingh Region is the most densely populated area of the Western Australian coast and the coast has been extensively modified. Hence more criteria for onshore boundaries and the terrestrial section of alongshore boundaries are related to engineering works.	Rivers, creeks and outwash plains are common features of the Pilbara Region, with fluvial breakouts and interactions with marine processes at multiple scales. Due to this interaction of estuarine and alluvial land systems, onshore boundaries at a primary cell scale cannot be represented by the landward extent of Holocene and alluvial land systems because the onshore boundaries would be more than 70km landward of mean sea level.
	Natural *onshore boundaries* of cells in the Vlamingh Region are mainly the landward extent of Holocene land systems. Two exceptions are included for the Mid-West Region to ensure exclusion of dunes without a connection to the coast and inclusion of dunes abutting rocky topography to landward, such as colluvial foot slopes and cliffs.	*Onshore boundaries* for primary cells in the Pilbara Region are linked to elevation contours for the extensive systems of outwash plains, where Holocene land systems are used in the Vlamingh Region. Onshore boundaries for secondary and tertiary cell scales relate to the landward extent of supratidal landforms and inter-tidal landforms respectively, excluding the presence of dunes, cliffs and engineered coasts.
	Terrestrial sections of the alongshore boundaries also include discontinuities in large mobile dunes or narrow dune barriers for the Mid-West Region.	*Terrestrial sections* of the alongshore boundaries cannot easily be resolved in the Pilbara Region due to extensive marine and fluvial interactions at multiple scales over the low-lying topography. Most frequently the boundary was mapped to ridgelines and connecting high points that separate basins.

Appendix D

Comparison to previously defined cells in the Mid-West Region

Table D.1: Mid-West Region cells compared to cells in Landform Vulnerability Report 1

Comparison between 29 of the cells identified in a previous landform vulnerability study for Shires of Gingin and Dandaragan[1] to the revised hierarchy of boundaries in this report. The cell hierarchy presented in this report should be used in coastal studies rather than the cell boundaries used in the 2012 study. Further discussion is included in the Results section of the report.

Cell Hierarchy			Cells from Shires of Gingin and Dandaragan Report[1]	
Primary	**Secondary**	**Tertiary**	**No. Cells**	**Old cells per new tertiary cell**
R07C. Middle Head to South Illawong	7	See Table D.2 for cell 7b details.		
		a. Middle Head to North Head	2	31. Middle Head to Pumpkin Hollow, 32. Pumpkin Hollow to North Head
R07B. North Wedge to Middle Head	6	f. Island Point to Middle Head	1	30. Island Point to Middle Head
		e. South Booka Valley to Island Point	1	29. South Booka Valley to Island Point
		d. Black Point to South Booka Valley	2	27. Black Head (now Black Point) to South Hill River, 28. South Hill River to South Booka Valley
		c. Thirsty Point to Black Point	1	26. Thirsty Point to Black Head (now Black Point)
		b. Kangaroo Point to Thirsty Point	2	24. Kangaroo Point to Hansen Head, 25. Hansen Head to Thirsty Point
		a. Grey to Kangaroo Point	2	22. Grey to Boggy Bay, 23. Boggy Bay to Kangaroo Point
	5	b. Kearn Reef to Grey	1	21. South Grey (now Kearn Reef) to Grey
		a. North Wedge to Kearn Reef	1	20. Wedge to South Grey (now Kearn Reef)
R07A. Moore River to North Wedge	4	b. Wedge to North Wedge	1	19. Wedge to North Wedge
		a. Magic Reef to Wedge	1	18. Magic Reef to Wedge Island
	3	c. Narrow Neck to Magic Reef	1	17. Narrow Neck to Magic Reef
		b. Dide Point to Narrow Neck	1	16. Dide Point to Narrow Neck
		a. North Break Reef to Dide Point	0.5	15. Lancelin Island to Dide Point (Part)
	2	c. Edward Island to North Break Reef	1.5	14. Edward Island to Lancelin Island, 15. Lancelin Island to Dide Point (Part)
		b. Fence Reef to Edward Island	1	13. South Pacific Reef (now Fence Reef) to Edward Island
		a. Ledge to Fence Reef	1	12. Ledge Point to South Pacific Reef (now Fence Reef)
	1	c. South First Bluff to Ledge	3	9. South First Bluff to Manakoora Sand Patch, 10. Manakoora Sand Patch to Green Reef, 11. Green Reef to Ledge Point
		b. Seabird to South First Bluff	3	6. Seabird to Eagles Nest Bluff, 7. Eagles Nest Bluff to Second Bluff, 8. Second Bluff to South First Bluff
		a. Guilderton N to Seabird	1	5. Moore River to Seabird
		32d. Guilderton S to Guilderton N	1	4. South Moore River (beyond Study Area) to Moore River

(Footnotes)

1 Eliot I, Gozzard B, Eliot M, Stul T and McCormack G. (2012a) *The Coast of the Shires of Gingin and Dandaragan, Western Australia: Geology, Geomorphology & Vulnerability*. Damara WA Pty Ltd and Geological Survey of Western Australia, Innaloo, Western Australia.

Table D.2: Mid-West Region cells compared to cells in Landform Vulnerability Report 2

Comparison between 46 of the cells identified in a previous landform vulnerability study for Shires of Coorow to Northampton[6] to the revised hierarchy of boundaries in this report. The cell hierarchy presented in this report should be used in coastal studies rather than the cell boundaries used in the 2012 study. Further discussion is included in the Results section of the report.

Cell Hierarchy			Cells from Shires of Coorow to Northampton Report[1]	
Primary	**Secondary**	**Tertiary**	**No. Cells**	**Old cells per new tertiary cell**
R07F. Phillips Road Coast to Glenfield	15	c. Chapman to Glenfield	1	46. Chapman to Glenfield
		b. Geraldton West to Chapman	4	42. Geraldton West to Geraldton East, 43. Geraldton East to Marina, 44. Marina to Saint Georges, 45. Saint Georges to Chapman
		a. Point Moore to Geraldton West	4	38. Point Moore to West End, 39. West End to Pages, 40. Pages to Connell Road, 41. Connell Road to Geraldton West
	14	b. Separation Point to Point Moore	1	37. Separation Point to Point Moore
		a. Cape Burney South to Separation Point	3	34. Cape Burney South to Greenough North, 35. Greenough North to Cape Burney North, 36. Cape Burney North to Separation Point
	13	a. Phillips Road coast to Cape Burney South	2	32. Phillips Road Coast to West Bank, 33. West Bank to Cape Burney South
R07E. Leander Point to Phillips Road Coast	12	b. Headbutts to Phillips Road coast	4	28. Headbutts to Flat Rocks, 29. Flat Rocks to Duncans Pool, 30. Duncans Pool to Lucys, 31. Lucys to Phillips Road Coast
		a. Nine Mile Beach to Headbutts	3	25. Nine Mile Beach to Bookara South, 26. Bookara South to Shire Boundary, 27. Shire Boundary to Headbutts
	11	c. Seven Mile Beach to Nine Mile Beach	1	24. Seven Mile Beach to Nine Mile Beach
		b. Harleys Hole to Seven Mile Beach	1	23. Harleys Hole to Seven Mile Beach
		a. Leander Point to Harleys Hole	2	21. Leander Point to Dongara North, 22. Dongara North to Harleys Hole
R07D. South Illawong to Leander Point	10	b. White Point to Leander Point	2	19. White Point to South Leander Point, 20. South Leander Point to Leander Point
		a. Cliff Head to White Point	1	18. Cliff Head to White Point
	9	a. South Illawong to Cliff Head	2	16. South Illawong to North Knobby Head, 17. North Knobby Head to Cliff Head
R07C. Middle Head to South Illawong	8	d. Coolimba to South Illawong	2	14. Coolimba to Gum Tree Bay, 15. Gum Tree Bay to South Illawong
		c. Leeman to Coolimba	2	12. Leeman to Tailor Bay, 13. Tailor Bay to Coolimba
		b. Point Louise to Leeman	4	8. Point Louise to Little Anchorage, 9. Little Anchorage to Unsurveyed Point, 10. Unsurveyed Point to Webb Islet, 11. Webb Islet to Leeman
		a. Fisherman Islands to Point Louise	3	5. Fisherman Islands to South Bay, 6. South Bay to Green Head, 7. Green Head to Point Louise
	7	c. Sandy Cape to Fisherman Islands	2	3. Sandy Point to South Fisherman, 4. South Fisherman to Fisherman Islands
		b. North Head to Sandy Cape	2	1. North Head to Sandland, 2. Sandland to Sandy Point (now Sandy Cape)
		See Table D.1 for cell 7a details.		

(Footnotes)

1 Eliot I, Gozzard B, Eliot M, Stul T and McCormack G. (2012b) *The Mid-West Coast, Western Australia: Shires of Coorow to Northampton. Geology, Geomorphology & Vulnerability*. Damara WA Pty Ltd and Geological Survey of Western Australia, Innaloo, Western Australia.

Appendix E

Beachface points and cell boundary information

Table E.1: Rationale for selection of primary cell beachface points in the Mid-West Region

Co-ordinates in Latitude and Longitude rounded to 3 decimal places.

Beachface Point Name	Lat.	Long.	Other Boundaries	Alongshore Boundary Character	Beachface Point	Associated Primary Cells
Glenfield	-28.685	114.606	2°, 3°	Point, Fixed, Open	Rock structures restricting sediment transport at a decadal scale (rock outcrop); Geomorphic feature (north limit of Greenough-Chapman paleo-delta)	R07F, R08A
Phillips Road Coast	-28.934	114.690	2°, 3°	Zone, Fixed, Open	Rock structures restricting sediment transport at a decadal scale (rocky salient)	R07E, R07F
Leander Point	-29.277	114.915	2°, 3°	Point, Fixed, Closed	Rock structures restricting sediment transport at a decadal scale (north end of fossil coral reef platform); Engineered structure or shipping channel (Port Denison)	R07D, R07E
South Illawong	-29.705	114.959	2°, 3°	Point, Fixed, Open	Rock structures restricting sediment transport at a decadal scale; Geomorphic feature (north limit of perched barrier/lagoon complex)	R07C, R07D
Middle Head	-30.258	115.038	2°, 3°	Point, Fixed, Open	Rock structures restricting sediment transport at a decadal scale; Geomorphic feature (northern limit of Cervantes-Jurien foredune plain)	R07B, R07C
North Wedge	-30.753	115.173	2°, 3°	Zone, Ambulatory, Open	Geomorphic feature (north limit of cuspate foreland)	R07A, R07B
Moore River	-31.353	115.499	2°	Zone, Ambulatory, Open	Rock structures restricting sediment transport at a decadal scale; Geomorphic feature (Moore River channel)	R06I, R07A

Table E.2: Rationale for selection of primary cell onshore, offshore and alongshore boundaries in the Mid-West Region

Primary Cell	Offshore Boundary	Onshore Boundary	"From" Alongshore Boundary			"To" Alongshore Boundary		
			Point	Marine Section	Terrestrial Section	Point	Marine Section	Terrestrial Section
R07F. Phillips Road Coast to Glenfield	-30m AHD isobath farthest from shore	Landward extent of Holocene land system, except for a transgressive dune system overlying older and higher land surfaces; Late Holocene dunes abutting rocky topography to landward	Phillips Road Coast	Fixed by a submerged ridge with rock outcrops or islands, then, a marine extension from the edge of the outermost rock outcrop to the offshore boundary (ridge at northern end of the rocky inshore reef area)	Boundary of, or discontinuity in, a Holocene land system	Glenfield	Deepest point of depression or contour reentrant	An extension of marine section and beachface point directly to the onshore boundary if there is no change in land system between adjacent cells; Boundary of, or discontinuity in, a Holocene land system
R07E. Leander Point to Phillips Road Coast	-30m AHD isobath farthest from shore	Landward extent of Holocene land system, except for a transgressive dune system overlying older and higher land surfaces	Leander Point	Deepest point of depression or contour reentrant; Fixed by a submerged ridge with rock outcrops or islands, then, a marine extension from the edge of the outermost rock outcrop to the offshore boundary (remnant surge channel and unclear influence of Irwin River)	Boundary of, or discontinuity in, a Holocene land system; Centre line of engineered structure or feature (Port Denison harbour; northern extent of parabolics and break in foredune plain)	Phillips Road Coast	Fixed by a submerged ridge with rock outcrops or islands, then, a marine extension from the edge of the outermost rock outcrop to the offshore boundary (ridge at northern end of the rocky inshore reef area)	Boundary of, or discontinuity in, a Holocene land system
R07D. South Illawong to Leader Point	-30m AHD isobath farthest from shore	Landward extent of Holocene land system, except for a transgressive dune system overlying older and higher land surfaces; Late Holocene dunes abutting rocky topography to landward ; Landgate MHWM to 2006 on cliffed coast without dunes	South Illawong	Fixed by a submerged ridge with rock outcrops or islands, then, a marine extension from the edge of the outermost rock outcrop to the offshore boundary	Boundary of, or discontinuity in, a Holocene land system	Leander Point	Deepest point of depression or contour reentrant; Fixed by a submerged ridge with rock outcrops or islands, then, a marine extension from the edge of the outermost rock outcrop to the offshore boundary (remnant surge channel and unclear influence of Irwin River)	Boundary of, or discontinuity in, a Holocene land system; Centre line of engineered structure or feature (Port Denison harbour; northern extent of parabolics and break in foredune plain)
R07C. Middle Head to South Illawong	-30m AHD isobath farthest from shore	Landward extent of Holocene land system, except for a transgressive dune system overlying older and higher land surfaces	Middle Head	Fixed by a submerged ridge with rock outcrops or islands, then, a marine extension from the edge of the outermost rock outcrop to the offshore boundary	Boundary of, or discontinuity in, a Holocene land system	South Illawong	Fixed by a submerged ridge with rock outcrops or islands, then, a marine extension from the edge of the outermost rock outcrop to the offshore boundary	Boundary of, or discontinuity in, a Holocene land system
R07B. North Wedge to Middle Head	-30m AHD isobath farthest from shore	Landward extent of Holocene land system, except for a transgressive dune system overlying older and higher land surfaces; Landward extent of coast-linked transgressive dune system overlying older and higher land surfaces; Landgate MHWM to 2006 on cliffed coast without dunes	North Wedge	Fixed by a submerged ridge with rock outcrops or islands, then, a marine extension from the edge of the outermost rock outcrop to the offshore boundary (orthogonal rock ridge supporting reefs and islands)	Boundary of, or discontinuity in, a Holocene land system	Middle Head	Fixed by a submerged ridge with rock outcrops or islands, then, a marine extension from the edge of the outermost rock outcrop to the offshore boundary	Boundary of, or discontinuity in, a Holocene land system
R07A. Moore River to North Wedge	-30m AHD isobath farthest from shore	Landward extent of Holocene land system, except for a transgressive dune system overlying older and higher land surfaces	Moore River	Broad area of sediment transport convergence (Moore River paleochannel)	Boundary of, or discontinuity in, a Holocene land system	North Wedge	Fixed by a submerged ridge with rock outcrops or islands, then, a marine extension from the edge of the outermost rock outcrop to the offshore boundary (orthogonal rock ridge supporting reefs and islands)	Boundary of, or discontinuity in, a Holocene land system

Table E.3: Rationale for selection of secondary cell beachface points in the Mid-West Region

Co-ordinates in Latitude and Longitude rounded to 3 decimal places

Beachface Point Name	Lat.	Long.	Other Boundaries	Alongshore Boundary Character	Beachface Point	Associated Secondary Cells
Glenfield	-28.685	114.606	1°, 3°	Point, Fixed, Open	Rock structures restricting sediment transport at an annual scale (rock outcrop); Geomorphic feature (northern limit of Greenough-Chapman paleo-delta)	R07F15, R08A1
Point Moore	-28.784	114.576	3°	Point, Fixed, Open	Rock structures restricting sediment transport at an annual scale (rock outcrop and Point Moore reef); Geomorphic feature (tombolo); Adjacent cells have a different shoreline aspect restricting sediment transport at an annual scale (SW to NW embayments)	R07E14, R07F15
Cape Burney South	-28.868	114.634	3°	Point, Fixed, Open	Rock structures restricting sediment transport at an annual scale (Greenough coral reef); Geomorphic feature (southern bank of Greenough River and southern limit of Greenough-Chapman paleo-delta); Adjacent cells have a different shoreline aspect restricting sediment transport at an annual scale (SW to WSW)	R07E13, R07F14
Phillips Road Coast	-28.934	114.690	1°, 3°	Zone, Fixed, Open	Rock structures restricting sediment transport at an annual scale (rocky salient)	R07E12, R07F13
Nine Mile Beach	-29.126	114.873	3°	Point, Fixed, Open	Rock structures restricting sediment transport at an annual scale (rock outcrops on a rock headland); Adjacent cells have a different shoreline aspect restricting sediment transport at an annual scale (WSW to SW)	R07E11, R07E12
Leander Point	-29.276	114.915	1°, 3°	Point, Fixed, Closed	Rock structures restricting sediment transport at an annual scale (northern end of fossil coral reef platform); Engineered structure or dredged channel (Port Denison)	R07D10, R07E11
Cliff Head	-29.515	114.997	3°	Zone, Fixed, Open	Geomorphic feature (transition from rocky coast to long-walled parabolic dunes); Adjacent cells have a different shoreline aspect restricting sediment transport at an annual scale (WNW to SW)	R07D9, R07D10
South Illawong	-29.705	114.959	1°, 3°	Point, Fixed, Open	Rock structures restricting sediment transport at an annual scale; Geomorphic feature (northern limit of perched barrier and lagoon complex)	R07C8, R07D9
Fisherman Islands	-30.116	114.994	3°	Zone, Fixed, Open	Rock structures restricting sediment transport at an annual scale (rock platform and bluffs); Geomorphic feature (broad salient controlled by the Fisherman Islands ridge. Major change in orientation of offshore reefs and onshore dunes [More N-S])	R07C7, R07C8
Middle Head	-30.258	115.038	1°, 3°	Point, Fixed, Open	Rock structures restricting sediment transport at an annual scale; Geomorphic feature (northern limit of Cervantes-Jurien foredune plain)	R07B6, R07C7
Grey	-30.667	115.134	3°	Point, Fixed, Open	Rock structures restricting sediment transport at an annual scale (rocky salient); Geomorphic feature (cliffed headland)	R07B5, R07B6
North Wedge	-30.753	115.173	1°, 3°	Zone, Ambulatory, Open	Geomorphic feature (northern limit of cuspate foreland)	R07A4, R07B5
Magic Reef	-30.869	115.243	3°	Zone, Ambulatory, Open	Rock structures restricting sediment transport at an annual scale (rock platform); Geomorphic feature (change in the inshore morphology with rock platform to the north; salient)	R07A3, R07A4
North Break Reef	-30.988	115.320	3°	Zone, Ambulatory, Open	Geomorphic feature (northern extent of Lancelin dunes)	R07A2, R07A3
Ledge	-31.110	115.371	3°	Zone, Ambulatory, Open	Geomorphic feature (foreland); Adjacent cells have a different shoreline aspect restricting sediment transport at an annual scale	R07A1, R07A2
Moore River	-31.353	115.499	1°	Zone, Ambulatory, Open	Rock structure restricting sediment transport at an annual scale; geomorphic feature (Moore River channel)	R06I32, R07A1

Table E.4: Rationale for selection of secondary cell onshore, offshore and alongshore boundaries in the Mid-West Region

Secondary Cell	Offshore Boundary	Onshore Boundary	"From" Alongshore Boundary			"To" Alongshore Boundary		
			Point	Marine Section	Terrestrial Section	Point	Marine Section	Terrestrial Section
R07F15. Point Moore to Glenfield	Continuous -15m AHD isobath farthest from shore within primary cell boundaries	Landward extent of foredune plain	Point Moore	A marine extension of the beachface point to the offshore boundary	An extension of marine section and beachface point directly to the onshore boundary if there is no change in foredune plains, parabolic dunes or frontal dunes between adjacent cells	Glenfield	Deepest point of depression or contour reentrant	An extension of marine section and beachface point directly to the onshore boundary if there is no change in foredune plains, parabolic dunes or frontal dunes between adjacent cells
R07F14. Cape Burney South to Point Moore	Continuous -15m AHD isobath farthest from shore within primary cell boundaries	Landward extent of foredune plain; Landward extent of large mobile dune (Southgate dune)	Cape Burney South	Fixed by submerged rock outcrops or islands; Area of sediment transport convergence on banks or reefs ; Deepest point of depression or contour reentrant (rock control at coast at Greenough reef, then remnant southern Greenough River bank followed by paleochannel)	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune	Point Moore	A marine extension of the beachface point to the offshore boundary	An extension of marine section and beachface point directly to the onshore boundary if there is no change in foredune plains, parabolic dunes or frontal dunes between adjacent cells
R07F13. Phillips Road coast to Cape Burney South	Continuous -15m AHD isobath farthest from shore within primary cell boundaries	Landward extent of frontal dunes	Phillips Road Coast	Fixed by submerged rock outcrops or islands	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune	Cape Burney South	Fixed by submerged rock outcrops or islands; Area of sediment transport convergence on banks or reefs ; Deepest point of depression or contour reentrant (rock control at coast at Greenough reef, then remnant southern Greenough River bank followed by paleochannel)	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune
R07E12. Nine Mile Beach to Phillips Road Coast	Continuous -15m AHD isobath farthest from shore within primary cell boundaries	Landward extent of frontal dunes	Nine Mile Beach	A marine extension of the beachface point to the offshore boundary	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune	Phillips Road Coast	Fixed by submerged rock outcrops or islands	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune

Secondary Cell	Offshore Boundary	Onshore Boundary	"From" Alongshore Boundary			"To" Alongshore Boundary		
			Point	Marine Section	Terrestrial Section	Point	Marine Section	Terrestrial Section
R07E11. Leader Point to Nine Mile Beach	Continuous -15m AHD isobath farthest from shore within primary cell boundaries	Landward extent of frontal dunes	Leander Point	Fixed by submerged rock outcrops or islands	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune; Centreline of engineered structure or feature (Port Denison harbour; foredune plain)	Nine Mile Beach	A marine extension of the beachface point to the offshore boundary	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune
R07D10. Cliff Head to Leander Point	Continuous -15m AHD isobath farthest from shore within primary cell boundaries	Landward extent of frontal dunes	Cliff Head	A marine extension of the beachface point to the offshore boundary (followed some high points)	An extension of marine section and beachface point directly to the onshore boundary if there is no change in foredune plains, parabolic dunes or frontal dunes between adjacent cells	Leander Point	Fixed by submerged rock outcrops or islands	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune; Centreline of engineered structure or feature (Port Denison harbour; foredune plain)
R07D9. South Illawong to Cliff Head	Continuous -15m AHD isobath farthest from shore within primary cell boundaries	Landward extent of foredune plain; Landward extent of small parabolic dunes; Landgate MHWM to 2006 on cliffed coast without dunes	South Illawong	Fixed by submerged rock outcrops or islands	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune	Cliff Head	A marine extension of the beachface point to the offshore boundary (followed some high points)	An extension of marine section and beachface point directly to the onshore boundary if there is no change in foredune plains, parabolic dunes or frontal dunes between adjacent cells
R07C8. Fisherman Islands to South Illawong	Continuous -15m AHD isobath farthest from shore within primary cell boundaries	Landward extent of small parabolic dunes; Landgate MHWM to 2006 on cliffed coast without dunes	Fisher-man Islands	Fixed by submerged rock outcrops or islands (Fishermans Islands)	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune	South Illawong	Fixed by submerged rock outcrops or islands	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune
R07C7. Middle Head to Fisherman Islands	Continuous -15m AHD isobath farthest from shore within primary cell boundaries	Landward extent of small parabolic dunes; Landgate MHWM to 2006 on cliffed coast without dunes	Middle Head	Fixed by submerged rock outcrops or islands (Seaward Ledge Reef)	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune	Fisherman Islands	Fixed by submerged rock outcrops or islands (Fishermans Islands)	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune

Secondary Cell	Offshore Boundary	Onshore Boundary	"From" Alongshore Boundary			"To" Alongshore Boundary		
			Point	Marine Section	Terrestrial Section	Point	Marine Section	Terrestrial Section
R07B6. Grey to Middle Head	Continuous -15m AHD isobath farthest from shore within primary cell boundaries	Landward extent of foredune plain (comprising the cuspate foreland); Landward extent of frontal dunes; Landgate MHWM to 2006 on cliffed coast without dunes	Grey	Fixed by submerged rock outcrops or islands (Green Islands separate two basins)	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune	Middle Head	Fixed by submerged rock outcrops or islands (Seaward Ledge Reef)	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune
R07B5. North wedge to Grey	Continuous -15m AHD isobath farthest from shore within primary cell boundaries	Landward extent of frontal dunes; Landgate MHWM to 2006 on cliffed coast without dunes	North Wedge	Fixed by submerged rock outcrops or islands	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune	Grey	Fixed by submerged rock outcrops or islands (Green Islands separate two basins)	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune
R07A4. Magic Reef to north wedge	Continuous -15m AHD isobath farthest from shore within primary cell boundaries	Landward extent of foredune plain (comrpising the cuspate foreland); Landward extent of frontal dunes	Magic Reef	Fixed by submerged rock outcrops or islands; A marine extension of the beachface point to the offshore boundary	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune	North Wedge	Fixed by submerged rock outcrops or islands	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune
R07A3. North Break reef to Magic Reef	Continuous -15m AHD isobath farthest from shore within primary cell boundaries	Landward extent of frontal dunes	North Break Reef	Fixed by submerged rock outcrops or islands; A marine extension of the beachface point to the offshore boundary	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune	Magic Reef	Fixed by submerged rock outcrops or islands; A marine extension of the beachface point to the offshore boundary	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune
R07A2. Ledge to North Break reef	Continuous -15m AHD isobath farthest from shore within primary cell boundaries	Landward extent of foredune plain (comrpising the cuspate foreland); Landward extent of small parabolic dunes; Landward extent of frontal dunes	Ledge	Fixed by submerged rock outcrops or islands	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune	North Break Reef	Fixed by submerged rock outcrops or islands; A marine extension of the beachface point to the offshore boundary	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune
R07A1. Moore River to Ledge	Continuous -15m AHD isobath farthest from shore within primary cell boundaries	Landward extent of foredune plain; Landward extent of frontal dunes	Moore River	Area of sediment transport convergence on banks or reefs (Moore River paleochannel)	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune	Ledge	Fixed by submerged rock outcrops or islands	Boundary of, or discontinuity in, a foredune plain, large mobile dune, narrow dune barrier, small parabolic dune or frontal dune

Table E.5: Rationale for selection of tertiary cell beachface points in the Mid-West Region

Co-ordinates in Latitude and Longitude rounded to 3 decimal places.
No information was reported for offshore boundaries, onshore boundaries and the marine and terrestrial sections of the alongshore boundaries.

Beachface Point Name	Lat.	Long.	Other Boundaries	Alongshore Boundary Character	Beachface Point	Associated Tertiary Cells
Glenfield	-28.685	114.606	1°, 2°	Point, Fixed, Open	Rock structures restricting sediment transport at a seasonal scale (rock outcrop); Geomorphic feature (northern limit of Greenough-Chapman paleo-delta)	R07F15c, R08A1a
Chapman	-28.731	114.620	-	Point, Fixed, Open	Rock structures restricting sediment transport at a seasonal scale (northern extent of platform); Geomorphic feature (southern bank of Chapman River mouth); Adjacent cells have a different shoreline aspect restricting sediment transport at a seasonal scale (slight change from WNW to WSW)	R07F15b, R07F15c
Geraldton West	-28.775	114.604	-	Point, Fixed, Closed	Engineered structure or dredged channel (eastern limit of Geraldton Harbour)	R07F15a, R07F15b
Point Moore	-28.784	114.576	2°	Point, Fixed, Open	Rock structures restricting sediment transport at a seasonal scale (rock outcrop and Point Moore reef); Geomorphic feature (tombolo); Adjacent cells have a different shoreline aspect restricting sediment transport at a seasonal scale (SW to NW embayments)	R07F14b, R07F15a
Separation Point	-28.790	114.596	-	Zone, Fixed, Open	Rock structures restricting sediment transport at a seasonal scale (outcrop of north extent of Southgate reef); Geomorphic feature (perched salient); Adjacent cells have a different shoreline aspect restricting sediment transport at a seasonal scale (WSW to SSW)	R07F14a, R07F14b
Cape Burney South	-28.868	114.634	2°	Point, Fixed, Open	Rock structures restricting sediment transport at a seasonal scale (Greenough coral reef); Geomorphic feature (south bank of Greenough River; south end of Greenough-Chapman paleo-delta); Adjacent cells have a different shoreline aspect restricting sediment transport at a seasonal scale (SW to WSW)	R07F13a, R07F14a
Phillips Road Coast	-28.934	114.690	1°, 2°	Zone, Fixed, Open	Rock structures restricting sediment transport at a seasonal scale (rocky salient)	R07E12b, R07F13a
Headbutts	-29.039	114.802	-	Point, Fixed, Open	Rock structures restricting sediment transport at a seasonal scale (rock outrop); Geomorphic feature (small perched salient. Southern limit of supratidal platform)	R07E12a, R07E12b
Nine Mile Beach	-29.126	114.873	2°	Point, Fixed, Open	Rock structures restricting sediment transport at a seasonal scale (rock outcrops on a rock headland); Adjacent cells have a different shoreline aspect restricting sediment transport at a seasonal scale (WSW to SW)	R07E11c, R07E12a

Beachface Point Name	Lat.	Long.	Other Boundaries	Alongshore Boundary Character	Beachface Point	Associated Tertiary Cells
Seven Mile Beach	-29.170	114.888	-	Zone, Fixed, Open	Rock structures restricting sediment transport at a seasonal scale (rock outcrops); Geomorphic feature (small perched salient)	R07E11b, R07E11c
Harleys Hole	-29.212	114.902	-	Point, Fixed, Open	Rock structures restricting sediment transport at a seasonal scale (rock outcrop); Geomorphic feature (change in reef and dune structure. Shallow salient)	R07E11a, R07E11b
Leander Point	-29.276	114.915	1°, 2°	Point, Fixed, Closed	Rock structures restricting sediment transport at a seasonal scale (northern end of fossil coral reef platform); Engineered structure of dredged channel (Port Denison)	R07D10b, R07E11a
White Point	-29.395	114.956	-	Zone, Ambulatory, Open	Geomorphic feature (cuspate foreland in the lee of Long Reef/White Point Reef, northern limit of a wide reef structure)	R07D10a, R07D10b
Cliff Head	-29.515	114.997	2°	Zone, Fixed, Open	Geomorphic feature (transition from rocky coast to long-walled parabolic dunes); Adjacent cells have a different shoreline aspect restricting sediment transport at a seasonal scale (WNW to SW)	R07D9a, R07D10a
South Illawong	-29.705	114.959	1°, 2°	Point, Fixed, Open	Rock structures restricting sediment transport at a seasonal scale; Geomorphic feature (northern limit of perched barrier and lagoon complex)	R07C8d, R07D9a
Coolimba	-29.856	114.979	-	Point, Fixed, Open	Rock structures restricting sediment transport at a seasonal scale (limestone point)	R07C8c, R07C8d
Leeman	-29.946	114.974	-	Point, Fixed, Open	Rock structures restricting sediment transport at a seasonal scale (limestone point)	R07C8b, R07C8c
Point Louise	-30.051	114.956	-	Point, Fixed, Closed	Rock structures restricting sediment transport at a seasonal scale (rocky headland); Geomorphic feature (perched tombolo)	R07C8a, R07C8b
Fisherman Islands	-30.116	114.994	2°	Zone, Fixed, Open	Rock structures restricting sediment transport at a seasonal scale (rock platform and bluffs); Geomorphic feature (broad salient controlled by the Fisherman Islands ridge. Major change in orientation of offshore reefs and onshore dunes [More N-S])	R07C7c, R07C8a
Sandy Cape	-30.183	114.992	-	Point, Fixed, Closed	Rock structures restricting sediment transport at a seasonal scale (rocky headland); Geomorphic feature (perched tombolo)	R07C7b, R07C7c
North Head	-30.233	114.995	-	Point, Fixed, Closed	Rock structures restricting sediment transport at a seasonal scale (rocky headland); Geomorphic feature (perched tombolo)	R07C7a, R07C7b

Beachface Point Name	Lat.	Long.	Other Boundaries	Alongshore Boundary Character	Beachface Point	Associated Tertiary Cells
Middle Head	-30.258	115.038	1°, 2°	Point, Fixed, Open	Rock structures restricting sediment transport at a seasonal scale; Geomorphic feature (northern limit of Cervantes-Jurien foredune plain)	R07B6f, R07C7a
Island Point	-30.317	115.020	-	Zone, Ambulatory, Open	Geomorphic feature (cuspate foreland in lee of Boullanger Island); Adjacent cells have a different shoreline aspect restricting sediment transport at a seasonal scale (W to WNW)	R07B6e, R07B6f
South Booka Valley	-30.349	115.043	-	Point, Fixed, Open	Rock structures restricting sediment transport at a seasonal scale (rock outcrop); Geomorphic feature (small salient landward of a rock outcrop. Northern limit of the Hill River delta)	R07B6d, R07B6e
Black Point	-30.456	115.063	-	Point, Fixed, Open	Rock structures restricting sediment transport at a seasonal scale (rock headland); Geomorphic feature (rocky salient. Southern limit of the Hill River delta)	R07B6c, R07B6d
Thirsty Point	-30.511	115.058	-	Zone, Ambulatory, Open	Geomorphic feature (cuspate foreland in lee of Cervantes Islands); Adjacent cells have a different shoreline aspect restricting sediment transport at a seasonal scale (WSW to W)	R07B6b, R07B6c
Kangaroo Point	-30.578	115.089	-	Zone, Ambulatory, Open	Geomorphic feature (cuspate foreland in lee of Inner 7 Foot Rock)	R07B6a, R07B6b
Grey	-30.667	115.134	2°	Point, Fixed, Open	Rock structures restricting sediment transport at a seasonal scale (rocky salient); Geomorphic feature (cliffed headland)	R07B5b, R07B6a
Kearn Reef	-30.729	115.1594	-	Point, Fixed, Closed	Rock structures restricting sediment transport at a seasonal scale (rock outcrops)	R07B5a, R07B5b
North Wedge	-30.753	115.173	1°, 2°	Zone, Ambulatory, Open	Geomorphic feature (northern limit of cuspate foreland)	R07A4b, R07B5a
Wedge	-30.825	115.190	-	Zone, Ambulatory, Open	Geomorphic feature (cuspate foreland in lee of Wedge Island); Adjacent cells have a different shoreline aspect restricting sediment transport at a seasonal scale (SW to W)	R07A4a, R07A4b
Magic Reef	-30.869	115.243	2°	Zone, Ambulatory, Open	Rock structures restricting sediment transport at a seasonal scale (rock platform); Geomorphic feature (change in the inshore morphology with rock platform to the north; salient)	R07A3c, R07A4a
Narrow Neck	-30.912	115.268	-	Point, Fixed, Open	Rock structures restricting sediment transport at a seasonal scale (rock outcrop); Geomorphic feature (cuspate foreland in lee of a reef)	R07A3b, R07A3c

Beachface Point Name	Lat.	Long.	Other Boundaries	Alongshore Boundary Character	Beachface Point	Associated Tertiary Cells
Dide Point	-30.945	115.290	-	Point, Fixed, Open	Rock structures restricting sediment transport at a seasonal scale (rock outcrop); Geomorphic feature (salient in lee of Dide Bay reef)	R07A3a, R07A3b
North Break Reef	-30.988	115.320	2°	Zone, Ambulatory, Open	Geomorphic feature (northern extent of Lancelin dunes)	R07A2c, R07A3a
Edward Island	-31.027	115.326	-	Zone, Ambulatory, Open	Rock structures restricting sediment transport at a seasonal scale (Edward Island); Geomorphic feature (cuspate foreland in lee of Edward Is., part of narrow reef closing with the coast)	R07A2b, R07A2c
Fence Reef	-31.064	115.347	-	Zone, Ambulatory, Open	Rock structures restricting sediment transport at a seasonal scale (Fence Reef); Geomorphic feature (small salient associated with Fence Reef, northern limit of a wide reef complex)	R07A2a, R07A2b
Ledge	-31.110	115.371	2°	Zone, Ambulatory, Open	Geomorphic feature (foreland); Adjacent cells have a different shoreline aspect restricting sediment transport at a seasonal scale	R07A1c, R07A2a
South First Bluff	-31.179	115.399	-	Point, Fixed, Open	Rock structures restricting sediment transport at a seasonal scale; Geomorphic feature (change in dune patterns); Adjacent cells have a different shoreline aspect restricting sediment transport at a seasonal scale (slight change in WSW to W)	R07A1b, R07A1c
Seabird	-31.276	115.440	-	Zone, Ambulatory, Open	Geomorphic feature (salient)	R07A1a, R07A1b
Guilderton N	-31.354	115.499	-	Point, Fixed, Open	Engineered structure or dredged channel (groyne)	R06I32d, R07A1a
Guilderton S	-31.363	115.504	-	Zone, Ambulatory, Open	Geomorphic feature (salient)	R07D10a, R07D10b

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