5.4 Coastal and Marine Assets

5.4.1 Overview - Description and Values

The terrestrial and oceanic processes of the Burnett Mary region have produced a dynamic and diverse coastal, estuarine and marine ecosystem.

The Burnett Mary region lies within the Tweed-Moreton marine bioregion where the landmark Fraser Island (which traps warm waters in Hervey Bay and created the Great Sandy Strait) marks the southern boundary of the Great Barrier Reef lagoon (the largest and most diverse coral reef system in the world). The mix of tropical and subtropical zones that characterises the Burnett Mary region has resulted in some of Australia's greatest coastal, estuarine and marine biodiversity. This biodiversity underpins environmental, commercial and recreational growth in the Burnett Mary region.

Our diverse range of coastal, estuarine and marine habitats (some of which are protected or conserved under World Heritage or Ramsar listings) include: the deep continental shelf located just off Fraser Island (influenced by the East Australian Current), rocky shores, dunes, coastal and tidal wetlands - mangrove forests, salt marsh and samphire flats (backed by peat swamps), seagrass meadows, coral and other reefs (including GBR's southernmost reef-forming reefs); and soft-bottom habitats. This habitat mosaic has critical connections that enable and are influenced by the movement of water, sediment, plants and animals that are essential for life processes.

The region's plants and animals, including significant iconic and migratory species such as shorebirds, grey nurse sharks, humpback whales, dugongs, and Indo-Pacific humpback dolphins, rely on healthy and available habitat. Our region contains the east coast's largest dugong population south of Torres Strait and six of the world's seven species of endangered and vulnerable marine turtles. Of these, loggerhead, green and flat-back turtles regularly nest along the region's foreshores. Other significant species have iconic or economic value and sustain our tourist and fishing industries.

Coastal, estuarine and marine habitats are often affected, to varying degrees, by natural events such as extreme tides, floods and severe storms. These physical processes are normal, natural and essential for ecosystem health. In contrast, human-induced impacts often cause changes in the natural systems from which the plants and animals cannot recover effectively (their resilience to disturbances has been reduced) and these impacts contribute to major losses of biodiversity. Pressures on coastal, estuarine and marine environments include: coastal development, pollution such as sewage and stormwater runoff, recreational and commercial fisheries, public access, weeds and pests and catchment land management that can impact on both environmental flows and water quality.

Balancing healthy ecosystems with natural resource use will continue to support our lifestyle and wellbeing and provide a sustainable future for our region.

5.4.2 Asset Delineation

The most logical benthic (non-water) asset delineation at the strategic level was a combination of the following classification classes:

- Aquatic Zones
- Dominant Energy Regimes
- Dominant Biotic Structure
- Consolidation Type

This system was designed by the Queensland Wetlands Program (Department of Environment & Heritage Protection) as part of a project entitled: *Queensland coastal marine and estuarine habitat classification for enhanced coastal planning and management outcomes.*

Marine and estuarine ecosystems are dynamic and influenced by a complex range of environmental variables and undergo cyclic changes at temporal and spatial scales. Both marine and estuarine systems can contain intertidal and subtidal habitats. Intertidal habitat is exposed at low tides and inundated by tides. Subtidal habitat is continuously submerged.

While no two estuarine or marine habitats are entirely the same, many provide similar functions to each other. A comprehensive classification of habitats into ecologically relevant groups that share similar ecological and physical drivers is essential for effective management. The table below simplifies the classification of the region's coastal, estuarine and marine assets. It is recognised that there is some variation between individual river basins – these differences can be attributed to spatial differences in temperature, water availability and exposure to dominant energy sources – such as wind/waves and climatic events – these are particularly evident in asset classes ME 6 and ME 7. Further delineation by geographic area for these asset classes may be necessary at the implementation level to capture the discrete differences in asset sensitivity and adaptive capacity in the region.

Figure 1 identifies the list of Estuarine and Marine Benthic Assets that were defined through the Science Panel Assessment undertakings for the Plan.

FIGURE 11: COASTAL, ESTUARINE AND MARINE ECOSYSTEMS – BENTHIC ASSETS OF THE BURNETT MARY

Asset Code	Description	Aquatic Zone	Dominant Energy Regime	Dominant Biotic Structure	Consolidation
ME 1	Intertidal Rock Platform	Intertidal	Low	Bare	Consolidated
ME 2	Sandy Beach	Intertidal	Undifferentiated	Bare	Sand
ME 3	Mud Flat / Sand Flat	Intertidal	Low	Bare	Mud
ME 4	Basalt Boulder Beach / Cobble	Intertidal (HAT to MSL)	Undifferentiated	Bare	Boulders
ME 5	Tidal Salt Pan	Intertidal	Low	Encrusting	Unknown
ME 6	Intertidal Seagrass	Intertidal	Low	Low Veg	Unknown
ME 7	Tidal Salt Marsh	Intertidal	Low	Low Veg	Unknown
ME 8	Mangrove	Intertidal	Low	Med-High Veg	Unknown
ME 9	Intertidal Sessile (Corals and Sponges)	Intertidal	Low	Sessile Fauna	Unknown
ME 10	Subtidal Platform	Subtidal	Low	Bare	Consolidated
ME 11	Sandy Bottom	Subtidal	High/Low*	Bare	Sand
ME 12	Muddy Bottom	Subtidal	Low	Bare	Mud

ME 13	Pebbly Bottom (includes gravel)	Subtidal/Intertidal	Undifferentiated	Bare	Unconsolidated
ME 14a	Seagrass Subtidal - Baffle	Subtidal	High	Low-Med Veg	Mud /Sand
ME 14b	Seagrass Subtidal - Coastal Catchments	Subtidal	Low	Low-Med Veg	Mud /Sand
ME 15	Algae	Subtidal	High	Low-Med Veg	Mud /Sand
ME 16	Sessile (Corals, Sponges & Coralline Crustose Algae) fauna Inshore (GSS & 2km along Coast)	Subtidal	Low	Sessile Fauna	Consolidated
ME 17	Sessile (Corals, Sponges & Rhodoliths) fauna Inshore (GSS & 2km along Coast)	Subtidal	Low	Sessile Fauna	Unconsolidated
ME 18	Sessile (Corals and Sponges) fauna Offshore	Subtidal	High	Sessile Fauna	Unknown

* High energy regimes north of Agnes Water and south of Rainbow Beach (and offshore of Fraser Island) and low energy regimes restricted by Fraser Island, the Capricorn Bunker Group of islands and reefs to the north west.

Water Asset Types

In the same way that we recognise benthic assets as habitat for coastal and marine flora and fauna, we also have to include water itself as habitat for coastal, estuarine and marine species.

In terms of the region's waters, predominantly there are two wave energy regimes – the high energy regimes experienced north of Agnes Water and south of Rainbow Beach (and offshore of Fraser Island) and the comparatively low energy regimes restricted by Fraser Island, the Capricorn Bunker Group of islands and reefs to the north west.

In addition, various sub-regional water types, including individual seascapes, can be found within the region. Broadly these consist of eight areas A-H – although only seven of these (B-H) are located within the Burnett Mary region. The water types have been broadly classified using drivers such as dominant energy source and freshwater influence (surface water runoff) – which together define turbidity, and temperature. Spatial information also influences exchange time which is a key differential for individual seascapes within sub-regions C and G. Table 2 provides an overview of these key differences.

It is recognised that these water types have been identified through the classification process that is currently under development by the Queensland Wetlands Program (Department of Environment & Heritage Protection). This process has not been finalised for the Wide Bay Burnett with issues such as drivers versus attribute features not yet resolved. While attribute-based classification of waters can be applied independently, drivers and processes (which fall outside the water column descriptors) are likely to provide spatial and temporal influence on individual water types. It should also be notes that seascapes are also present in other sub-regions (and not just B, C & G) but the boundaries of these have not yet been considered.

TABLE 2: COASTAL, ESTUARINE AND MARINE ECOSYSTEMS – WATER TYPES OF THE BURNETT MARY

SR	Subregion	Energy source	Exchange time	Temperature	Water	Turbidity
A	Fitzroy-Keppels-Corio *(located outside the regional boundary)*	Tidal, some wind energy offshore. Tides are medium, 4.5-5m tides, north 6m tides. Wind energy is lower than tidal.	Medium - inner area near has comparatively long exchange time.	Fairly stable temperature, usually 23-26^{o}C. As low as 21 ^{o}C in cold winter. Fitzroy river can reach 15 ^{o}C in a cold winter. Temperature *range* is an important attribute.	Saline – after a flood may be low salinity for 6-9 weeks as far as Rockhampton. Mean annual salinity for Area 4 is lower than Hervey Bay. Three freshwater sources. Fitzroy, very episodic, ambient is dry tropics with little freshwater input for 8-9 months due to the regulated flow -some flow for 3 months JFM. Flow is strongly seasonal – can be high on a big flood or low volume wet season. Well-mixed, flood freshwater sits on top, but frequently mixed.	High; Dominated by Fitzroy R. Keppel Bay shallow, turbid inshore. Fitzroy flows out turbid most of the time. Small freshwater inputs from Coorooman Ck (turbid) & Corio Bay (cleaner, sand based system, poorer nutrients, tannins). East of the Keppel Islands is usually clear water, except during Fitzroy floods when the plume extends far beyond the Keppels. Shallow area north of Curtis Island is either turbid or clear depending on prevailing conditions.
B	Gladstone Harbour *(the bottom section of this water type is located within the Burnett Mary region)* Highly modified system, a lot of development on periphery, dredging, shallow. Harbour dredged to 20m. Remainder of the subregion averages 5-10m average depth.	Tidal, currents are very strong due to tidal exchange. Tidal amplitude is 30-50cm lower than in subregion A. High due to going through channels. Tidal water going up the Narrows doesn't leave the harbour. There are two tidal feeders: one north of Facing Island between Facing and Curtis islands creates 3 tidal effects.	Medium, except for the Narrows.		Saline - fresh during large events. Calliope & Boyne Rivers are the two main feeders. The Calliope is unregulated, whereas there is little exchange of freshwater from the Boyne: 2002-2011 all freshwater runoff was retained within Awonga dam, with Boyne estuary acting as an enclosed bay. During 2011, 12, 13 Awonga dam overflowed – Boyne changed from being an enclosed bay, to a normal river system. Harbour can become fairly fresh except for the outer harbour areas. Calliope medium, Boyne low are comparatively smaller freshwater input than Fitzroy. Well mixed.	High-medium; ranging from turbid to clear. During big tides highly turbid, persistent SE prevailing winds create turbidity. During winter the area becomes clearer during the low tides. Boyne is naturally clearer, due to its gravel based rock. The Calliope is only turbid in lower reaches, clearer upstream even on a medium size flood. Seasonally turbid with low light in summer.
C	Colosseum-Rodds-Bustard Head-south to Roundhill Head High condition area, highly valued area is a draft HEV. Shallow bay, <10m, extensive	Half tidal energy of B: force is medium – 2-3m tidal range. A complex tidal mix exists due to the number of contributing channels.	Reasonably confined – Medium to high.		Saline bay most of the time, seldom low salinity. Creeks have short catchments, experience intermittent flow for a day or two. Limited freshwater, more sand than mud, Creeks feeding into the area are a natural system with no barriers. Overland	Medium; 75% turbid, 25% clear. Clearer system, sand based, not mud based. Due to the smaller tidal range, less energy contributes to turbidity. C is a much clearer system than area B.

	intertidal areas, extensive channels, estuaries include Colosseum, 12 mile, 7 mile Ck, Worthington, Pancake Ck.	There is a tidal channel behind Hummock Hill Island. Wind - Medium; wind *direction* differs greatly from B. Wave exposure – SE swells are deflected around the peninsulas.			flow is low. SR C misses the heavy tropical rain events. Worthington Creek is a very minor freshwater source. Well-mixed, quite shallow.	
D	Capricorn Channel inter-reefal area, east side of Port Clinton Most water here is 20-30m deep, which is the depth where wind-waves & bottom shear meet. East of Shoalwater Bay is slightly deeper– “fern grounds”- soft coral /gorgonian to 1m in height on bottom.	Ocean currents medium, wind medium; tidal energy is quite *high* to the north towards Shoalwater Bay which experiences 6m – to the south tidal energy is *medium*– 3m tides. D2 has a higher tidal range than D1, where offshore the tides are much smaller.	Medium residence time.	Uniform, usual sea temp, 23 -26 °C.	Saline - usually r***ainfall***. Episodic ***riverine*** input from the Fitzroy River during the largest flood events. Well mixed, not aware of any vertical stratification.	Low with low light attenuation.
E	Capricorn Bunker group including Lady Musgrave Island Islands reduce the energy flow, although there is less reef matrix than the rest of the GBR to the north.	East side of the islands experience high wave energy – moderate tidal flows through the reefs.			Saline - Water type is close enough to D1 & D2 - should it be D3? [May not differ enough to make it a different water body]. Well-mixed vertically, although topographic effects are slight compared with the rest of the GBR.	
F	Round Hill Head to Elliott Heads Benthos is a “desolate sand area” with very few features Is the Capricorn Eddy drawing in nutrients by upwelling? Probably there is a high delivery of nutrients. Chlorophyll A is low, high uptake & growth? BENTHIC	Wave action via wind as the energy driver for the SE swell. Exposure to some SE swell i.e. through the gap between Fraser Island and the GBR – surf experienced at Agnes Water. Few topographic features	Low - very high exchange rates.	21-25°C.	Saline – similar to seawater. Input is small: Kolan River has interbasin freshwater transfers to the Burnett, means it acts like an enclosed bay; Littabella; Burnett is impounded thus ambient flows are low; there is moderate freshwater input into the system during highly seasonally episodic events. Freshwater input dispersed evenly along the whole coastline during ambient conditions, experiencing low levels of input	Low turbidity. Light availability is good.

	BIOTA are species diagnostic of a sandy bottom and reasonably clear water, characteristics that are very important for main fishery species in this area: scallops, Moreton Bay bugs, spanner crabs (sandy substrate users) all benthic feeders. Sandy areas are important ecologically to coral, bacterial layer on sediment fixes N from the atmosphere into a biologically usable form that coral can use. In this area is some coffee rock substrate with soft coral growing on these areas but due to reworking of sediment through sand movement there is less coffee rock & soft coral than in Hervey Bay. DPIF & Roland Pitcher mapped deepwater seagrass, sponge/gorgonian/soft coral gardens.	including Lady Elliott reduce the wave energy flow. Its eastward boundary is Lady Elliott to Breaksea Spit (excluding the Spit). (South of here Fraser Island is the energy boundary).			except in events. M-L volumes. Well-mixed, shallow, wind driven.	
G	Hervey Bay (Elliott Heads-Breaksea Spit to Wide Bay Bar) Consists of 3 areas: a) Platypus Bay ciguatera, dinoflagellates, water sits / slack. b) Hervey Bay & northern Great Sandy Strait c) Remainder of Great Sandy Strait.	3 energy drivers – wind, tides, slight waves during SE winds, up to 1.5m waves during northerlies. Blocking all wave energy is Fraser Island. Sand pushed from east to west. Western side is slightly more wind exposed in	Very low to high. South is always tidal. Tides running to south & north – relief shows the boundary of fast tidal flows. Amphidromal	Warmer water than further north– a degree warmer than north, especially in winter. Summer inshore water	High nutrients in close to the shore. There us another waterbody at the bottom (G2) – the highly stratified highly saline water for 9-10. This is unique; it drives the current circulation, where the water from the sea (Ribbe, Grawe references).Mary is the major water input – highly episodic / seasonal. Burrum is a minor influence.	Intermittently turbid. Mid Strait is mostly turbid. Locally wind generated turbidity in northerly – from Burrum to Hervey Bay city. 2-3m tides. Turbid except at slack tide. Clearer in northern Straits. Very significant groundwater input from Fraser Island – freshwater. Middleton et al 1987 describe Fraser Island 'mangrove winter waters'

	Benthic biota driven by benthic structure. More substrate structure than SRF: such as old river channel, lots of broken patches of coffee rock reef & coral, deep holes associated with the old river bed that were isolated from the remainder of the river bed due to sand. Coffee rock reef around Rooney's Pt. Sand dunes are moving west from Fraser Island. The Great Sandy Strait is a complex system. Extensive intertidal and subtidal banks mostly composed of sand. Subtidal consolidated substrates within the Strait are a mixture of coffee rock and sandstone reefs.	SE (Jan-Aug); south side exposed in NW (Aug-Jan).	point mid Strait, north of Moonboom Island where tides meet from both north and south. Exchange in Platypus Bay / Hervey Bay is very low.	temperatures can go to 32^{o}C.		nutrient rich, low oxygen, entering EAC at 100m depth both N and S of Fraser. 3 states exist when a fresh.
H	Breaksea Spit to NSW Border and beyond – the Tweed Narrow distance between the coast and the 100m contour, steep drop off close to shore. Banks occur offshore e.g. Gardener banks etc. Reefs off Moreton Island are northernmost extent of kelp. Demersal fish populations are changing - fish moving down on EAC due to climate change include: Red Emperor, Nannygai off the Gold Coast;	Current dominated by EAC & wind (waves, swell). Strongly oceanic. Energy magnitude is high-energy wind & wave, drives high coastal erosion.	Moderate nutrients.	Temperature of Area 2^{o}C in summer is elevated 1.5-2degrees over 25years, in the southern GBR lagoon. See Sea Surface Temperature maps – deeper waters have less temperature	Saline – seawater. Inputs are scattered and even i.e.: Noosa, Maroochy, Mooloola, Nerang, Tallebudgera Creek, Tweed River. Diverse point source.	Clearest of all subregions.

	Red throat emperor were previously north of Fraser Island in 1970s-80s, now off Cape Moreton; Central Qld species including finger mark & golden snapper are now common as far south as Tin Can Bay.			change than surface waters.		

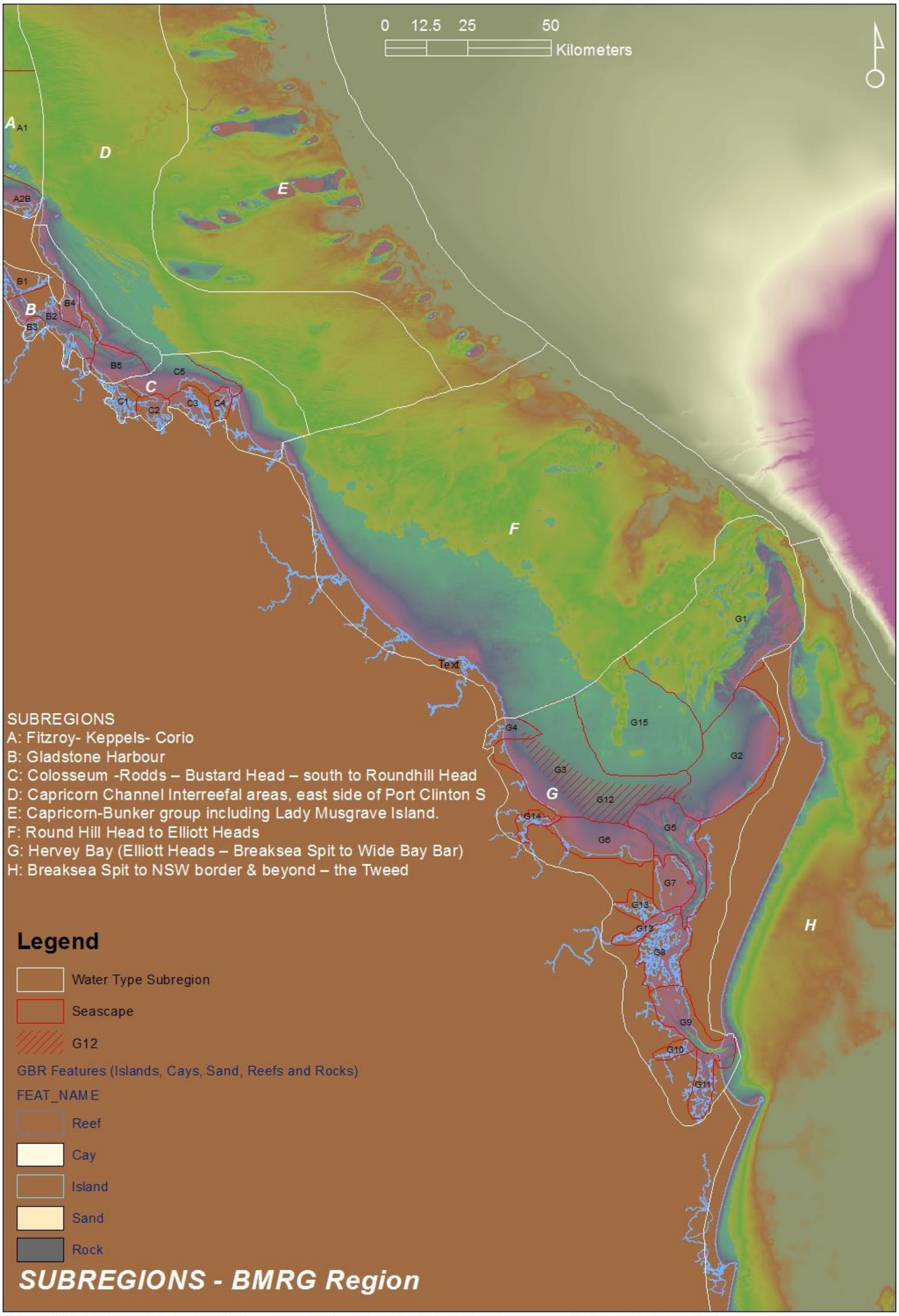
If required, it is also possible to further sub-divide these assets into individual **seascapes**. This is particularly relevant for the near coastal systems (C & G) where there is greater sub-regional variation.

Colosseum to 1770 seascapes (C): Colosseum Inlet (C1), 7 mile creek (C2), Turkey Beach Rodds Harbour (C3), Pancake outer – Jenny Lind connection is very limited only (C4), Rodd's Bay (C5), Bustard Bay to 1770 (C6).

Hervey Bay / Great Sandy Strait seascapes: Breaksea spit to Mary palaeochannel (G1), Platypus Bay (G2), Mid to western Hervey Bay (G3), Elliott River (G4), Northern Great Sandy Strait to tidal delta of Hervey Bay (G5), Burrum Coastal to Hervey Bay City (G6), Booral wetlands (G7), Mary Delta /central Great Sandy Strait (G8), Wide Bay Harbour (G9), Kauri Creek (G10), Tin Can Inlet (G11), Hypersaline bottom water south west Hervey Bay (G12), Mary-Susan (G13), Burrum Estuary (G14) and Central Hervey Bay (H15).

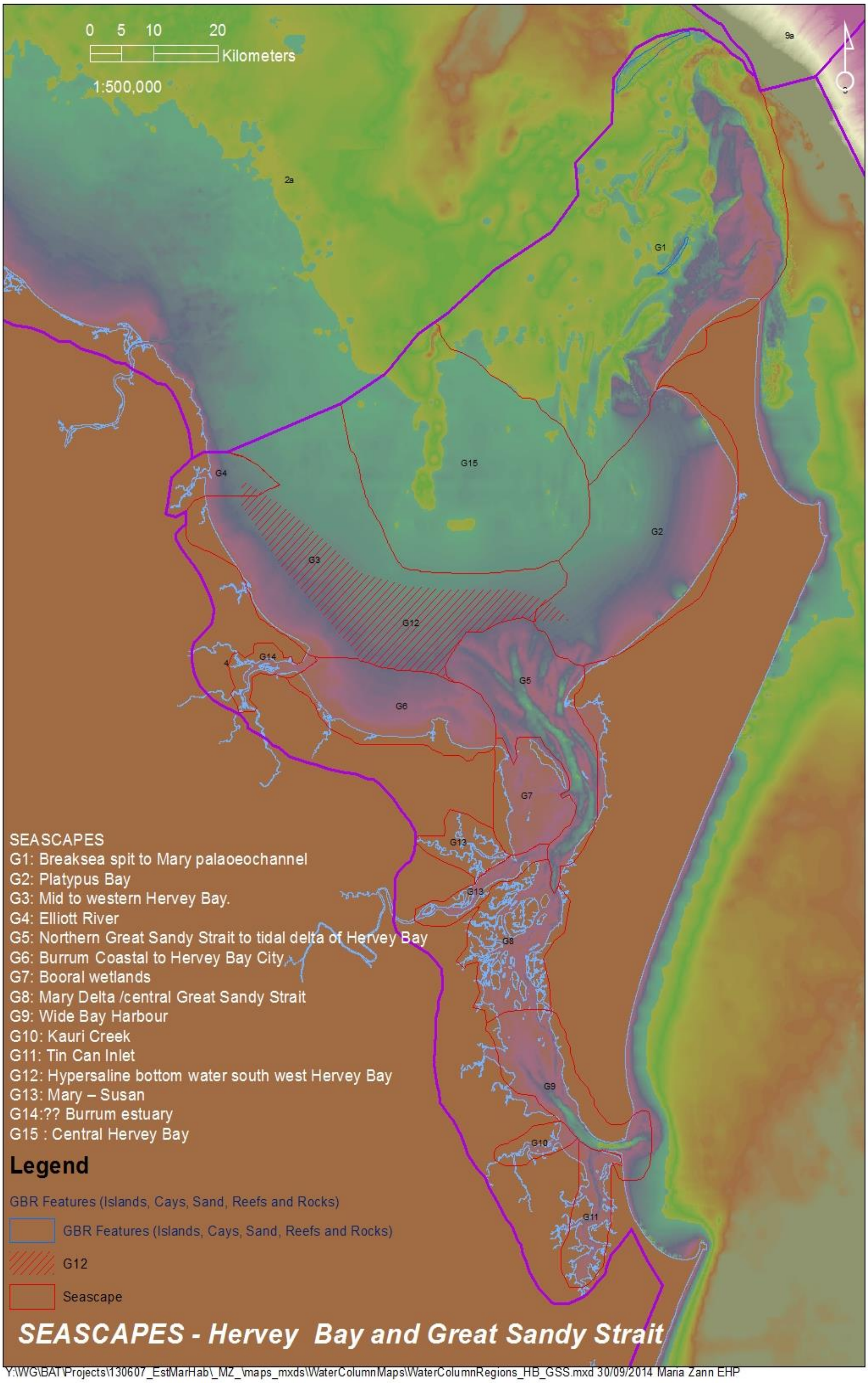
As these classifications are currently based on a provisional classification system, the higher level or water column types were used for the purposes of this assessment.

FIGURE 1: COASTAL, ESTUARINE AND MARINE ECOSYSTEMS WATER TYPES OF THE BURNETT MARY



Y:\WG\BAT\Projects\130607_EstMarHab_MZ_\maps_mxds\WaterColumnMaps\WaterColumnRegions.mxd 30/09/2014 Maria Zann EHP

FIGURE 2: SEASCAPES OF HERVEY BAY AND THE GREAT SANDY STRAIT



Y:\WG\BAT\Projects\130607_EstMarHab_MZ_\maps_mxds\WaterColumnMaps\WaterColumnRegions_HB_GSS.mxd 30/09/2014 Maria Zann EHP

5.4.3 Potential Climate Futures

Under a Potential Future Climate at **2030 and 2090**, a number of climate model simulations have been made by the CSIRO and Bureau of Meteorology. These are based on climate model simulations following a set of greenhouse gas, aerosol and land-use scenarios that are consistent with socio-economic assumptions of how the future may evolve. The well mixed concentrations of greenhouse gases and aerosols in the atmosphere are affected by emissions as well as absorption through land and ocean sinks.

There are four Representative Concentration Pathways (RCPs) underpinned by different emissions. They represent a plausible range of radiative forcing (in W/m^2) during the 21st century relative to pre-industrial levels. Radiative forcing is a measure of the energy absorbed and retained in the lower atmosphere. The RCPs are:

- RCP8.5: high radiative forcing (high emissions)
- RCP4.5 and 6.0: intermediate radiative forcing (intermediate emissions)
- RCP2.6: low radiative forcing (low emissions).

RCP8.5, represents a future with little curbing of emissions, with carbon dioxide concentrations reaching 940 ppm by 2100. The higher of the two intermediate concentration pathways (RCP6.0) assumes implementation of some mitigation strategies, with carbon dioxide reaching 670 ppm by 2100. RCP4.5 describes somewhat higher emissions than RCP6.0 in the early part of the century, with emissions peaking earlier then declining, and stabilisation of the carbon dioxide concentration at about 540 ppm by 2100.

RCP2.6 describes emissions that peak around 2020 and then rapidly decline, with the carbon dioxide concentration at about 420 ppm by 2100. It is likely that later in the century active removal of carbon dioxide from the atmosphere would be required for this scenario to be achieved.

For the purposes of this assessment, only RCP4.5 and RCP8.5 were considered as current emissions are already tracking above this level and radical intervention would be required to reduce radiative forcing below these levels.

The Coastal & Marine systems of the region were assessed by an External Expert Panel (2014) to determine the vulnerabilities to climate change of the various asset classes. The detailed results of the Assessment are contained within Appendix X. It was deemed that, in general, Coastal & Marine systems of the region were sensitive to the following climate change exposure indicators:

- Air temperature Increases;
- Increasing lengths of dry periods;
- Increased frequency of intense rainfall events;
- Extreme coastal sea levels;
- Riverine and ocean temperature increase; and
- Ocean Acidification.

Under a Potential Future Climate at **2030 and 2090**, the following predictions have been made by the CSIRO and Bureau of Meteorology:

Climate Scenario	**Potential Climate Future 2030**	**Potential Climate Future 2090**
RCP 4.5	• Air temperature increase (annual maximum) **0.9°C** (0.6-1.3). • Time spent in drought is projected, with medium confidence, to increase over the course of the century. • Understanding of the physical processes that cause extreme rainfall, coupled with modelled projections, indicate with high confidence a future increase in the intensity of extreme rainfall events, although the magnitude of the increases cannot be confidently projected. • Increase in sea level (Gladstone) **0.13m** (0.09-0.17). • Ocean temperature increase (Gladstone) **0.7°C** (0.5 to 1.0). • Ocean acidification (predicted pH change) **-0.07** (-0.07 to -0.06).	• Air temperature increase (annual maximum) **1.9°C** (1.2 to 2.9). • Time spent in drought is projected, with medium confidence, to increase over the course of the century. • Understanding of the physical processes that cause extreme rainfall, coupled with modelled projections, indicate with high confidence a future increase in the intensity of extreme rainfall events, although the magnitude of the increases cannot be confidently projected. • Increase in sea level (Gladstone) **0.47m** (0.30 to 0.64). • Ocean temperature increase (Gladstone) **1.5°C** (1.1 to 1.9). • Ocean acidification (predicted pH change) **-0.10** (-0.18 to 0.38).
RCP 8.5	• Air temperature increase (annual maximum) **1.0°C** (0.5-1.4). • Time spent in drought is projected, with medium confidence, to increase over the course of the century. • Understanding of the physical processes that cause extreme rainfall, coupled with modelled projections, indicate with high confidence a future increase in the intensity of extreme rainfall events, although the magnitude of the increases cannot be confidently projected. • Increase in sea level (Gladstone) **0.13m** (0.09 to 0.18). • Ocean temperature increase (Gladstone) **0.8°C** (0.5 to 1.0). • Ocean acidification (predicted pH change) **-0.08** (-0.08 to -0.07).	• Air temperature increase (annual maximum) **3.6°C** (2.9 to 4.7). • Time spent in drought is projected, with medium confidence, to increase over the course of the century. • Understanding of the physical processes that cause extreme rainfall, coupled with modelled projections, indicate with high confidence a future increase in the intensity of extreme rainfall events, although the magnitude of the increases cannot be confidently projected. • Increase in sea level (Gladstone) **0.64m** (0.44 to 0.86). • Ocean temperature increase (Gladstone) **2.9°C** (2.1 to 3.5). • Ocean acidification (predicted pH change) **-0.14** (-0.26 to 0.45).

(10th percentile to 90th percentile values)

From Exposure Indicators, as per Vulnerability Assessments – based on Dowdy, A. et al. 2015, East Coast Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports, eds. Ekström, M. et al., CSIRO and Bureau of Meteorology, Australia.

From this, it is clear that coastal and marine assets and their associated values (Individual habitats and species) would be vulnerable. Ultimately, each of the Coastal and Marine asset classes will be susceptible to one or multiple climate change exposure indicators. For example – mangroves in the Burnett River will respond to changes in air temperature, increasing length of dry periods (drought), increased frequency of intense rainfall events and changes in sea level. These are summarised below.

TABLE 3: BROAD ASSESSMENT OF BENTHIC ASSET VULNERABILITY TO DIFFERENT COMPONENT OF CLIMATE CHANGE EXPOSURE.

Asset code	Asset description	Air temperature	Drought	Storms	Sea Level Rise	Ocean temperature	Ocean acidification
ME 1	Intertidal Rock Platform	X	X	XXX	X	X	X[1]
ME 2	Sandy Beach	X		X	X	X	X[2]
ME 3	Mud Flat / Sand Flat	X	X	X	X	X	X[2]
ME 4	Basalt Boulder Beach / Cobble	X	X			X	
ME 5	Tidal Salt Pan	X		X	X	X	
ME 6	Intertidal Seagrass	X	X	X	X	X	X[2]
ME 7	Tidal Salt Marsh	X	X	X	X	X	X[2]
ME 8	Mangrove	X	X	X	X	X	X[2]
ME 9	Intertidal Sessile (Corals and Sponges)	X	X	X	X	X	X[3]
ME 10	Subtidal Platform			X	X	X	X[1]
ME 11	Sandy Bottom			X	X	X	X[2]
ME 12	Muddy Bottom			X	X	X	X[2]
ME 13	Pebbly Bottom (includes gravel)			X		X	X[2]
ME 14a	Seagrass Subtidal - Baffle		X	X	X	X	X[1]
ME 14b	Seagrass Subtidal - Coastal Catchments		X	X	X	X	X[1]
ME 15	Algae			X		X	X[1]
ME 16	Sessile (Corals, Sponges & CCA) fauna Inshore			X	X	X	X[3]

ME 17	Sessile (Corals, Sponges & Rhodoliths) fauna Inshore			X	X	X	X[3]
ME 18	Sessile (Corals and Sponges) fauna Offshore			X	X	X	X[3]

X[1] Molluscs will struggle to lay down shell, leading to algal dominated rock platforms
X[2] Implications for both macro- and meiofauna
X[3] Calcareous structures more susceptible to borers

To enable vulnerability to be prioritised across each of the assets (habitat – 18 and marine water types – 6), response and vulnerability to six potential climate change impacts were more formally assessed. These were:

1. Increase in annual maximum (change in ^{o}C)
2. Duration of time spent in drought (% change from baseline)
3. Increased frequency of intense rainfall events (% increase from baseline)
4. Extreme Coastal Sea Level Rise (increase in sea level in metres)
5. Increased Ocean Temperatures (increase in ^{o}C)
6. Increased Ocean Acidification (predicted pH).

From this the following vulnerability assessment was derived (see Appendix X for full results).

Table 4a: Vulnerability Assessment for Burnett Mary Coastal, Estuarine and Marine Benthic Assets (Ordered by Average Vulnerability)

Asset		Exposure	Sensitivity - average	Sensitivity - max	Potential Impact - average	Potential Impact - max	Adaptive capacity	Vulnerability - average	Vulnerability - max
ME8	Mangrove	5	4.5	6.0	22.5	30.0	2.4	11.7	15.6
ME9	Intertidal sessile	5	3.7	6.0	18.3	30.0	2.1	10.6	17.4
ME17	Inshore subtidal sessile (Corals, Sponges & Rhodoliths)	5	3.7	6.0	18.3	30.0	2.3	9.9	16.2
ME1	Rocky intertidal	5	3.0	6.0	15.0	30.0	1.8	9.6	19.2
ME16	Inshore subtidal sessile (Corals, Sponges & Coralline Crustose Algae)	5	3.5	6.0	17.5	30.0	2.3	9.5	16.2
ME4	Basalt boulder beach - e.g. Woongarra	5	3.0	6.0	15.0	30.0	2.0	9.0	18.0
ME5	Salt pan	5	3.3	6.0	16.7	30.0	2.4	8.7	15.6
ME6	Intertidal Seagrass	5	2.8	6.0	14.2	30.0	2.0	8.5	18.0
ME2	Sandy beach	5	2.8	5.0	14.2	25.0	2.1	8.2	14.5
ME7	Salt Marsh	5	3.0	6.0	15.0	30.0	2.4	7.8	15.6
ME18	Offshore subtidal sessile	5	3.5	6.0	17.5	30.0	3.0	7.0	12.0
ME3	Mud or Sand flat	5	2.3	3.0	11.7	15.0	2.4	6.1	7.8
ME11	Sandy bottom	5	2.3	3.0	11.7	15.0	2.5	5.8	7.5
ME13	Pebbly bottom (includes gravel)	5	2.7	6.0	13.3	30.0	3.0	5.3	12.0
ME10	Subtidal platform	5	2.2	3.0	10.8	15.0	2.6	5.2	7.2
ME12	Muddy bottom	5	2.2	3.0	10.8	15.0	2.6	5.2	7.2
ME14	Subtidal Seagrass	5	2.2	3.0	10.8	15.0	2.6	5.2	7.2
ME15	Algae	5	2.2	3.0	10.8	15.0	2.9	4.6	6.3

TABLE 4B: VULNERABILITY ASSESSMENT FOR BURNETT MARY COASTAL, ESTUARINE AND MARINE WATER TYPES

Asset		Exposure	Sensitivity - average	Sensitivity - max	Potential Impact - average	Potential Impact - max	Adaptive capacity	Vulnerability - average	Vulnerability - max
MWG	Hervey Bay	5	4.8	6.0	24.2	30.0	1.8	15.5	19.2
MWF	Round Hill Head to Elliott Heads	5	4.0	3.0	20.0	15.0	2.4	10.4	7.8
MWC	Colosseum-Rodds-Bustard Head-south to Roundhill Head	5	4.0	3.0	20.0	15.0	3.0	8.0	6.0
MWH	Breaksea Spit to NSW Border	5	2.8	2.0	14.2	10.0	2.6	6.8	4.8
MWE	Capricorn Bunker group	5	2.8	2.0	14.2	10.0	3.2	5.1	3.6
MWD	Capricorn Channel inter-reefal area	5	2.8	2.0	14.2	10.0	3.4	4.5	3.2

From these, we can surmise that the top ranking assets could be considered more vulnerable to the implications of Climate Change. What is notable is the number of highly ranked assets – both benthic and water types. Given their proximity and exposure to such a large number of potential impacts, this is not surprising.

Of the benthic assets, those most vulnerable include mangroves, intertidal sessile (corals and sponges), inshore subtidal sessile (coral, sponges, coralline crustose algae and rhodoliths), intertidal rocky, basalt boulder and sandy foreshores, salt pan, seagrass and saltmarsh. Productivity is generally driven by the salt marsh, mangroves and seagrass tidal wetlands – all of which are highly vulnerable. Those considered least vulnerable were algae. As the region is located in the sub-tropics, it is not characterised by persistent macro algae beds, like the kelp forests of the temperate zone, with both temporal and spatial variation in algae including Sargassum and red macro-algae – these will still shift with increases in temperature.

For the water types, Hervey Bay (or more specifically the marine waters of Hervey Bay / Great Sandy Strait) were the most vulnerable coastal and marine asset in the Burnett Mary region. This is of concern as this water type supports the Great Sandy Strait Ramsar wetland and is intrinsically linked to many of the tidal wetlands listed above and their associated species (including *Environmental Protection and Biodiversity Conservation Act 1999* listed migratory and resident shorebirds, dugongs, Australian humpback dolphins, turtles and sea snakes).

For all actions, these assets should be considered a high priority to maintain healthy and resilient coastal, estuarine and marine ecosystems.

5.4.4 Estuarine and Marine Ecosystems Vision, Targets & Desired Outcomes

The visions and targets listed in the NRM Plan are non-statutory. They seek to achieve and align with long-term sustainability outcomes and principles referred to in the Wide Bay Burnett, Central Queensland and South East Queensland Regional Plan's and other relevant State and Commonwealth Plans.

The indicative Vision, 2020 Target and Desired Outcomes for the Estuarine and Marine Ecosystem Assets are summarised below.

ASSET	VISION 2031	2020 Target Theme	TARGETS 2020	
COASTAL, ESTUARINE & MARINE ECOSYSTEMS	**Coastal, estuarine and marine resources and their processes:** • **are healthy and resilient** • **are appreciated for their value and vulnerability to changes in climate and human activity** • **underpin our community's industries and lifestyles.**	**Physical and Biological Processes**	CM1	Critical ecological connections (interactions) and processes are identified by 2020 (e.g. food webs etc.).
			CM2	That surface water and groundwater flows are measured and maintain ecological connections that underpin coastal values by 2020.
			CM3	That geomorphological processes (including riverine and shoreline) maintain or restore sediment transport that sustains beaches and coastal dunes by 2020. *Significant coastal dunes are those considered to be a system or landform that has a high degree of ecological integrity and biodiversity conservation value (and satisfies a number of criteria as defined in the M&E strategy).*
		Coastal, Estuarine and Marine Habitats	CM4	That by 2020, the extent of all coastal, estuarine and marine benthic habitats will be mapped and a baseline created.
			CM5	That by 2020, the function and value of all coastal, estuarine and marine benthic habitats are improved or maintained. [=condition]
			CM6	There is no net loss of the extent of natural wetlands.
			CM7	There is an improvement in the ecological processes and environmental values of natural wetlands.
		Coastal, Estuarine and Marine Plants & Animals	CM8	That by 2020, there is no adverse change in biological diversity in coastal, estuarine and marine species. *Given climate change, there will be dramatic changes to the region's coastal, estuarine and marine ecosystems. This will lead to the inevitable loss of some species and potential gains in species from outside the region. By supporting resilient ecosystems, the term 'no adverse change' means that biological diversity is maintained to support ecological processes and ecosystem services.*
		Water quality	CM9	That by 2020, actions as identified in the Burnett Mary Water Quality Improvement Plan* are implemented to achieve water quality targets to maintain coastal, estuarine and marine ecosystem health.

Physical and Biological Processes

CM1 – Critical ecological connections (interactions) and processes are identified by 2020 (e.g. food webs etc.).

CM2 – That surface water and groundwater flows are measured and maintain ecological connections that underpin coastal values by 2020.

CM3 – That geomorphological processes (including riverine and shoreline) maintain or restore sediment transport that sustains beaches and coastal dunes* by 2020.

The Wide Bay Burnett coast contains some of the most diverse shorelines in Australia. Some shorelines are exposed to oceanic swells whereas others are protected resulting in muddier shores. The region contains stretches of exposed sandy beaches such as Fraser Island and at Double Island Point, several estuarine systems such as the Great Sandy Strait, a diverse range of rivers and creeks such as the Mary and Burnett rivers, Baffle and Theodolite creeks, and coral cay islands such as Lady Elliot and Lady Musgrave Islands.

Coastal and ocean processes involve the movement of water, sediment, plants and animals caused by wind, wave and currents, between rivers, the shoreline and the open ocean. The Wide Bay Burnett region's shoreline (or coastline) is constantly changing as a consequence of coastal ocean processes that occur naturally (through erosion or accretion), but are also accelerated through the combined effects of coastal hazards (storm and tidal flooding), coastal development (removal of coastal and marine habitats) and climate change.

Coastal development in erosion prone areas (areas that have a determined vulnerability) alters natural wave, current and sediment transport patterns, resulting in increased erosion or accretion. Inappropriate placement of new coastal development in erosion prone areas poses social, economic and environmental consequences and costs. This results in the loss of shorelines, habitats and places development is at risk of loss or damage. Man-made protection structures such as seawalls, groynes, or activities such as excavation, extractive industries, dredging, marine infrastructure or beach nourishment may also disrupt natural coastal processes and impact on coastal and marine habitats.

In addition, climate change is expected to make the Wide Bay Burnett region's dune systems, wetlands and low-lying estuarine systems more vulnerable to storms, floods and drought. Sea level rise is expected to inundate low lying areas and alter wetland type, extent and condition.

Maintaining critical areas free of development within erosion prone areas and along tidal waterways and ensuring that our coastal and marine habitats are buffered from development will allow for natural coastal processes to occur, reducing or perhaps negating the need to protect property and life. After all, our natural coastal and marine habitats (such as sand dunes and wetlands) are like our kidneys -filtering agents that provide coastal protection, and reduce the impacts of coastal flooding.

Any impacts associated with development and climate change need to be monitored on an ongoing basis to determine their status and any possible mitigation measures required for their protection. The *Coastal Protection and Management Act 1995* identifies erosion prone areas and the coastal management district where these coastal processes occur.

The Queensland Herbarium is responsible for recording and publishing the extent and type of wetlands. This baseline information and mapping service will be integrated into extent assessment and monitoring activities. The Queensland Wetlands Program provides tools for wetland buffer planning and assessment. These tools will be used in integrated wetland planning and assessment processes.

Increases in the frequency and intensity of climatic events – particularly cyclones – will lead to increases in coastal erosion, while sea level rise reduces coastal accretion, resulting in less sand build–up along our foreshores. Both have implications for adjacent natural and built infrastructure.

Coastal, Estuarine and Marine Habitats

CM4 – That by 2020, the extent of all coastal, estuarine and marine benthic habitats will be known and a baseline created.

CM5 – That by 2020, the function and value of all coastal, estuarine and marine benthic habitats are improved or maintained. [=condition]

CM6 – There is no net loss of the extent of natural wetlands.

Coastal, estuarine and marine habitats of the Wide Bay Burnett lie between the well-known Moreton Bay and Great Barrier Reef. But, in comparison, very little is known about our region's habitats, diversity, health and connectivity. Gaining a baseline level of knowledge about all the habitats in the region is the first step before ecological health and connectivity can be assessed. Several types of connectivity that are important for the natural function of marine habitats are a result of aquatic flows between catchments and reefs. These flows transport chemicals, nutrients, sediments, plants and animals between aquatic habitats and their qualities or condition affect:

- Land and Sea (east-west) connections between estuarine and marine habitats. For example, the importance and ability of coastal dunes and wetlands to filter nutrients, sediments and chemicals from water – from urban, industrial and agricultural activities, before entering inshore marine habitats such as seagrass and coral reefs.
- North-south connections in the Wide Bay Burnett associated with ocean and nearshore currents, and between the seafloor and top of the water column. For example, the currents between the Great Barrier Reef and Great Sandy Strait Ramsar area.
- The reliance of species on different habitats for different parts of their lifecycle. For example, mullet rely on freshwater rivers and the open ocean at different stages of growth and development.

Ultimately, unhealthy and disconnected habitats in the region will mean there will be a reduction in recreational enjoyment and economic productivity. Therefore, knowledge about the coastal, estuarine and marine habitats of the region, how they are connected and what state they are in, is imperative to the community and its lifestyle and will assist in its future management.

Increasing air temperatures will impact on intertidal wetlands – leading to desiccation, while increases in sea temperatures will lead to higher incidences of coral bleaching events (and ultimately the collapse of coral reefs). Greater air and sea temperatures place greater physiological stress on plants and animals living in intertidal habitats, such as on rock platforms and in wetlands. These animals are part of the critical ecological functioning of these habitats. Plants and animals under increased stress from climate change are less able to resist and recover from other perturbations, such as pollution and eutrophication, introduced pests and physical disturbances.

Coastal, Estuarine and Marine Plants and Animals

> CM8 - That by 2020, there is no adverse change in biological diversity in coastal, estuarine and marine species.

The Wide Bay Burnett region has an international, national and state obligation to protect many of its plants and animals, their populations and habitats, and to maintain the ecosystems upon which they rely.

There are many species that are considered significant for a variety of reasons including those that are iconic or valued by the community, or in need of conservation because they are considered endangered, vulnerable or near-threatened. Others species are used to measure environmental health or economic importance and are considered significant indicators.

Whales, dolphins and turtles in the region for example, are considered iconic and important both culturally and economically. They have become significant for tourism activities in some coastal areas (like humpback whales), and have totemic value to traditional owners such as the Butchulla people. Dugongs are also considered iconic and a conservation significant species as they are classified as vulnerable under Queensland Government legislation and are identified as a critical priority under the Back on Track species prioritisation framework. Healthy dugongs and green turtles require healthy seagrass meadows in which to forage. Many economically significant fishery species are also reliant on seagrass meadows, but also the mangroves and near-shore reefs. Coral reef fish in particular are keystone species with an essential links to and indicators of reef condition. These habitats play a vital role in ecosystem health and the presence and location of many plants and animals in the region.

Better information is needed in the region about significant species, their populations, habitat requirements and key life cycles –that is, where they spawn, spend their adult life and their movement (or connectivity) between these. Monitoring other species considered indicators (reflecting habitat health) or keystone (reflecting roles in an ecosystem, and ecosystem health or resilience) is also required. It is important to gain more knowledge about human interactions with significant species, through activities such as fisheries, tourism, resource and coastal planning, and the implications this may have for the region's coastal, estuarine and marine habitats. (For example, marine pests are plants and animals that potentially impact on marine habitats and resources.) This will allow us to have a greater understanding about the region's significant species, their population numbers, extent and connectivity to the landscape and seascape into the future.

It should also be noted that within the context of the climate change scenarios, that ocean currents are expected to intensify and this will have implications for the spread of species (including invasive species). Ocean acidification will also impact on fish larvae, molluscs, crustaceans, corals and plankton which will impact on food webs and fisheries productivity.

Water Quality

CM9 – That by 2020, actions as identified in the Burnett Mary Water Quality Improvement Plan* are implemented to achieve water quality targets to maintain coastal, estuarine and marine ecosystem health.

Water quality of the Wide Bay Burnett region is affected by discharge (from an identifiable location) or runoff from either surface or groundwater. Sediments, nutrients and chemicals are suspended in the water column and enter the estuarine and marine environment (the receiving waters of catchments) from major coastal streams like the Burnett, Mary and Burrum Rivers.

At the mouths of the catchments are the coastal habitats such as seagrass meadows, coral reefs, and mangroves (and includes the southern portion of the Great Barrier Reef lagoon, which receives their flood waters). These habitats depend on good water quality to be healthy and in turn supply essential habitat and food to many plants and animals. Some actions (e.g. the Reef Plan on-ground works through BMRG and MRCCC) have started to address these issues; but require local monitoring of the coastal habitats to determine their effectiveness.

Valuing water quality services and having a healthy coastal, estuarine and marine ecosystem has been recognised as important to the Wide Bay Burnett community especially for human health. What is regularly and traditionally measured for water quality are physio-chemical indicators such as dissolved oxygen, pH, temperature, salinity and nutrients (nitrogen and phosphorus). These water quality indicators provide information about what is impacting on the ecosystem.

In contrast, biological water quality indicators such as algae, fish species or crab burrows are intended to measure the health of the plants and animals and the habitats on which they rely, which may provide a broader picture of ecosystem condition.

Changing land management practices, improving or maintaining healthy vegetation along waterways and addressing water use in urban and agricultural development can have positive outcomes for the quality of coastal and marine waters and for our sustained consumption and enjoyment of the Wide Bay Burnett region.

The impacts of dramatic climatic events such as cyclones and flooding have a considerable impact on coastal water quality leading to increased runoff of sediment and a corresponding increase in turbidity.

5.4.6 INVESTMENT STRATEGY

We need to take action to reduce risks and threats and improve biophysical condition. However, we also need to improve policy and planning, awareness and behaviour, adoption of improved management practices and improve the region's understanding and knowledge of natural systems and the interaction of human activities on those systems. All of these activities have one thing in common, which is the need for investment of resources - both people and funding.

To follow are the specific activities identified for the delivery of outcomes for the Coastal, Estuarine and Marine Assets as identified through Community Consultation and Scientific Expert Panels. The activities were identified for addressing key issues for the Priority Assets of the Estuarine and Marine Ecosystems Asset Group and were subject to a prioritisation process examining:

- Cost
- Benefit
- Risk
- Barriers to Adoption
- Social Acceptability
- Carbon Sequestration Potential
- Maladaptation

Priorities have been ranked from 1 to 3, where 1 is high, 2 moderate and 3 low.

2020 Targets	Desired Outcomes	Activity Category	Activity	Priority Ranking	Climate change adaptation or mitigation co-benefit
CM1 – Critical ecological connections (interactions) and processes are identified by 2020 (e.g. food webs etc.).	Critical ecological connections – such as food webs and habitat mosaics are understood, informing future prioritisation and delivery.	Planning & Governance	CM1.1 Provide best-available advice to all planning processes that potentially impact the ecological connectivity of terrestrial and marine environments.	1	Coastal, estuarine and marine connectivity will support greater resilience to climate change and movement of species enabling species spread and migration. Healthy tidal wetlands (saltmarshes, mangroves and seagrass) store 'blue carbon' mitigating greenhouse gas emissions.
		On-Ground	CM1.2 Support actions to protect, maintain or restore coastal, estuarine and marine ecological connectivity; including those with links to freshwater and terrestrial programs.	1	
		Community Capacity Building	CM1.3 Create "it's all connected" education tools (e.g. website, guidelines, brochures, DVDs, YouTube, videos) explaining ecological connectivity, its significance for where and how we live and regional economic implications viz. tourism, fisheries productivity, natural hazard reduction etc.	2	
			CM1.4 Highlight the importance of connectivity through education programs such as Marvellous Mangroves and Shorebird activities.	3	
		Science	CM1.5 Review current knowledge to build a conceptual model of ecological connectivity in the coastal, estuarine and marine systems of the Burnett Mary (including identification and prioritisation of knowledge gaps)	1	
			CM1.6 Prioritise and implement research activities to address knowledge gaps	2	
CM2 – That surface water and groundwater flows are measured and maintain ecological connections that underpin coastal values by 2020.	Of these critical ecological connections, surface and ground water flows maintain ecological connectivity and coastal values such as seagrass production.	Planning & Governance	CM2.1 Provide best-available advice to planning and policy reviews related to the management of surface and ground waters, emphasising the significance of surface and ground water flows to maintaining coastal ecological values.	1	Groundwater dependent ecosystems such as some riparian vegetation and tidal wetlands (for example seagrass beds) are maintained, increasing resilience to climate change and maintaining carbon storage capacity.
		On-Ground	CM2.2 Design and deliver innovative programs that restore surface and groundwater flows in areas where such flows have declined due to irrigation or other "take." (Links to rural water use efficiency and irrigation efficiency programs)	1	
		Community Capacity Building	CM2.3 Create "it's all connected" education tools (e.g. website, guidelines, brochures, DVDs, YouTube, videos) explaining ecological connectivity, its significance for where and how we live and regional economic implications viz. tourism, fisheries productivity, natural hazard reduction etc.	2	
		Science	CM2.4 Compile existing data sets to identify current surface flows and establish baselines to maintain ecological connectivity.	1	
			CM2.5 Address data gaps, principally groundwater flows, to establish baseline flows required to maintain ecological connectivity.	2	

CM3 – That geomorphological processes (including riverine and shoreline) maintain or restore sediment transport that sustains beaches and coastal dunes by 2020.	Reduction of development (or coastal retreat) will enable greater adaptation to sea level rise and natural adaptation of coastal ecosystems and less impacts to built infrastructure / development. Sand movement (sand budget, imports and exports) is maintained resulting in stable beaches. The natural extent and dynamics of coastal beaches and tidal wetlands is maintained resulting in a stable natural environment able to limit flood discharge and support diverse populations and ecosystems that maintain coastal and marine ecosystem services (e.g. fisheries).	Planning & Governance	CM3.1 Facilitate information sharing to ensure that planning schemes, new or revised erosion management plans and strategic plans for development in marine areas recognise the importance of maintaining coastal processes, including maintaining sediment transport regimes.	1	Enabling the efficient and natural movement of sand enables coastal accretion and reduces the impacts of sea level rise and severe coastal erosion during dramatic climatic events e.g. cyclones. Beaches are also a natural buffer protecting natural and built infrastructure. As sea level rises, beaches and tidal wetlands will try to migrate landward. If there are no buffers between these systems and built infrastructure, these ecosystems will be lost – reducing habitat, fisheries productivity and impacting the economy through recreational and commercial fishing and tourism.
			CM3.2 Develop guidelines for use by local government and the general community that identify threats to biodiversity, life and property in the coastal zone; reflecting current scientific, economic and legal information.	1	
			CM3.3 Review the location and legal standing of existing structures in tidal waterways (e.g. boat ramps or other private and public maritime infrastructure) and coastal developments on significant coastal dunes to inform future planning / management strategies.	2	
		On-Ground	CM3.4 Approve, modify or remove unlawful structures in tidal wetlands and on significant coastal dunes.	2	
		Community Capacity Building	CM3.5 Provide training for local and state government planners on the statutory requirements (and options) for maintaining coastal ocean processes in development assessment and planning.	1	
			CM3.6 Create education tools (e.g. -website, guidelines, brochures, DVDs, YouTube, videos) that explain the importance of: - coastal ocean processes and the effects/risks of altering the natural coastal environment - retaining tidal wetlands and coastal dunes and allowing natural coastal processes to occur.	2	
		Science	CM3.7 Coordinate and integrate the existing local science regarding coastal ocean processes (e.g. climate change, hazards, oceanography and sand movement).	1	
			CM3.8 Coordinate and integrate intertidal and contour data.	2	
			CM3.9 Undertake a sediment volume study (Beach Protection Authority) to enable better understanding of regional sediment composition over time (palaeo-sedimentology).	2	
			CM3.10 Establish the baselines required for monitoring (e.g. significant coastal dunes, tidal wetlands, and undeveloped tidal waterways) and seek community involvement and support.	1	
			CM3.11 Seek ownership and involvement from the greater community to undertake coastal monitoring programs (This may require the development of new citizen science programs Dune Watch).	2	
CM4 – That by 2020, the extent of all coastal,	Maintaining the extent of our tidal wetlands is key	Planning & Governance	CM4.1 Provide best-available advice to planning and development processes that potentially impact on coastal, estuarine and benthic	1	Tidal wetlands sequester carbon faster and in

estuarine and marine benthic habitats will be mapped and a baseline created.	to providing both ecological processing capacity and habitat to maintain biodiversity and fisheries values of the region.		habitats (and their buffers) with provision for climate change (2050 horizon).		greater quantities than land-based systems (this is sometime referred to as *blue carbon).* Mangroves and saltmarsh can sequester 6-8 tonnes of CO2/Ha/yr. Tidal wetlands support fisheries and tourism, reduce the run-off of sediments and nutrients and act as a physical buffer protecting coastlines (and coastal communities) from dramatic climatic events.
		On-Ground	CM4.2 Support actions to protect, maintain or restore key coastal, estuarine (and marine) habitat sites where feasible (given constraints such as sea level rise). For example through the installation of seagrass friendly moorings to protect habitat.	1	
		Community Capacity Building	CM4.3 Promote key messages that reinforce the value of coastal, estuarine and marine habitats to the regional economy through fisheries productivity and tourism e.g. No habitat, no fish.	2	
			CM4.4 Highlight the importance of coastal, estuarine and marine habitats through education programs such as Marvellous Mangroves and the Reef Guardian Schools program.	3	
		Science	CM4.5 Classify and map intertidal and subtidal estuarine and marine habitats for the region, including groundwater dependence.	1	
			CM4.6 Coordinate and integrate existing local science on coastal, estuarine and marine habitats (including marine water bodies) and undertake future research.	1	
			CM4.7 Ground truth mapping and establish baselines for all regional estuarine and marine benthic habitats, such as rhodolith and bivalve beds.	2	
			CM4.8 Identify and prioritise habitats of high ecological significance (utilising HES methodology) to inform policy, planning and management outcomes.	1	
			CM4.9 Align terrestrial and aquatic connectivity methodology and processes to the coastal, estuarine and marine environment.	1	
			CM4.10 Develop regionally specific conceptual models to increase the understanding of ecosystem processes and services of habitats.	1	
			CM4.11 Seek ownership and involvement from the greater community to undertake monitoring programs e.g. Seagrass Watch, Mangrove Watch, Reef Check.	2	
			CM4.12 Assess buffer implementation within or adjacent to riparian areas, tidal wetlands and significant coastal dunes.	1	
CM5 – That by 2020, the function and value of all coastal, estuarine and marine benthic habitats are improved or maintained. [=condition]	Although we have some information about key habitats such as saltmarsh, mangroves, seagrass and coral habitat our knowledge regarding extent is incomplete or outdated	Planning & Governance	CM5.1 Provide the best available science and technical advice to planning and policy reviews to ensure the function and value of estuarine and marine habitats continue to be recognised and are improved or maintained through future planning and policy initiatives.	1	While the role of coral, seagrass, mangroves and salt marsh in carbon sequestration are well established, there has been little research on some of our less common habitats – such as
		On-Ground	CM5.2 Support community and other initiatives that undertake coastal and estuarine habitat protection, rehabilitation and restoration e.g. saltmarsh fencing, mangrove planting, hydrology	1	

	(>10 years). In order to better manage our benthic habitats we need to classify and map them.		restoration, estuarine rehabilitation and urban stormwater quality improvement/flow reduction, dune fencing and revegetation.		rhodoliths and bivalve beds.
			CM5.3 Undertake marine debris clean up initiatives	2	
		Community Capacity Building	CM5.4 Support community information days through industry, coastal and other care groups to enhance awareness of the function and values of coastal, estuarine and marine habitats to the Burnett Mary region (and the potential risks to these values through Climate Change). E.g. Seafood Festivals.	2	
			CM5.5 Highlight the function and values of coastal, estuarine and marine habitats through education programs such as Marvellous Mangroves and the Reef Guardian Schools program.	3	
			CM5.6 Promote the cultural heritage value of coastal and estuarine habitats to Aboriginal people to the wider community through joint initiatives with local Traditional Owner groups.	3	
		Science	CM5.7 Develop regionally specific conceptual models to increase the understanding of ecosystem processes and services of habitats.	1	
			CM5.8 Identify and prioritise habitats of high ecological significance (utilising HES methodology) to inform policy, planning and management outcomes.	1	
			CM5.9 Coordinate and integrate existing local science on coastal, estuarine and marine habitats (including water) and undertake further research.	2	
CM6 – There is no net loss of the extent of natural wetlands.		Planning & Governance	CM6.1 Provide best-available advice to planning and development processes that potentially impact on natural wetlands (and their buffers) with provision for climate change (2050 horizon).	1	Tidal wetlands sequester carbon faster and in greater quantities than land-based systems (this is sometime referred to as *blue carbon).* Mangroves and saltmarsh can sequester 6-8 tonnes of CO2/Ha/yr. Tidal wetlands support fisheries and tourism, reduce the run-off of sediments and nutrients and act as a physical buffer protecting coastlines (and coastal communities) from
		On-Ground	CM6.2 Provide incentives, or other extension services, for lower impact land uses, best management practices technical support and education (particularly for agricultural practices in tidal wetlands)	1	
			CM6.3 Undertake riparian restoration and promote buffer implementation, particularly adjacent to forested areas.	1	
			CM6.4 Support tidal wetland fencing and removal of stock from sensitive tidal wetlands.	1	
		Community Capacity Building	CM6.5 Foster lower impact land uses and provide best management practices technical support and education to managers of land uses in tidal wetlands.	1	
			CM6.6 Highlight the importance of natural wetlands through education programs such as Marvellous Mangroves and the Reef Guardian Schools program.	3	
		Science	CM6.7 Coordinate and integrate existing data sets regarding the extent of natural coastal, estuarine and marine wetlands	1	

			CM6.8 Classify and map all natural wetland habitats in the Burnett Mary region to establish baseline extent mapping.	1	dramatic climatic events. Natural wetlands remove sediment and nutrients from surface water increasing the resilience of inshore marine ecosystems such as seagrass beds and coral reefs.
			CM6.9 Prioritise and implement research activities to address knowledge gaps.	2	
			CM6.10 Establish the baselines required for natural wetland extent monitoring and seek community involvement and support.	1	
CM7 – There is an improvement in the ecological processes and environmental values of natural wetlands.		On-Ground	CM7.1 Provide incentives, or other extension services, for lower impact land uses, best management practices technical support and education (particularly for agricultural practices in tidal wetlands).	1	Water quality improvement and hydrological connectivity will increase the resilience of coastal, estuarine and marine species.
			CM7.2 Expand and implement the biopassage strategy in the region.	1	
CM8 - That by 2020, there is no adverse change in biological diversity in coastal, estuarine and marine species.	EPBC and NCA Act listed species deserve the highest level of protection and conservation. Actions should contribute to the conservation and recovery of these species (where feasible).	Planning & Governance	CM8.1 Influence planning and development processes to consider development impacts on marine resources, particularly species' vulnerabilities associated with life cycle changes and migration.	1	While some marine species may have a small role to play in the fixing of carbon – such as hard corals and sea cucumbers, many EPBC and NCA Act listed species are highly susceptible to the impacts of climate change through reduced habitat, food availability and less optimal conditions for their life cycles (for example increased sand temperature will impact on turtle hatchling success). Climate change mitigation will have a positive impact on key species.
			CM8.2 Use the Queensland Coastal Plan and other instruments to inform local and state government planners of the statutory requirements for maintaining species extent and connectivity in planning and development assessment.	1	
		On-Ground	CM8.3 Implement actions from Species Recovery Plans to improve outcomes for species of conservation significance.	1	
			CM8.4 Encourage adoption of "best practice" by commercial and recreational fishers and marine tourism operators.	1	
			CM8.5 Promote viable land and marine based aquaculture that is appropriately located and does not impact on natural habitats or species.	3	
			CM8.6 Increase compliance and enforcement of existing regulations.	1	
			CM8.7 Support the development and implementation of Traditional Use of Marine Resource Agreements (TUMRAs) to assist in species management delivery.	2	
			CM8.8 Restore habitat connectivity and riparian catchment condition to enhance species resilience and natural life cycle processes.	1	
		Community Capacity Building	CM8.9 Support community information days through industry, coastal and other care groups to enhance awareness of coastal,	2	

			estuarine and marine biodiversity and its significance to the Burnett Mary region through fisheries productivity and tourism (and potential risks to species through Climate Change).		
			CM8.10 Highlight the unique biodiversity values of the Burnett Mary region (and threats to these species) through targeted education programs and campaigns e.g. shorebirds, Marvellous Mangroves and the Reef Guardian Schools program.	3	
		Science	CM8.11 Establish a list of scheduled and significant local species (plants and animals of ecological, economic, conservation or iconic value), considering the Back on Track prioritisation process, to target research funding opportunities.	1	
			CM8.12 Model and map species habitats including climate change predictions.	1	
			CM8.13 Establish a baseline of presence and extent for significant species and fisheries population.	1	
			CM8.14 Conduct social and economic studies of services provided by significant species and fisheries	1	
			CM8.15 Seek ownership and involvement from the greater community to undertake monitoring programs e.g. Queensland Turtle Research program, or by Coastcare and universities, and promote involvement in species incidence reporting.	2	
			CM8.16 Identify keystone or indicator species for habitat condition and health.	1	
			CM8.17 Identify where negative interactions with species exist and develop management responses to reduce these risks.	1	
CM9: That by 2020, actions as identified in the Burnett Mary Water Quality Improvement Plan* are implemented to achieve water quality targets to maintain coastal, estuarine and marine ecosystem health.	Improved water quality entering the coastal and marine environments (including healthier seagrass meadows and reef). Improved catchment retention of nutrients, sediments, chemicals etc. (through appropriate urban and rural land use), resulting in less algal blooms and reduced impacts to the marine environment.	Planning & Governance	CM9.1 Support moves to amend Queensland Government legislation to: • amend the Water Act to allow for marine water quality standards to be addressed in Water Resource Plans • integrate the Queensland Coastal Plan with Environmental Protection Policy (Water) and Water Quality Improvement Plans, in relation to coastal development • revise and reschedule WQIP Ecological Values and Water Quality Objectives e.g. pursue accreditation of the Baffle-Burnett WQIP as a Healthy Waters Management Plan under the Environmental Protection Policy (Water).	1	Water quality will decline under climate change scenarios becoming warmer, more acidic and more turbid (as a result of an increasing frequency of dramatic climatic events and run-off) and more saline in closed embayments such as Hervey Bay. Improving water quality will have a net benefit to tidal wetland habitats,
		On-Ground	CM 9.2 Coordinate activities across agencies and the community to implement Water Quality Improvement Plans.	1	
			CM9.3 Provide education and technical support, as required, and incentives to encourage industry adoption of best management	1	

			practice that improves water quality.		significant species and fisheries both in the Great Sandy Strait and adjacent Great Barrier Reef lagoon.
			CM9.4 Retain, enhance and restore vegetated filters / buffers that are capable of improving water quality.	1	
		Community Capacity Building	CM9.5 Implement the education and monitoring components of the Wide Bay Burnett Healthy Waterways Strategy.	1	
			CM9.6 Increase awareness of the unaccounted costs of poor water quality on assets e.g. reduced prawn fishery production, economic losses in the ecotourism sector as a consequence of seagrass loss due to increased sediment inflow.	1	
		Science	CM9.7 Undertake event monitoring and remote sensing of receiving waters and link to habitat condition monitoring.	1	
			CM9.8 Gain better understanding of groundwater processes, acid sulfate soils and pollution studies and link findings to land management activities.	1	
			CM9.9 Establish nutrient hazardous coastal land mapping (as per State Planning Policy (Healthy Waters))	1	
			CM9.10 Model sediments and nutrients coming from the Mary River (including the cumulative effects).	1	
			CM9.11 Maintain (and extend) EHP's ambient water quality monitoring. Extend to target biological indicators of water quality such as seagrass meadows, corals, scribbled angelfish, mud crabs and crab holes.	2	
			CM9.12 Establish better mapping products for biological indicators including tidal wetlands, riparian and foreshore vegetation, and link to management outcomes/practices.	2	
			CM9.13 Gain better understanding of the total water cycle management for the Wide Bay Burnett region e.g. the catchment sources of sediment, pesticides, pine discharge and path in receiving waters.	2	
			CM9.14 Provide support to (and standardise) community groups' monitoring programs for total water cycle management (i.e. water quality, habitat protection, vegetation filter restoration,…) and integrate into regional planning/management.	2	

5.4.7 MONITORING & EVALUATION OF THE ESTUARINE AND MARINE ECOSYSTEM ASSETS

The NRM Plan provides an opportunity to coordinate the region's effort towards monitoring the state of the environment and the health and condition of our natural resources. We need both monitoring systems and an evaluation process to get a true picture of how we are tracking.

Monitoring systems are about 'measurements' and aim to tell us something the state or condition of an asset. Monitoring is generally about data collection, analysis and interpretation and uses indicators that tell us something about the important asset. The indicators are a particular aspect of an environmental asset we can measure over time. When we combine these measurements with a good understanding of how an environmental systems works we are able to assess the condition and identify any trends associated with an asset.

Evaluation tells us about the effectiveness of what we have been doing and if we have achieved the results and outcomes we are looking for from our activities. Evaluation is based on having a good understanding of the 'cause and effect' relationship between the actions we undertake and the variety of outcomes and changes we hope to see along the way to achieving our targets.

The following information details the Monitoring and Evaluation Framework for this Asset Group.

MONITORING & EVALUATION FRAMEWORK

The following Table outlines the methods proposed to monitor our progress towards the achievement of our targets. In many cases Baseline data does not exist and is the first action necessary to complete to establish an operable monitoring program.

Target	**Indicators**	**Data Availability**		**Comments**
		(Y / N)	**Comments**	
CM1 – Critical ecological connections (interactions) and processes are identified by 2020 (e.g. food webs etc.).	Conceptual model of ecological connectivity in the coastal, estuarine and marine systems of the Burnett Mary (including identification and prioritisation of knowledge gaps) completed Knowledge is being applied to planning and other decision making processes to reduce impacts to the ecological connectivity of terrestrial and marine environments.	Y/N	• There is a considerable amount of data and knowledge in the public domain but not all ecological connections have been formally recognised. E.g. Why is population decline for shorebird in the Great Sandy Strait lower than national trends?	This target can be evaluated through the following processes: • Completion and publishing (knowledge dissemination) of the conceptual model • Uptake of knowledge and incorporation into key plans / decision making processes at an appropriate scale. [This could be undertaken through a survey of key partners]. • Prioritisation and implementation of research to address knowledge gaps.

CM2 – That surface water and groundwater flows are measured and maintain ecological connections that underpin coastal values by 2020.	That surface and ground water flows are measured and monitored to ensure they meet ecological requirements for coastal values That biological indicators of healthy surface and ground water flows can be established and are incorporated into an ongoing monitoring program e.g. Seagrass Watch and data is synthesised and incorporated into resource allocation planning reviews.	Y/N	• While surface water information is available for the region's managed catchments / water resources, information relating to smaller non-impeded coastal catchments and groundwater is limited.	

CM3 – That geomorphological processes (including riverine and shoreline) maintain or restore sediment transport that sustains beaches and coastal dunes by 2020.	Extent of development along the coastline/shoreline.	Y	Baseline needs development with existing datasets: For erosion prone areas: • Statutory Erosion prone areas 2012 • Current DCDB layer 2012 • Satellite imagery 2012 • Town planning precincts (current and future zones) date? Undeveloped tidal waterways (shoreline): Existing 2007 baseline created for the draft WBB Regional Coastal Management Plan (see metadata for further information)	The extent of development along the coast/shoreline can be determined by combining the erosion prone area and undeveloped tidal waterway datasets. Statutory Erosion prone areas for WBB region are mapped as of 2012, overlaid with current DCDB layer, satellite imagery and town planning precincts (current and future zones) to provide extent of coastal development within erosion prone areas. The undeveloped tidal waterway dataset would need to be updated and some attributes added (since the introduction of the urban footprint in the WBB region, for example). The undeveloped tidal waterways map shows where development along the shore is located, and if placed within appropriate urban areas, close to infrastructure, and limits loss of tidal wetlands (the natural buffers from ocean processes to the coast)
CM4 - That by 2020, the extent of all coastal, estuarine and marine benthic habitats will be mapped and a baseline created.	Extent of tidal wetlands and dunes affected by ocean processes	Y	Baseline needs review with existing datasets: For tidal wetlands: • Queensland Wetland Data (estuarine component - Version 3, 2012) For significant coastal dunes: • Existing 2006 baseline created for the draft WBB Regional Coastal Management Plan (see metadata for further information)	The extent of tidal wetlands and significant coastal dunes can be determined by combining the tidal wetland and coastal dune datasets. Types of tidal wetlands to be included in the dataset are those defined by the estuarine component of the Queensland wetland data. Mangrove & Tidal Wetlands baseline (Mackenzie & Duke, 2010) could be integrated into the Regional Ecosystem framework with MangroveWatch monitoring to review and evaluate change. Significant coastal dunes are those considered to be a system or landform that has a high degree of ecological integrity and biodiversity conservation value (and

				satisfies a number of criteria as defined in the M&E strategy – (note this definition is taken from the State Coastal Management Plan of 2001)).
CM5 – That by 2020, the function and value of all coastal, estuarine and marine benthic habitats are improved or maintained. [=condition]	Baseline of condition for all coastal, estuarine and marine benthic habitats will need to be established.	Y/N	Baselines will need to be established with existing datasets with data gaps prioritised and implemented (when funding will allow): • Seagrass Watch (JCU ongoing program) • Coral (Alquesar & Boyd (2007), Alquezar et al (2011), • Mangroves & Tidal Wetlands (Mackenzie & Duke 2010) Monitoring programs to be implemented at a minimum of every 5 years or on an as needs basis e.g. climatic event.	

CM6 – There is no net loss of the extent of natural wetlands.	Extent of seagrass beds, tidal wetlands, and nearshore coral reef communities	Y/N	Incomplete existing datasets for each attribute: • Seagrass - existing 2002 baseline (but does not take into consideration major changes due to flooding events) and therefore would require updating. (Consider using 2012/2013 baseline currently being developed by the Australian Centre for Ecological Analysis and Synthesis) • Tidal wetlands - Queensland Wetland Data (estuarine component - Version 3, 2012) • Nearshore coral reef communities – existing 2008 baseline for Hervey Bay corals (see Zann 2012a, b) but scant information available for remaining WBB region.	There are limited marine datasets available for the WBB region. A program has been established to classify and map estuarine and marine habitats of the Wide Bay region by 2013 (Queensland Wetlands Program Project) and will include a number of other estuarine and marine habitats for future indicators. Types of tidal wetlands to be included in the dataset are those defined by the estuarine component of the Queensland wetland data. MangroveWatch baseline is as 2010 and could be integrated into the Regional Ecosystem framework. The nearshore coral reef community baseline could be developed based on a number published reports and data including Beger study (2010), Butler (2012 in draft), DeVantier (2010), Alquezar & Boyd (2007), Alquezar et al (2011), Bleachwatch report, Bennett (2004), Thorogood (1993), RHIS surveys (Parks).
CM7 – There is an improvement in the ecological processes and environmental values of natural wetlands.			•	

CM8 - That by 2020, there is no adverse change in biological diversity in coastal, estuarine and marine species.	Known population and extent of Indo-pacific humpback dolphin, dugong, turtles, shorebirds, water mouse and grey nurse sharks	Y and N	CEM4 – Incomplete existing datasets for each attribute:
			• Indo-pacific humpback dolphin
			  ○ Known population baseline (2007), see Cagnazzi report 2006 to BMRG
			  ○ Extent baseline 2006 created for the draft WBB Regional Coastal Management Plan (see metadata for further information)
				For significant species datasets, also refer to the Great Sandy Marine Park planning process and data collection (refer ex-DERM metadata).
				
				There are limited marine species datasets available for the WBB region, particularly the mapping of their extent. Known populations are based on taggings (mark and recapture), sightings including photoID etc. Extent is based on either feeding, roosting/nesting, resting

			• Dugong ○ Known population baseline unknown? ○ Extent baseline (2007, 2010) based on a relative density grid provided by Helene Marsh (see metadata for further information) • Turtle ○ Known population baseline (unknown)? ○ Extent baseline (unknown) but could be developed based on Col Limpus database, tagging project, and Go-slow project • Shorebirds ○ Known populations baseline (2007) based on the Queensland Wader Study Group surveys ○ Extent baseline (2007) for roosts and habitats created for the draft WBB Regional Coastal Management Plan (see metadata for further information) • Water mouse ○ Known population baseline (unknown)? ○ Extent baseline (2006) created for the draft WBB Regional Coastal Management Plan (see metadata for further information) • Grey nurse shark ○ Known population baseline (2011) (cited in Bansemer (2009) and Bansemer and Bennett (2011)) ○ Extent baseline (2006) based on aggregation site at Wolf Rock, unknown other aggregation sites at present	sites. A number of datasets are needed to be updated or created from a variety of data sources and attributes. There are a number of community groups involved in monitoring species within the WBB region and data could be further integrated into the baselines. For example, Coastcare groups are currently monitoring the water mouse at certain locations. Refer CHRIS web on the Agriculture, Fisheries and Farming website for metadata and other data sources.

	Recreational and commercial wild fisheries stocks of mackerel, prawns, spanner crabs		Incomplete datasets for each attribute but could be developed using: • Commercial fisheries log books • Commercial seasonal, bag and size limits • Fisheries stock estimates (reviews and reports) • Impoundment stock data? • Voluntary recreational catch records • Fishing club and charter records • Reef-check fish monitoring projects • CAP-reef Correlate with freshwater flows, flood mapping	
CM9: That by 2020, actions as identified in the Burnett Mary Water Quality Improvement Plan* are implemented to achieve water quality targets to maintain coastal, estuarine and marine ecosystem health.	**CEM9 – Coastal water quality in receiving waters (biological indicators)**	Y/N	Incomplete datasets for each attribute: • Chlorophyll a – EHP's ambient WQ monitoring for estuarine. No event information currently. • Seagrass - existing 2002 baseline (but does not take into consideration major changes due to flooding events) and therefore would require updating. (Consider using 2012/2013 baseline currently being developed by the Australian Centre for Ecological Analysis and Synthesis) • Corals (nearshore coral reef communities) – existing 2008 baseline for Hervey Bay corals (see Zann 2012a, b) but scant information available for remaining WBB region. • Scribbled Angelfish – no existing baseline (refer Berger UQ, Zann and Wortel ex-DERM datasets/reports) • Mud Crabs and crab holes – no existing baseline (refer Mangrove	Further work is required to develop the event information for chlorophyll a (using remote sensing and sediment levels etc.) Establishing a baseline for scribbled angelfish and mud crabs/holes is required.

			Watch and Fisheries for bioassays)	

Expert Panel Contributors:

Expert Panel Workshop 1, held 15 August 2014

Kevin Bowden	Burnett Mary Regional Group for NRM
Ian Butler	University of Queensland
Norm Duke	James Cook University
Saranne Giudice	Burnett Mary Regional Group for NRM
Matthew Griffith	Queensland Department of Environment and Heritage Protection
Stacey Hodge	Burnett Mary Regional Group for NRM
Rachel Lyons	Burnett Mary Regional Group for NRM
Mike Ronan	Queensland Department of Environment and Heritage Protection
Sue Sargent	Burnett Mary Regional Group for NRM
David Scheltinga	Queensland Water
Kirsten Wortel	Burnett Mary Regional Group for NRM

Expert Panel Workshop 2, held 7 July 2015

Kevin Bowden	Burnett Mary Regional Group for NRM
Ian Butler	University of Queensland
Norm Duke	James Cook University
Emma Krusic	Queensland Department of Agriculture and Fisheries
George Martin	Burnett Mary Regional Group for NRM
Mike Ronan	Queensland Department of Environment and Heritage Protection
Sue Sargent	Burnett Mary Regional Group for NRM
Kirsten Wortel	Burnett Mary Regional Group for NRM
Maria Zann	Queensland Department of Environment and Heritage Protection

Additional input was also provided by Dr Greg Skilleter.