Final Report to the Great Sandy Strait Research Consortium.

Hydrodynamics & Materials

Transport in the Mary River & Great Sandy Strait An Initial Assessment

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Executive Summary

Context.

The Mary River emanates from the Sunshine Coast hinterland west of Landsborough and ends in an estuary within the southern section of the Great Sandy Strait; a larger estuarine ecosystem between the mainland and Fraser Island. Notably, the river passes through a range of predominantly rural land use areas which include the towns of Kenilworth, Gympie, Tiaro and Maryborough. The total river catchment covers approximately 9595 km2 with several major tributaries contributing to the Mary River including Obi Obi, Yabba, Little Yabba, Six Mile, Amamoor, Kandanga, Tinana, Deep, Munna and Wide Bay Creeks.

The Mary River enters the Great Sandy Strait Biosphere Reserve in close proximity to wetlands recognised under the International agreement of the Ramsar Convention and flows into the UNESCO Fraser Island World Heritage Area.

The proposed Colton Coal mine, at Aldershot near Maryborough would discharge water and contaminants into the Mary River which would result in the dispersal of metals and other substances downstream of the discharge location.

The modelling and measurement of metal dispersal contained in the management plan focuses on specific locations in the Mary River and the river mouth but overlooks the potential impact of contaminant dispersal on the nearby UNESCO Great Sandy Strait Ramsar wetland and the UNESCO Fraser Island World Heritage site. The Great Sandy Strait Ramsar wetland is approximately 12 Km downstream from the site of proposed water discharge from the Colton Coal mine and 4.5 Km downstream from the HEV location determined in the management plan (Figure 1).

The potential for the Mary River to alter water quality and deliver catchment materials to the GSS has been identified previously (e.g. Butler *et al*., 2013 & 2015), however these studies had a very limited spatial coverage due to their focus on the coral reefs in the southern nearshore areas of Hervey Bay, at the northern end of the GSS. As noted by Butler et al (2013), the available water quality data for the GSS was limited to a few northern GSS sites, such that their insights could only be applied to these southern Hervey Bay sites, a site at the mouth of the Mary River, and a few limited sites within the most northern reaches of the GSS. A review undertaken for the current study similarly reflected limited spatial coverage of water quality data that could be accessed, and so a clear outline of the extent and dynamics of any outputs from the Mary River could not be confidently ascertained using water quality data. This significantly undermined efforts to accurately define how the waters of the Mary River and the GSS were interacting, and how materials emanating from the Mary River might therefore be distributed under different tidal and weather conditions.

In view of these concerns, the Fraser Island Defenders Group (FIDO), the Mary River Catchment Coordinating Committee (MRCCC) and the Greater Mary Association (GMA) sought to establish a baseline survey and modelling study to assess the potential for contaminants arising from the Colton mine to reach and potentially impact habitats within the Great Sandy Strait ecosystem including those associated with Ramsar and World Heritage protection zones.

The current study was undertaken by a team from the University of Queensland under the auspices of FIDO, MRCCC and GMA, to make an initial assessment of the potential for the Mary River and its tributaries to deliver materials such as sediments and heavy metals into the Sandy Strait.

Sediments are a common export from the landscape being transported by wind and water and, therefore, represent a potential carrier of pollutants such as heavy metals as well as nutrients. Whilst coastal ecosystems rely on a level of sediment input for their sustainability, the quantity and quality of these materials can have profound impacts on specific organisms, habitats and the ecosystem at large.

In this context, the study examined how the water within the Sandy Strait and the associated Mary River catchment interacted, as well as how these dynamics changed under different flood and weather conditions.

This work led to a hydrodynamic model that allows for the finer scale examination of different areas of the estuary in terms of how fast the water might move, the volumes of water and sediment involved, and the propensity for sedimentary material to be deposited or moved away from a given location. Collectively, these aspects provide an ability to predict locations that might be of a higher or lower risk of pollutant delivery and impact, as well as insights into how factors such as tide, wind, storms, and flood events might alter the risks.

Associated with this model development, the study also collected sediment samples from a range of sites considered to be potentially vulnerable to sediment deposition and also from sites where sediment removal or re-suspension was likely.

Hydrodynamic Modelling.

Hydrodynamics of the Great Sandy Strait and the Mary River were modelled using Delft3D-Flow Hydro-Morphodynamic modelling suite (https://oss.deltares.nl/web/delft3d/). Delft3D-Flow is a widely used hydrodynamic model platform used for both consulting and research purposes. The primary inputs used to run the Delft3D-Flow model for this study were: bathymetry, tidal forcing, river discharge, and local winds.

During model development the model was run for time periods of between days and weeks to test function, logic, reliability, and accuracy. In this final report, the model was run for a month under a Spring/Neap/Spring tidal cycle that reflected average tidal conditions for the region (e.g. August 2019). Tides were derived from the TXPO version 7.2 global tidal database (Egbert and Erofeeva, 2002) with the astronomic tidal cycle applied at the boundaries of the Delft3D-Flow model every 100 m. Average wind conditions were determined form the long-term records obtained from Sandy Cape lighthouse and compared to the analysis conducted by Levin et al. (2008) for southeast QLD.

The core insights gained from the Hydrodynamic Modelling are:

- A focus on the Mary River when investigating contaminant discharge will neglect the potential impact in the GSS.
- Water residence time results suggest that contaminants can stay within the GSS for over a month. However, winds have the potential to substantially reduce the residence time of waters within the GSS.
- The long water residence times in the Mary River and GSS suggest that contaminants that are toxic in even small concentrations or that have the potential to bioaccumulate in the ecosystem could have substantial impact in the estuary over time.
- The type of contaminant and the concentration level of the initial discharge will be key in predicting the potential for negative impact in the GSS from Mary River contaminate discharge.
- During low flow conditions contaminants remain in the Mary River and surrounding region in the GSS for most of the modelling period. This suggests that under low flow conditions most of the contaminant will remain in the Mary River for a period of weeks to months unless cleaned via chemical or biological processes.
- The northern locations in the GSS incur higher contaminant load but disperse the contaminant faster. In the southern locations the opposite occurs, the contaminant load is lower, but remains in the system for longer.
- The intertidal regions that are near the mean high water spring tidal range do not interact with the estuarine environment as often. This has the effect of extending the potential residence time of a contaminant. Contaminant may settle in higher elevated intertidal regions during spring tides and cannot be removed during neap tides. Only once spring tides return will contaminant be dispersed if it is still available for suspension into the water column.

Sediment Composition and Analysis

Using the model as a backdrop to understanding sediment distribution, a range of sediment samples were collected across the Strait ecosystem. Notably, the sediment type ranged from a very fine muddy sand to coarse sands mixed with shell fragments and sometimes small gravel fragments.

Most noteworthy is the general tendency toward finer sediments in the northern target zone, north east of River Heads, compared to the majority of sites in the more south-eastern sampling zone. This supports the predictions drawn from the hydrodynamic model which indicated that, depending on conditions (river flows, winds, and tide), materials emanating from the Mary River are likely to move over and into this northern zone. Accordingly, fine materials that are transported most easily are more likely to be deposited in this area over the majority of prevailing weather and flow conditions reported for the Great Sandy Straits (see modelling section above).

In view of the above, it should also be noted that there was a high level of variation or "patchiness" in sediment grain size composition across both sampling zones. This also applied between some replicate samples collected at a given sampling site illustrating that this variability occurs over small (<50m) and large scales (>1km). This again suggests the influence of physical transport processes operating at local and larger scales, as well as the potential influence of benthic organisms. Such patchiness has been described in numerous sediment studies in estuarine ecosystems and is well defined in terms of small and larger scale perspectives by Reinicke*,* (2000). As highlighted by the hydrodynamic model the bed shear varies at different scales in the Strait so that it also contributes to the variations observed in sediment distribution and grain size composition at different spatial scales.

Importantly, the levels of heavy metals observed in sediments from the GSS were all below the default guidelines set by the Australian and New Zealand Governments for fresh water and marine ecosystems (ANZECC & ARMCANZ, 2000).

It is noted here that, the ANZECC guidelines provide a default background value for metals of concern (DGV) but not for metals where its level of potential toxicity is low. Notably, none of the observed metal concentrations exceeded their respective DGV-High value, with many also below the background DGV and below detection for the method used.

Similar to metal concentrations, the range observed for the different forms of carbon, nitrogen, and reactive phosphate all fall within the ranges reported elsewhere for estuarine ecosystems in Australia and elsewhere and did not reflect levels associated with nutrient enrichment as defined by the ANZECC guidelines.

In view of the results from this study it is clear that there is a high potential for materials emanating from the Mary River catchment to enter and be deposited within the Great Sandy Strait. In addition, depending on weather conditions during any significant discharge, the distribution of these materials can be very widespread or more localised depending on river flows, tidal conditions and wind. This highlights the need for careful planning of land use practices and human activities within the Mary River catchment and an awareness of the inherent risks if materials are transported into the estuary as whole.

Clearly, further research is required in order to better estimate the direct ecological risks to different habitats and species at different locations and scales, but this initial research now provides the basis for effectively targeting any future research and management planning.

General Comments and Observations

It is important to recognise that there are extensive intertidal areas associated with the conservation zones within the GSS, especially the Ramsar areas. In this light, the potential for deposition of materials transported within the GSS in these conservation areas is significant, but dependent on the physical characteristics of the materials (e.g. size, density, chemical composition), as well as the prevailing conditions of tide, wind and inflow levels from the Mary River.

As shown in the full report, the retention and widest distribution of potential contaminants delivered by the Mary River would occur under conditions of no wind with significant inflow from the river. Under these conditions any waterborne contaminants from the Mary River would likely reach the Ramsar boundaries. Depending on the length of time over which such conditions prevailed, the amount of contaminant settling onto the benthos in these sites would vary. It is important also to note, however, that, as shown in the hydrodynamic modelling, when wind speeds and direction change, both the water retention time and the speed of water passing over the benthos can change significantly. This then may lead to the resuspension and further transport of materials that have landed on the sediment surface, as well as the flushing of water and suspended materials out of the GSS.

As discussed by Tiwary (2001) coal mines are capable of releasing a range of materials that can have a range of negative impacts on water quality and the environment. These pollutants can include metals such as Iron, Copper, Manganese, and Nickel, but may also occur in the form of acids from the oxidation of sulphides, and organic substances such as oils and other hydrocarbons released during mining activities. In addition, the simple release of non-toxic but high levels of soil or other particles can also have a detrimental effect on ecosystems through smothering of benthic habitats and the blocking of light necessary for plant growth (e.g., Wright *et al.,* 2017 & articles cited within).

Importantly, the impact that such pollutants can have in aquatic systems can occur at significant distances from the source and vary in terms of type and distribution of the impacts that occur (see e.g., Wright *et al.,* 2017). Based on this and the combined results of the hydrodynamic modelling and sediment sampling, the current study indicates that there is risk to the RAMSAR areas and other reaches of the GSS should there occur a significant release of pollutant materials into the Mary River under the conditions described previously. Even where conditions are favourable for maximum flushing of materials through and out of the GSS, some areas are still likely to receive materials due to their specific local water residence times.

At both the national and State government levels under the EPBC and Ramsar Conventions, there are number of services such as the natural cleansing and maintenance of water quality, biodiversity sustainability, and ecological or environmental services that need to be considered. More specifically, depending on the particular location around the GSS, this also includes the consideration of High Ecological Significance wetlands on the map of Referable Wetlands, High Ecological Value (HEV) wetlands, High Ecological Value (HEV) waterways and threatened (endangered or vulnerable) wildlife (terrestrial and marine). Accordingly, any deposition of contaminants that might be assimilated into biological and geochemical processes at these sites stands to negatively impact on them. This is especially true where, for example, the ingestion of food may directly include the ingestion of contaminated sediments such as occurs with wader birds such as Oyster catchers and similar intertidal feeders, as well as in filter feeders (e.g. cockles) that intertidal waders feed upon. Given the potential distribution of contaminants and sediments that the modelling predicted and the sampling substantiated in this study, there is good reason to further assess the vulnerability and specific conditions that exist within the broader zones identified here. As further suggested below, in order to better understand the full extent of any risk to specific habitats or species, it is suggested that the outputs from this study be used to target areas where water residence times and materials deposition are most likely to be high with the aim to identify vulnerable or "at risk" habitats, communities or species.

Further Research

Whilst there are many elements of the GSS and its function that could be investigated, the following aspects are proposed based on the results of this study and the background aim to better understand the potential impacts that might arise from pollutant discharges in the GSS from the Mary River and its catchment. In general, further research into the distribution and behaviour of pollutants and sediments in the GSS should take an integrative approach whereby further development of hydrodynamic models should incorporate an understanding of the ecology and behaviour of keystone habitats within the GSS, as well as the biogeochemical cycles that underpin the ecology and its sustainability. Within this broader approach, some of the key aspects to consider include the following:

- Whilst the modelling work and sediment analysis in this study indicate the relative load levels and the types of materials depositing within the GSS ecosystem, we were unable to find any direct measurements of actual sediment deposition rates or deposition loads. By filling this knowledge gap for the different tidal, inflow, and wind conditions (see modelling section), a more accurate risk assessment could be made in terms of the amount of materials actually reaching areas of concern.
- The modelling work in this study showed a clear connection between the GSS and the southern areas of Hervey Bay. In view of this exchange and the potential changes in land uses, catchment condition, and the resultant materials entering the GSS, further investigation into the connectivity between the GSS and Hervey Bay is warranted in order to better understand the potential risks this poses to keystone habitats such as the coral reefs and seagrass beds that exist in the exchange zone.
- In order to better understand the full extent of any risk to specific habitats or species, it is suggested that the outputs from this study be used to target areas where water residence times and materials deposition are most likely to be high with the aim to identify vulnerable or "at risk" habitats, communities or species. This could focus on specific aspects such as Ramsar values at relevant scales within key zones of the Ramsar conservation zones associated with the GSS.
- At the time of writing this report we are aware of some localised dredging activities within the Maryborough reaches of the Mary River (e.g. Byrne Brothers, DEHP Permit: EPPR00365213, Queens St., and adjacent areas), we are unable to obtain information as to the scale and potential significance of these limited operations. However, it should be noted here that where dredging is planned or expected in the future, activities like this can lead to the liberation of pollutant materials that have been deposited historically and buried, so that they are unavailable to current biological systems. In this light, and in order to understand historical conditions and potential periods of pollution, a more substantive study is required where deeper sediment cores are collected and analysed for nutrients and heavy metals as performed on surface sediments in this study. If performed correctly, this could also provide estimations of historic deposition rates so that current loads can be better contextualised against catchment management activities.
- During this study we were unable to identify any similar study for the GSS and only few studies in Australia where such high-resolution bathymetry and locally focussed modelling has been undertaken as done in this project. In this context, and with the view to better understanding the interactions between the GSS and Hervey Bay, consideration might be given to developing a higher resolution bathymetry data set for Hervey bay, or zone of potential GSS-Hervey Bay interaction. In doing so, the influence of management strategies influencing water quality in one ecosystem can be tested or assessed in terms of possible outcomes for the other.

Hydrodynamics & Materials Transport in the Mary River Estuary: An Initial Assessment

Background and Context:

The Mary River emanates from its source in the Sunshine Coast hinterland west of Landsborough and ends in an estuary within the southern section of the Great Sandy Strait; a larger estuarine ecosystem between the mainland and Fraser Island. Notably, the river passes through a range of predominantly rural land use areas which include the towns of Gympie, Tiaro and Maryborough. The total river catchment covers approximately 9595 km^2 with several major tributaries contributing to the Mary River including Obi Obi, Yabba, Little Yabba, Six Mile, Amamoor, Kandanga, Tinana, Deep, Munna and Wide Bay Creeks.

Notably, the Mary River enters the Great Sandy Strait in close proximity to wetlands recognised under the International agreement of the Ramsar Convention and flows into the UNESCO Fraser Island World Heritage Area. Within this context, there is concern among a wide range of stakeholders that land use and other practices in the Mary River catchment may have a negative impact on these protected and iconic ecosystems, as well as on some of the key species they support.

Adding to the concerns raised above is the approval for open cut coal mining to be undertaken in the New Hope mine project located at Aldershot near Maryborough. The proposed Colton Coal mine will discharge water and contaminants into the Mary River which will result in the dispersal of metals and other substances downstream of the discharge location. While no spatial boundaries prescribing the allowed range of contaminant dispersal are outlined in the management plan, a site of high ecological value (HEV) is determined where there should be no major change to water quality. The modelling and measurement of metal dispersal contained in the management plan focuses on specific locations in the Mary River and the river mouth but overlooks the potential impact of contaminant dispersal on the nearby UNESCO Great Sandy Strait Ramsar wetland and the UNESCO Fraser Island World Heritage site. The Great Sandy Strait Ramsar wetland is approximately 12 Km downstream from the site of proposed water discharge from the Colton Coal mine and 4.5 Km downstream from the HEV location determined in the management plan (Figure 1).

The potential for the Mary River to alter water quality and deliver catchment materials the GSS has been identified previously (e.g. Butler *et al.*, 2013 & 2015), however these studies had a very limited spatial coverage due to their focus on the coral reefs in the southern nearshore areas of Hervey Bay, at the northern end of the GSS. As noted by Butler et al (2013), the available water quality data for the GSS was limited to a few northern GSS sites, such that their insights could only be applied to these southern Hervey Bay sites, a site at the mouth of the Mary River, and a few limited sites within the most northern reaches of the GSS. A review undertaken for the current study similarly reflected limited spatial coverage of water quality data that could be accessed, and so a clear outline of the extent and dynamics of any outputs from the Mary River could not be confidently ascertained using water quality data. This significantly undermined efforts to accurately define how the waters of the Mary River and the GSS were interacting, and how materials emanating from the Mary River might therefore be distributed under different tidal and weather conditions.

In view of these concerns, the Fraser Island Defenders Group (FIDO), the Mary River Catchment Coordinating Committee (MRCCC) and the Greater Mary Association (GMA) sought to undertake a baseline survey and modelling study to assess the potential for contaminants arising from the Colton mine to reach and potentially impact habitats within the Great Sandy Strait ecosystem and, in particular, those associated with Ramsar and World Heritage protection zones.

The main features of the study area are summarised below in Figure 1. It should be noted that habitat areas encompassed by the Ramsar convention are distributed throughout the estuary and are thus open to influences from a range of point and diffuse sources of materials and pollutants within the wider Great Sandy Strait ecosystem. Whilst the current study is focussing on potential influences from the Mary River specifically, it is recognised that other potential sources may also warrant investigation as more is learnt about the ecosystem.

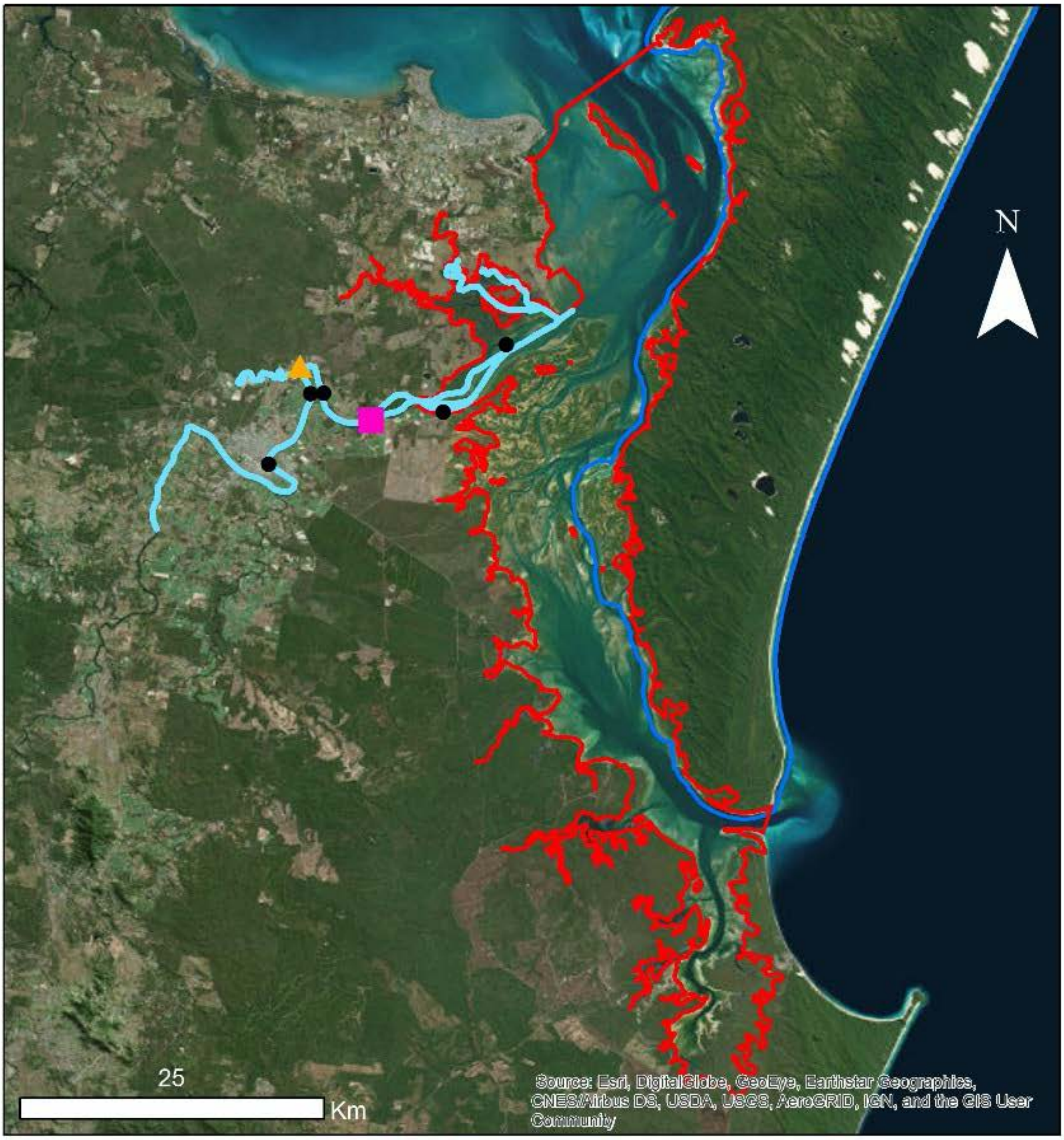


Figure 1. The Colton Mine discharge location into the Mary River and monitoring sites noted in the Environmental Management Plan for the Colton Mine with regard to the location of the Great Sandy Strait Ramsar wetland and Fraser Island World Heritage Site. The location of the hydrodynamic modelling (Mike11 1D modelling pathway) is also shown. The proposed scope of the hydrodynamic modelling in this study is to extend into the Great Sandy Strait via the use of a suite of 2DH modelling packages (Delft3D Flow and Water Quality).

General Approach

The central aim of the proposed work was to assess the potential for metal and other waterborne contaminants from the Mary River catchment a proposed Colton Mine to reach and effect downstream Ramsar and World Heritage Sites in the Great Sandy Strait ecosystem.

Accordingly, the overarching aims of the modelling were:

- to determine if there was any potential increase in metal accumulation in the Mary River and the Great Sandy Strait, specifically into sites with UNESCO protection status, based on proposed metal discharge from the Colton Mine;
- to assess what effect this change may potentially have on the benthic and marine environment in the Great Sandy Strait.

As much as possible the project built on previous investigations and assessments of metal dispersal in the Mary River and incorporates the Great Sandy Strait into the boundaries set for geomorphological, sediment distribution, contaminant distribution and modelling studies.

As set out in the proposal, the project consisted of three components undertaken in a phased approach to maximise work effort and cost efficiencies. The respective phases are summarised below in Figure 2 together with the main areas of activity within each phase.

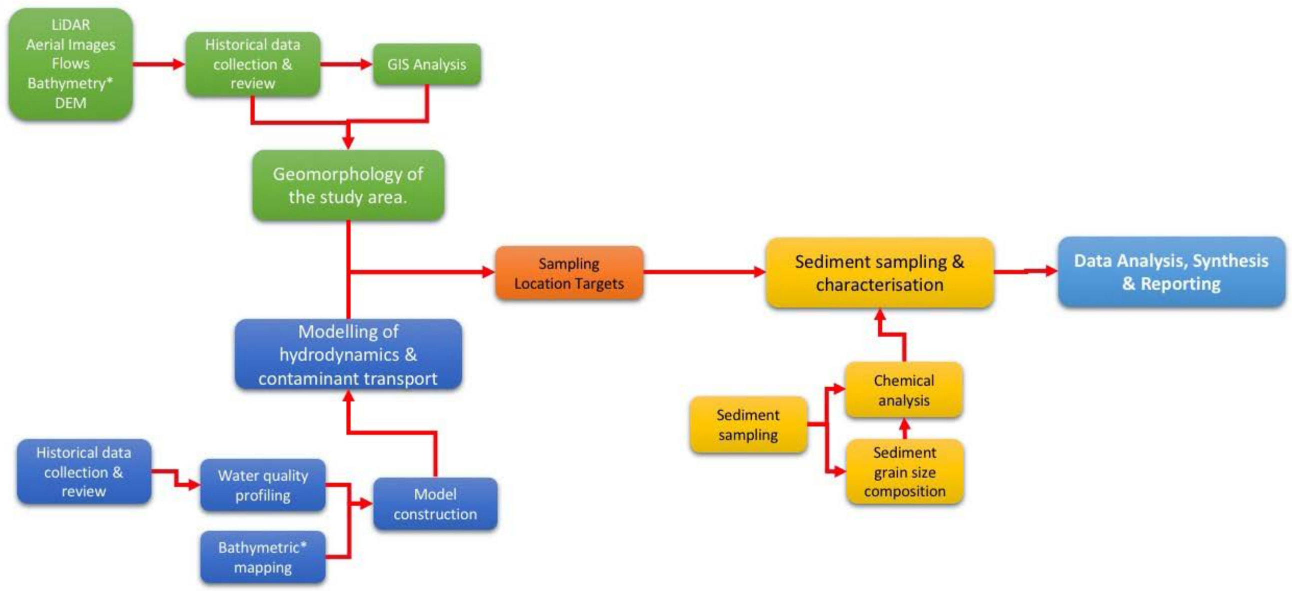


Figure 2. Summary of the main activities in the Mary River-Sandy Strait study.

Geomorphology

Analysis of Historic Imagery and LiDAR

This aspect of the project involved a desktop analysis of historic imagery and LiDAR data to ascertain its usefulness in underpinning the overall project aims, as well as the outright cost/benefit of different data sets relative to project goals. Based on this initial assessment the *Planet Labs Cube-Sat* database was used to extract daily-weekly scale high resolution aerial images of the study area and these were examined over time to determine changes in coastline position on key areas within the Great Sandy Strait and to identify potential plumes within the Mary River-Great Sandy Strait system.

In addition to imagery, LiDAR data was also used and included the 5 m Digital Elevation Model (DEM) of Australia available online as well as the 2.5 m DEM LiDAR data set available in the 2016 Worley Parsons report (Hydrologic and Hydraulic Modelling - Mary River) undertaken for the Moreton Bay Council in 2009. The LiDAR data was used to verify and augment the imagery noted above for the construction of geomorphic maps and assessment of the dynamics in the system.

Results and Discussion

Evidence of flood plumes/sediment from the Mary River reaching the Fraser coast

As noted, the Planet Labs Cube-Sat database images were used in conjunction with those from QImagery to search for evidence of flood plume migration and transport to the Fraser Coast image is geo-rectified, and the geomorphic change and plume extent mapped in ARC GIS. Plume migration was analysed in relation to the hydrograph of each flood using river discharge, stage, and rainfall data over 15 min intervals. The return interval of floods was also used to identify the relative flood magnitude and frequency at which plumes impact the Fraser Coast. Fluvial data was extracted from aerial images for analysis. As an example, Figure 3 (below) shows the sequence of plume migration following the 2011 floods. The 2011 flood event is placed relative to the long-term mean daily discharge record of the Mary River at Home Park (-25.77 °S, 152.53 °E), being the closest gauge to the river mouth (Figure 4). There is evidence of floodwaters and sediment plumes reaching the Fraser Coast and then being deflected north. As the 2013 flood was of a larger magnitude and fluvial energy higher, we would expect this flood to also deliver sediment to the coast. Marine conditions would control the movement of the plume and the extent of transport/reworking.

(a) 10 Jan 2011 - few days prior to flooding; (b) 28 Jan 2011 - sediment within basin; (c) 5 Mar 2011 - plume reaching Fraser Coast.

Figure 3a-c. Migration of flood plumes of the Mary River following the 2011 flood: (a) 10/01; (b) 28/01; (c) 05/03. The plume can be seen entering the Great Sandy Strait on 28/01 with the front of the plume entering the open Fraser Coast on 05/03 to drift north. Imagery from Planet Labs (Planet Team, 2017).

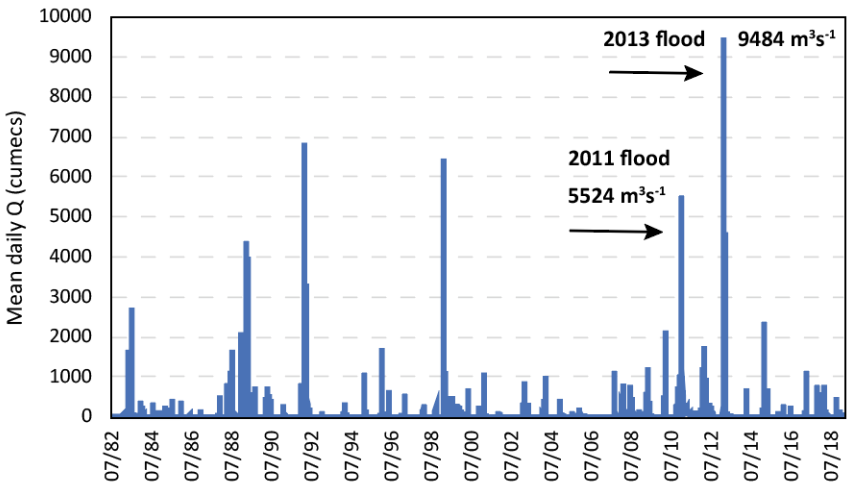


Figure 4. Mary River mean daily discharge (1982 to 2019) at Home Park showing multiple flood events.

In addition to these fixed images, the movement of materials between the Great Sandy Strait and areas outside its boundaries can be seen in image time-lapse animations available on Google Earth Engine® Timelapse. This can be viewed on the attached link by entering Great Sandy Strait into the search function at the top of the web page.

https://earthengine.google.com/timelapse/

Shoreline Dynamics

As part of the analysis described above an assessment was also made of the shoreline dynamics associated with key areas central to the Great Sandy Strait. As presented in Figure 5, and reflected in the historical aerial images, there is some local variability in the extent to which the shoreline moves however the overall position and extent of features such as the sand banks and islands remains consistent over time. This is further verified by the time-lapse imagery available on Google Earth Engine® which shows small local changes in some areas within the Great Sandy Strait with interactions between the Strait, Hervey Bay, and the Pacific Ocean around Inskip Point.

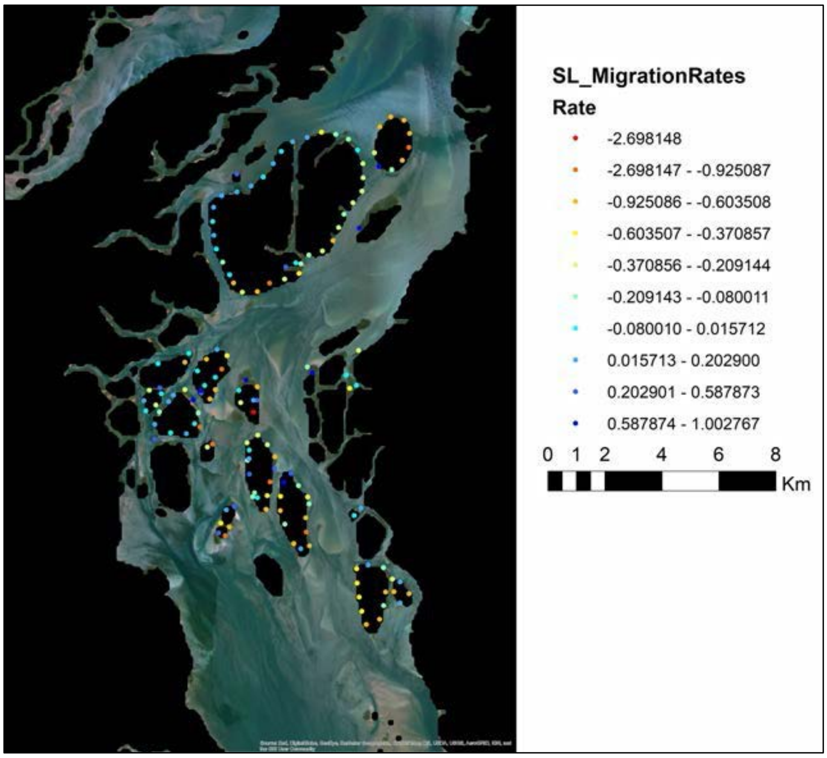


Figure 5. Migration rates for coastline areas within the Great Sandy Strait. A negative value denotes loss of shoreline whilst a positive value denotes accretion or expansion. Values are in meters.

Setting Initial Sediment and Modelling Target Areas

Using the results and insights gained from the geomorphology assessments and the aerial imagery, an initial set of target areas were defined as potential zones for sediment accumulation (Figure 6a) and a coarse benthic habitat zonation was defined (Figure 6b) for comparison to reports in the literature and use in contextualising field data to be collected on sediments.

The subsequent hydrodynamic modelling aimed to test the initial targets area and to also examine issues of materials transport, materials distribution, water residence times, and the possibility for materials such as heavy metals to be held within the Great Sandy Strait. By corollary, the combined insights from the geomorphology work and the modelling were then used to set specific target zones for sediment sampling.

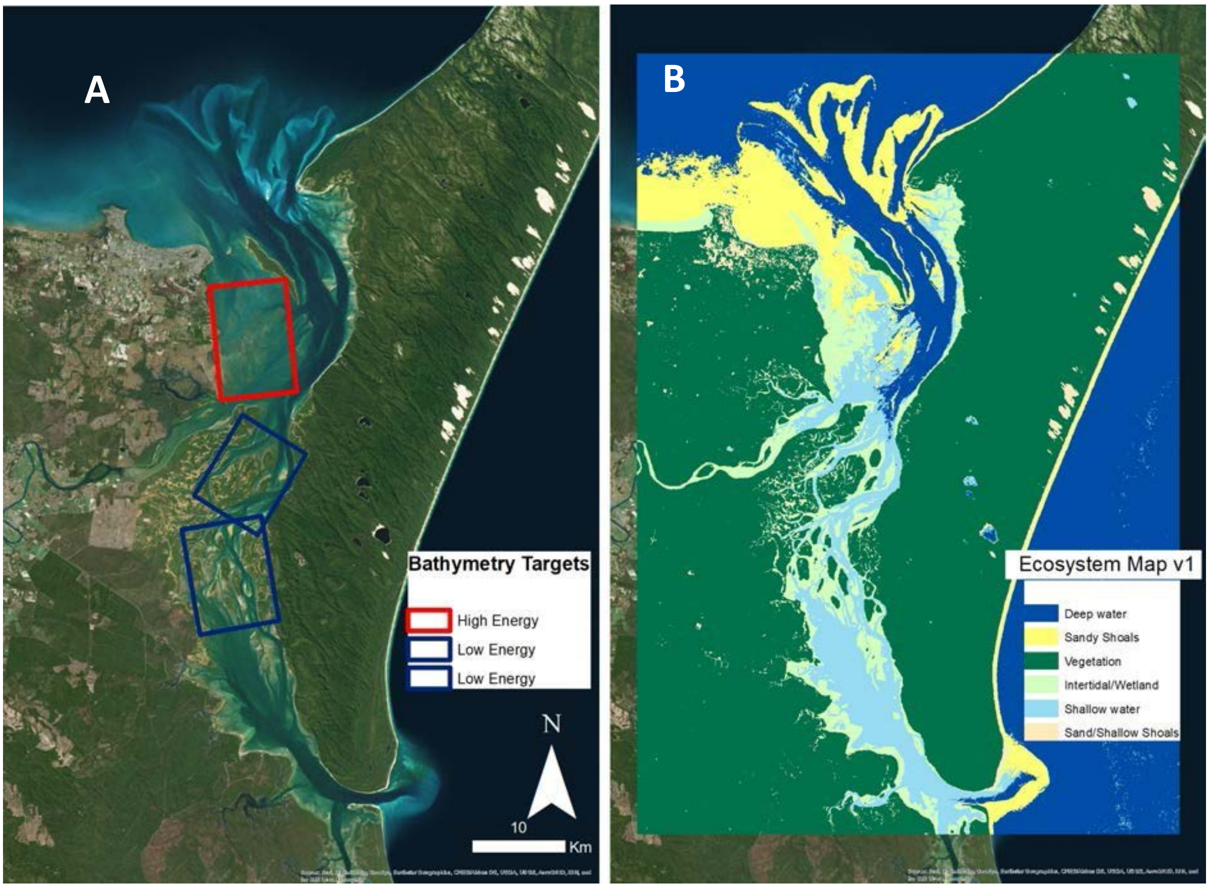


Figure 6. A) Initial areas of interest for sediment sampling and model focus based on geomorphological features; **B)** Coarse habitat map based on aerial and bathymetric data sets.

Hydrodynamic and Water Quality Modelling: Delft3D model v0.01

The hydrodynamic and water quality modelling was developed in two stages.

1) A first pass model incorporating the Great Sandy Strait into the modelling of potential dispersal of metal contaminants. This allowed for targeted sediment and hydrodynamic field surveys which were then incorporated into the second stage of hydrodynamic and water quality modelling.
2) Final hydrodynamic and water quality model outlining the potential dispersal of metal contaminants in the Great Sandy Strait as well as the estimation of water residence times at different locations within the Great Sandy Strait.

As outlined in the project proposal, the first phase of the work involved the identification and collection of existing data sets for use in constructing of the initial model framework, the verification of the logical function of the model, and establishing the geographic and potential performance boundaries that the final model would contain. As indicated below, this phase also included the field-based collection of bathymetric data at higher spatial resolution (50-100m) to improve the rigour and accuracy of the model; especially in area of specific interest such as zones of potential sediment deposition or removal.

Description of Initial Modelling and Approach

Hydrodynamics of the Great Sandy Strait and the Mary River were modelled using Delft3D-Flow Hydro-Morphodynamic modelling suite (https://oss.deltares.nl/web/delft3d/). Delft3D-Flow is a widely used hydrodynamic model platform used for both consulting and research purposes. The primary inputs used to run the Delft3D-Flow model for this study were: bathymetry, tidal forcing, river discharge, and local winds. During model development the model was run for time periods of between days and weeks to test function, logic, reliability, and accuracy. In this final report, the model was run for a month under a Spring/Neap/Spring tidal cycle that reflected average tidal conditions for the region (e.g. August 2019). Tides were derived from the TXPO version 7.2 global tidal database (Egbert and Erofeeva, 2002) with the astronomic tidal cycle applied at the boundaries of the Delft3D-Flow model every 100 m. Average wind conditions were determined form the long-term records obtained from Sandy Cape lighthouse and compared to the analysis conducted by Levin et al. (2008) for southeast QLD.

Bathymetry for the Delft3D model was derived from the 100 m Queensland Bathymetric Dataset from Beaman (2010) and augmented with field measurements at higher spatial resolutions ranging from 50 to 100m. Having confirmed model behaviours, bathymetric and computational grid size in the final model reported here was kept at 100 m to enable a reasonable computational time step for the Delft3D-Flow model. Computational steps in Delft3D were at 1-minute intervals with average conditions reported every 30 minutes. The short time steps of 1 minute were selected to minimise the potential for confounding flow velocity artefacts that can occur during modelling given the comparatively high-resolution bathymetry for such a large region (Figure 1). Flow discharge was obtained from the long-term monitoring station at the Mary River Barrage (Figure 7). Generalised extreme value curves were produced using MATLAB® computational routines developed by Cheynet (2020) to derive the 1 in 10-year flow event at the Mary River Barrage. Based on these analyses a 1 in 10-year flow event for the Mary River is approximately 4000 m^2s^{-1} (cumecs). We chose a 1 in 10-year event it represents the conditions that will likely lead to increased contaminant input into the GSS and it is also the condition that was considered adequate for the discharge of unfiltered water into the Mary River from the Colton Coal Mine development proposal.

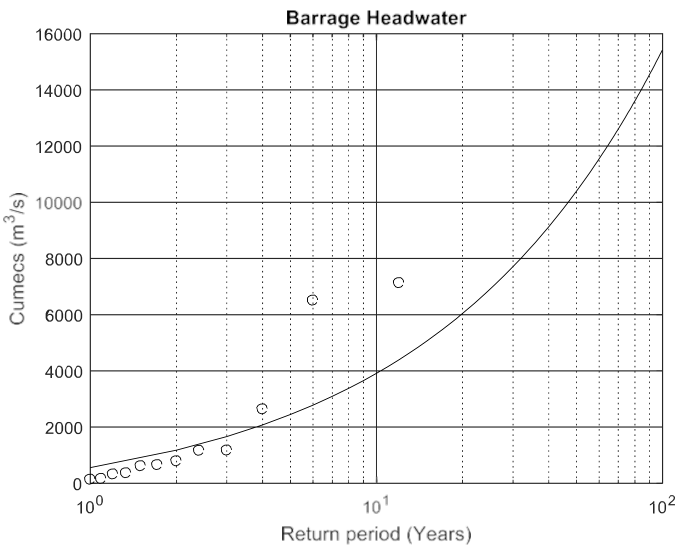


Figure 7. Generalised extreme value curve showing the return period for river discharge from long-term records at the Barrage Headwater. Return period is in a log-scale on the x-axis.

Model and Water Residence Time Scenarios

The physical transport, dispersion or removal of a contaminant within a water body is closely related to the concepts of water renewal (replacement), or water residence time. Water residence time has numerous definitions but all reflect the length of time it takes to remove a particle or package of water from a region (Baléo et al., 2001). Residence time studies are usually conducted in coastal systems with mixed or tidally influence energy regimes, such coastal lakes, lagoons and estuaries, where the renewal of water is an important component of ecosystem function (Cucco and Umgiesser, 2006). These ecosystems are also frequently impacted by human development that disrupts natural water renewal and can have significant impact on coastal ecosystem performance and sustainability. One common approach to calculate water residence time is to investigate the length of time a particle or "parcel" of water takes to travel outside the boundary of a region; such as from a river mouth or central basin of an estuary to the ocean (Sanford et al., 1992). Other studies have investigated residence time as the length of time it takes to replace water for the entire coastal system or for specific areas of a coastal system, such as for evenly spaced computational grids (Cucco and Umgiesser, 2006). This study investigated the removal of contaminants under three different scenarios for a 1 in 10-year discharge event from the Mary River into the Great Sandy Strait (GSS).

We investigate the removal of contaminants discharged into the Great Sandy Strait from Mary River during a 1 in 10-year discharge event. The discharge from the Mary River starts at 4000 m^3s^{-1} and reduces linearly over the first week of the model run to 1000 m^3s^{-1} where it remains for the rest of the model run. The contaminant load similarly starts at a 100% load then reduces down to 0 linearly over the first week of the model run. We use the percentage change in contaminant level here, rather than attempting to compute a specific change in value of contaminant concentration in the water over time, since it can be used to model the dispersal of any concentration of contaminant initially released into the Mary River. The simulations are therefore testing a scenario where there is a "pulse" of river discharge and contaminant load which slowly reduces over one week. We do not simulate flow into the GSS from any other river due to their relatively small size in comparison to the Mary River and a lack of data.

We tested the dispersal of contaminants under three scenarios based on approaches from previous research (e.g. Cucco and Umgiesser, 2006; Sheldon and Alber, 2002; Wang et al., 2004), during average south-east (7 ms^{-1} at 120°N) trade winds, common north-east winds (7 ms^{-1} at 60°N), and no wind. The model was run for two days prior to starting the discharge event from the Mary River (model "spin up" time) in order to reduce potential errors in the setup of the initial model conditions.

Water residence time was calculated based on the length of time a contaminant was continuously present in each computational grid cell for the simulation period. That is, in every 100 x 100 m region in the GSS. We consider a contaminant to be present if 1% of the original contaminant load is recorded over the 30-minute simulation interval of the Delft3D-Flow model. Future research will investigate other contaminant threshold values that may better reflect *in situ* measurement of contaminants in the GSS. We also assume a fully mixed saline environment and also that the contaminants are not removed via another cleaning process, such as sedimentation or biological filtering. Eventual dispersal of contaminants could be influenced by either of these processes. Based on this, and some of the above assumptions in the modelling scenarios, the water residence times calculated here err on the side of longer periods than what might naturally occur for a 1 in 10-year flow event. Computation of water residence time was conducted in MATLAB ® using the M_MAP (Pawlowicz, 2000) suite of tools to provide spatial context to the results.

Results and Discussion

The modelling conducted in this report is the first of its kind in the GSS. To the authors knowledge there have been no similar modelling studies conducted in and estuary similar to the GSS. That is, an estuary with two tidal inlets that results in a set of hydrodynamic conditions that are most likely of greater complexity than estuaries with a single tidal inlet. In spite of this, a widely used hydrodynamic model (Delft3D-Flow) successfully reproduced tidal flow conditions in the estuary, however, without *in situ* data to compare and calibrate against the modelling results can be considered a first version at this stage.

Water residence times show the regions that are at the highest risk of contamination and also the locations where contaminant is quickly removed from a region. The values recorded range from only one to two days, during the two scenarios that included wind effects, to 29 days or almost the entire model simulation (Figure 8a:c). The long residence times may appear larger than expected but they are consistent with results observed in previous similar studies (e.g. Cucco and Umgiesser, 2006).

The first important result is that the Mary River is usually the location where residence times are the shortest in all scenarios (Figure 8a:c). During average wind conditions the 1 in 10-year river discharge results in a removal of all contaminants quickly within the river (Figure 8b:c). This result suggests that solely focusing on the contaminant load within the Mary River itself after a discharge event will indicate that the system is very effective in cleaning contaminant loads. However, this may overlook most of the potential impact of contaminant discharge in the ecosystems that associate with the Mary River, such as those found in the GSS and Wide Bay (Figure 8b:c). This result, however, does not suggest that the Mary River is free from potential contaminant impact under flow conditions below a 1 in 10-year event. In fact, preliminary modelling (not shown here) suggests that without a high flow event, discharge into the Mary River will likely remain within the river itself for a long period.

Once contaminant is discharged into the GSS the simulation with no winds suggests that contaminants will remain in the water column for well over a month (Figure 8a). The contaminant in this scenario remains "trapped" in the GSS under an oscillating flow regime driven by ebb and flood tides. Most of the residence time values are near the entire length of the simulation period at ≈ 29 days. Contaminant is slowly removed via the northern and southern inlets of the GSS but "pools" in the centre of the GSS for most of the model simulation (Figure 8a). The locations of long residence times are similar to the low-flow and low bed shear stress values recorded over the model simulation (Figure 9). As reported previously, the bed shear values reflect the relative energy acting on the benthos at a given location. Higher values indicate a higher likelihood that materials will be moved or res-suspended in these locations, whereas materials are more likely to be deposited in areas of low bed shear.

In contrast, both the SE and NE wind scenarios show regions with relatively short residence times (Figure 8b:c). These include the Mary River and areas in centre of the GSS (Figure 8a:c). Contaminant still "pools" in the north east and southwest regions of the GSS leading to longer-residence times (Figure 8b:c). In the northern region of the GSS most of the contaminant is removed by the end of the model runs and dispersed into Hervey Bay and perhaps further into Wide Bay. The southern region, however, contains locations where contaminant remains for most of the simulation period (e.g. Tin Can Bay). However, since we are only modelling discharge from the Mary River, it is likely that some of the smaller rivers and tributaries that flow into the GSS in the south would help remove some of the contaminant. Perhaps the most surprising result is that the wind direction does not greatly change the outcome of the water residence time calculations. Since the winds are only average conditions, they encourage greater exchange of water between the GSS and the surrounding oceanic environment, but they do not provide sufficient change to the flow regime in the GSS to substantially impact contaminant dispersal within the estuary. However, initial modelling very high south-easterly winds (i.e. > 15 ms^{-1}) shows faster removal of contaminant and greater discharge out of the GSS into Hervey Bay with little impact on the southern regions of the GSS.

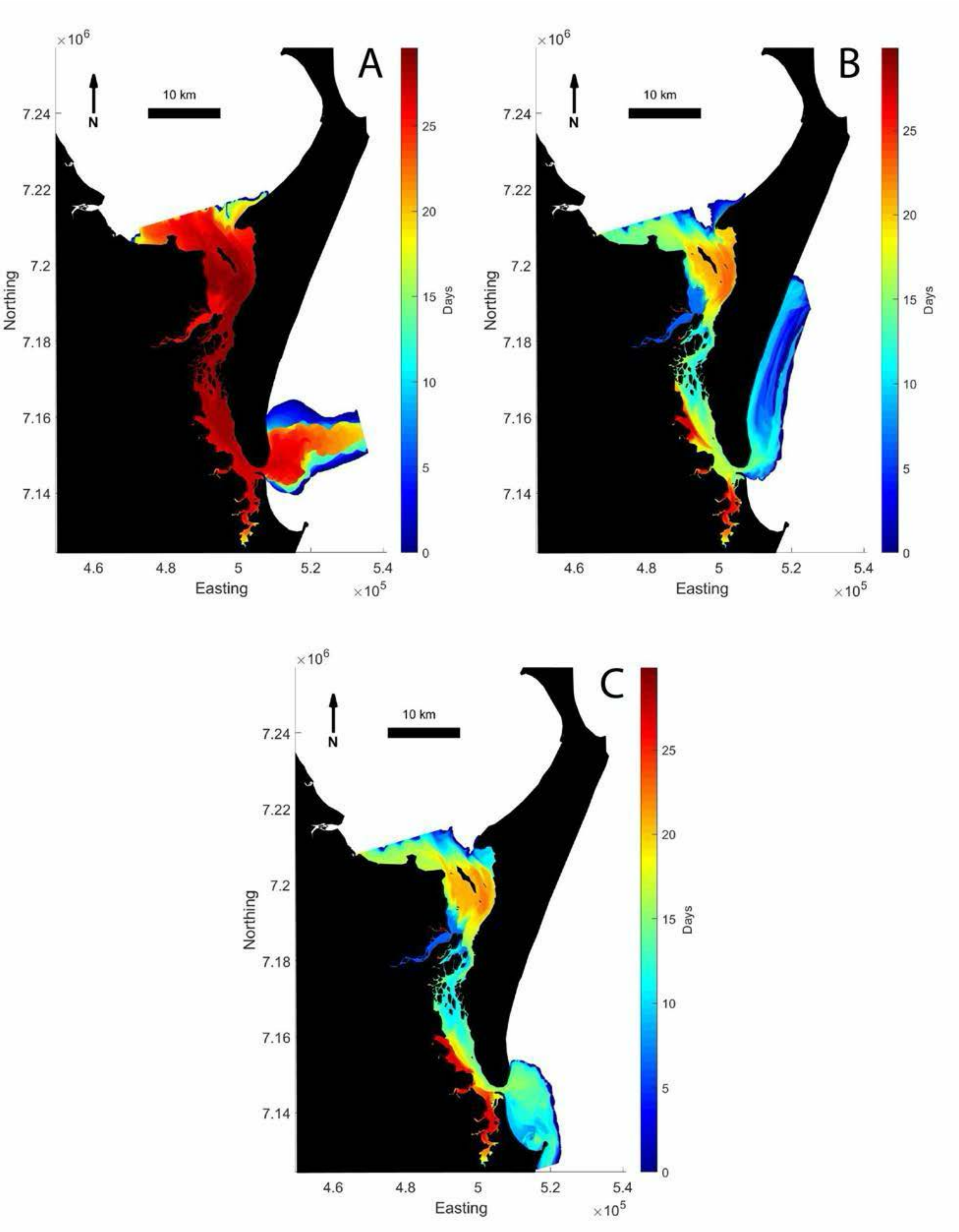


Figure 8. Water residence time calculations for three wind scenarios. A) No wind; B) South-easterly winds at 7 ms^{-1}, and C) North-easterly winds at 7 ms^{-1}.

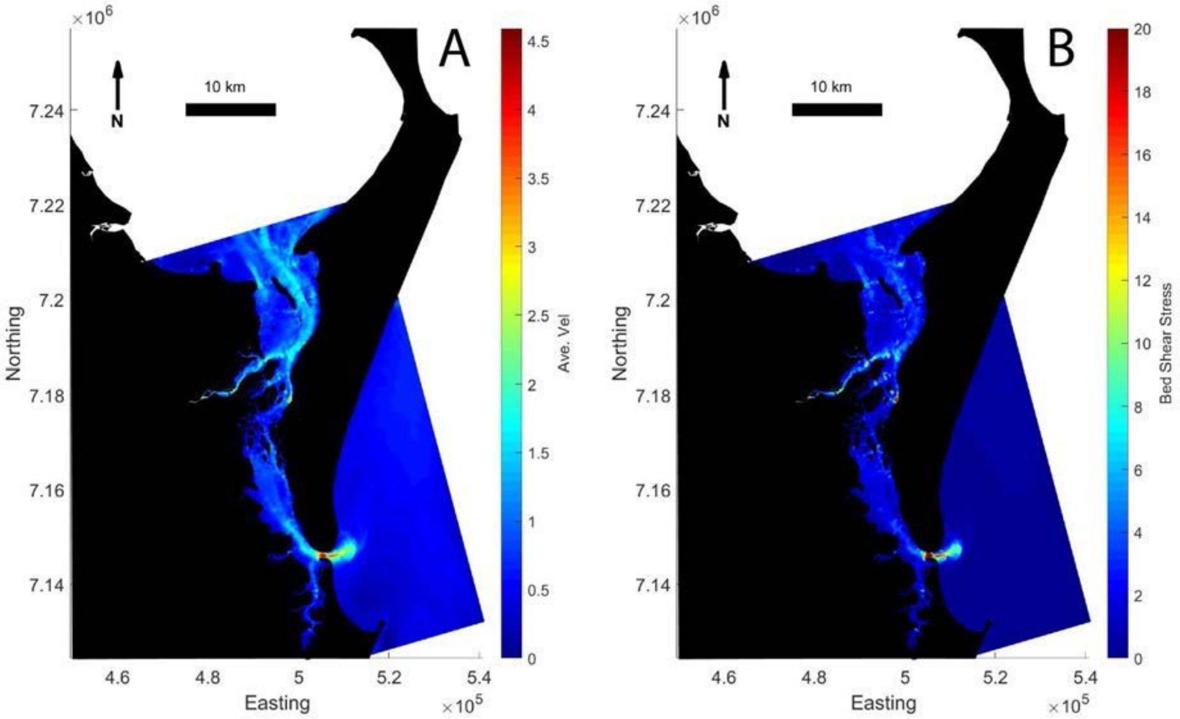


Figure 9. Delft3D-Flow modelling results showing A) the maximum values recorded for the 30-minute depth average water velocity records, and B) the maximum bed shear stress values.

Concluding Remarks on Initial Modelling Results.

This report presents the first attempt to model the hydrodynamics of the GSS and the fate of contaminant discharge from the Mary River into the GSS. It provides insights into the factors that may lead to negative impacts within the GSS should sustained or severe releases of contaminants in the Mary River occur during high flow conditions. The results above provide the following insights:

- A focus on the Mary River when investigating contaminant discharge will neglect the potential impact in the GSS.
- Water residence time results suggest that contaminants can stay within the GSS for over a month. However, winds have the potentially to substantially reduce the residence time of the GSS.
- The long water residence times in the Mary River suggest that toxic contaminants entering the GSS, even in small concentrations, could have substantial impact in the estuary over time. This is of particular importance for toxic compounds with a potential to bioaccumulate in the ecosystem as the time of exposure may extend over multiple biological production and trophic cycles.

The type of contaminant and the concentration level of the initial discharge will be key in predicting the potential for negative impact in the GSS from Mary River contaminate discharge.

Future work in the region should focus on the *in-situ* collection of hydrodynamic and sediment deposition data as well as contaminant loads in the water column and sediment, or adequate proxies, during high flow events. This would allow for improved calibration of the model used here and would allow for a more comprehensive assessment of potential ecosystem-level impact in the GSS from anthropogenic input via the Mary River.

Extended Modelling and Analysis

Based on feedback and the associated requests made by the Research Consortium, the initial hydrodynamic modelling and analysis was extended in four key areas:

1. Hydrodynamic models were rerun to better reflect flow regimes for specific events and to include a low flow event specifically in the results. The high flow event used here is based on flooding events in March 1956 and the low flow event December 2010 (Tables 1 and 2).
2. Additional analysis was conducted under SE winds and high flow conditions (SE High Flow scenario) to investigate the interaction of contaminants with different regions of the GSS.
3. Time series analysis was performed for four locations in the GSS to investigate the change in contaminant load over time based on tidal cycles.
4. Analysis was made on intertidal regions where the tidal cycle influences the frequency of interaction between the estuarine environments. This analysis was conducted in ArcGIS 10.7 using the 30 m Queensland bathymetry (Beaman 2017) and tidal range information from Maritime Safety Queensland.

Methods

Residence Time Modelling

The same Delft3D-Flow model was used as in the initial model setup however the flow regime was changed to reflect the historic flow events in the Mary River in March 1956 and December 2010 (Tables 1 and 2). We have specifically included a low flow regime in the analysis. This was to investigate in detail the discharge from the Mary River into the GSS under low flow conditions. The wind speed and direction were also updated based on feedback from the initial report. The discharge regime is similar to the modelling in the initial modelling effort. The main difference observed is the faster reduction in discharge rate from 7 to 4 days and then a slow reduction over the following 27 days to a low or no flow regime. A low flow regime was added to the residence time analysis for contaminant dispersal which followed the methods outlined in the initial modelling analysis. Low flow conditions were previously assessed in preliminary analyses and have been included here in detail to provide a wider range of conditions in the final analysis.

Intertidal classification

Analysis of intertidal regions where the tidal cycle influences the frequency of interaction between the estuarine environments. This may indicate the regions that are more likely to be exposed during spring or neap tide conditions. This analysis was conducted in Esri ArcGIS 10.7 (™) using the 30 m Queensland (QLD) bathymetry (Beaman 2017) and tidal range information for Point Vernon from Maritime Safety Queensland (MSQ) (https://www.msq.qld.gov.au/Tides/Tidal-planes). Tidal elevations from (MSQ) were converted to Mean Sea Level which is approximately the same vertical datum as the 30 m QLD bathymetry. The *contour* tool was used in ArcMap with contour polygons as the main output.

Time-series analysis of contaminant dispersal

Four sites in the GSS were selected for further investigation of contaminant dispersal over time. The water depth and contaminant load expressed as a percentage of the initial contaminant concentration were plotted over time. The period of analysis is the same harmonic tidal cycle as observed during August 2019 and this is the temporal range used in our analysis (Figure 9). Analysis and coordinate conversion was conducted using the M_MAP tools written for MATLAB ® (Pawlowicz, 2000.)

Table 1. Physical processes during the different model runs. Harmonic tidal conditions during all modelling scenarios were based on tidal ranges for August 2019 (01/08/2019 - 31/08/2019).

Event	Wind Speed	Bearing	Flow Regime
SE Low Flow	7 m/s	120	168 m^3/s
SE High Flow	7 m/s	120	4000 m^3/s
NE High Flow	7 m/s	70	4000 m^3/s
No Wind High Flow	0	N/A	4000 m^3/s

Table 2. Flow regime for the Mary River for high flow and low flow conditions based on flow record from the long-term monitoring record at Miva. The Low Flow regime is based on an event on 7 December 2010 and High Flow during March 1956.

Flow Regime	0 Days	4 Days	31 days
Low Flow	168 m^3/s	44 m^3/s	0 m^3/s
High Flow	4000 m^3/s	1000 m^3/s	44 m^3/s

Extended Analysis and Additional Findings

The extended analysis conducted here provides greater quantitative evidence regarding the interaction of potential contaminants in different regions in the Great Sandy Strait (GSS). This includes new analysis of intertidal regions in the GSS, an updated flow regime to reflect specific events in the flow history of the Mary River, and time series analysis of contaminant dispersal in the GSS. As discussed later, this provided insights and results that are in addition to the initial analysis and results.

The only results that take primacy in this extended modelling over the initial work is the contaminant residence time results (Figure 10 below). However, there is no difference between the results, or the general conclusions obtained on water residence time in this extended work compared to those obtained in the initial assessment & analysis, i.e., the main findings in the initial modelling are still valid. For ease of understanding we have included below a summary of the findings of the initial work here and the additional findings of the extended analysis.

Main findings of initial hydrodynamic modelling and analysis:

- A focus on the Mary River when investigating contaminant discharge will neglect the potential impact in the GSS.
- Water residence time results suggest that contaminants can stay within the GSS for over a month. However, winds have the potential to substantially reduce the residence time of waters within the GSS.
- The long water residence times in the Mary River and the GSS suggest that contaminants that are toxic in even small concentrations or that have the potential to bioaccumulate in the ecosystem could have substantial impact in the estuary over time.
- The type of contaminant and the concentration level of the initial discharge will be key in predicting the potential for negative impact in the GSS from Mary River contaminate discharge.

Main findings from the extended modelling analysis:

- During low flow conditions contaminants remain in the Mary River and surrounding region in the GSS for most of the modelling period (Figure 9B). This suggests that under low flow conditions most of the contaminant will remain in the Mary River for a period of weeks to months unless cleaned via chemical or biological processes.
- The northern locations in the GSS incur higher contaminant load but disperse the contaminant faster. In the southern locations the opposite occurs, the contaminant load is lower, but remains in the system for longer (Figures 9, A - D).
- The intertidal regions that are near the mean high water spring tidal range do not interact with the estuarine environment as often. This has the effect of extending the potential residence time of a contaminant. Contaminants may settle in higher elevated intertidal regions during spring tides and cannot be removed during neap tides (Figures 10 and 11). Only once spring tides return will contaminant be dispersed if it is still available for suspension into the water column.

Results and Discussion

Contaminant Residence Time

There is no substantial change in residence time results and conclusions between the original modelling and the extended modelling. However, given that the residence time results in this report were generated from updated and/or new scenarios we will summarise the results here.

The updated scenarios show that a contaminant emanating from the Mary River can remain in the GSS in some regions, even under high flow conditions, for the entire modelling period (i.e. 31 days) (Figure 10). Winds are crucial for the removal of contaminant from the GSS and under high flow conditions and no wind, there is limited dispersal of contaminant out of the Mary River and the GSS (Figure 10A). By comparison, under NE and SE winds the modelled contaminant is discharged from the Mary River quickly under high flow conditions. Further, the scenario with the greatest removal of contaminant from the GSS is where SE winds occur with High Flow from the river (Figure 10C). It should, however, be noted that even in these conditions, there are still locations in this scenario with long water residence times as indicated by the yellow and red zones in the figure. Notably, NE winds reduce the dispersal of contaminant from the river mouth which leads to longer residence times at the mouth of the Mary River (Figure 10D) and to the west of Big Woody Island.

The longest residence times and most limited contaminant dispersal from the mouth of the Mary River is seen to occur during the Low Flow scenario (Figure 10B) where tidal processes are predominantly responsible for most of the water movement.

This results in the oscillation of the contaminant in and out of the river mouth and local to the river mouth in the GSS. This is in stark contrast to the other scenarios where the contaminant is transported towards the connection zones between the GSS and the open sea. Consequently, as stated, most of the contaminant remains in the Mary River and the immediate region surrounding the river mouth under such low flow scenarios.

Intertidal classification of the Great Sandy Strait

Based on the 30 m QLD bathymetry data set, a large proportion of the GSS is intertidal with only one clear navigable channel through the strait. Given the limited bathymetric data sources available for the GSS it is likely that the 30 m bathymetry has allocated some regions as intertidal when, in fact, a location may just be very shallow when inundated at low tide. Nevertheless, most of the central region of the GSS is intertidal and much of the marine protected area to the West of Big Woody Island is also classed as intertidal. The complex bathymetry and islands in the central GSS have the highest proportion of locations that only interact with the marine environment during spring tides (Figures 10 & 11).

Time-series analysis of contaminant dispersal

The northern monitoring sites in the GSS (Urangan Jetty and West BWI) incurred relatively high loads of contaminant when compared to other locations but also quick dispersal of contaminant during the model run (Figures 12 and 13). In contrast the South GSS has a lower maximum contaminant level but it remains in the region for much longer with contaminant values still above the 1% threshold in the residence time analysis by the end of the model run (i.e. after 31 days).

The intertidal regions that are near the mean high water spring tidal range do not interact with the estuarine environment as often. This has the effect of extending the potential residence time of a contaminant. Contaminant may settle in higher elevated intertidal regions during spring tides and cannot be removed during neap tides. Only once spring tides return will contaminant be dispersed if it is still available for suspension into the water column. During neap tides these sites may not be inundated by contaminant load due to their elevation but given the temporal length of the residence time results, it is likely that these locations will incur similar trends as those described above and observed here in Figures 12 and 13.

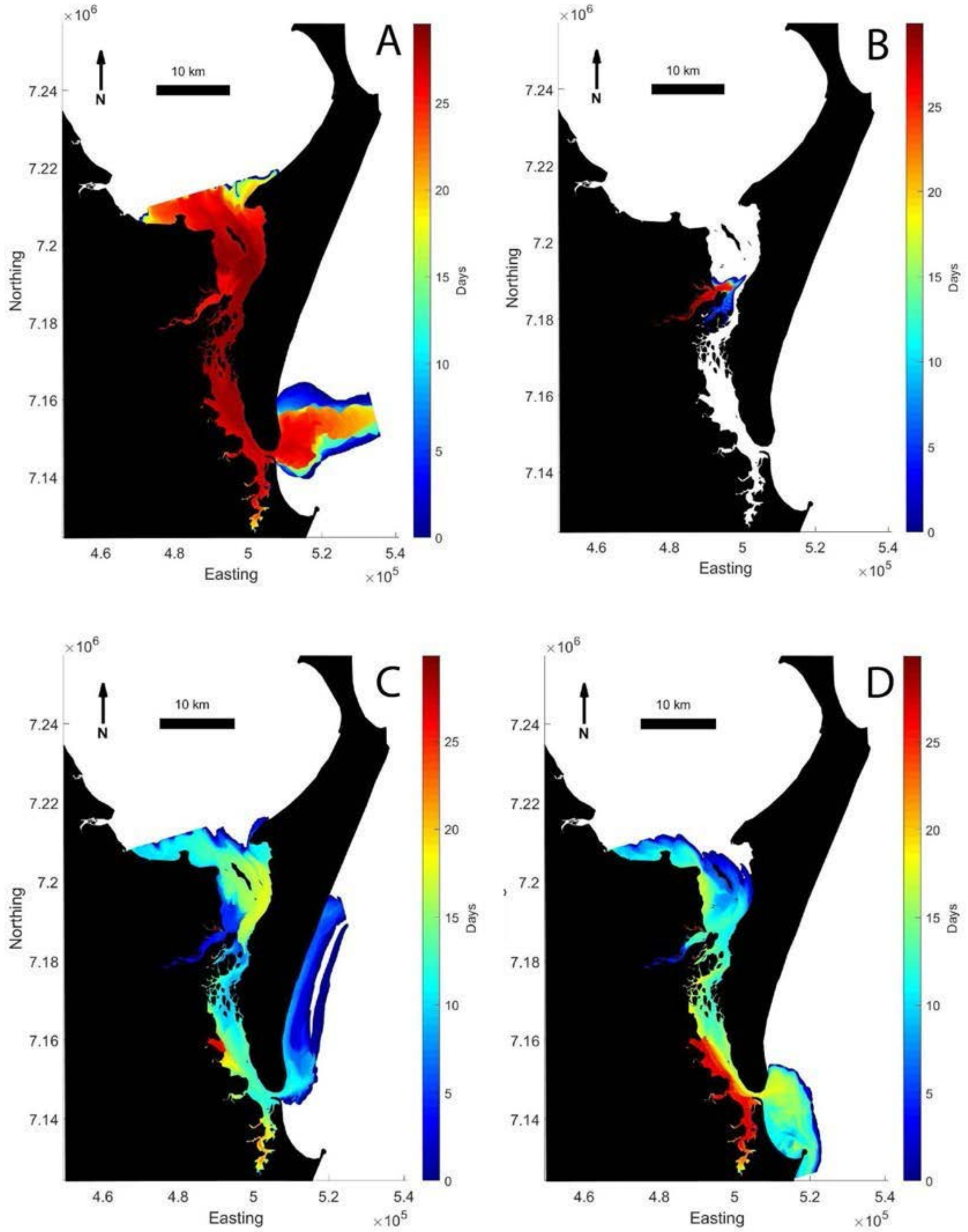


Figure 10. Water residence time calculations for the four scenarios outlined in Table 1. The scenarios are: A) No wind; B) SE wind Low Flow C) SE wind High Flow, D) NE wind High Flow.

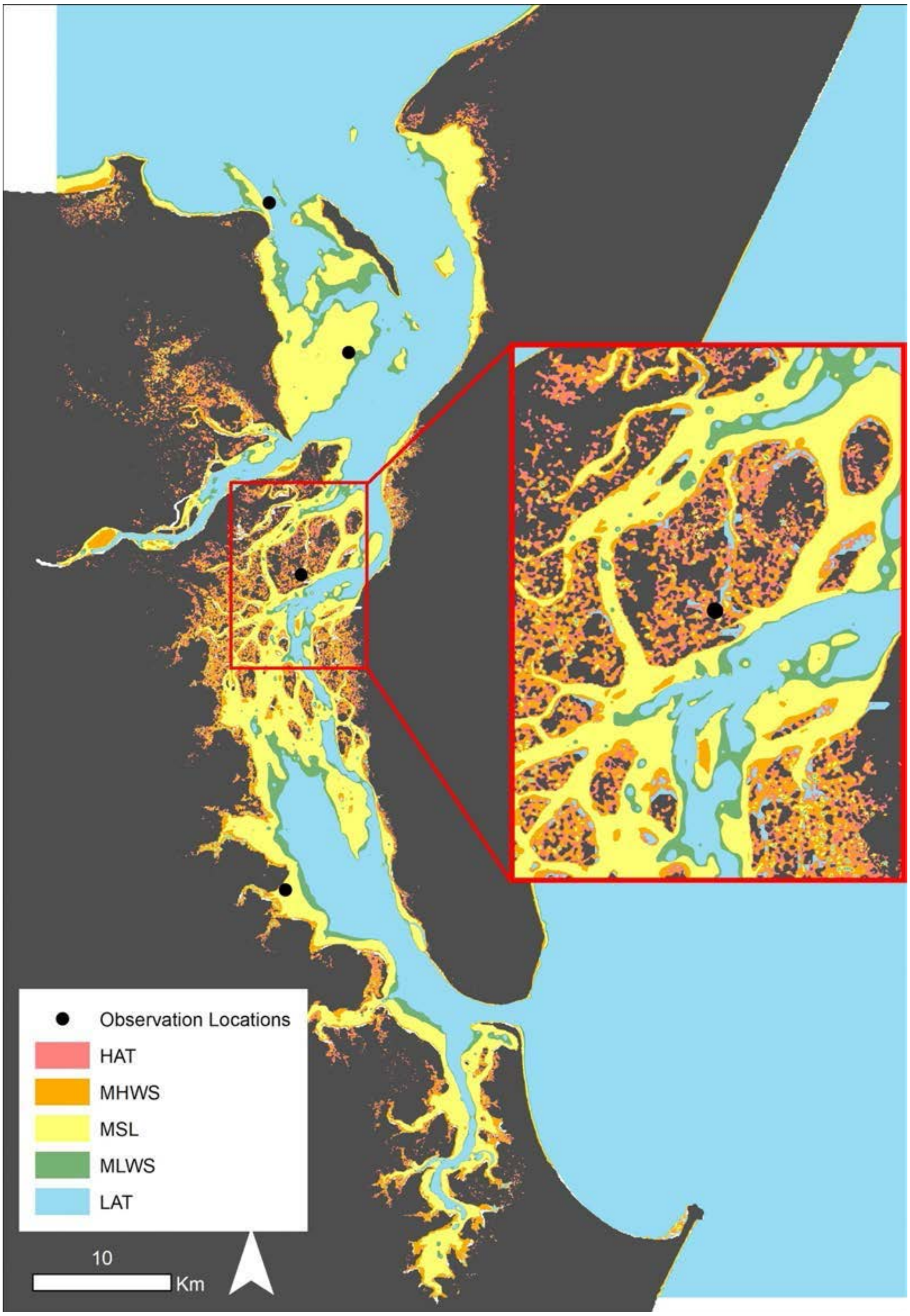


Figure 11. Intertidal regions of the Great Sandy Strait, Hervey Bay and the Mary River determined from the 30m Queensland bathymetry data set. Tidal heights are Highest Astronomical Tide (HAT), Mean High Water Springs (MHWS), Mean Sea Level (MSL), Mean Low Water Springs (MLWS), and Lowest Astronomical Tide (LAT). The regions with the warmer colours (HAT and MHWS) will be inundated only during spring tide conditions. The yellow colour represents a region that is intertidal. The green colour (MLWS) shows regions that are only exposed during spring low tides. The blue colour (LAT) shows regions that are always inundated with water. The black dots show the observation points detailed in Figures 5 and 6.

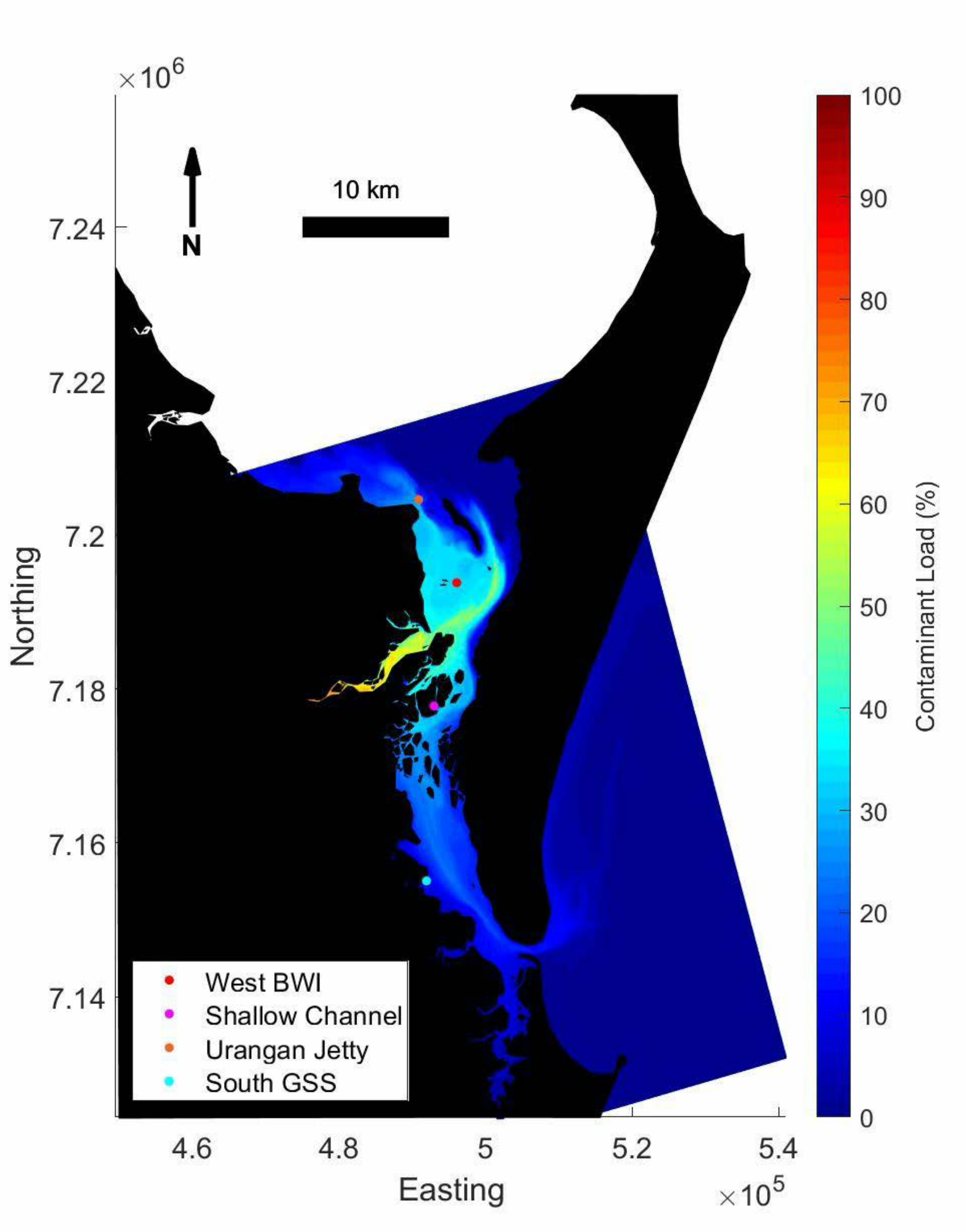


Figure 12. A map of the maximum observed contaminant load as a percentage of the initial contaminant concentration for each grid cell. Four observation locations are shown as dots with detailed time-series change displayed for each location in Figure 13 next page.

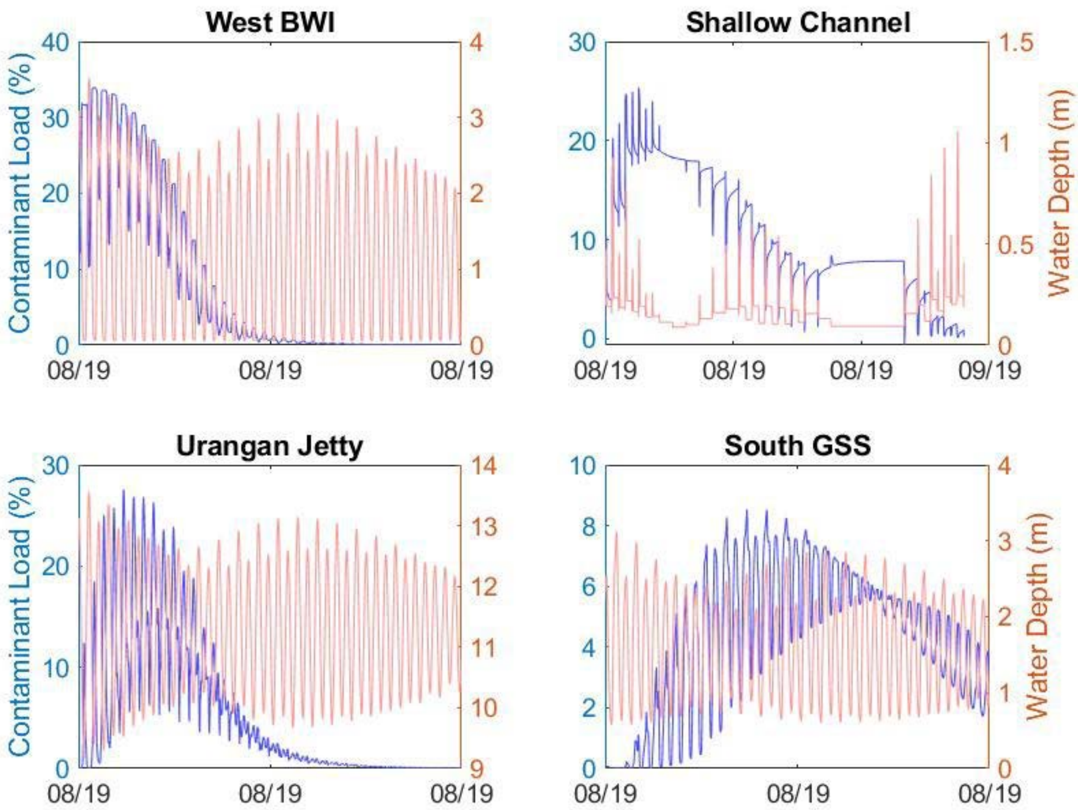


Figure 13. Time series observations for four sites of: contaminant load as a percentage of the initial contaminant concentration (blue), and water depth (red) during the SE High Flow model scenarios. The location of the four site locations as shown in Figure 12.

Sediment Composition and Distribution

In order to ascertain the current levels of potential risk pollutants existing in sediments within the GSS, benthic sediments were sampled at sites across the GSS. In addition to chemical constituents, the sediments were also assessed based on their physical composition and grain size. The results of this work were then considered within the context of the insights gained from the hydrodynamic modelling such as likely deposition sites, sediment type distribution, and the implications for potential risk to conservation areas such as the Ramsar areas associated with the GSS.

Sediment Sampling

Replicate sediment samples were collected randomly from several sites within the broad target areas suggested by the hydrodynamic modelling; Figure 14.

Figure 14. Target sampling zones and sites used for sediment sampling. Sites outside of target areas provided background and contextual values for comparison.

Samples were collected by means of an Ekman-style box corer which was then sub-sampled for analytical material. All samples were obtained from the upper 4cm of sediment and individual samples were homogenised after collection.

Samples were divided to allow for the determination of water content, grainsize distribution, and heavy metal content. The methods summarised in Table 3 were used to determine the respective sediment components:

Sediment water content was determined by drying the respective subsamples at 100oC to constant weight and calculating the water loss by weight difference.

Prior to chemical analyses all sediment samples were ground and homogenised using an agate mortar to achieve an average particle size of approximately 64µm.

Table 3. Methods used to determine respective sediment components.

Analyte	Method
Heavy Metals and Soluble Reactive P (SRP)	*Nitric (Hydrochloric) Peroxide Digestion of Soils (USEPA 3050 equiv.) for ICP / ICPMS Elements*
Total Carbon (TC), Total Organic Carbon (TOC), Total Inorganic carbon (TIC).	Schumacher, B A. METHODS FOR THE DETERMINATION OF TOTAL ORGANIC CARBON (TOC) IN SOILS AND SEDIMENTS. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-02/069 (NTIS PB2003-100822), 2002.
Total Nitrogen (TN, TKN), Nitrate/Nitrite (NOx)	USEPA Method 351.2, Revision 2.0: Determination of Total Kjeldahl Nitrogen by Semi-Automated Colorimetry

Results and Discussion

Sediment Water Content and Grain Size Distribution

Sediment water content provides an estimate for the porosity or relative level of compaction in a sediment and can thus be used as part of determining potential exchanges between sediment-bound water and the overlying water column. In the current context, the results for sediments in this study indicate that there are clear differences in sediment porosity between replicate samples within a sampling site as well as between the respective sampling sites themselves. The results are presented in Figure 15 below.

As shown in Figure 15, sediment water content varied within both of the broader target areas, and there were different levels of variability within each specific sampling site. For example, within the northern red zone, sediment water content varied between approximately 18% w/w to 24% w/w, compared to a range of 18% w/w to 26% w/w in the more southern blue zone. Most notable is the different levels of variation seen within a given site. For example, sites Z2A and Z2B showed very low variation between replicate samples taken randomly within the sites, compared to the higher variation seen at sites such as Z1D, Z1E1 and B4 in the south.

This difference in water content and porosity is reflective of grain size composition, the structure of the sediment grains, the levels of mixing or physical disturbance (re-suspension) in an area, and the influence of animals living within the sediments (Gingras *et al.,* 2012).

Aligned with this was a difference in the grain size distribution in the sediments from each of the target zones and, again, a substantial variation between specific sampling sites within each zone. The images of sediment samples from different sites highlight the extent of the differences observed and highlight the presence of shells and other carbonate remnants in some locations (Figure 16a,b,c).

Because of the presence of large shell fragments in many samples, grains-size analysis involved an initial separation of the >1mm fraction from all larger components, and then the characterisation of the <1mm fraction to determine the contribution of the finer sized components. Again, as shown in the images in Figure 16 sandy and fine grain size materials are found across the entire range of sediments spanning the fine sands with a mud component, to coarse sands mixed with larger shell fragments and other carbonate remnants, with a small fine grain component.

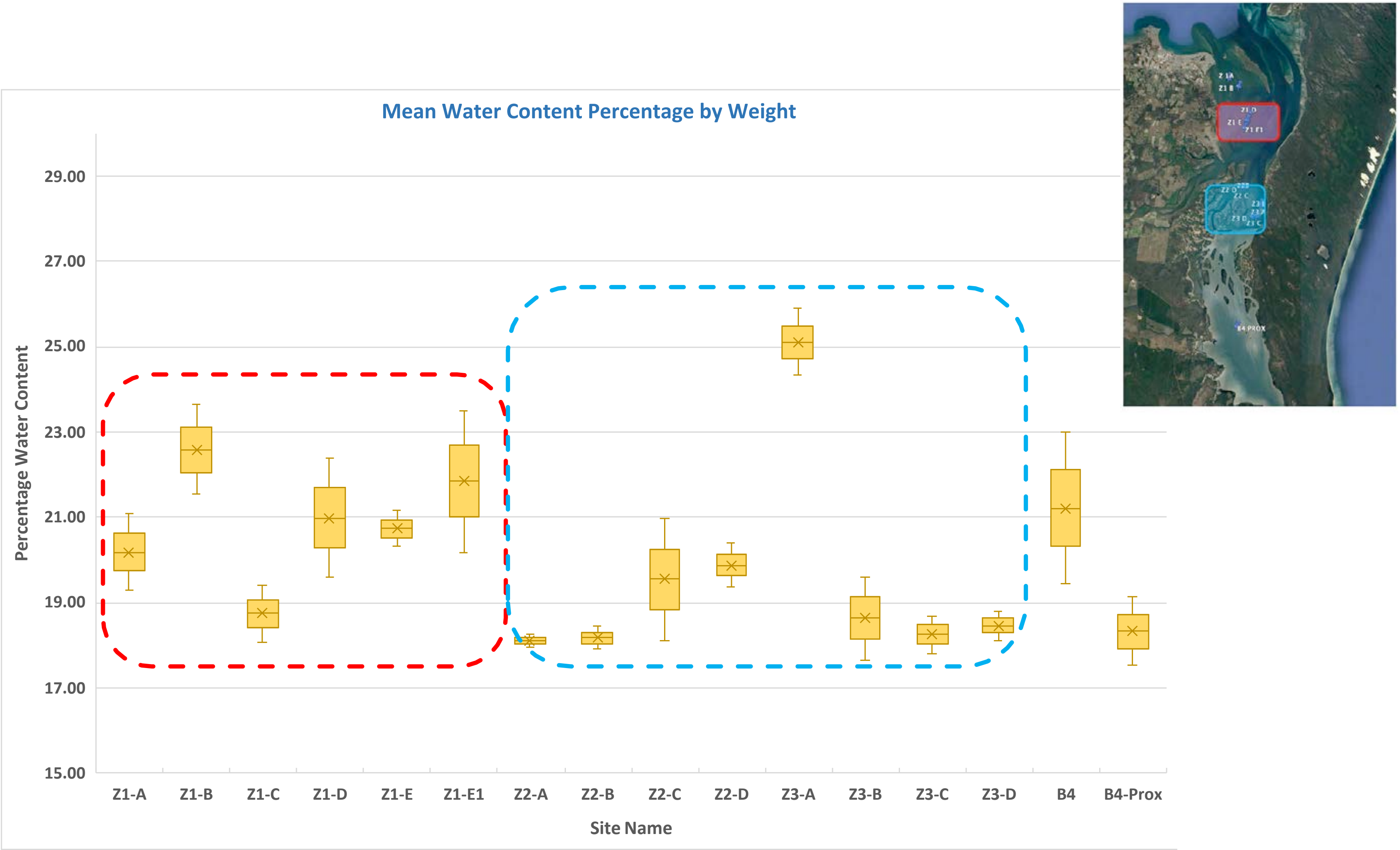
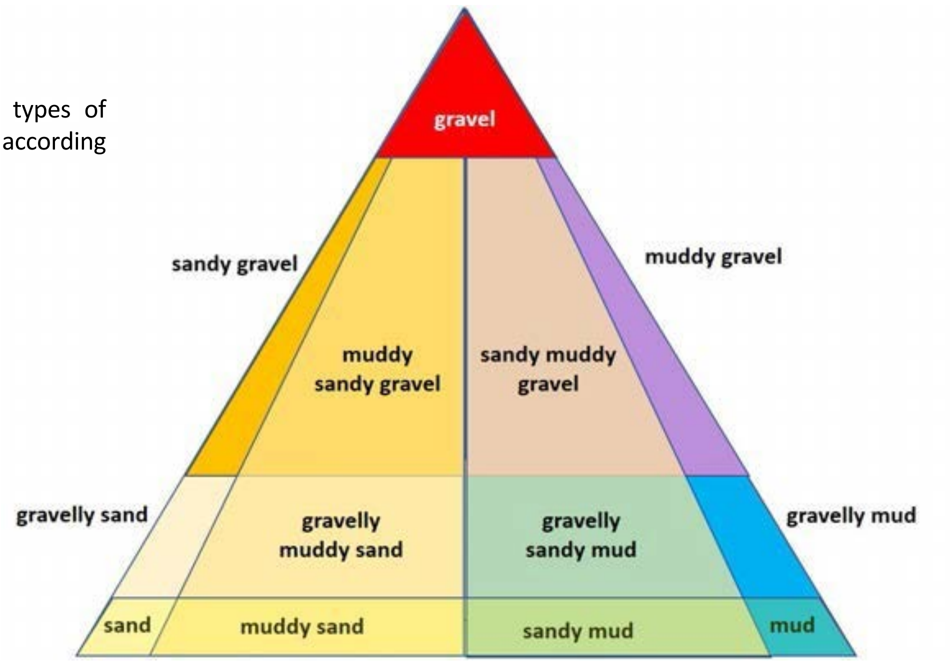


Figure 15. Mean sediment water content values with ranges for each sampling area. The blue and red outlined values correspond to the broad sampling areas denoted in the map insert. Boxes around the mean value represent then 80th percentile for each value, and the bars reflect the overall range of values obtained for the site.

Figure 16. Example sediment samples showing the gross variation in composition between sites across the Great Sandy Strait.

Based on particle size content, the sediments from each sample were classified according to the categories suggested by Blair and McPherson (1999) for graded marine sediments. The categories are summarised in Figure 17 below;

Figure 17. Classes of different types of graded marine sediment beds according to Blair & McPherson (1999)



Using the categories proposed by Blair and McPherson (1999), the type of sediment was plotted on the map for the GSS, Figure 18, below.

Most noteworthy is the general tendency toward finer sediments in the northern target zone, north east of River Heads, compared to the majority of sites in the more south-eastern sampling zone.

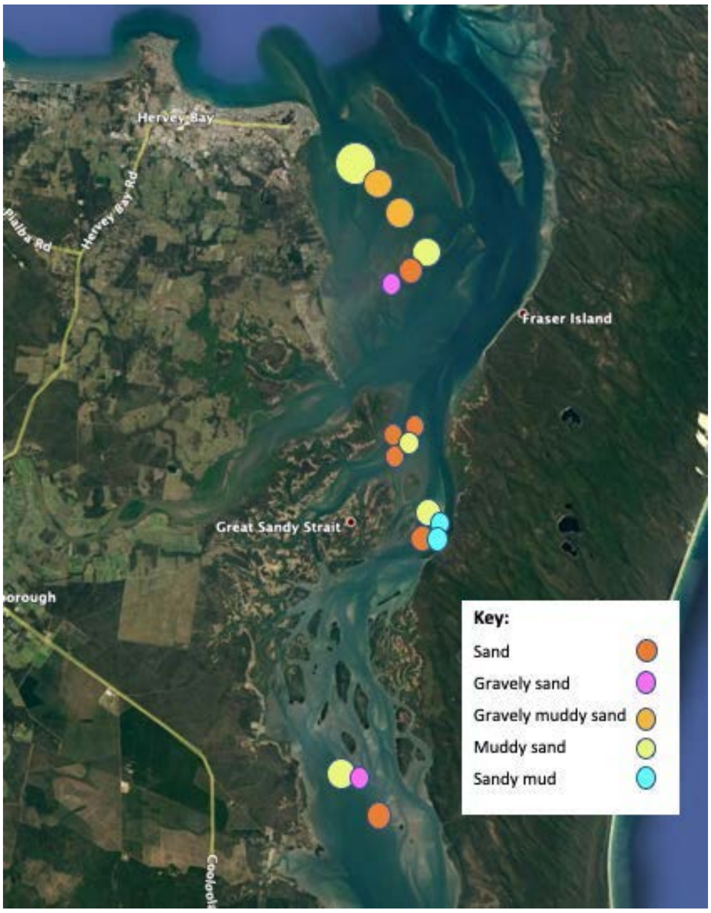


Figure 18. Distribution of different sediment types within the GSS as reflected by the respective sampling sites used in this study.

This supports the predictions drawn from the hydrodynamic model which indicated that, depending on conditions (river flows, winds, and tide), materials emanating from the Mary River are likely to move over and into this northern zone. Accordingly, fine materials that are transported most easily are more likely to be deposited in this area over the majority of prevailing weather and flow conditions reported for the Great Sandy Strait (see modelling section above).

In view of the above, and as illustrated in Figures 14 & 15, it should also be noted that there was a high level of variation or "patchiness" in sediment grain size composition across both sampling zones. This also applied between some replicate samples collected at a given sampling site illustrating that this variability occurs over small (<50m) and large scales (>1km). This again suggests the influence of physical transport processes operating at local and larger scales, as well as the potential influence of benthic organisms (see summary in Gingras *et al,* 2012). Such patchiness has been described in numerous sediment studies in estuarine ecosystems and is well defined in terms of small and larger scale perspectives by Reinicke*,* (2000). As highlighted by the hydrodynamic model (Figure 8B), the bed shear varies at different scales in the Strait so that it also contributes to the variations observed in sediment distribution and grain size composition at different spatial scales.

Heavy Metal, Carbon and Nutrient Content in Sediments.

Overview:

As reflected by the colour of dried sediment samples, the minerology of the sediments varied across the different sampling zones (Figure 19). As discussed below, this is likely due to the difference in their mineral composition with the most pronounced orange-brown colouration occurring in samples from the Z2 zone with a high manganese content.

Overall, the levels of heavy metals observed in sediments were all below the default guidelines set by the Australian and New Zealand Governments for fresh water and marine ecosystems (ANZECC & ARMCANZ, 2000).

Importantly, the ANZECC guidelines provide a default background value for metals of concern (DGV) but not for metals where its level of potential toxicity is low. These low potential toxicity levels are designated as N/A in Table 4. A description of how the guidelines were defined is available on the ANZECC web site https://www.waterquality.gov.au/anz-guidelines/guideline-values/default/sediment-quality- toxicants

Figure 19. Dried and ground sediment samples illustrating the colouration of each. The samples to the right are from Zone 2 and correspond to sampling sites Z2B and Z2C.

The ANZECC guidelines also provide an upper DGV or DGV-High value. As stated in the guidelines, this provides an indication of concentrations at which toxicity-related adverse effects may already start to occur.

a

Analyte	*Units*	*Range*	*DGV*	*DGV-High*
Heavy Metals				
Arsenic	mg/kg	6 - 19	20	70
Barium	mg/kg	<10	N/A	N/A
Beryllium	mg/kg	<1	N/A	N/A
Boron	mg/kg	<50	N/A	N/A
Cadmium	mg/kg	<1	1.5	10
Chromium	mg/kg	<2 - 19	80	370
Cobalt	mg/kg	<2 - 6	N/A	N/A
Copper	mg/kg	<5	65	270
Lead	mg/kg	<5	50	220
Manganese	mg/kg	48 - 1470	N/A	N/A
Nickel	mg/kg	<2 - 13	21	52
Selenium	mg/kg	<5	N/A	N/A
Vanadium	mg/kg	<5 - 23	N/A	N/A
Mercury	mg/kg	<0.1	0.15	1.0
Zinc	mg/kg	<5 - 55	200	410

b

Nutrients & Carbon		
Total N (TKN)	mg/kg	90 - 480
NOx	mg/kg	<0.1 - 0.2
SRP	mg/kg	<0.1 - 0.4
TC	% w/w	0.1 – 5.4
TIC	% w/w	0.03 – 6.2
TOC	% w/w	0.05 – 0.39

Table 4a,b: The range of values found for heavy metals and nutrients in sediments from the Great Sandy Strait compared against the Australian Guideline values for marine sediments. **DGV** is the baseline or background toxicant guide value, and the **DGV-H** is the upper guideline value where definable negative ecological impacts would be expected to occur. No toxicant guideline values are provided for N, P, or C.

Notably, none of the observed metal concentrations exceeded their respective DGV-High value, with many also below the background DGV and below detection for the method used; designated by a "<X" value.

Similar to metal concentrations, the range observed for the different forms of carbon, nitrogen, and reactive phosphate all fall within the ranges reported elsewhere for estuarine ecosystems in Australia and elsewhere (e.g. Hanington et al., 2016; Hanington, 2015; Simpson & Batley, 2016 & others)

Sediment Heavy Metal Content

It is commonly viewed that the bioavailability and toxicity of contaminants is influenced by sediment geochemical and physical characteristics including grain size due to aspects such as the binding capacity of sediments for contaminants, and surface area to volume ratios (e.g. Zhang et al., 2014; Rohwerder and Sand,2007; Saeedi *et al*, 2013). The exception to this is where a contaminant occurs as a discrete particle itself (e.g. ash particles) or as part of a mineral fragment or grain. As discussed below, this later aspect may be involved in the distribution of manganese and the other metals detected here.

As presented in the Appendix, Figure 1, manganese (Mn) concentrations in sediments across the GSS study area significantly exceeded that of all other metals. Manganese is widespread and common in many coastal/marine sediments (e.g. Sundby & Silverberg, 1981; Dessai & Nayak, 2009) and no direct toxicity warnings or guidelines are provided for manganese under the ANZECC guidelines for marine sediments. Further, the levels observed in the GSS sediments all fall within the range reported for similar coastal sediments (Dessai & Nayak, 2009 and others). It is also notable that significant manganese levels have been found in the geology within the Mary River catchment to the extent that mining of manganese has been considered locally; see article on attached link: https://eclipseuranium.com.au/projects/manganese-projects/.

Manganese exists in marine sediments in a number of chemical phases including bioavailable phases encompassing direct exchangeable, carbonate bound and Fe–Mn oxide associated phases. Like iron (Fe), manganese (Mn) can play an important role in the sedimentary carbon cycling in both freshwater and marine systems. For example, the dissimilatory reduction of Fe and Mn oxides has been shown to be a major pathway of anoxic organic matter remineralization in surface sediments, (e.g., Egger et al., 2015). In addition, it has been shown in some ecosystems that there is a correlation between the level of fine sediments, organic carbon, and exchangeable Mn. This supports the observation in this study where the highest levels of Mn occurred in areas with the highest levels of fine and muddy sediments (Site Z2-C) but does not explain the elevated levels at sites with medium to coarse sediments (e.g. Z2-A & B; Z3-D). It is proposed that Mn levels in sediments at the later sites are more reflective of particulate mineral contributions rather than more easily exchangeable forms of Mn.

As noted previously, none of the key heavy metals investigated here showed levels that indicate recent high inputs from the Mary River or associated catchment, and there is no indication of a direct ecological risk due to the observed low levels for each metal. The levels of each metal within a given site are summarised in Figure 2, Appendix.

In this context, however, it should be noted that the sampling method used in this study only collected materials from the upper 5cm of sediment which is most reflective of recent and potentially more mobile sediment deposition. This was deliberately done to assess current and recent potential risks due to heavy metal inputs. In order to understand if there have been larger, more significant inputs of these metals historically, it would be necessary to collect sediments using deeper coring techniques (e.g. to 0.5-1.0m depth). By analysing these sediments for metal content, and simultaneously dating the different profiles within the sediment column, it would be possible to better assess historic inputs and their potential significance. This would also assist in assessing the environmental risk from activities such as dredging, or other modifications of the benthos that could liberate deeper, potentially toxic, historic sediments; if they exist.

Similarly, there are no estimates of the loads or deposition rates for sediments within the GSS or its associated tributaries. This greatly limits the ability to more accurately project the loads that might result from a given anthropogenic source into the future and, in view of the long water residence times in the GSS (see modelling results), how it might ultimately distribute across the GSS and the critical habitats it supports; including the Ramsar conservation wetland areas.

Carbon and Nutrients

As with the levels observed for metals, the levels of total inorganic carbon (TIC), total organic carbon (TOC), and nutrients all fall within the range reported elsewhere for similar estuarine ecosystems (e.g. Alongi *et al.,* 1988; Wollast, 1999). As discussed by a range of authors (e.g. Alongi, 1989; Maher & Eyre, 2010; Hanington *et al.,* 2016; Hanington, 2015), the dynamics of carbon and the associated nutrients in estuarine ecosystems is complex and involves a range of interacting processes and influential factors. In this light, the variation in levels of carbon observed in the GSS sediments fall within the range observed elsewhere but also align with the different dynamics at play. This includes the delivery and removal of particulate carbon through different transport processes, the transformation of carbon through biological processes, and the interplay between local biological production versus the import of carbon from sources such as adjacent mangrove forests or similar catchment inputs. These dynamics and processes are well described in the review by Alongi (2019).

Most notable in the observed results is the dominance of inorganic carbon (TIC) in its contribution to the total level of carbon (TC) in the sediments. The results are summarised in Figure 3, in the Appendix. Inorganic carbon levels can typically result from the presence of limestone from historic geological deposits, or from carbonate, and aragonite formed biologically by a range of organisms including shellfish, and corals. Notably, the GSS ecosystem is well known for corals, mussels and its associated carbonate geology (see for example: https://wetlandinfo.des.qld.gov.au/wetlands/ecology/aquatic-ecosystems- natural/estuarine-marine/descriptions/21/). As mentioned previously, shell remnants were widespread in sediment samples collected in this study and areas of muscles and oysters were commonly encountered during field sampling events. Accordingly, the observed levels of TIC are within the range for an ecosystem with such carbonate-forming components.

By comparison, the observed levels of organic carbon (TOC) did not vary significantly across sites with the exception of site Z3-A which had a high level of mud and fine sediments, and a concomitantly high level of total nitrogen, which is discussed later. In general, the range of TOC values again fell within the range reported for similar estuaries (Alongi *et al.,* 1988; Wollast, 1999; Hanington, 2015; Simpson & Batley, 2016). Notably, the GSS supports a range of benthic habitats including seagrass beds (see https://parks.des.qld.gov.au/__data/assets/pdf_file/0031/165847/gsmp-benthic-habitat-map.pdf and Andrew Olds, USC; *pers. comm*.) and is fringed by mangrove forests; all of which provide organic carbon to the benthos in the GSS. Whilst no reports could be found on the contributions of internal organic carbon production (autochthonous) or the input of external organic carbon sources (allochthonous), the variations in TOC across the GSS is likely due to the same biogeochemical processes reported elsewhere for similar estuaries (see review by Alongi, 2019). In addition, it is now recognised that a range of other processes and factors play a role in determining the standing stocks of organic carbon and the associated nutrients in estuaries (e.g. Matson & Brinson, 1990; Lucotte et al., 1991; Maher & Eyre, 2010; and others), such that further research is required in order to more accurately define the main controls on C, N, and P in the GSS benthos and associated habitats or ecosystem.

Total nitrogen levels in GSS sediments were again within the range reported for similar estuaries in Australia (. E.g. Hanington, 2015; Alongi *et al.,* 1989) and are well below values observed in degraded eutrophic estuaries such as reported by Boyle *et al,* (2004) in southern California. As noted previously, the processing and cycling of N in marine ecosystems is tightly linked to the biogeochemistry of C as well as other elements such as P and a number of metals (see Capone *et al,* 2008). The key processes underpinning the nitrogen budget and the associated links to C, P, and other elements in the current study area are difficult to define without further process-based research. Despite this, one broad observation can be made based on the C:N ratios observed across all sediment sites.

As summarised in Figure 6 in the Appendix, C:N ratios are consistently close to 6 with only four sites equal to, or exceeding 7, with the highest ratio of 8.6 at site Z3-A. This range of low C:N ratios reflects Redfield ratios for microbial communities rather than higher ratios that would indicate the presence of organic carbon derived from higher plants such as mangrove and seagrass detritus (e.g. Alongi *et al.,* 1989). As suggested in their review of estuarine sedimentary processes, Alongi *et al.,* (2019) this suggests efficient processing of dissolved organic carbon in benthic sediments and the conservation of N relative to C within these communities. The significance of this in terms of ecosystem nitrogen and carbon budgets cannot be fully assessed here but this observation advocates for further research to understand how increased nutrient and organic carbon loads into the GSS might be processed and influence overall ecosystem sustainability.

Concluding Remarks and Environmental Risk Implications

As noted in the preamble for this report, the stated objective by FIDO, MRCCC and GMA for this study was to undertake a baseline survey and modelling study to assess the potential for contaminants arising from the Colton mine to reach and potentially impact habitats within the Great Sandy Strait ecosystem and, in particular, those associated with Ramsar and World Heritage protection zones.

In light of this, the hydrodynamic modelling has illustrated the potential for materials emanating from the Mary River to be dispersed at different ranges and loads throughout the GSS depending on conditions such as wind speed and direction, tidal range, and riverine flows into the GSS.

In order to fathom the level of potential risk posed to the Sandy Strait ecosystem from materials delivered from the Mary River it is important to understand the relative amounts of materials (pollutants) entering the Strait, the resultant distribution of the materials, and the time over which such materials linger or reside within the different areas. To better clarify this, the results from the modelling scenarios described previously (see Tables 1 and 2, page 21) were used to provide additional calculations on the likely contaminant load in addition to material residence times under each scenario. Whilst these results do not alter the insights gained from this original modelling, they do highlight the locations where the concentration of contaminant may be greatest for the longest periods under different scenarios. When considering these results it is important to note that the release being modelled is not a continuous release but a pulsed input delivered at the proposed mine discharge location. A continuous discharge would augment the results discussed here and prolong contaminant occurrence in the areas described.

The results are summarised in Figures 20-23 (below) and highlight the likely distribution of contaminant load based on the percentage of the initial contaminant concentration released in the Mary River at the proposed mine site discharge location. These results allow for an estimate of likely contaminant load over time if the initial concentration is known. This aspect of load estimation is discussed further below.

For clarity of interpretation, the figures show the distribution of the contaminant (coloured) as well as the amount of time the contaminant is likely to reside in a given area (colour scheme on right axis). So, for example, in Figure 21, an estimated 1% of the original contaminant load released at the mine discharge location is distributed across the entire Sandy Strait for >20 days and also extends out into Hervey Bay and through the passage at Inskip. Under the same scenario, an estimated 25% of the original contaminant load is distributed across the central and northern parts of the Sandy Strait with some load entering the southwestern shores of Hervey Bay. As indicated by the colour gradient, this level of load distribution is estimated to exist for up to 10 days under these scenario conditions.

By considering all of the scenarios and timeframes for contaminant load distributions, the locations that are most likely to be at risk when outputs are highest (during high flow events) are in the Great Sandy Strait to the North and South of the entrance to Mary River. This is made most obvious in Figure 22 (25%) and Figure 23 (25%) where 25 % of the contaminant release resides over these areas for up to between 5 and 10 days. Accordingly, this suggests that the shallow intertidal zones in these areas and the RAMSAR values associated with them are at most risk relative to other areas (see discussion on RAMSAR values below)

Notably, under low flow conditions the Mary River does not flush contaminants outward and so they remain in the river for most of the simulation time (Figure 20). Tidal processes help disperse contaminant into the GSS but, without sufficient flow from the Mary River, contaminant inputs are likely to remain in the Mary River and its confluence with the Great Sandy Strait for periods greater than the simulation time for the models (i.e. greater than one month).

The results underpinning Figures 20 – 23 are also provided as .xyz files as an electronic addendum to this report so that they can be imported into any GIS program and used for specific site estimations.

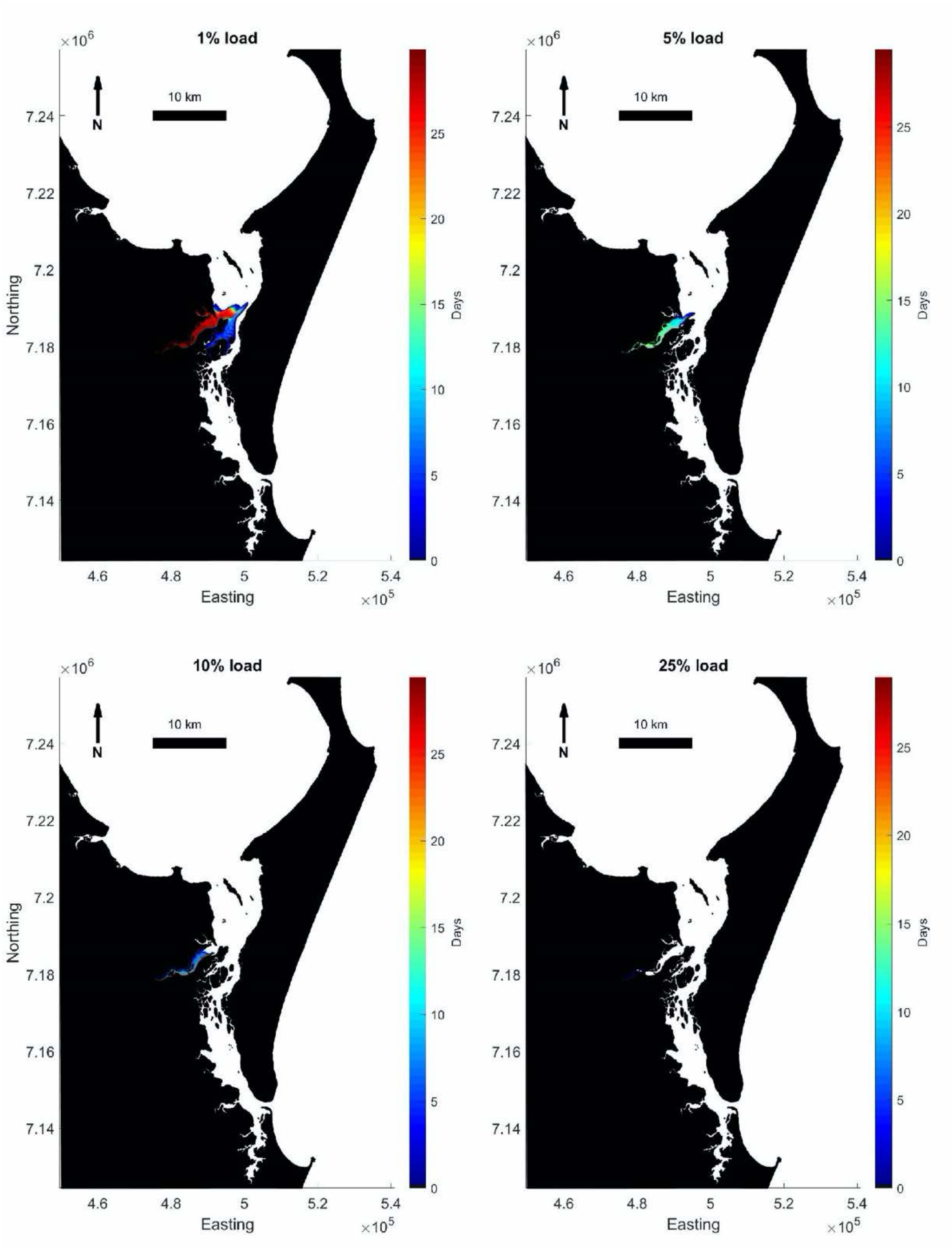


Figure 20. Contaminant dispersal during low flow conditions with southeast wind in the Mary River. The results show the length of time contaminant is observed in a location that is above a threshold percentage of initial contaminant load. The threshold percentages are: 1% (top left), 5% (top right), 10% (bottom left), 25% (bottom right).

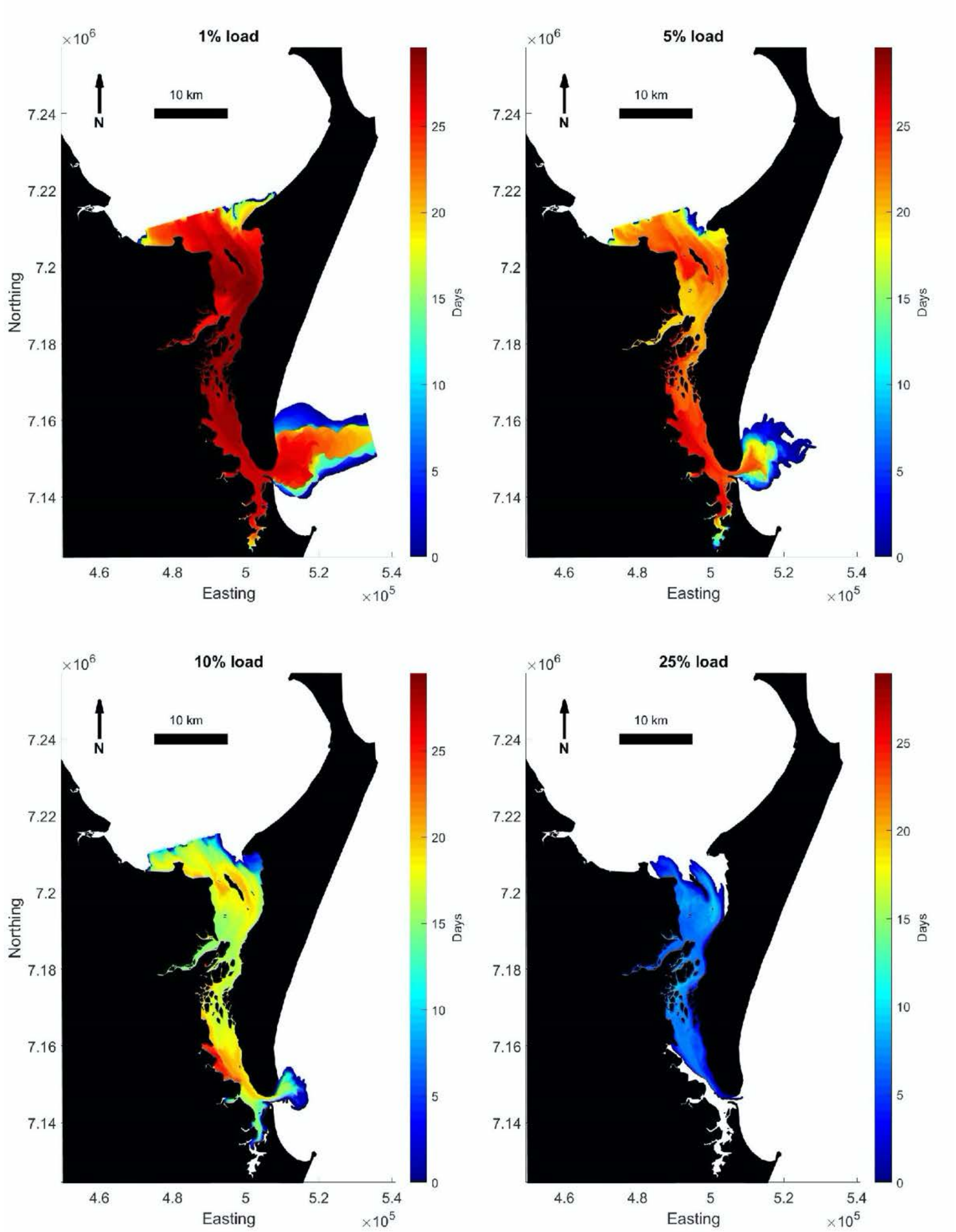


Figure 21. Contaminant dispersal during high flow conditions with no wind in the Mary River. The results show the length of time contaminant is observed in a location that is above a threshold percentage of initial contaminant load. The threshold percentages are: 1% (top left), 5% (top right), 10% (bottom left), 25% (bottom right).

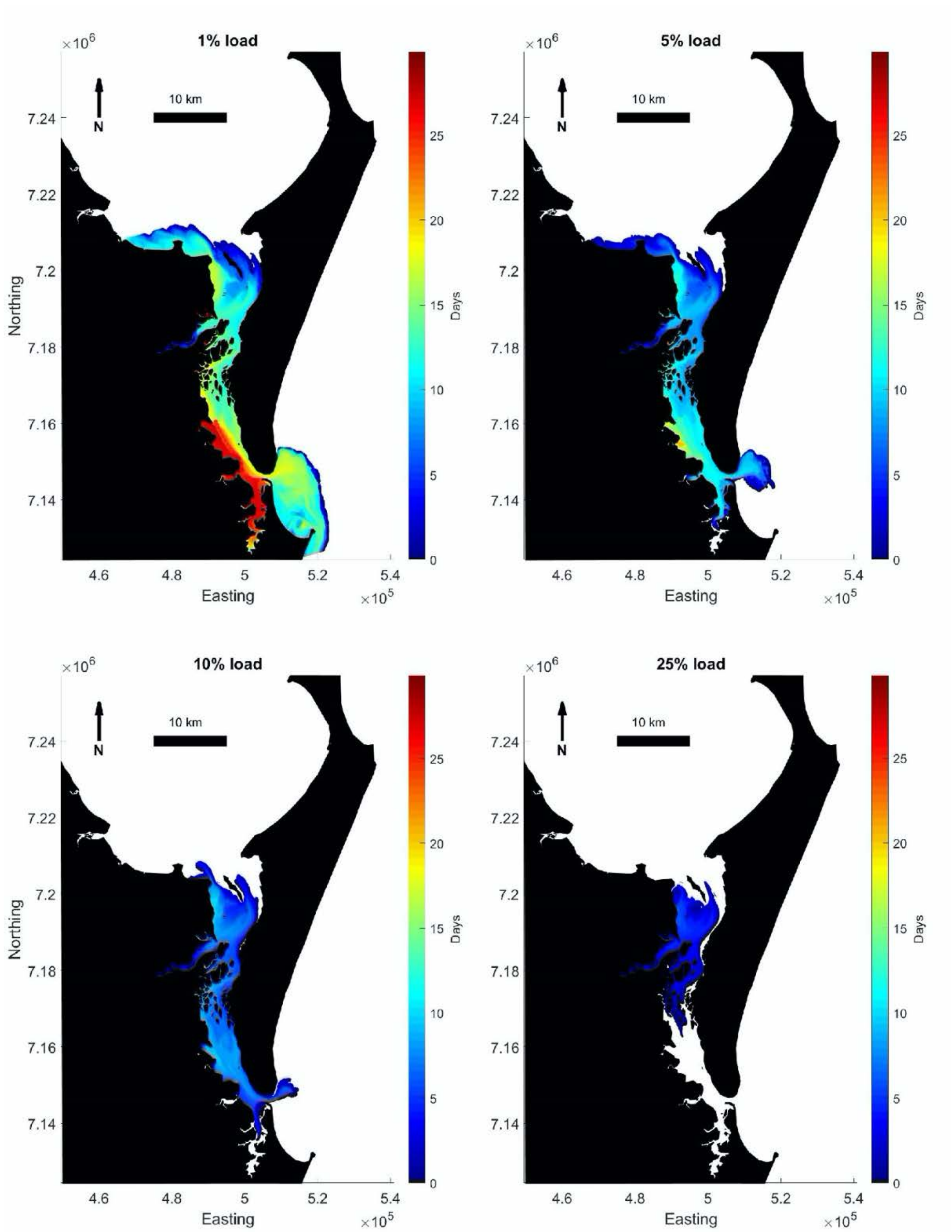


Figure 22. Contaminant dispersal during high flow conditions with northeast winds in the Mary River. The results show the length of time contaminant is observed in a location that is above a threshold percentage of initial contaminant load. The threshold percentages are: 1% (top left), 5% (top right), 10% (bottom left), 25% (bottom right).

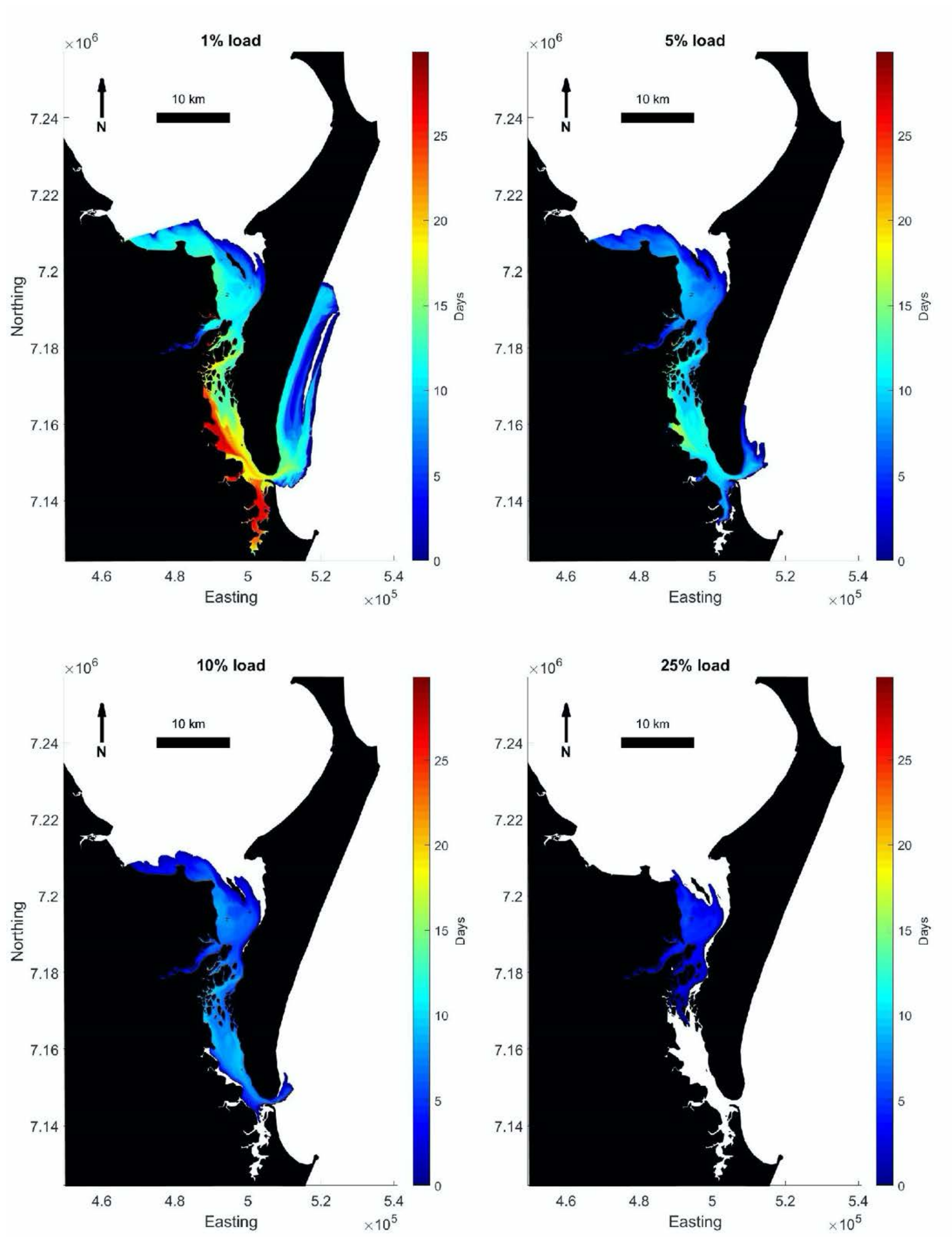


Figure 23. Contaminant dispersal during high flow conditions with southeast winds in the Mary River. The results show the length of time contaminant is observed in a location that is above a threshold percentage of initial contaminant load. The threshold percentages are: 1% (top left), 5% (top right), 10% (bottom left), 25% (bottom right).

Against this context, the sediment study shows that such riverine-derived materials (particulates/sediments) distribute in a broad spatial range reflective of the patterns illustrated by the modelling study (Figure 19) Importantly though, local conditions and system-wide variations in water residence times also lead to patchiness within these broader zones. Notably, however, this study, and the limited measures of metals and nutrients it has undertaken, do not indicate that the GSS is polluted or eutrophic in its current state. This does not preclude possible historical pollutant events that might be reflected in deeper sediments for example (e.g. Saunders *et al, 2013*), but does offer a sound baseline for future comparisons to be made as the catchment and potential inputs into the GSS may change. As demonstrated in the study by Saunders *et al* (2013), mining activities within catchments pose potentially significant risks to the receiving waters and estuaries they may connect with, and this includes current as well as historic activities.

An important aspect to highlight here is the limited knowledge and information available about the actual contaminant loads likely to be discharged from the proposed Colton mine (or other sources) entering the Mary River under different operational situations and weather conditions. Whilst some modest studies have highlighted the importance of catchment-derived sediments for the development and ecology of some mangrove and wetland areas in the Great Sandy Strait domain (e.g. Moss *et* al., 2012; Moss *et* al., 2013), these have largely focussed on the influence of fire and groundwater with some discussion of the role of wider catchment inputs. Given this, it is not possible to build an accurate estimate of baseline catchment sediment and materials loads into the Strait and into RAMSAR wetland areas. Further, the methods used to predict the types and size of contaminant loads given in the Environmental Management Plan (EMP) for the proposed Colton mine are, unfortunately, also so limited as to hinder validation here. From the information contained in the EMP it is not clear how the yearly average load it provides was derived, with no explanation of how the variability in rainfall and operational conditions that can occur in this area were addressed (see previous discussion for model development). On this basis alone it is suggested that further investigation of the load estimates made for the mine discharges be considered along with the measurement of current sediment loads settling along the Mary River channel and across the key areas of risk that have been identified in this study. This later aspect has been done elsewhere by means of techniques such as sediment traps and the use of *in situ* nephelometers (e.g. Whinney *et al* 2017). The results from such an investigation could also be integrated into the model used in this study to refine its ability to address internal processes along the river and in the Sandy Strait such as settling and resuspension dynamics at different reaches of the river and in the estuary.

Given the above observations, it is recommended that support also be considered for an ongoing monitoring program for the GSS that encapsulates the target areas defined in this study as well as habitats and intertidal zones that are key to understanding the risk and potential impacts on keystone ecological services and conservation areas such as the Ramsar intertidal wetlands. In order to understand historical conditions and potential periods of pollution, a more substantive study is required where deeper sediment cores are collected and analysed for nutrients and heavy metals as performed on surface sediments in this study.

Further, as observed, the carbon and nitrogen cycling in the benthos is heavily influenced by microbially mediated processes. In this light, investigation of how these processes might change under altered anthropogenic loads into the estuary (pollution) is clearly warranted and this should consider how this may, in turn, influence the sustainability of key habitats such as seagrass beds and the organisms they support. For example, studies undertaken by Johnstone *et al.* (2007), Hanington et al, (2016); Hanington, (2015) illustrate how altered sediment conditions may lead to the development of toxic algal blooms, for example. In this context, research aiming to define and describe the major processes influencing the benthic and wider ecosystem nitrogen and phosphorous budgets in the GSS would significantly bolster the ability of managers to understand how the ecosystem currently functions as well as how vulnerable it may be to increased nutrient and pollutant loads. An example of how this might be initially approached is given in a nutrient budget model developed for Moreton Bay Qld., by Wulff, *et al,* (2011).

In this context, any further research into the distribution and behaviour of pollutants and sediments in the GSS should take an integrative approach whereby further development of hydrodynamic models should incorporate an understanding of the ecology and behaviour of keystone habitats within the GSS, as well as the biogeochemical cycles that underpin the ecology and its sustainability. As highlighted by the numerous studies undertaken within the Future Earth (LOICZ[1]) framework, the sustainable management of estuarine ecosystems is most effective when a systems approach is taken that integrates an understanding of ecosystem structure with a description and understanding of the biogeochemical processes (nutrient and carbon cycling) that underpins it. In addition, in view of the lack of historical information and data on catchment inputs into the GSS, and the potential for historic materials to be resuspended under human intervention and storm events, an investigation into the historic and ongoing evolution of the sedimentary environments within the GSS would also greatly improve the basis for long-term planning and strategy development for the management of the GSS.

Finally, the modelling work in this study showed a clear connection between the GSS and the southern areas of Hervey Bay. In view of this exchange and the potential changes in land uses, catchment condition, and the resultant materials entering the GSS, further investigation into the connectivity between the GSS and Hervey Bay is warranted in order to better understand the potential risks this poses to keystone habitats such as the coral reefs and seagrass beds that exist in the exchange zone.

Risk to Ramsar Sites and Areas of Concern.

As note in the introduction to this report, the GSS is associated with significant intertidal areas that include Ramsar-listed zones (Figure 24 below)

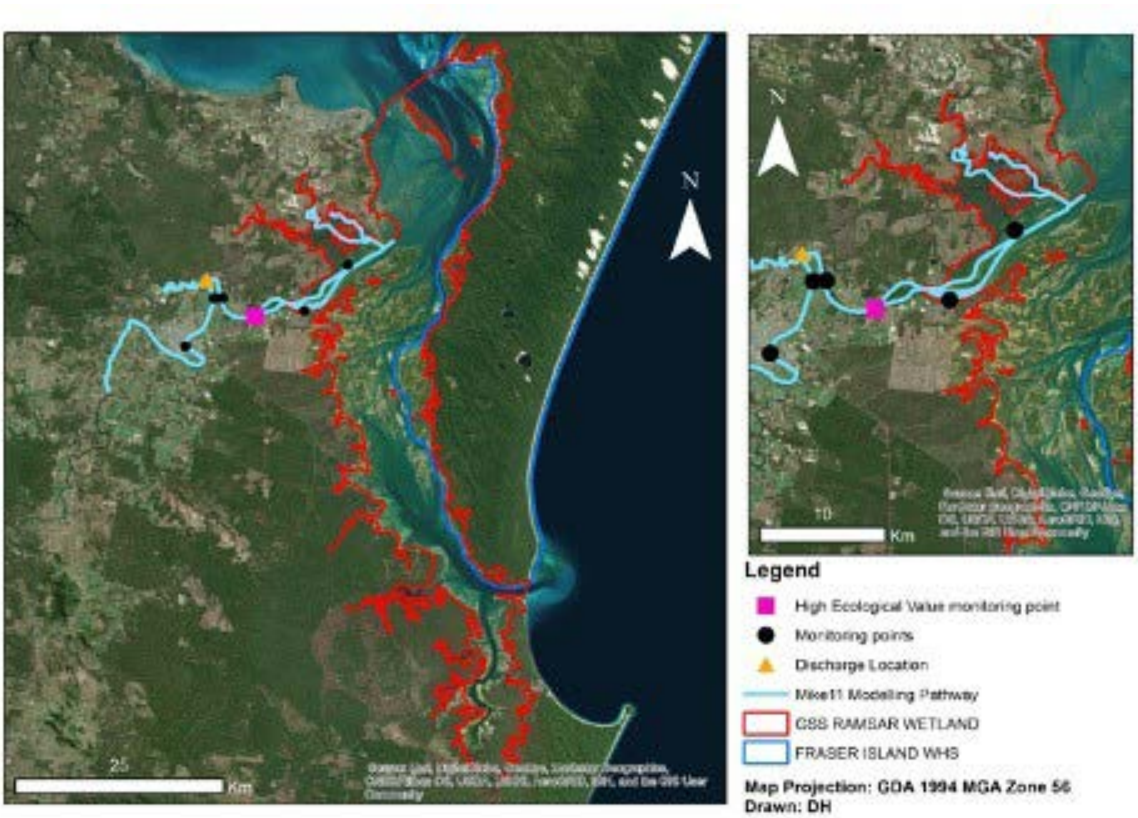


Figure 24: Satellite images of the Great Sandy Strait indicating the boundaries to Ramsar and World Heritage zones it is associated with.

[1] Future Earth Coasts was originally named Land-Ocean Interactions in the Coastal Zone (LOICZ), launched by IGBP (International Geosphere-Biosphere Programme) and IHDP (International Human Dimensions Programme), and became a core project of Future Earth in January 2015.

Given the extensive intertidal areas associated with these conservation zones, especially the Ramsar areas the potential for deposition of materials transported within the GSS is significant depending on the physical characteristics of the materials (e.g. size, density, chemical composition), as well as the prevailing conditions of tide, wind and inflow levels from the Mary River. As shown in Figure 9a and Figure 21, the retention and widest distribution of potential contaminants delivered by the Mary River would occur under conditions of no wind but significant inflow from the river with between 10 and 20% of the contaminant load discharged from the Colton Mine site remaining in the estuary for up to 10 days after a single pulse release. Under these conditions any waterborne contaminants from the Mary River would likely reach the Ramsar boundaries. Depending on the length of time over which such conditions prevailed (e.g. extended contaminant release periods and high river discharge), the amount of contaminant settling onto the benthos in these sites would vary. It is important to note, however, that, as shown in the hydrodynamic modelling, when wind speeds and direction change, both the water retention time and the speed of water passing over the benthos can change significantly. This then may lead to the resuspension and further transport of materials that have landed on the sediment surface, as well as the flushing of water and suspended materials out of the GSS – see Figure 10, page 24.

As discussed by Tiwary (2001) coal mines are capable of releasing a range of materials that can have a range of negative impacts on water quality and the environment. These pollutants can include metals such as Iron, Copper, Manganese, and Nickel, but may also occur in the form of acids from the oxidation of sulphides, and organic substances such as oils and other hydrocarbons released during mining activities. These and additional heavy metals have been identified as components in the planed discharges from the proposed Colton Mine into the Mary River. In addition, the simple release of non-toxic but high levels of soil or other particles can also have a detrimental effect on ecosystems through smothering of benthic habitats and the blocking of light necessary for plant growth (e.g., Wright *et al.,* 2017 & articles cited within).

Importantly, the impact that such pollutants can have in aquatic systems can occur at significant distances from the source and vary in terms of type and distribution of the impacts that occur (see e.g., Wright *et al.,* 2017). Based on this and the combined results of the hydrodynamic modelling and sediment sampling, the current study indicates that there is risk to the Ramsar areas and other reaches of the GSS should there occur a significant release of pollutant materials into the Mary River under the conditions described previously (page 24, Figure 10). Even where conditions are favourable for maximum flushing of materials through and out of the GSS (Figure 10c, d), some areas are still likely to receive materials due to their specific local water residence times (red zones in each figure).

In view of this, it is useful to consider which of the Ramsar wetland values might be influenced or negatively impacted by potential sediment and/or heavy metal loads. As summarised in Appendices 2 and 3, there are a number of ecological matters that warrant protection under Federal and State EPBC and Ramsar legislation. At both levels of oversight there are number of services such as the natural cleansing and maintenance of water quality, biodiversity sustainability, and ecological or environmental services that need to be considered. More specifically, depending on the particular location around the GSS, this also includes the consideration of High Ecological Significance wetlands on the map of Referable Wetlands, High Ecological Value (HEV) wetlands, High Ecological Value (HEV) waterways and threatened (endangered or vulnerable) wildlife (terrestrial and marine). Accordingly, any deposition of contaminants that might be assimilated into biological and geochemical processes at these sites stands to negatively impact on them. This is especially true where, for example, the ingestion of food may directly include the ingestion of contaminated sediments such as occurs with wader birds such as Oyster catchers and similar intertidal feeders, as well as in filter feeders (e.g. cockles) that intertidal waders feed upon. Given the potential distribution of contaminants and sediments that the modelling predicted and the sampling substantiated in this study, there is good reason to further assess the vulnerability and specific conditions that exist within the broader zones identified here.

In view of the preceding comments, and in order to better understand the full extent of any risk to these specific environmental services, habitats or species, it is suggested that the outputs from this study be used to target areas where water residence times and materials deposition are most likely to be high with the aim to identify vulnerable or “at risk” habitats, communities or species.

Further Research

Whilst there are many elements of the GSS and its function that could be investigated, the following aspects are proposed based on the results of this study and the background aim to better understand the potential impacts that might arise from pollutant discharges in the GSS from the Mary River and its catchment. In general, further research into the distribution and behaviour of pollutants and sediments in the GSS should take an integrative approach whereby further development of hydrodynamic models should incorporate an understanding of the ecology and behaviour of keystone habitats within the GSS, as well as the biogeochemical cycles that underpin the ecology and its sustainability. Within this broader approach, some of the key aspects to consider include the following:

- Whilst the modelling work and sediment analysis in this study indicate the relative load levels and the types of materials depositing within the GSS ecosystem, we were unable to find any direct measurements of actual sediment deposition rates or deposition loads. By filling this knowledge gap for the different tidal, inflow, and wind conditions (see modelling section), a more accurate risk assessment could be made in terms of the amount of material(s) actually reaching areas of concern. As noted earlier in this report, in the absence of validated and representative estimations or measures of sedimentation and sediment loads across the Mary River and within the Great Sandy Strait, the full extent of the loads reaching key habitats and the risk they pose cannot be fully determined.
- The modelling work in this study showed a clear connection between the GSS and the southern areas of Hervey Bay. In view of this exchange and the potential changes in land uses, catchment condition, and the resultant materials entering the GSS, further investigation into the connectivity between the GSS and Hervey Bay is warranted in order to better understand the potential risks this poses to keystone habitats such as the coral reefs and seagrass beds that exist in the exchange zone.
- In order to better understand the full extent of any risk to specific habitats or species, it is suggested that the outputs from this study be used to target areas where water residence times and materials deposition are most likely to be high with the aim to identify vulnerable or “at risk” habitats, communities or species. These sites should be central to any field-based sedimentation investigations and any futurte monitoring.
- At the time of writing this report we are aware of some localised dredging activities within the Maryborough reaches of the Mary River (e.g. Byrne Brothers, DEHP Permit: EPPR00365213, Queens St., and adjacent areas), we are unable to obtain information as to the scale and potential significance of these limited operations. However, it should be noted here that where dredging is planned or expected in the future, activities like this can lead to the liberation of pollutant materials that have been deposited historically and buried, so that they are unavailable to current biological systems. In this light, and in order to understand historical conditions and potential periods of pollution, a more substantive study is required where deeper sediment cores are collected and analysed for nutrients and heavy metals as performed on surface sediments in this study. If performed correctly, this could also provide estimations of historic deposition rates so that current loads can be better contextualised against catchment management activities.
- During this study we were unable to identify any similar study for the GSS and only few studies in Australia where such high-resolution bathymetry and locally focussed modelling has been undertaken as done in this project. In this context, and with the view to better understanding the interactions between the GSS and Hervey Bay, consideration might be given to developing a higher resolution bathymetry data set for Hervey bay, or zone of potential GSS-Hervey Bay interaction. In doing so, the influence of management strategies influencing water quality in one ecosystem can be tested or assessed in terms of possible outcomes for the other.

References

Alongi, D.M. (2019) Coastal Ecosystem Processes**.** CRC Press Published September 27, 2019 Reference - 448 Pages ISBN 9780367400798 - CAT# K449611

Alongi, D. M., K. G. Boto, and F. Tirendi. (1989), Effect of exported mangrove litter on bacterial productivity and dissolved organic carbon fluxes in adjacent tropical nearshore sediments, *Mar. Ecol. Prog. Ser.*, 56, 133–144.

ANZECC & ARMCANZ (2000), Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Baléo, J.-N., Humeau, P., Cloirec, P.L., (2001). Numerical and experimental hydrodynamic studies of a lagoon pilot. Water Research 35, 2268-2276.

Beaman, R., (2010). Project 3DGBR: A high-resolution depth model for the Great Barrier Reef and Coral Sea. Marine and Tropical Sciences Research Facility (MTSRF) Project 2.5i.1a Final Report, MTSRF, Cairns, Australia, p. pp. 13.

Beaman, R.J. 2017. High-resolution depth model for the Great Barrier Reef - 30 m. Geoscience Australia, Canberra. http://dx.doi.org/10.4225/25/5a207b36022d2

Blair, T.C. and McPherson, J.G. (1999). Grain-size and textural classification of coarse sedimentary particles. Journal of Sedimentary Research 69: 6–19

Butler, I. R., B. Sommer, M. Zann, J-x Zhao and J. M. Pandolfi. (2013) The impacts of flooding on the high-latitude terrigenoclastic influenced coral reefs of Hervey Bay, Queensland, Australia. Coral Reefs 32(4):1149-1163

Butler, I. R., B. Sommer, M. Zann, J-x Zhao (2015) The cumulative impacts of repeated heavy rainfall, flooding and altered Water quality on the high-latitude coral reefs of Hervey Bay, Queensland, Australia. Marine Pollution Bulletin 96(1-2)

CCME (2002), Canadian Sediment Quality Guidelines for the Protection of Aquatic Life — Summary Tables, Update 2002, Canadian Council of Ministers of the Environment, Winnipeg, Canada.

Cheynet, E., (2020). Short introduction to generalized extreme value (GEV) distribution., MATLAB Central File Exchange.

Cucco, A., Umgiesser, G., (2006). Modelling the Venice Lagoon residence time. Ecological modelling 193, 34-51.

Egbert, G.D., Erofeeva, S.Y., (2002). Efficient Inverse Modelling of Barotropic Ocean Tides. Journal of Atmospheric and Oceanic Technology 19, 183-204.

Egger, M. et al., Environmental Science and Technology 49(1), 277-283, 2015

Gingras, M.K. (2012) Porosity and Permeability in: Bioturbated Sediments Developments in Sedimentology, Vol. 64.http://dx.doi.org/10.1016/B978-0-444-53813-0.00027-7#2012 Elsevier B.V.

Hanington, P. (2015) Biogeochemical Processes in permeable estuarine sediments following benthic community change: implications for system dynamics & Lyngbya Majuscule blooms in Deception Bay, Queensland. PhD Thesis, University of Queensland.

Hanington, P, Rose, A. and Johnstone R. (2016). The potential of benthic iron and phosphorus fluxes to support the growth of a bloom forming toxic cyanobacterium Lyngbya majuscula, Moreton Bay, Australia. Marine and Freshwater Research. http://dx.doi.org/10.1071/MF15219

Johnstone, R. W., Pantos, O. & Hanington, P. J. 2007. The role of benthic sediments in Lyngbya majuscula blooms in Deception Bay. Technical Report. South East Queensland Healthy Waterways Partnership, Brisbane.

Levin, N., Kidron, G.J., Ben-Dor, E., (2008). A field quantification of coastal dune perennial plants as indicators of surface stability, erosion or deposition. Sedimentology 55, 751-772.

Lucotte, M., Hillaire-Marcel, C. & Louchouarn, P. (1991) First-order organic carbon budget for the St. Lawrence Lower Estuary from 13C data. Estuarine, Coastal and Shelf Science 32, 297–312.

Maher, D.T. and Eyre, B.D. (2010). Benthic fluxes of dissolved organic carbon in three temperate Australian estuaries: Implications for global estimates of benthic DOC fluxes, J Geophys. Res: Biogeosciences. https://doi.org/10.1029/2010JG001433

Matson, E. A. & Brinson, M. M. (1990) Stable carbon isotopes and the C:N ratio in the estuaries of the Pamlico and Neuse Rivers, North Carolina. Limnology and Oceanography 35, 1290–1300.

Moss, P., Tibby, J., Shapland, F., Barr, C. and Fairfax, R. (2012). A report into the fire history of the Patterned Fens of the Great Sandy Region, South East Queensland. Unpublished report to the Burnett Mary Regional Group, Bundaberg, Queensland.

Moss, P., Dudgeon, A., Shapland, F., Withers, L., Brownhall, C., Terzano, D, Petherick, L. and Sloss, C. (2013). Investigation into the vegetation and fire history of the EPBC, Ramsar and WHA wetlands of the Great Sandy Straits, South East Queensland. Unpublished report to the Burnett Mary Regional Group, Bundaberg, Queensland.

Pawlowicz, R., (2000). M_Map: A mapping package for Matlab. University of British Columbia Earth and Ocean Sciences. (Online]. Available: http://www. eos. ubc. ca/rich/map. html.

Reinicke, G.B. (2000) Small-scale Patchiness of Benthos and Sediment Parameters in a Tidal Mud-flat of the River Elbe Estuary (Germany). *Limnologica* 30: 183-192

Rohwerder, T. and W. Sand (2007) Microbial processing of metal sulfides, Springer, Netherlands. pp. 35-58, 10.1007/1-4020-5589-7_2

Roy, P.S. and Crawford E.A. (1984) Heavy Metals in a Contaminated Australian Estuary-Dispersion and Accumulation Trend. Estuarine, Coastal and Shelf Science 19,34 l-358

Saeedi, M., L.Y. Li, A.R. Karbassi and A.J. Zanjani (2013). *Environ Monit Assess*, 185, pp. 1737-1754, 10.1007/s10661-012-2664-3

Sanford, L.P., Boicourt, W.C., Rives, S.R., (1992). Model for estimating tidal flushing of small embayments. Journal of Waterway, Port, Coastal, and Ocean Engineering 118, 635-654.

Saunders, K. M., Harrison, J.J., Butler, E.C.V., Hodgson, D.A., and McMinn, A. (2013). Recent environmental change and trace metal pollution in World Heritage Bathurst Harbour, southwest Tasmania, Australia. J Paleolimnol (2013) 50:471–485. DOI 10.1007/s10933-013-9740-8

Sheldon, J.E., Alber, M., (2002). A comparison of residence time calculations using simple compartment models of the Altamaha River Estuary, Georgia. Estuaries 25, 1304-1317.

Simpson, SL & Batley, GE (2016), Sediment quality assessment; a practical handbook, CSIRO Publishing, Clayton, Vic., 346 pp.

Wang, C.-F., Hsu, M.-H., Kuo, A.Y., (2004). Residence time of the Danshuei River estuary, Taiwan. Estuarine, Coastal and Shelf Science 60, 381-393.

Whinney, J., Jones, R., Duckworth, A. *et al.* (2017). Continuous in situ monitoring of sediment deposition in shallow benthic environments. *Coral Reefs* **36,** 521–533. https://doi.org/10.1007/s00338-016-1536-7

Wollast, R. (1991), The coastal organic carbon cycle: Fluxes, sources and sinks, in *Ocean Margin Processes in Global Change*, edited by R. F. Mantoura, J.-M. Martin, and R. Wollast, pp. 365–381, John Wiley, Hoboken, N. J., Wright, I.A., Belmer, N., & Davies, P.J. (2017) Coal mine water pollution and ecological impairment of one of Australia's most 'protected' high conservation-value rivers. *Water, Air, Soil, Poll.*228(3):1-18.

Wulff, F., Eyre, B., & Johnstone, R. (2011) Nitrogen versus phosphorus limitation in a subtropical coastal embayment (Moreton Bay; Australia): Implications for management. *Ecological Modelling* 222: 120-130.

Zhang C., Zhi-gang Yu, Guang-ming Zeng, Min Jiang, Zhong-zhu Yang, Fang Cui, Meng-ying Zhu, Liu- qing Shen, and Liang Hu (2014) Effects of sediment geochemical properties on heavy metal bioavailability. *Env. International* 73: 270-281.

APPENDIX 1 Summary figures for sediment metal and nutrient content.

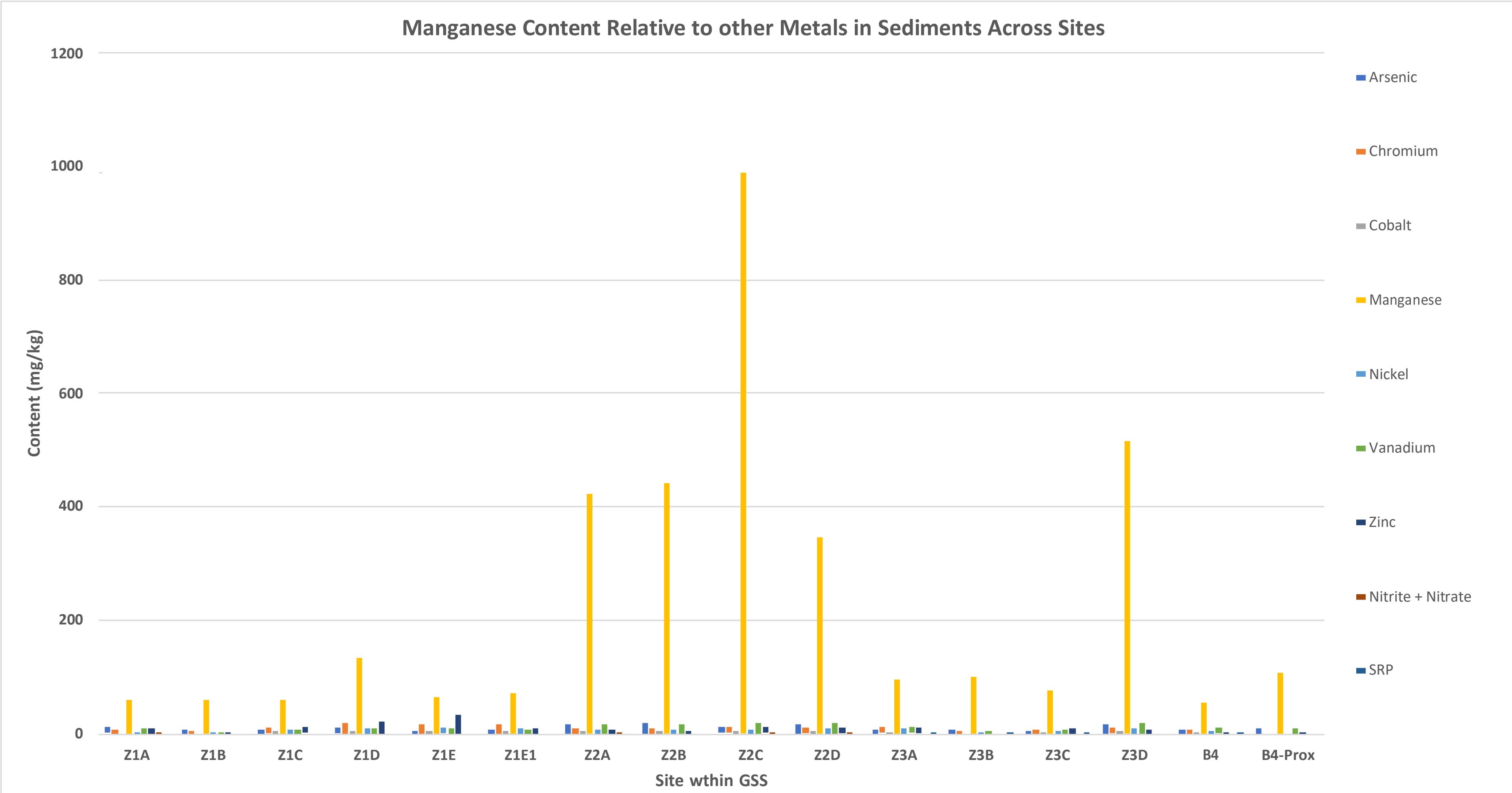


Figure 1. Average concentrations for heavy metals in sediments collected within the Great Sandy Strait. All values are in mg/kg of sediment.

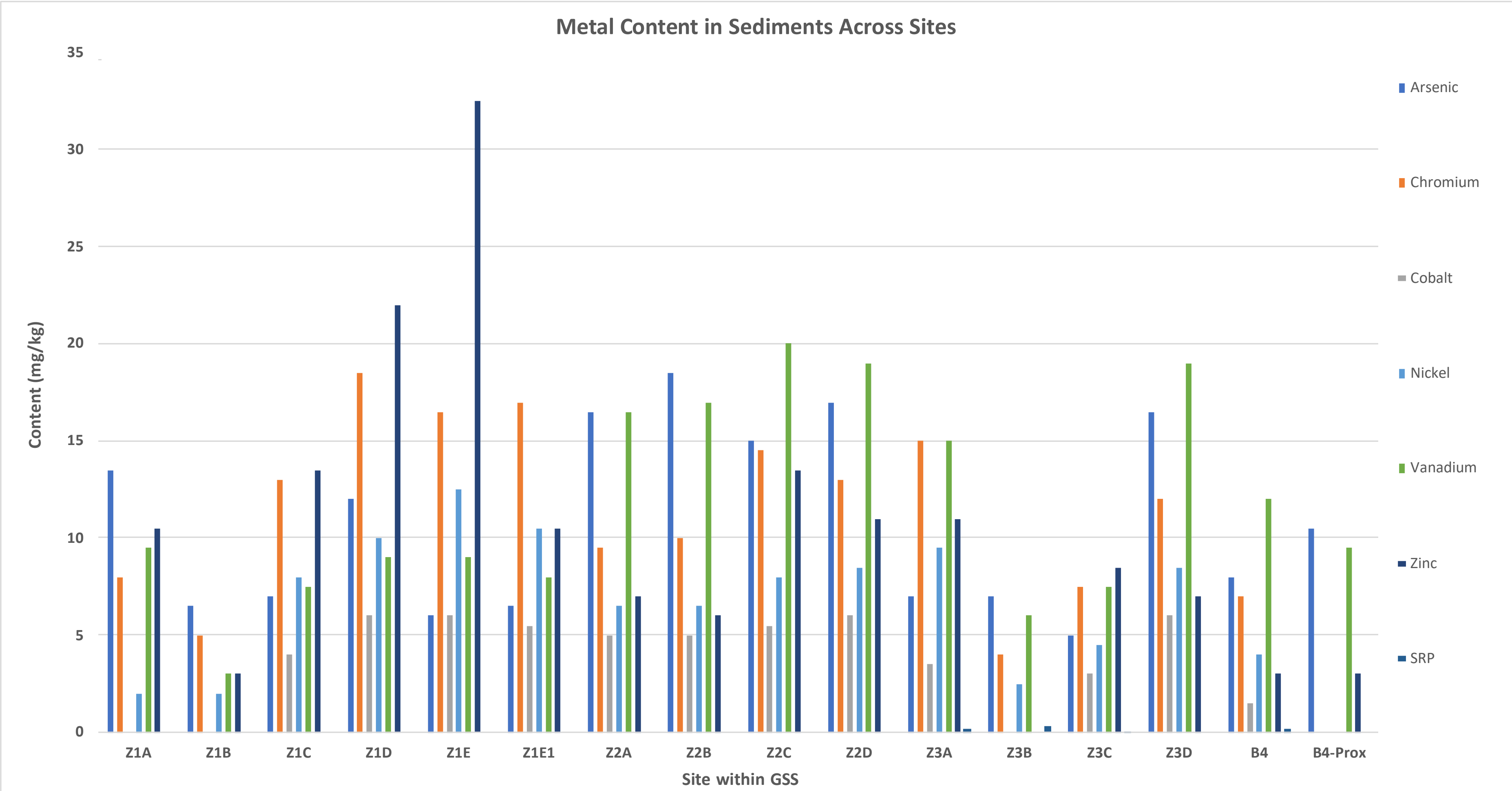


Figure 2. Average concentrations for heavy metals in sediments collected within the Great Sandy Strait excluding manganese. All values are in mg/kg of sediment.

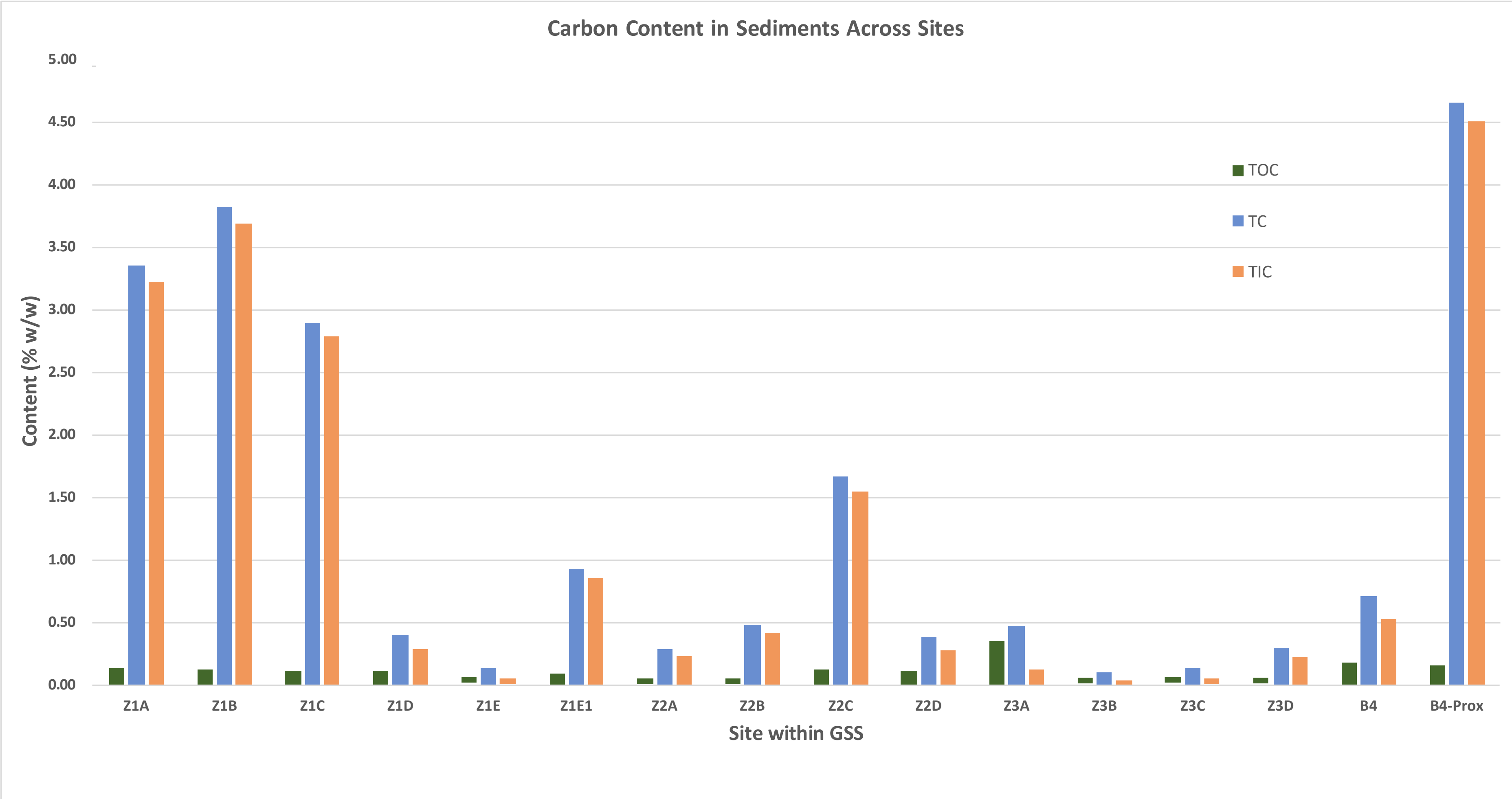


Figure 3. Average levels of total carbon (TC), total carbon (TOC), and total organic carbon (TOC) in sediments sampled across the Great Sandy Strait. All values are expressed as % composition weight for weight (%w/w), component/sediment.

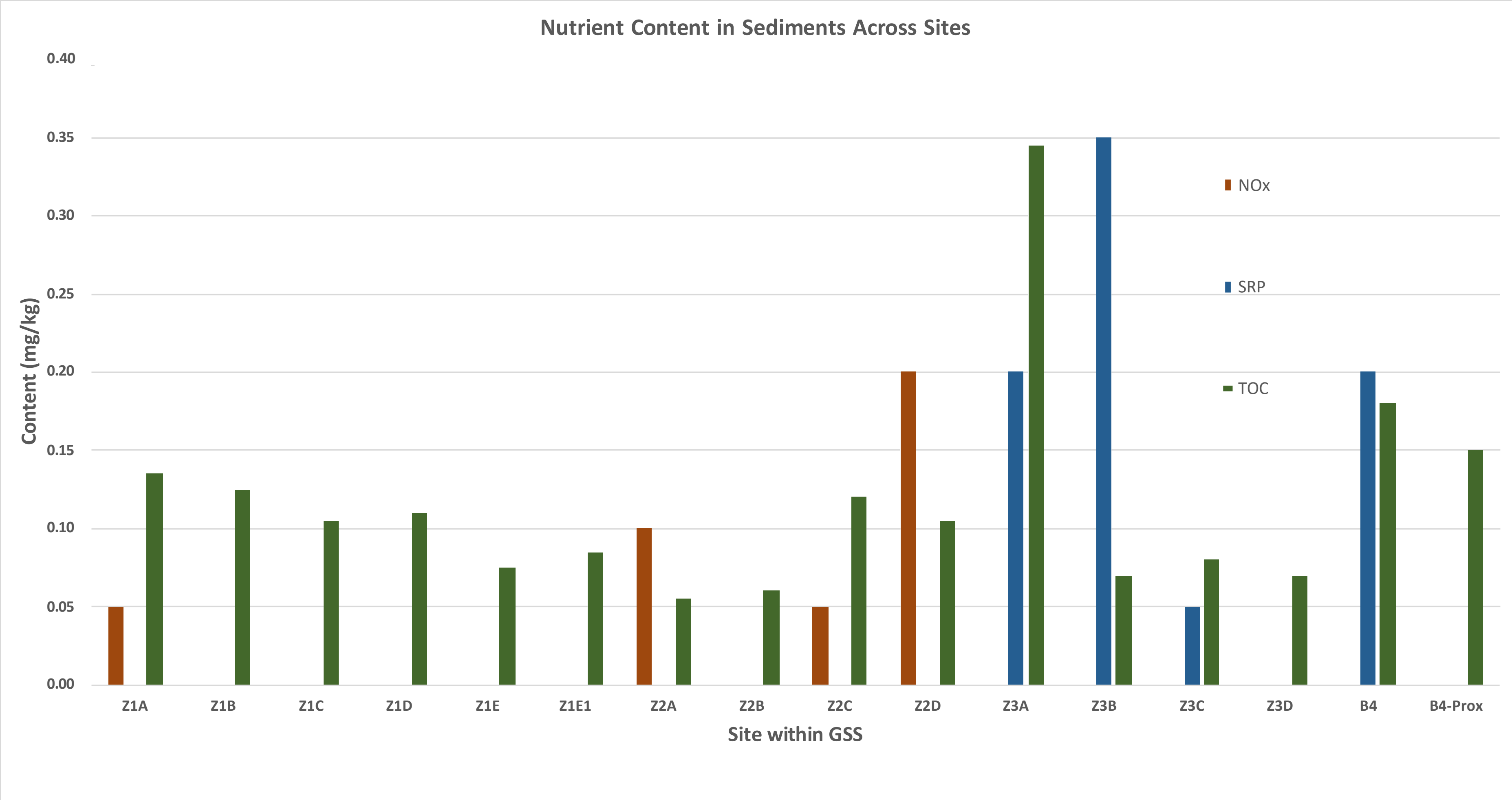


Figure 4. Total organic carbon (TOC), soluble nitrite and nitrate (NOx) and soluble reactive phosphorous (SRP) content in sediments collected across the Great Sandy Strait. All values are in mg/kg of sediment.

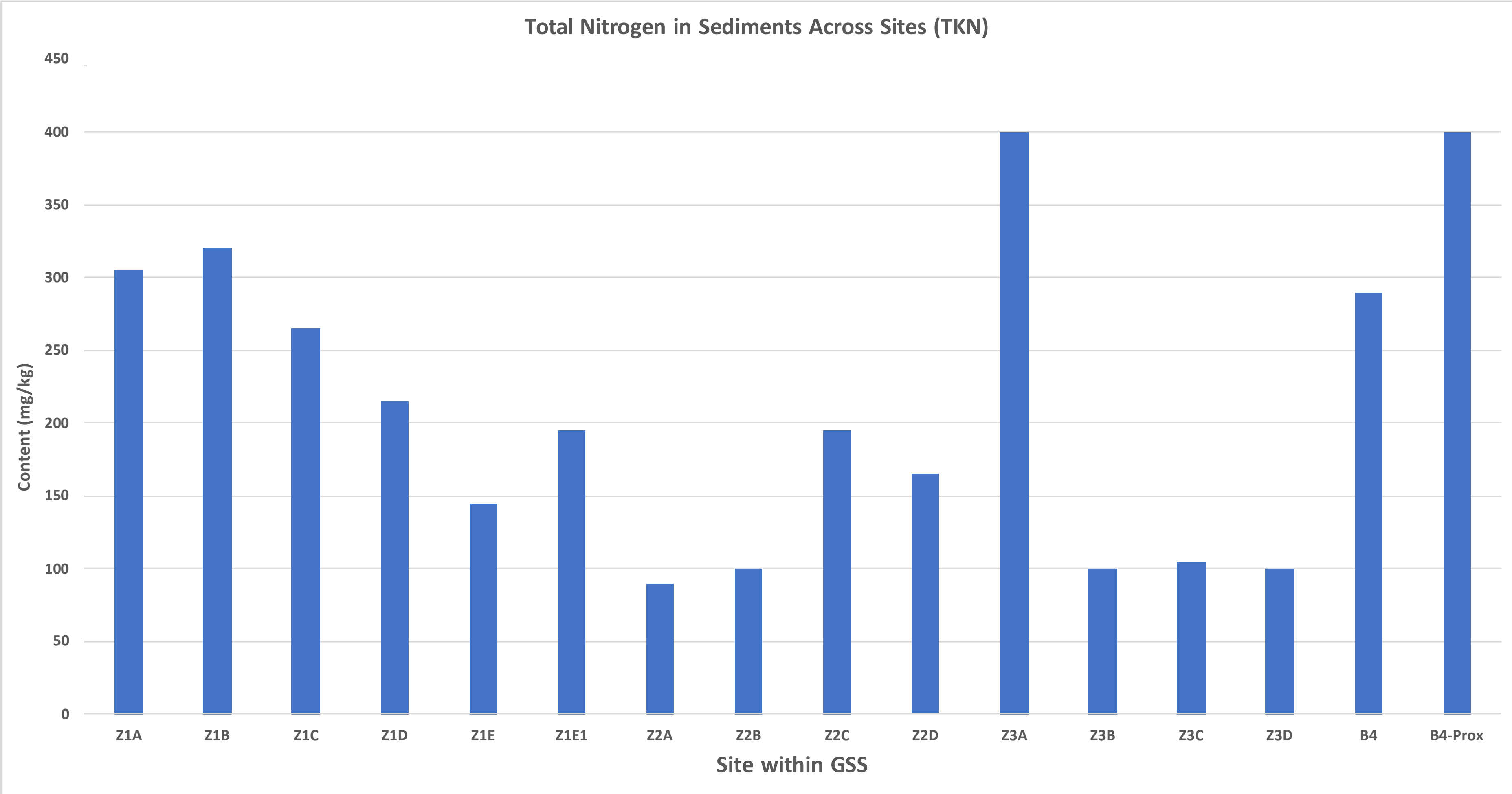


Figure 5. Average levels of total nitrogen (TKN) in sediments sampled across the Great Sandy Strait. All values are expressed as mg/kg of sediment.

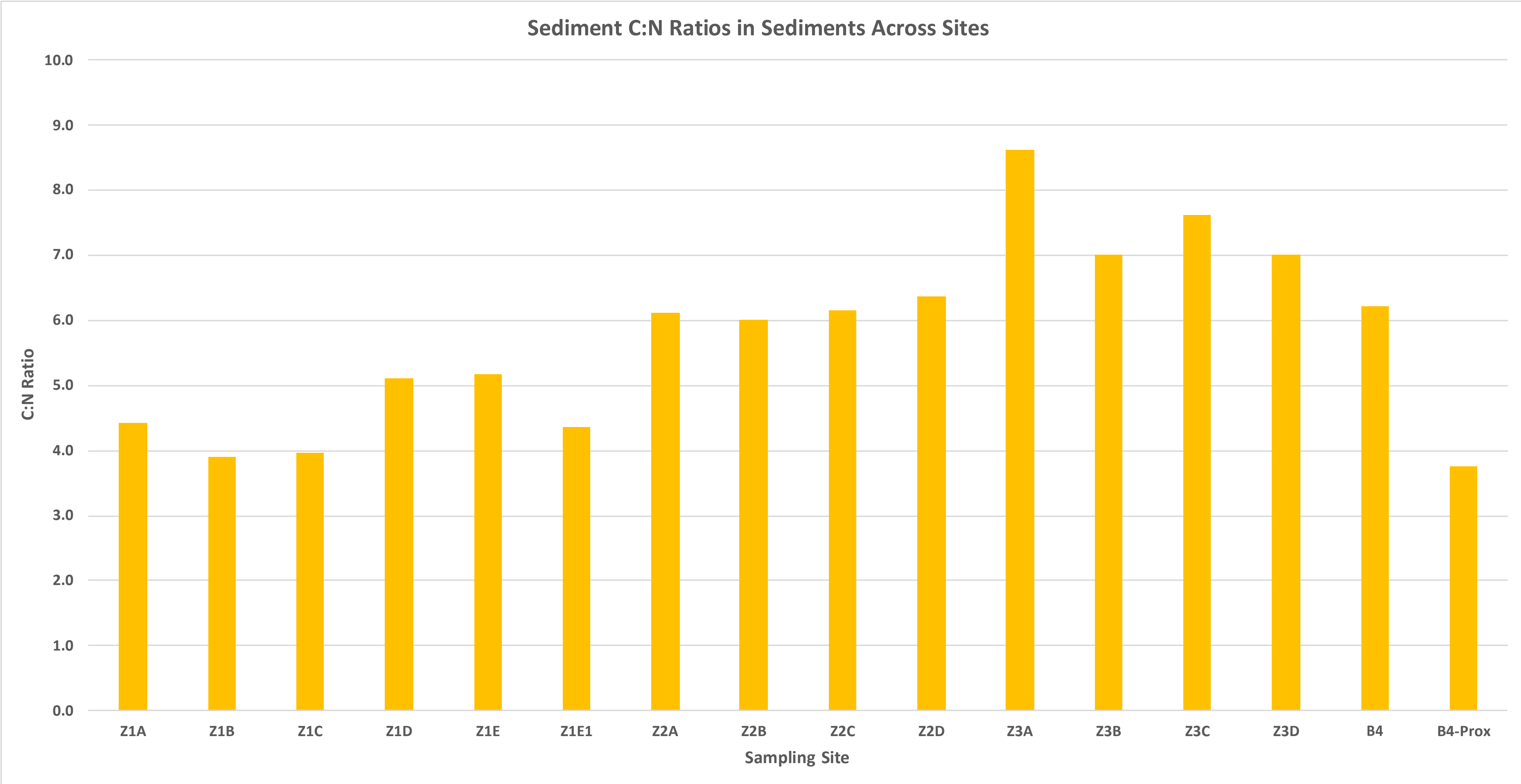


Figure 6 Average C:N ratios in sediments sampled across the Great Sandy Strait.

APPENDIX 2 Summary Report on Matters of National Ecological Significance

This summary was produced using the MNES reporting tool provided by the Australian Federal Government.
http://www.environment.gov.au/webgis-framework/apps/pmst/pmst.jsf

Australian Government

Department of Agriculture, Water and the Environment

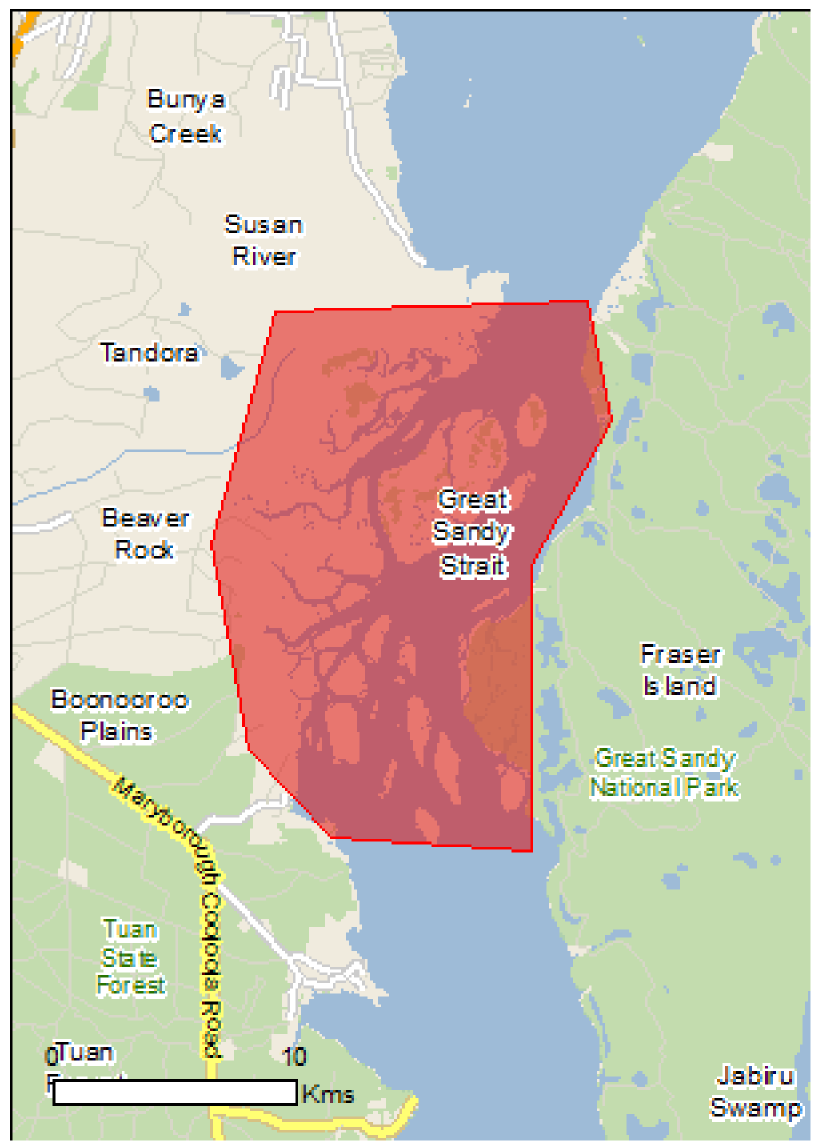
EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

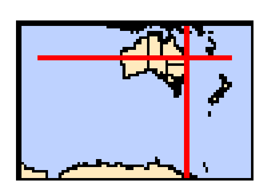
Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 31/03/21 20:11:54



Coordinates

Buffer: 0.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	1
National Heritage Places:	1
Wetlands of International Importance:	1
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	3
Listed Threatened Species:	68
Listed Migratory Species:	72

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	109
Whales and Other Cetaceans:	13
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	3
Regional Forest Agreements:	None
Invasive Species:	30
Nationally Important Wetlands:	2
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

World Heritage Properties [Resource Information]

Name	State	Status
Fraser Island	QLD	Declared property

National Heritage Properties [Resource Information]

Name	State	Status
Natural		
Fraser Island	QLD	Listed place

Wetlands of International Importance (Ramsar) [Resource Information]

Name	Proximity
Great sandy strait (including great sandy strait, tin can bay and tin can	Within Ramsar site

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Name	Status	Type of Presence
Coastal Swamp Oak (Casuarina glauca) Forest of New South Wales and South East Queensland ecological community	Endangered	Community likely to occur within area
Lowland Rainforest of Subtropical Australia	Critically Endangered	Community may occur within area
Subtropical and Temperate Coastal Saltmarsh	Vulnerable	Community likely to occur within area

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Anthochaera phrygia		
Regent Honeyeater [82338]	Critically Endangered	Foraging, feeding or related behaviour may occur within area
Botaurus poiciloptilus		
Australasian Bittern [1001]	Endangered	Species or species habitat may occur within area
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris tenuirostris		
Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius leschenaultii		
Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Roosting known to occur within area
Charadrius mongolus		
Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Erythrotriorchis radiatus		
Red Goshawk [942]	Vulnerable	Species or species habitat known to occur within area

Name	Status	Type of Presence
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat likely to occur within area
Fregetta grallaria grallaria White-bellied Storm-Petrel (Tasman Sea), White-bellied Storm-Petrel (Australasian) [64438]	Vulnerable	Species or species habitat likely to occur within area
Geophaps scripta scripta Squatter Pigeon (southern) [64440]	Vulnerable	Species or species habitat may occur within area
Hirundapus caudacutus White-throated Needletail [682]	Vulnerable	Species or species habitat known to occur within area
Lathamus discolor Swift Parrot [744]	Critically Endangered	Species or species habitat may occur within area
Limosa lapponica baueri Bar-tailed Godwit (baueri), Western Alaskan Bar-tailed Godwit [86380]	Vulnerable	Species or species habitat known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pachyptila turtur subantarctica Fairy Prion (southern) [64445]	Vulnerable	Species or species habitat likely to occur within area
Pterodroma neglecta neglecta Kermadec Petrel (western) [64450]	Vulnerable	Foraging, feeding or related behaviour may occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Species or species habitat may occur within area
Thalassarche eremita Chatham Albatross [64457]	Endangered	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche salvini Salvin's Albatross [64463]	Vulnerable	Species or species habitat may occur within area

Name	Status	Type of Presence
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Turnix melanogaster Black-breasted Button-quail [923]	Vulnerable	Species or species habitat likely to occur within area
Fish		
Hippocampus whitei White's Seahorse, Crowned Seahorse, Sydney Seahorse [66240]	Endangered	Species or species habitat likely to occur within area
Pseudomugil mellis Honey Blue Eye, Honey Blue-eye [26180]	Vulnerable	Species or species habitat may occur within area
Frogs		
Litoria olongburensis Wallum Sedge Frog [1821]	Vulnerable	Species or species habitat known to occur within area
Insects		
Argynnis hyperbius inconstans Australian Fritillary [88056]	Critically Endangered	Species or species habitat may occur within area
Mammals		
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat may occur within area
Chalinolobus dwyeri Large-eared Pied Bat, Large Pied Bat [183]	Vulnerable	Species or species habitat may occur within area
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat likely to occur within area
Dasyurus maculatus maculatus (SE mainland population) Spot-tailed Quoll, Spotted-tail Quoll, Tiger Quoll (southeastern mainland population) [75184]	Endangered	Species or species habitat may occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Congregation or aggregation known to occur within area
Petauroides volans Greater Glider [254]	Vulnerable	Species or species habitat may occur within area
Phascolarctos cinereus (combined populations of Qld, NSW and the ACT) Koala (combined populations of Queensland, New South Wales and the Australian Capital Territory) [85104]	Vulnerable	Species or species habitat known to occur within area
Potorous tridactylus tridactylus Long-nosed Potoroo (SE Mainland) [66645]	Vulnerable	Species or species habitat likely to occur within area
Pteropus poliocephalus Grey-headed Flying-fox [186]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Xeromys myoides Water Mouse, False Water Rat, Yirrkoo [66]	Vulnerable	Species or species habitat known to occur within area
Plants		

Name	Status	Type of Presence
Acacia attenuata [10690]	Vulnerable	Species or species habitat likely to occur within area
Archidendron lovelliae Bacon Wood, Tulip Siris [13451]	Vulnerable	Species or species habitat likely to occur within area
Bosistoa transversa Three-leaved Bosistoa, Yellow Satinheart [16091]	Vulnerable	Species or species habitat likely to occur within area
Cossinia australiana Cossinia [3066]	Endangered	Species or species habitat may occur within area
Cryptocarya foetida Stinking Cryptocarya, Stinking Laurel [11976]	Vulnerable	Species or species habitat may occur within area
Cryptostylis hunteriana Leafless Tongue-orchid [19533]	Vulnerable	Species or species habitat may occur within area
Cupaniopsis shirleyana Wedge-leaf Tuckeroo [3205]	Vulnerable	Species or species habitat likely to occur within area
Macadamia integrifolia Macadamia Nut, Queensland Nut Tree, Smooth-shelled Macadamia, Bush Nut, Nut Oak [7326]	Vulnerable	Species or species habitat likely to occur within area
Macrozamia pauli-guilielmi Pineapple Zamia [5712]	Endangered	Species or species habitat known to occur within area
Phaius australis Lesser Swamp-orchid [5872]	Endangered	Species or species habitat likely to occur within area
Rhodomyrtus psidioides Native Guava [19162]	Critically Endangered	Species or species habitat likely to occur within area
Samadera bidwillii Quassia [29708]	Vulnerable	Species or species habitat likely to occur within area
Reptiles		
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Coeranoscincus reticulatus Three-toed Snake-tooth Skink [59628]	Vulnerable	Species or species habitat likely to occur within area
Delma torquata Adorned Delma, Collared Delma [1656]	Vulnerable	Species or species habitat may occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Furina dunmalli Dunmall's Snake [59254]	Vulnerable	Species or species habitat may occur within

Name	Status	Type of Presence
		area
Lepidochelys olivacea		
Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour known to occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Sharks		
Carcharias taurus (east coast population)		
Grey Nurse Shark (east coast population) [68751]	Critically Endangered	Species or species habitat likely to occur within area
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding may occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus		
Common Noddy [825]		Species or species habitat known to occur within area
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardenna carneipes		
Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Species or species habitat known to occur within area
Ardenna grisea		
Sooty Shearwater [82651]		Species or species habitat may occur within area
Fregata ariel		
Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Fregata minor		
Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat likely to occur within area
Macronectes giganteus		
Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli		
Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Sternula albifrons		
Little Tern [82849]		Species or species habitat may occur within area
Thalassarche cauta		
Shy Albatross [89224]	Endangered	Species or species habitat may occur within area
Thalassarche eremita		
Chatham Albatross [64457]	Endangered	Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche salvini Salvin's Albatross [64463]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Migratory Marine Species		
Balaena glacialis australis Southern Right Whale [75529]	Endangered*	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat may occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat may occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Dugong dugon Dugong [28]		Species or species habitat known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Lamna nasus Porbeagle, Mackerel Shark [83288]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour known to occur within area
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat may occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific		Species or species

Name	Threatened	Type of Presence
Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		habitat may occur within area
Megaptera novaeangliae		
Humpback Whale [38]	Vulnerable	Congregation or aggregation known to occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcaella heinsohni		
Australian Snubfin Dolphin [81322]		Species or species habitat likely to occur within area
Orcinus orca		
Killer Whale, Orca [46]		Species or species habitat may occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding may occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Sousa chinensis		
Indo-Pacific Humpback Dolphin [50]		Breeding known to occur within area
Migratory Terrestrial Species		
Cuculus optatus		
Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat may occur within area
Hirundapus caudacutus		
White-throated Needletail [682]	Vulnerable	Species or species habitat known to occur within area
Monarcha melanopsis		
Black-faced Monarch [609]		Species or species habitat likely to occur within area
Monarcha trivirgatus		
Spectacled Monarch [610]		Species or species habitat likely to occur within area
Myiagra cyanoleuca		
Satin Flycatcher [612]		Species or species habitat known to occur within area
Rhipidura rufifrons		
Rufous Fantail [592]		Species or species habitat likely to occur within area
Migratory Wetlands Species		
Actitis hypoleucos		
Common Sandpiper [59309]		Species or species habitat known to occur within area
Arenaria interpres		
Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba		
Sanderling [875]		Roosting known to occur within area
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur

Name	Threatened	Type of Presence
		within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area
Calidris subminuta Long-toed Stint [861]		Roosting known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius bicinctus Double-banded Plover [895]		Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Roosting known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]		Species or species habitat likely to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting likely to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pandion haliaetus Osprey [952]		Species or species habitat known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Tringa brevipes Grey-tailed Tattler [851]		Roosting known to occur within area
Tringa incana Wandering Tattler [831]		Roosting known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur

Name	Threatened	Type of Presence
		within area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat known to occur within area
Anseranas semipalmata Magpie Goose [978]		Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat known to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area

Name	Threatened	Type of Presence
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area
Calidris subminuta Long-toed Stint [861]		Roosting known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius bicinctus Double-banded Plover [895]		Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Roosting known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Charadrius ruficapillus Red-capped Plover [881]		Roosting known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat likely to occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]		Species or species habitat likely to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Heteroscelus brevipes Grey-tailed Tattler [59311]		Roosting known to occur within area
Heteroscelus incanus Wandering Tattler [59547]		Roosting known to occur within area
Himantopus himantopus Pied Stilt, Black-winged Stilt [870]		Roosting known to occur within area
Hirundapus caudacutus White-throated Needletail [682]	Vulnerable	Species or species habitat known to occur within area
Lathamus discolor Swift Parrot [744]	Critically Endangered	Species or species habitat may occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area

Name	Threatened	Type of Presence
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat likely to occur within area
Monarcha trivirgatus Spectacled Monarch [610]		Species or species habitat likely to occur within area
Myiagra cyanoleuca Satin Flycatcher [612]		Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting likely to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pachyptila turtur Fairy Prion [1066]		Species or species habitat likely to occur within area
Pandion haliaetus Osprey [952]		Species or species habitat known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [1043]		Species or species habitat known to occur within area
Puffinus griseus Sooty Shearwater [1024]		Species or species habitat may occur within area
Recurvirostra novaehollandiae Red-necked Avocet [871]		Roosting known to occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat likely to occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat likely to occur within area
Sterna albifrons Little Tern [813]		Species or species habitat may occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Species or species

Name	Threatened	Type of Presence
		habitat may occur within area
Thalassarche eremita Chatham Albatross [64457]	Endangered	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche salvini Salvin's Albatross [64463]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area
Fish		
Acentronura tentaculata Shortpouch Pygmy Pipehorse [66187]		Species or species habitat may occur within area
Campichthys tryoni Tryon's Pipefish [66193]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys ocellatus Orange-spotted Pipefish, Ocellated Pipefish [66203]		Species or species habitat may occur within area
Festucalex cinctus Girdled Pipefish [66214]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Hippichthys cyanospilos Blue-speckled Pipefish, Blue-spotted Pipefish [66228]		Species or species habitat may occur within area
Hippichthys heptagonus Madura Pipefish, Reticulated Freshwater Pipefish [66229]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Hippocampus kelloggi Kellogg's Seahorse, Great Seahorse [66723]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Hippocampus whitei White's Seahorse, Crowned Seahorse, Sydney Seahorse [66240]	Endangered	Species or species habitat likely to occur within area
Lissocampus runa Javelin Pipefish [66251]		Species or species habitat may occur within area
Maroubra perserrata Sawtooth Pipefish [66252]		Species or species habitat may occur within area
Micrognathus andersonii Anderson's Pipefish, Shortnose Pipefish [66253]		Species or species habitat may occur within area
Micrognathus brevirostris thorntail Pipefish, Thorn-tailed Pipefish [66254]		Species or species habitat may occur within area
Microphis manadensis Manado Pipefish, Manado River Pipefish [66258]		Species or species habitat may occur within area
Solegnathus dunckeri Duncker's Pipehorse [66271]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus spinosissimus Spiny Pipehorse, Australian Spiny Pipehorse [66275]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Solenostomus paradoxus Ornate Ghostpipefish, Harlequin Ghost Pipefish, Ornate Ghost Pipefish [66184]		Species or species habitat may occur within area
Stigmatopora nigra Widebody Pipefish, Wide-bodied Pipefish, Black Pipefish [66277]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Urocampus carinirostris Hairy Pipefish [66282]		Species or species habitat may occur within area
Vanacampus margaritifer Mother-of-pearl Pipefish [66283]		Species or species habitat may occur within area
Mammals		
Dugong dugon Dugong [28]		Species or species habitat known to occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Laticauda colubrina a sea krait [1092]		Species or species habitat may occur within area
Laticauda laticaudata a sea krait [1093]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or

Name	Threatened	Type of Presence
		related behaviour known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans [Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat may occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Congregation or aggregation known to occur within area
Orcaella brevirostris Irrawaddy Dolphin [45]		Species or species habitat likely to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Breeding known to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area

Extra Information

State and Territory Reserves	[Resource Information]
Name	State
Great Sandy	QLD
Great Sandy	QLD
Poona	QLD

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Acridotheres tristis Common Myna, Indian Myna [387]		Species or species habitat likely to occur within area
Anas platyrhynchos Mallard [974]		Species or species habitat likely to occur within area
Carduelis carduelis European Goldfinch [403]		Species or species habitat likely to occur within area
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Lonchura punctulata Nutmeg Mannikin [399]		Species or species habitat likely to occur within area
Passer domesticus House Sparrow [405]		Species or species habitat likely to occur within area
Streptopelia chinensis Spotted Turtle-Dove [780]		Species or species habitat likely to occur within area
Sturnus vulgaris Common Starling [389]		Species or species habitat likely to occur within area
Turdus merula Common Blackbird, Eurasian Blackbird [596]		Species or species habitat likely to occur within area
Frogs		
Rhinella marina Cane Toad [83218]		Species or species habitat known to occur within area
Mammals		
Bos taurus Domestic Cattle [16]		Species or species habitat likely to occur within area
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area
Equus caballus Horse [5]		Species or species habitat likely to occur within area

Name	Status	Type of Presence
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Lepus capensis Brown Hare [127]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Rattus norvegicus Brown Rat, Norway Rat [83]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Sus scrofa Pig [6]		Species or species habitat likely to occur within area
Vulpes vulpes Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Chrysanthemoides monilifera Bitou Bush, Boneseed [18983]		Species or species habitat may occur within area
Chrysanthemoides monilifera subsp. rotundata Bitou Bush [16332]		Species or species habitat likely to occur within area
Cryptostegia grandiflora Rubber Vine, Rubbervine, India Rubber Vine, India Rubbervine, Palay Rubbervine, Purple Allamanda [18913]		Species or species habitat likely to occur within area
Lantana camara Lantana, Common Lantana, Kamara Lantana, Large-leaf Lantana, Pink Flowered Lantana, Red Flowered Lantana, Red-Flowered Sage, White Sage, Wild Sage [10892]		Species or species habitat likely to occur within area
Opuntia spp. Prickly Pears [82753]		Species or species habitat likely to occur within area
Parthenium hysterophorus Parthenium Weed, Bitter Weed, Carrot Grass, False Ragweed [19566]		Species or species habitat likely to occur within area
Salvinia molesta Salvinia, Giant Salvinia, Aquarium Watermoss, Kariba Weed [13665]		Species or species habitat likely to occur within area
Reptiles		
Hemidactylus frenatus Asian House Gecko [1708]		Species or species habitat likely to occur within area
Ramphotyphlops braminus Flowerpot Blind Snake, Brahminy Blind Snake, Cacing Besi [1258]		Species or species habitat may occur within area

Nationally Important Wetlands

[Resource Information]

Name	State
Fraser Island	QLD
Great Sandy Strait	QLD

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-25.445821 152.868957,-25.445821 152.868957,-25.44148 152.985343,-25.482087 152.993926,-25.530116 152.964401,-25.626425 152.964057,-25.621782 152.889556,-25.59175 152.859344,-25.5233 152.845268,-25.445821 152.868957

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

- -Office of Environment and Heritage, New South Wales
- -Department of Environment and Primary Industries, Victoria
- -Department of Primary Industries, Parks, Water and Environment, Tasmania
- -Department of Environment, Water and Natural Resources, South Australia
- -Department of Land and Resource Management, Northern Territory
- -Department of Environmental and Heritage Protection, Queensland
- -Department of Parks and Wildlife, Western Australia
- -Environment and Planning Directorate, ACT
- -Birdlife Australia
- -Australian Bird and Bat Banding Scheme
- -Australian National Wildlife Collection
- -Natural history museums of Australia
- -Museum Victoria
- -Australian Museum
- -South Australian Museum
- -Queensland Museum
- -Online Zoological Collections of Australian Museums
- -Queensland Herbarium
- -National Herbarium of NSW
- -Royal Botanic Gardens and National Herbarium of Victoria
- -Tasmanian Herbarium
- -State Herbarium of South Australia
- -Northern Territory Herbarium
- -Western Australian Herbarium
- -Australian National Herbarium, Canberra
- -University of New England
- -Ocean Biogeographic Information System
- -Australian Government, Department of Defence
- Forestry Corporation, NSW
- -Geoscience Australia
- -CSIRO
- -Australian Tropical Herbarium, Cairns
- -eBird Australia
- -Australian Government – Australian Antarctic Data Centre
- -Museum and Art Gallery of the Northern Territory
- -Australian Government National Environmental Science Program
- -Australian Institute of Marine Science
- -Reef Life Survey Australia
- -American Museum of Natural History
- -Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
- -Tasmanian Museum and Art Gallery, Hobart, Tasmania
- -Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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APPENDIX 3 Summary Report on Matters of State Ecological Significance

This summary was produced using the MSES reporting tool provided by the Queensland State Government.
https://www.qld.gov.au/environment/pollution/management/environmental-reports-online

Queensland Government

Department of Environment and Science

Environmental Reports

Matters of State Environmental Significance

For the selected area of interest
Longitude: 152.934817 Latitude: -25.465321 with 2 kilometre radius

Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or area of interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "central coordinates" option, the resulting assessment area encompasses an area extending for a 2km radius from the point of interest.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 1994). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no values have been identified within the site.

The information presented in this report should be considered as a guide only and field survey may be required to validate values on the ground.

Please direct queries about these reports to: Planning.Support@des.qld.gov.au

Disclaimer

Whilst every care is taken to ensure the accuracy of the information provided in this report, the Queensland Government makes no representations or warranties about its accuracy, reliability, completeness, or suitability, for any particular purpose and disclaims all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which the user may incur as a consequence of the information being inaccurate or incomplete in any way and for any reason.

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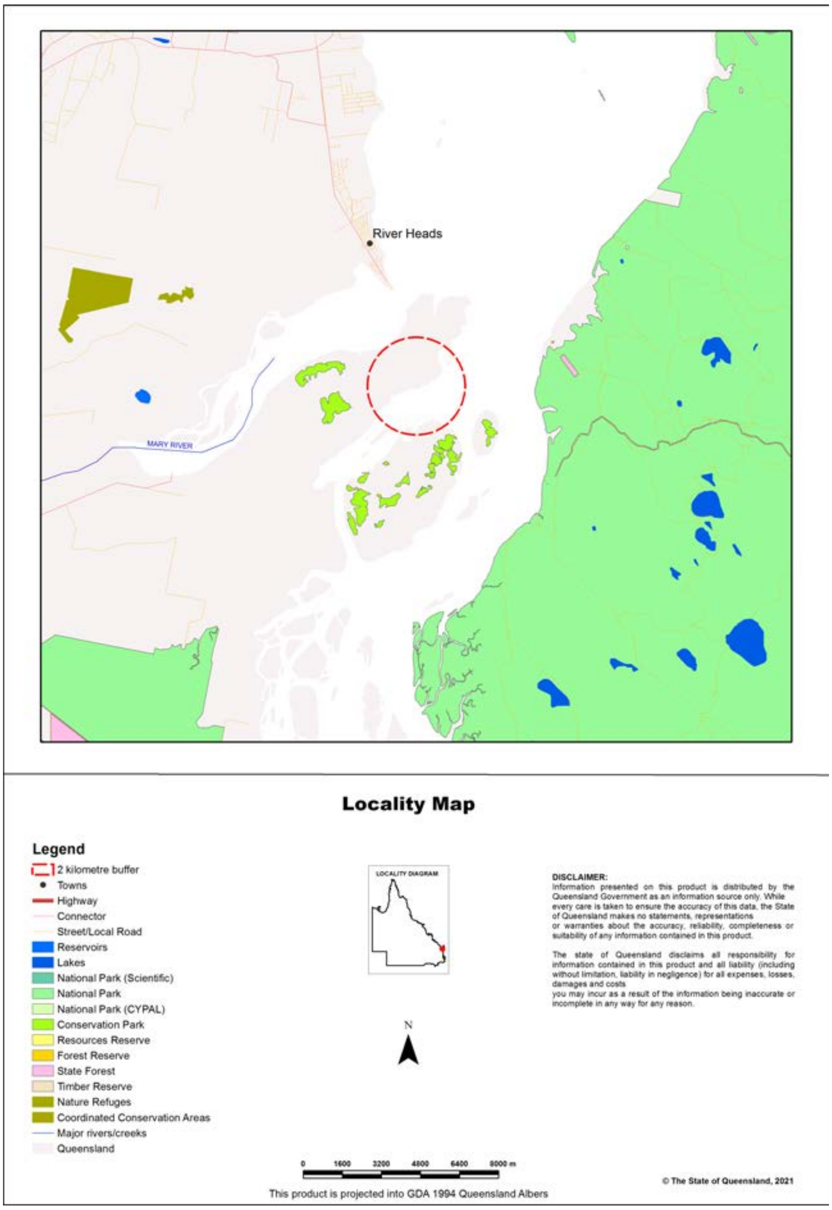
Assessment Area Details

The following table provides an overview of the area of interest (AOI) with respect to selected topographic and environmental values.

Table 1: Summary table, details for AOI Longitude: 152.934817 Latitude: -25.465321

Size (ha)	1,256.55
Local Government(s)	Fraser Coast Regional
Bioregion(s)	Southeast Queensland
Subregion(s)	Great Sandy, Burnett - Curtis Coastal Lowlands
Catchment(s)	Coral Sea, Noosa, Mary



Matters of State Environmental Significance (MSES)

MSES Categories

Queensland's State Planning Policy (SPP) includes a biodiversity State interest that states:

'The sustainable, long-term conservation of biodiversity is supported. Significant impacts on matters of national or state environmental significance are avoided, or where this cannot be reasonably achieved; impacts are minimised and residual impacts offset.'

The MSES mapping product is a guide to assist planning and development assessment decision-making. Its primary purpose is to support implementation of the SPP biodiversity policy. While it supports the SPP, the mapping does not replace the regulatory mapping or environmental values specifically called up under other laws or regulations. Similarly, the SPP biodiversity policy does not override or replace specific requirements of other Acts or regulations.

The SPP defines matters of state environmental significance as:

- Protected areas (including all classes of protected area except coordinated conservation areas) under the *Nature Conservation Act 1992* ;

- Marine parks and land within a 'marine national park', 'conservation park', 'scientific research', 'preservation' or 'buffer' zone under the *Marine Parks Act 2004* ;

- Areas within declared fish habitat areas that are management A areas or management B areas under the Fisheries Regulation 2008;

- Threatened wildlife under the *Nature Conservation Act 1992* and special least concern animals under the Nature Conservation (Wildlife) Regulation 2006;

- Regulated vegetation under the *Vegetation Management Act 1999* that is:

    • Category B areas on the regulated vegetation management map, that are 'endangered' or 'of concern' regional ecosystems;

    • Category C areas on the regulated vegetation management map that are 'endangered' or 'of concern' regional ecosystems;

    • Category R areas on the regulated vegetation management map;

    • Regional ecosystems that intersect with watercourses identified on the vegetation management watercourse and drainage feature map;

    • Regional ecosystems that intersect with wetlands identified on the vegetation management wetlands map;

- Strategic Environmental Areas under the *Regional Planning Interests Act 2014* ;

- Wetlands in a wetland protection area of wetlands of high ecological significance shown on the Map of Queensland Wetland Environmental Values under the Environment Protection Regulation 2019;

- Wetlands and watercourses in high ecological value waters defined in the Environmental Protection (Water) Policy 2009, schedule 2;

- Legally secured offset areas.

MSES Values Present

The MSES values that are present in the area of interest are summarised in the table below:

Table 2: Summary of MSES present within the AOI

1a Protected Areas- estates	0.0 ha	0.0 %
1b Protected Areas- nature refuges	0.0 ha	0.0 %
1c Protected Areas- special wildlife reserves	0.0 ha	0.0 %
2 State Marine Parks- highly protected zones	0.0 ha	0.0 %
3 Fish habitat areas (A and B areas)	1243.78 ha	99.0%
4 Strategic Environmental Areas (SEA)	0.0 ha	0.0 %
5 High Ecological Significance wetlands on the map of Referable Wetlands	575.82 ha	45.8%
6a High Ecological Value (HEV) wetlands	1228.78 ha	97.8%
6b High Ecological Value (HEV) waterways **	8.9 km	Not applicable
7a Threatened (endangered or vulnerable) wildlife	153.63 ha	12.2%
7b Special least concern animals	0.0 ha	0.0 %
7c i Koala habitat area - core (SEQ)	0.0 ha	0.0 %
7c ii Koala habitat area - locally refined (SEQ)	0.0 ha	0.0 %
8a Regulated Vegetation - Endangered/Of concern in Category B (remnant)	59.47 ha	4.7%
8b Regulated Vegetation - Endangered/Of concern in Category C (regrowth)	0.0 ha	0.0 %
8c Regulated Vegetation - Category R (GBR riverine regrowth)	0.0 ha	0.0 %
8d Regulated Vegetation - Essential habitat	120.46 ha	9.6%
8e Regulated Vegetation - intersecting a watercourse **	8.9 km	Not applicable
8f Regulated Vegetation - within 100m of a Vegetation Management Wetland	94.94 ha	7.6%
9a Legally secured offset areas- offset register areas	0.0 ha	0.0 %
9b Legally secured offset areas- vegetation offsets through a Property Map of Assessable Vegetation	0.0 ha	0.0 %

Additional Information with Respect to MSES Values Present

MSES - State Conservation Areas

1a. Protected Areas - estates

(no results)

1b. Protected Areas - nature refuges

(no results)

1c. Protected Areas - special wildlife reserves

(no results)

2. State Marine Parks - highly protected zones

(no results)

3. Fish habitat areas (A and B areas)

Type	Type abbreviated	Declared plan link
Fish Habitat Area	FHAA	http://www.npsr.qld.gov.au/managing/pdf/maaroom.pdf

Refer to **Map 1 - MSES - State Conservation Areas** for an overview of the relevant MSES.

MSES - Wetlands and Waterways

4. Strategic Environmental Areas (SEA)

(no results)

5. High Ecological Significance wetlands on the Map of Queensland Wetland Environmental Values

Natural wetlands that are 'High Ecological Significance' (HES) on the Map of Queensland Wetland Environmental Values are present.

6a. Wetlands in High Ecological Value (HEV) waters

Natural wetlands that occur in HEV (maintain) freshwater and estuarine areas under the Environmental Protection (water) Policy are present.

6b. Waterways in High Ecological Value (HEV) waters

Natural waterways that occur in HEV (maintain) freshwater and estuarine areas under the Environmental Protection (water) Policy are present.

Refer to **Map 2 - MSES - Wetlands and Waterways** for an overview of the relevant MSES.

MSES - Species

7a. Threatened (endangered or vulnerable) wildlife

Values are present

7b. Special least concern animals

Not applicable

7c i. Koala habitat area - core (SEQ)

Not applicable

7c ii. Koala habitat area - locally refined (SEQ)

Not applicable

Threatened (endangered or vulnerable) wildlife habitat suitability models

Species	Common name	NCA status	Presence
Boronia keysii		V	None
Calyptorhynchus lathami	Glossy black cockatoo	V	None
Casuarius casuarius johnsonii	Sthn population cassowary	E	None
Crinia tinnula	Wallum froglet	V	Core
Denisonia maculata	Ornamental snake	V	None
Litoria freycineti	Wallum rocketfrog	V	Core
Litoria olongburensis	Wallum sedgefrog	V	None
Melaleuca irbyana		E	None
Petaurus gracilis	Mahogany Glider	E	None
Petrogale persephone	Proserpine rock-wallaby	E	None
Phascolarctos cinereus	Koala - outside SEQ*	V	Core
Pezoporus wallicus wallicus	Eastern ground parrot	V	None
Taudactylus pleione	Kroombit tinkerfrog	E	None
Xeromys myoides	Water Mouse	V	None

**For koala model, this includes areas outside SEQ. Check 7c SEQ koala habitat for presence/absence.*

Threatened (endangered or vulnerable) wildlife species records

Scientific name	**Common name**	**NCA status**	**EPBC status**	**Migratory status**
Numenius madagascariensis	eastern curlew	E	CE	M-C/J/R/B/E
Acrodipsas illidgei	Illidge's ant-blue	V		

Special least concern animal species records

(no results)

**Nature Conservation Act 1992 (NCA) Status- Endangered (E), Vulnerable (V) or Special Least Concern Animal (SL). Environment Protection and Biodiversity Conservation Act 1999 (EPBC) status: Critically Endangered (CE) Endangered (E), Vulnerable (V)*

Migratory status (M) - China and Australia Migratory Bird Agreement (C), Japan and Australia Migratory Bird Agreement (J), Republic of Korea and Australia Migratory Bird Agreement (R), Bonn Migratory Convention (B), Eastern Flyway (E)

To request a species list for an area, or search for a species profile, access Wildlife Online at:
https://www.qld.gov.au/environment/plants-animals/species-list/

Refer to **Map 3a - MSES - Species - Threatened (endangered or vulnerable) wildlife and special least concern animals** and **Map 3b - MSES - Species - Koala habitat area (SEQ)** for an overview of the relevant MSES.

MSES - Regulated Vegetation

For further information relating to regional ecosystems in general, go to:
https://www.qld.gov.au/environment/plants-animals/plants/ecosystems/
For a more detailed description of a particular regional ecosystem, access the regional ecosystem search page at:
https://environment.ehp.qld.gov.au/regional-ecosystems/

8a. Regulated Vegetation - Endangered/Of concern in Category B (remnant)

Regional ecosystem	Vegetation management polygon	Vegetation management status
12.3.20	E-dom	rem_end
12.5.2a	E-dom	rem_end
12.3.11	O-dom	rem_oc

8b. Regulated Vegetation - Endangered/Of concern in Category C (regrowth)

Not applicable

8c. Regulated Vegetation - Category R (GBR riverine regrowth)

Not applicable

8d. Regulated Vegetation - Essential habitat

Values are present

8e. Regulated Vegetation - intersecting a watercourse**

A vegetation management watercourse is mapped as present

8f. Regulated Vegetation - within 100m of a Vegetation Management wetland

Regulated vegetation map category	Map number	RVM rule
B	9447	2

Refer to **Map 4 - MSES - Regulated Vegetation** for an overview of the relevant MSES.

MSES - Offsets

9a. Legally secured offset areas - offset register areas

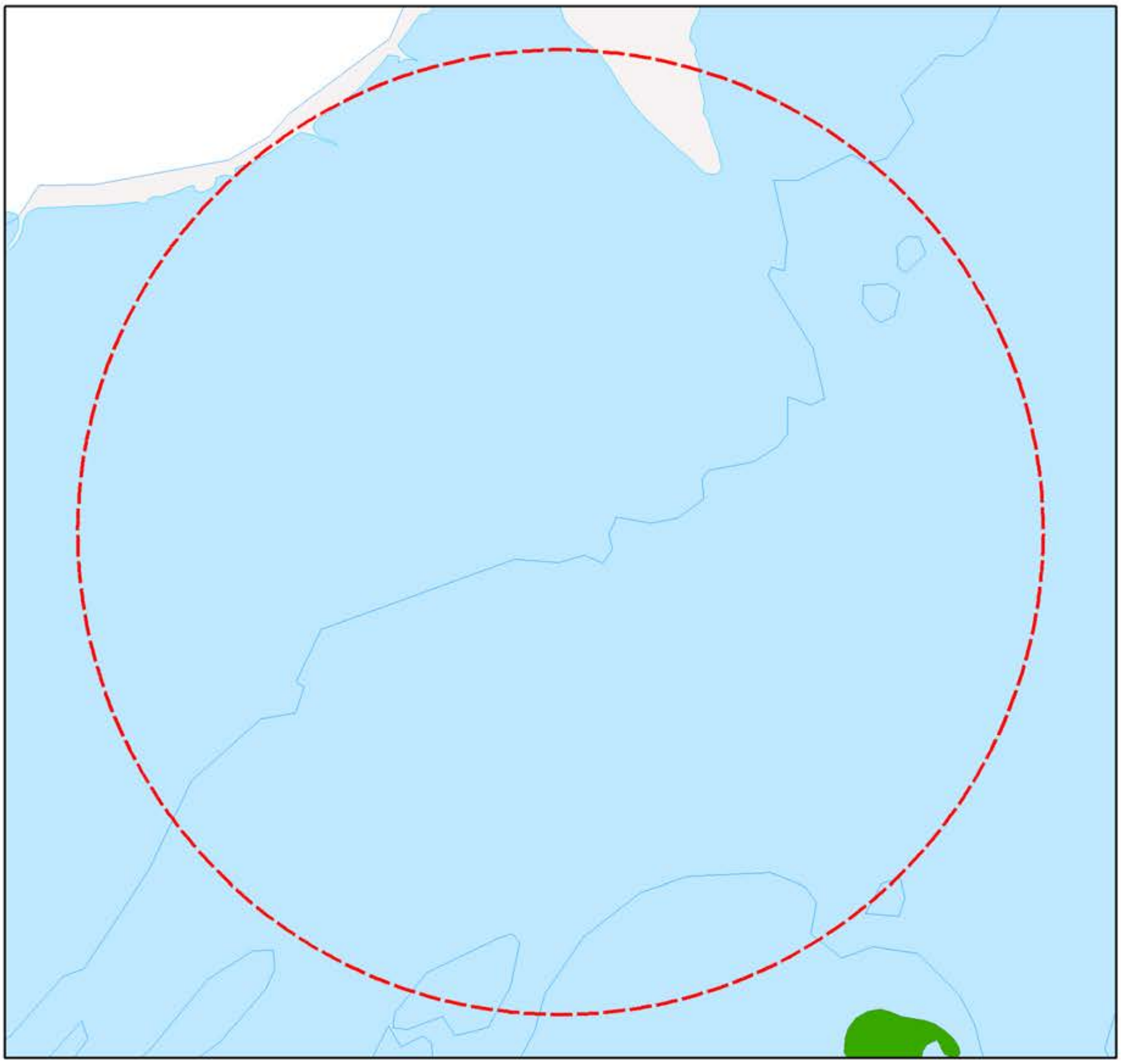
(no results)

9b. Legally secured offset areas - vegetation offsets through a Property Map of Assessable Vegetation

(no results)

Refer to **Map 5 - MSES - Offset Areas** for an overview of the relevant MSES.

Map 1 - MSES - State Conservation Areas



MSES - State Conservation Areas

Area of Interest

- 2 kilometre buffer
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Protected area (estates, nature refuges, special wildlife reserves)
- Declared fish habitat area (A and B areas)
- Marine park (highly protected)

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0 250 500 750 1000 1250 m

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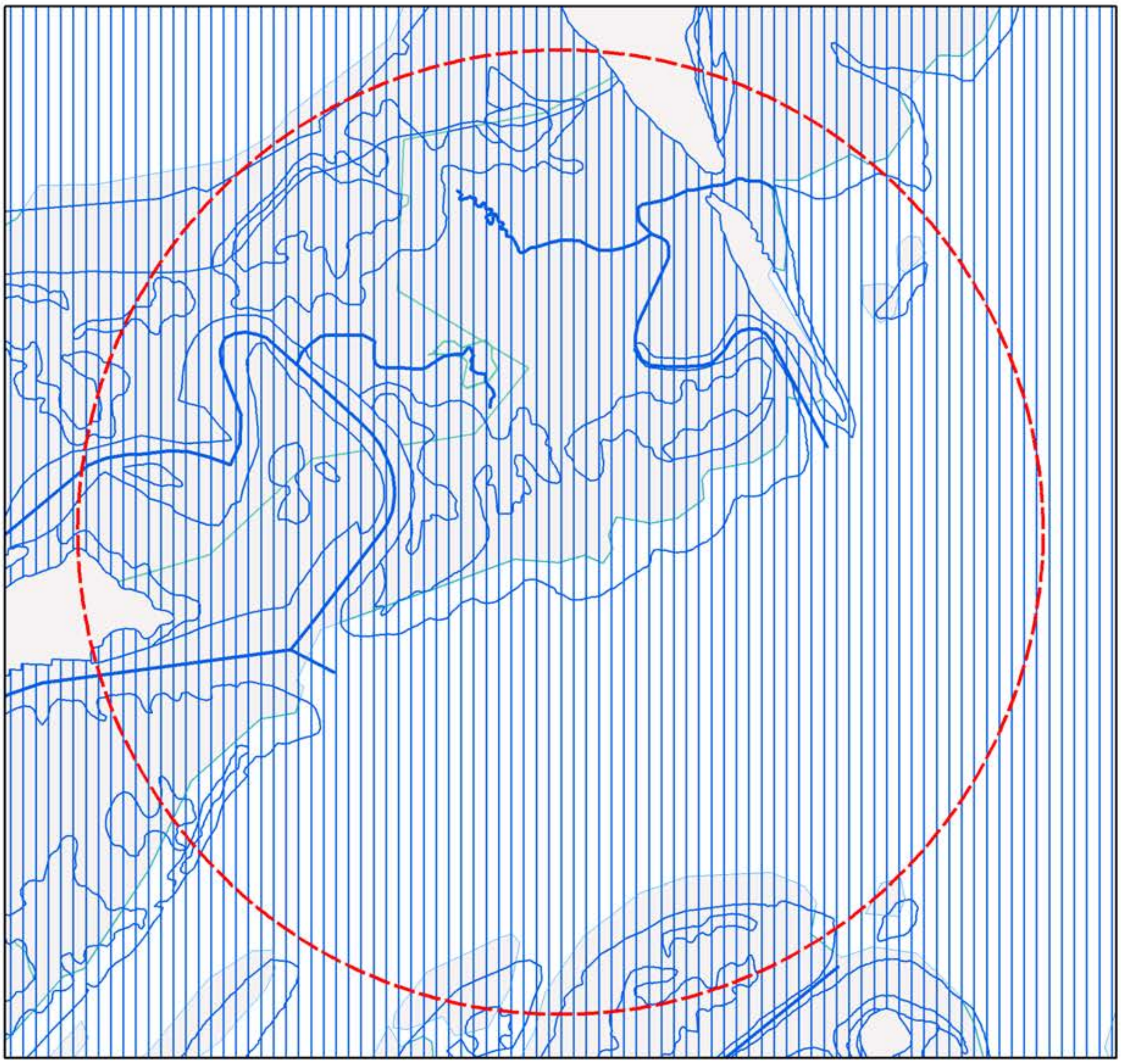
Map 2 - MSES - Wetlands and Waterways



MSES - Wetlands and Waterways

Area of Interest

- 2 kilometre buffer
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Declared high ecological value waters (watercourse)
- Strategic environmental area (designated precinct)
- Declared high ecological value waters (wetland)
- High ecological significance wetlands

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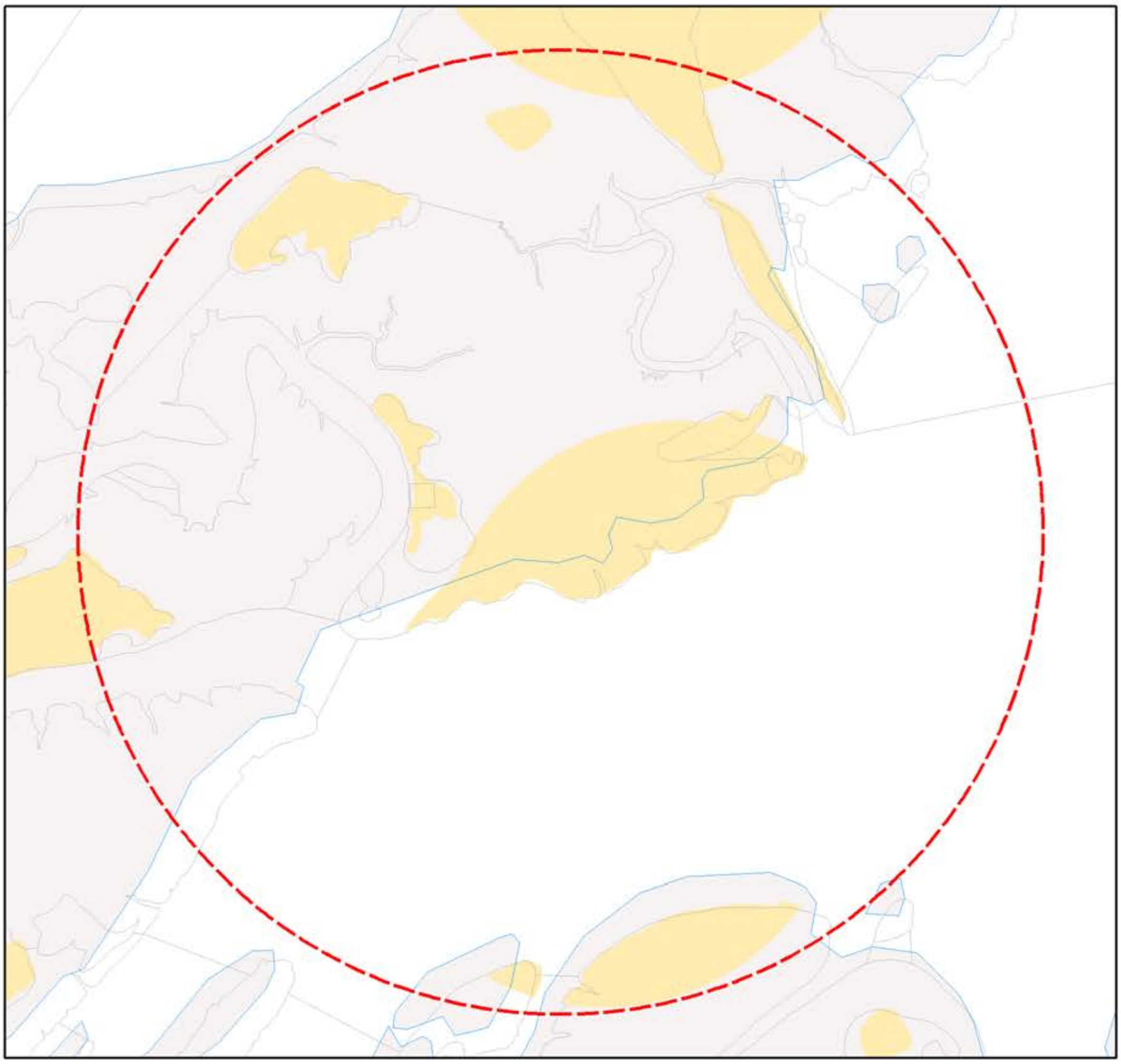
0 250 500 750 1000 1250 m

This product is projected into GDA 1994 Queensland Albers

Map 3a - MSES - Species - Threatened (endangered or vulnerable) wildlife and special least concern animals



MSES - Species
Threatened (endangered or vulnerable) wildlife and special least concern animals

Area of Interest

- 2 kilometre buffer
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Wildlife habitat (special least concern)
- Wildlife habitat (endangered or vulnerable)

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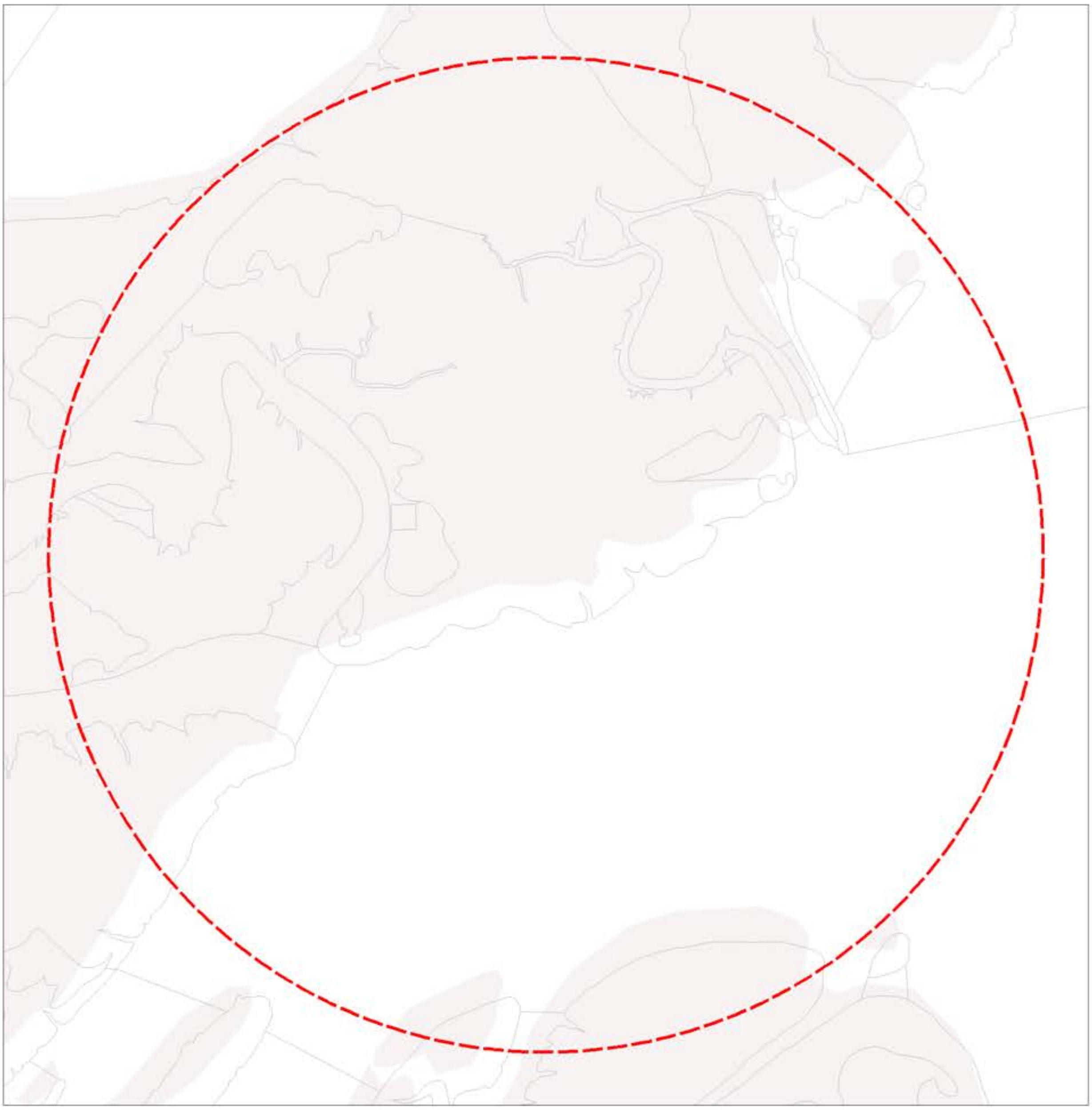
0 250 500 750 1000 1250 m

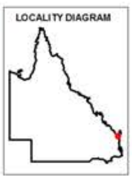
This product is projected into GDA 1994 Queensland Albers

Map 3b - MSES - Species - Koala habitat area (SEQ)



MSES - Species
Koala habitat area (SEQ)

Area of Interest
- 2 kilometre buffer
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Koala habitat area (core)
- Koala habitat area (locally refined)



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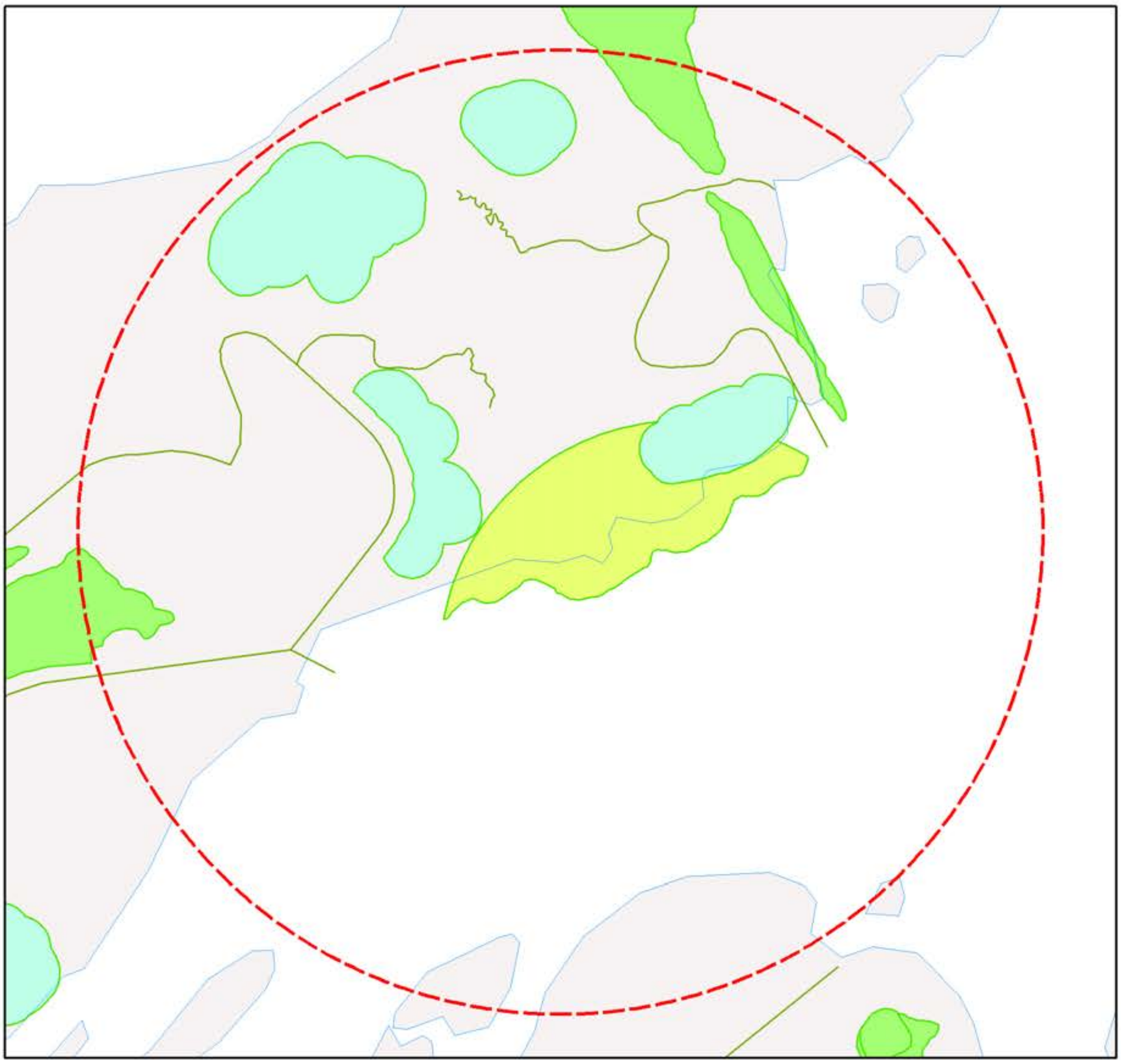
The represented layers for SEQ 'koala habitat area-core' and 'koala habitat area- locally refined' in MSES are sourced directly from the regulatory mapping under the Nature Conservation (Koala) Conservation Plan 2017. Whilst every effort is made to ensure the information remains current, there may be delays between updating versions. Please refer to the original mapping for the most recent version. See https://environment.des.qld.gov.au/wildlife/animals/living-with/koalas/mapping

The koala habitat mapping within South East Queensland uses regional ecosystem linework compiled at a scale varying from 1:25,000 to 1:100,000. Linework should be used as a guide only. The positional accuracy of regional ecosystem data mapped at a scale of 1:100,000 is +/- 100 metres.

0 225 450 675 900 1,125 m

This product is projected into GDA 1994 Queensland Albers

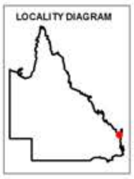
Map 4 - MSES - Regulated Vegetation



MSES - Regulated Vegetation

Area of Interest

- 2 kilometre buffer
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Regulated vegetation (intersecting a watercourse)
- Regulated vegetation (100m from wetland)
- Regulated vegetation (category B - endangered or of concern)
- Regulated vegetation (category C - endangered or of concern)
- Regulated vegetation (category R - GBR riverine)
- Regulated vegetation (essential habitat)



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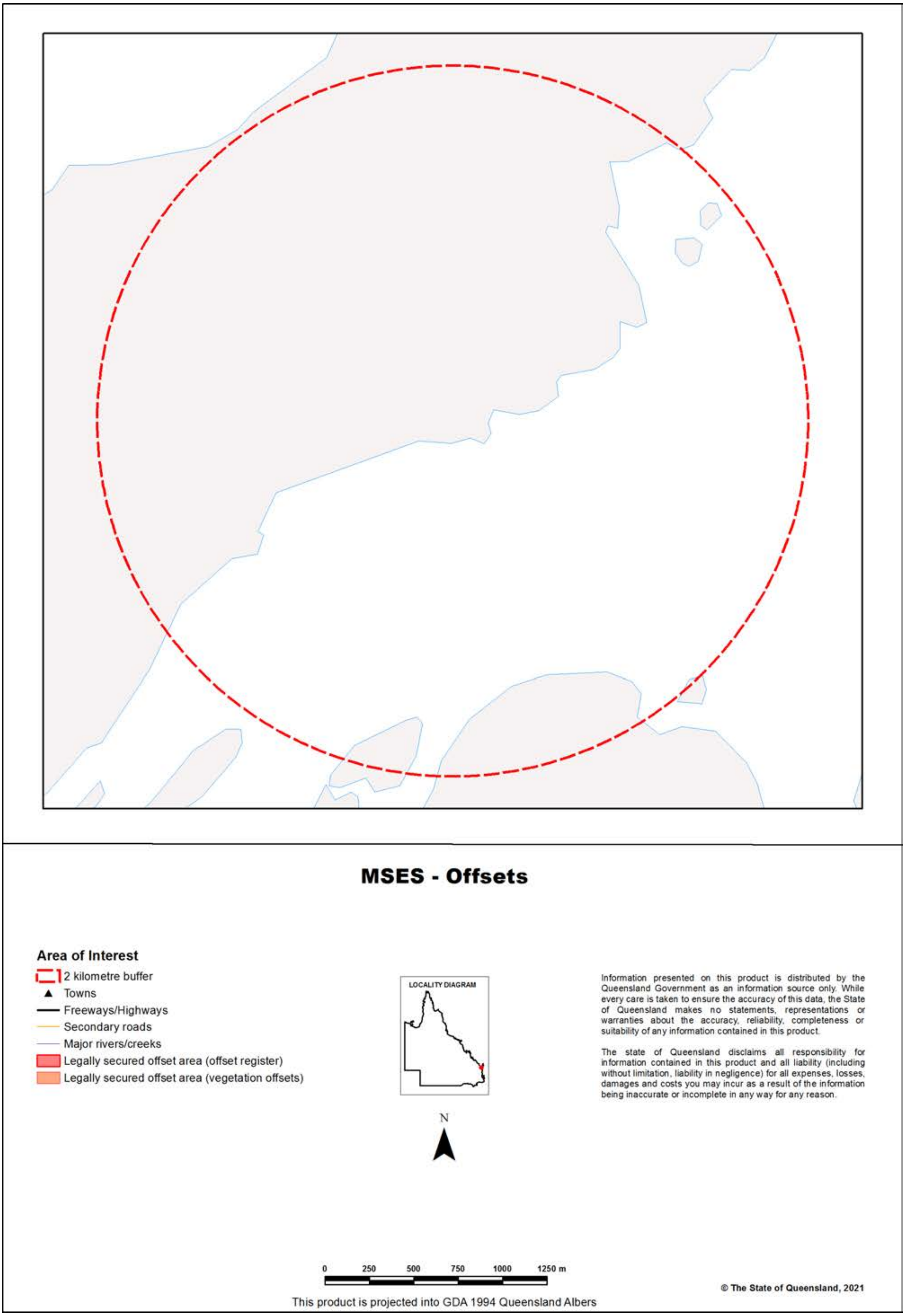
0 250 500 750 1000 1250 m

This product is projected into GDA 1994 Queensland Albers

Map 5 - MSES - Offset Areas



Appendices

Appendix 1 - Matters of State Environmental Significance (MSES) methodology

MSES mapping is a regional-scale representation of the definition for MSES under the State Planning Policy (SPP). The compiled MSES mapping product is a guide to assist planning and development assessment decision-making. Its primary purpose is to support implementation of the SPP biodiversity policy. While it supports the SPP, the mapping does not replace the regulatory mapping or environmental values specifically called up under other laws or regulations. Similarly, the SPP biodiversity policy does not override or replace specific requirements of other Acts or regulations.

The Queensland Government's "Method for mapping - matters of state environmental significance for use in land use planning and development assessment" can be downloaded from:

http://www.ehp.qld.gov.au/land/natural-resource/method-mapping-mses.html .

Appendix 2 - Source Data

The datasets listed below are available on request from:

http://qldspatial.information.qld.gov.au/catalogue/custom/index.page

- Matters of State environmental significance

Note: MSES mapping is not based on new or unique data. The primary mapping product draws data from a number of underlying environment databases and geo-referenced information sources. MSES mapping is a versioned product that is updated generally on a twice-yearly basis to incorporate the changes to underlying data sources. Several components of MSES mapping made for the current version may differ from the current underlying data sources. To ensure accuracy, or proper representation of MSES values, it is strongly recommended that users refer to the underlying data sources and review the current definition of MSES in the State Planning Policy, before applying the MSES mapping.

Individual MSES layers can be attributed to the following source data available at QSpatial:

MSES layers	**current QSpatial data (http://qspatial.information.qld.gov.au)**
Protected Areas-Estates, Nature Refuges, Special Wildlife Reserves	- Protected areas of Queensland - Nature Refuges - Queensland - Special Wildlife Reserves- Queensland
Marine Park-Highly Protected Zones	Moreton Bay marine park zoning 2008
Fish Habitat Areas	Queensland fish habitat areas
Strategic Environmental Areas-designated	Regional Planning Interests Act - Strategic Environmental Areas
HES wetlands	Map of Queensland Wetland Environmental Values
Wetlands in HEV waters	HEV waters: - EPP Water intent for waters Source Wetlands: - Queensland Wetland Mapping (Current version 5) Source Watercourses: - Vegetation management watercourse and drainage feature map (1:100000 and 1:250000)
Wildlife habitat (threatened and special least concern)	-WildNet database species records - habitat suitability models (various) - SEQ koala habitat areas under the Koala Conservation Plan 2019
VMA regulated regional ecosystems	Vegetation management regional ecosystem and remnant map
VMA Essential Habitat	Vegetation management - essential habitat map
VMA Wetlands	Vegetation management wetlands map
Legally secured offsets	Vegetation Management Act property maps of assessable vegetation. For offset register data-contact DES
Regulated Vegetation Map	Vegetation management - regulated vegetation management map

Appendix 3 - Acronyms and Abbreviations

AOI	- Area of Interest
DES	- Department of Environment and Science
EP Act	- *Environmental Protection Act 1994*
EPP	- Environmental Protection Policy
GDA94	- Geocentric Datum of Australia 1994
GEM	- General Environmental Matters
GIS	- Geographic Information System
MSES	- Matters of State Environmental Significance
NCA	- *Nature Conservation Act 1992*
RE	- Regional Ecosystem
SPP	- State Planning Policy
VMA	- *Vegetation Management Act 1999*