5 Components and processes

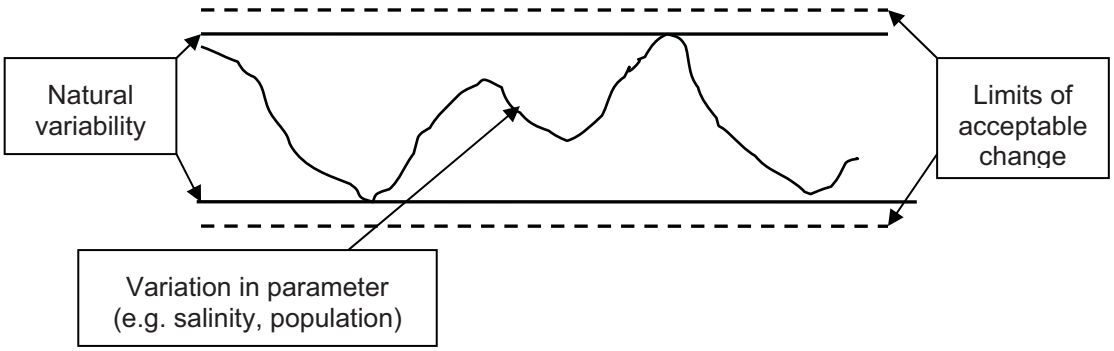
An ecosystem is defined according to its individual *components* and *processes,* and the ecosystem *benefits* and *services* are the result of interactions between the components and processes (Millennium Ecosystem Assessment 2003). It is important to monitor the components and processes of the ecosystem to ensure that these parameters do not move outside the limits of acceptable change for extended periods of time. A change in the components and/or processes may indicate a potential change in the site's ecological character. The general conceptual model illustrates how each set of parameters fits within the ecosystem and their influences.

The limits of acceptable change are values applied to particular parameters to prevent an adverse change in ecological character while allowing for natural variability. These limits may be used as a trigger for management authorities to act (Figure 26). Caution must be taken when referring to limits of acceptable change as adequate long-term data may not be available at the time of writing. It is therefore important that defined limits are updated with any new information.

In this section, components and processes that influence Towra Point Nature Reserve Ramsar site are summarised for when the site was listed in 1984. Critical components and processes are those that interact to support the critical values for which a site is listed. In the case of Towra Point Nature Reserve Ramsar site, those are primarily components and processes supporting the site's biodiversity and fisheries values, including the site's geomorphology, hydrology, physicochemical environment and biota. Those components and processes are given particular emphasis below.

Any change that has occurred to a component or process since listing is also summarised and limits of acceptable change are given for critical components and processes where adequate data exists to define them. Conceptual models are included to illustrate how each individual component and process works within the ecosystem.

This section forms a baseline assessment of the environmental condition of the wetland at the time of its listing as an internationally significant wetland and a comparison to the current condition. It also provides a baseline by which future change can be detected by management.



Source: Phillips (2006)

Figure 26: Example of natural variability and limits of acceptable change

5.1 Climate

Climate plays an important role in the regulation of the ecosystem and species have adapted to the temperate conditions at Towra Point. The Bureau of Meteorology has been collecting data since 1929 at Sydney Airport and provides long term information for the site, including temperature, rainfall and wind.

Climate change is an immediate threat to the ecological condition of Towra Point (section 6.8). El Niño and La Niña are climatic events on a broader scale that affect Towra Point by the change in the intensity of certain climate parameters such as rainfall, wind and storms.

5.1.1 Temperature

Data from the Bureau of Meteorology compiled in 1977 shows that the temperature ranges from a mean minimum of 6.2°C in July to a mean maximum of 26.2°C in January. Mean daily temperatures in winter vary from 6.2°C to 17.0°C, and mean daily temperatures in summer vary from 18.4°C to 26.2°C. The temperature at 3 pm is usually 2°C or 3°C higher than at 9 am (ALS 1977).

Temperature is an important factor for species distribution at Towra Point. High temperatures in conjunction with low rainfall, high winds and low humidity cause increased evaporation rates and therefore increased soil salinity. Extended periods of these conditions can stress the flora and fauna. Water temperature affects the solubility of oxygen and can affect the physiological processes of some species such as fish (section 6.8).

Changes in temperature since 1984

The climate monitoring station at Sydney Airport recorded temperature ranges from a mean minimum of 7.4°C in July and a mean maximum of 26.7°C in February for the period 1971–2000 (BoM 2007a). Mean daily temperatures in winter vary from 7.4°C to 19.3°C, and mean daily temperatures in summer vary from 17.0°C to 26.7°C (BoM 2007a). Global average surface temperature has increased over the past 100 years, with rates increasing by twice as much over the past 50 years (see section 6.8) (Solomon et al. 2007).

Water temperature in Woolooware Bay has been recorded by Sydney Water since 1994 and varies between 10°C and 27°C. Global ocean temperature has increased since 1955, and this has had an influence on sea level rise (Solomon et al. 2007). Water temperature is a factor in the viability of biota in the area and long term changes to overall water temperature may cause changes in the distribution of species (Bell et al. 1984).

5.1.2 Rainfall

Rainfall is a critical process in the ecosystem to recharge groundwater, offset surface and soil salinity levels, transfer nutrients and replenish soil moisture content. Rainfall is the primary freshwater source for Towra Point as it is surrounded by the marine environment of Botany Bay (SPCC 1979e). While most saltmarsh species can survive under highly saline environments, rainfall is critical for nutrient transfer and seedling growth (Clarke and Hannon 1967).

The Botany Bay area receives an annual average rainfall of 1100 millimetres, with more than 0.2 millimetres falling on 129 days of the year (ALS 1977). The highest amount of rainfall usually occurs around late autumn and early winter (March–June).

Changes in rainfall since 1984

Over the period 1971–2000 the Botany Bay area received an annual average rainfall of 1130 millimetres with more than one millimetre falling on 96 days of the year (BoM 2007a). It has been projected that winter rainfall is likely to decrease in Australia but extreme rainfall events are very likely to occur (Solomon et al. 2007) (section 6.8).

5.1.3 Storms

Due to its coastal location, Towra Point is subject to storms of varying duration and intensity throughout the year. Thunderstorms usually of short duration and higher daily rainfall occur about once a month in winter and about three times a month in summer. Occurring only four or five times a year, and not usually in winter, are storms that are associated with strong south to north-easterly winds that cause rough, high seas. These storms usually persist for a number of days and can have the most detrimental effect on Towra Point (ALS 1977).

A number of severe storms occurred in May–June 1974, August 1974 and June 1975, with waves recorded up to 7.8 metres off Botany Bay. Wave propagation in Botany Bay caused significant erosion to Towra Beach and the subsequent saltwater intrusion into Towra Lagoon (ALS 1977; McGuinness 1988; NPWS 2001a). It has been suggested that the dredging for Sydney Airport's third runway, which changed wave patterns in Botany Bay, was a factor in the erosion (ALS 1977; Roy and Crawford 1979; SPCC 1979d; McGuinness 1988; NPWS 2001a).

5.1.4 Limits of acceptable change for climate

Limits of acceptable change cannot be set for climate since the parameters cannot be managed on a local scale. Site specific data for temperature, rainfall, wind and storms should be collected and recorded for long-term monitoring of change in climate.

5.2 Geomorphology

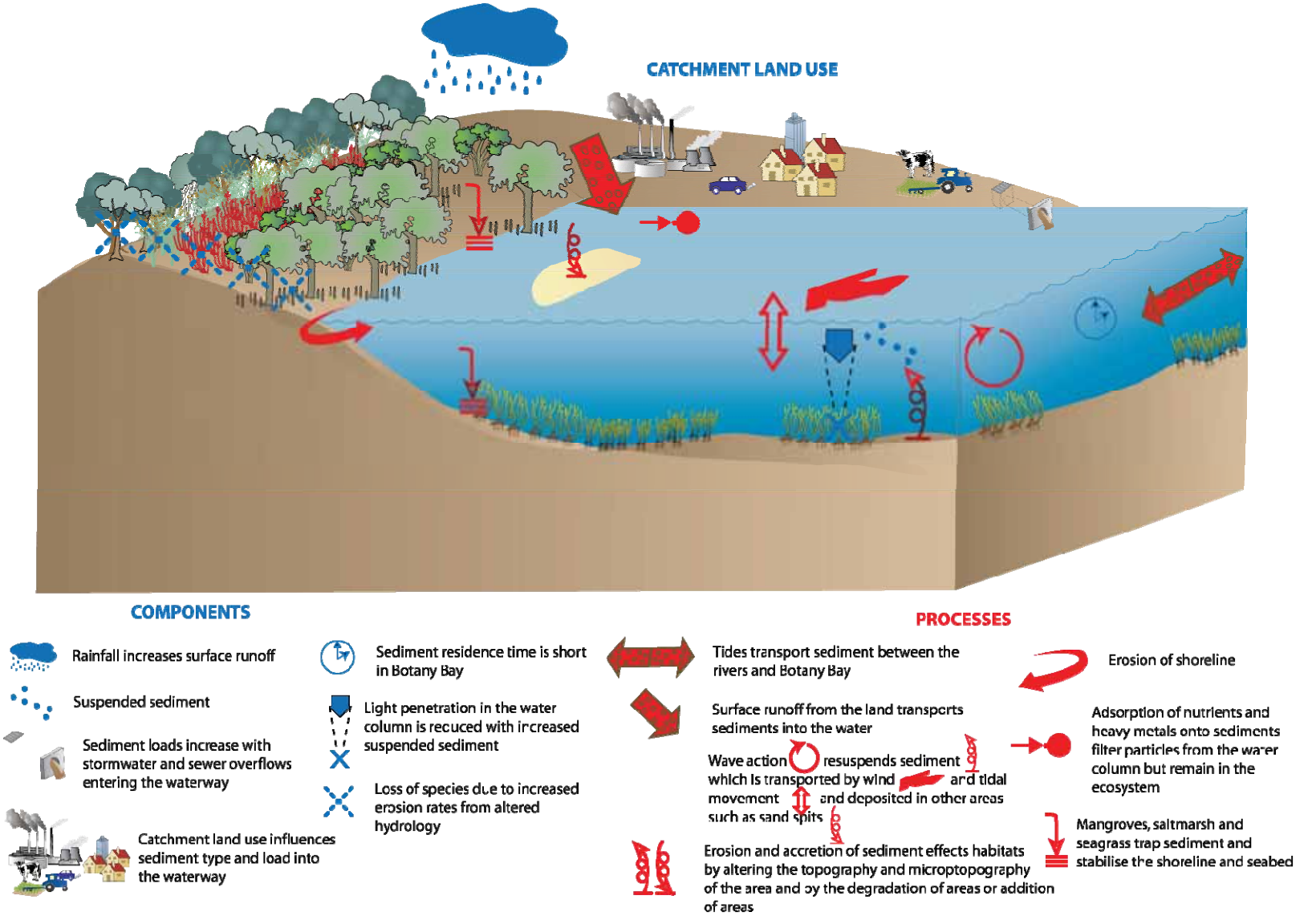
Geomorphology is the study of the characteristics, origin, and development of landforms. Critical geomorphological components and processes in Botany Bay include geology, morphology, topography and microtopography, and sedimentation. These components and processes are critical because they determine the habitats and therefore the flora and fauna species that are present. A conceptual model for the geomorphological components and processes illustrates their influences (Figure 27).

5.2.1 Geology and morphology

After the last ice age, approximately 10,000 years ago, glacial ice began to melt and slowly raised the sea level to where it stabilised 6,000 years ago (ALS 1977). The depositional events over the Holocene period (from 10,000 years ago) are described and illustrated by Roy and Crawford (1979) and summarised here.

Ten thousand years ago, sea level was about 25 metres below its current level and Towra Point did not exist, as it was the entrance for the Georges, Cooks and Hacking rivers into the ocean. Kurnell headland was separated from the rest of Kurnell Peninsula by the river mouth (Figure 28).

Further sea level rise over the following 3,000 years submerged the earlier Pleistocene sediment to form an estuary in both Botany Bay and Bate Bay and extended the rivers westward. Aeolian sand deposits from a source in Bate Bay formed a barrier between Botany Bay and Bate Bay. Dunes formed on this barrier



Source: K. Brennan 2007

Figure 27: Geomorphological components and processes at Towra Point Nature Reserve

due to the prevailing southerly winds and migrated northwards, towards Kurnell headland. Marine sand was transported through Botany Heads and deposited in the estuary, providing the sediment for future tidal deltas. Waves and tidal currents shaped Botany Bay by moving the older sediments and the new marine sand (Figures 29 and 30).

The effects of wind and waves destroyed the sand barrier and caused the reworking of sediments into beach ridges then into transgressive dunes at Kurnell. Marine sand from Botany Bay and fluvial mud from the Georges River evolved in stages to develop a levee along the southern shore of the bay and further reworking of sediments formed the basis of Towra Point. The development of Towra Point is a result of the dynamics between wind, wave and tidal processes (Figure 31).

The rising sea level raised the regional groundwater table and freshwater swamps formed in low lying areas of Towra. Muddy river-borne sediments that were deposited in low energy areas such as Woolooware and Quibray bays provided nutrient-rich sediment for the growth of mangroves and saltmarsh communities. Wind and wave action, especially from the south-east, have caused progressive erosion of Towra Beach and subsequent accretion on the western side of Towra Point where a sand spit formed. Anthropogenic alterations of the coast on the northern side of Botany Bay have changed natural wave patterns and have intensified the natural erosion and accretion on Towra Point.

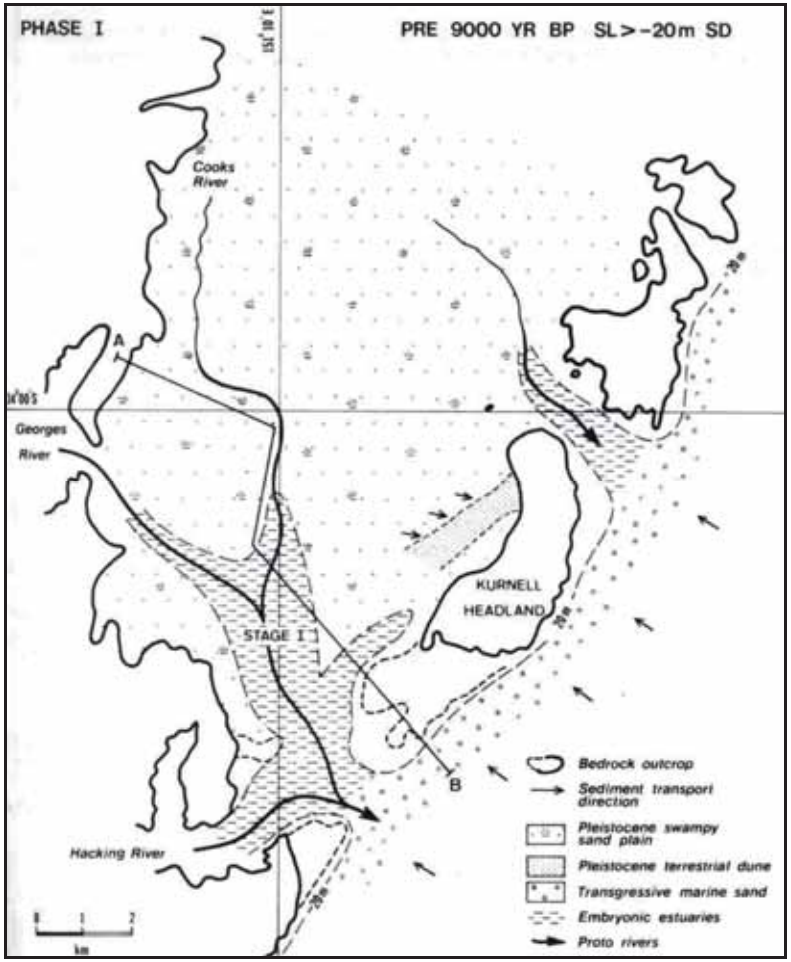
Changes in geology and morphology since 1984

Wind, wave energy and tidal currents are the most influential processes that change Towra Point's geomorphology. Anthropogenic alterations to the catchment, such as changed river flows and loads or by changing the shape of the north shore of Botany Bay, substantially change the geomorphology of the area and can change the magnitude, direction and frequency of the natural processes in the system.

Towra Spit Island was formed from Towra Point in 1991 due to erosion by wind and waves and is continuously changing shape and moving in a south-westerly direction (NPWS 1998) (Appendices F and G). Accretion of sediment caused Towra Spit Island to join the mainland at Carters Island in 1997, which gave land-based predators such as foxes and cats access to important bird roosting and nesting habitat. Severe erosion of Towra Beach, caused by natural processes but intensified by anthropogenic change, resulted in the death of fringing vegetation and saltwater inundation of Towra Lagoon in the mid 1970s. In 2004, sediment joining Towra Spit Island to Carters Island was dredged and used to restore Towra Beach and to maintain Towra Spit Island as an island.

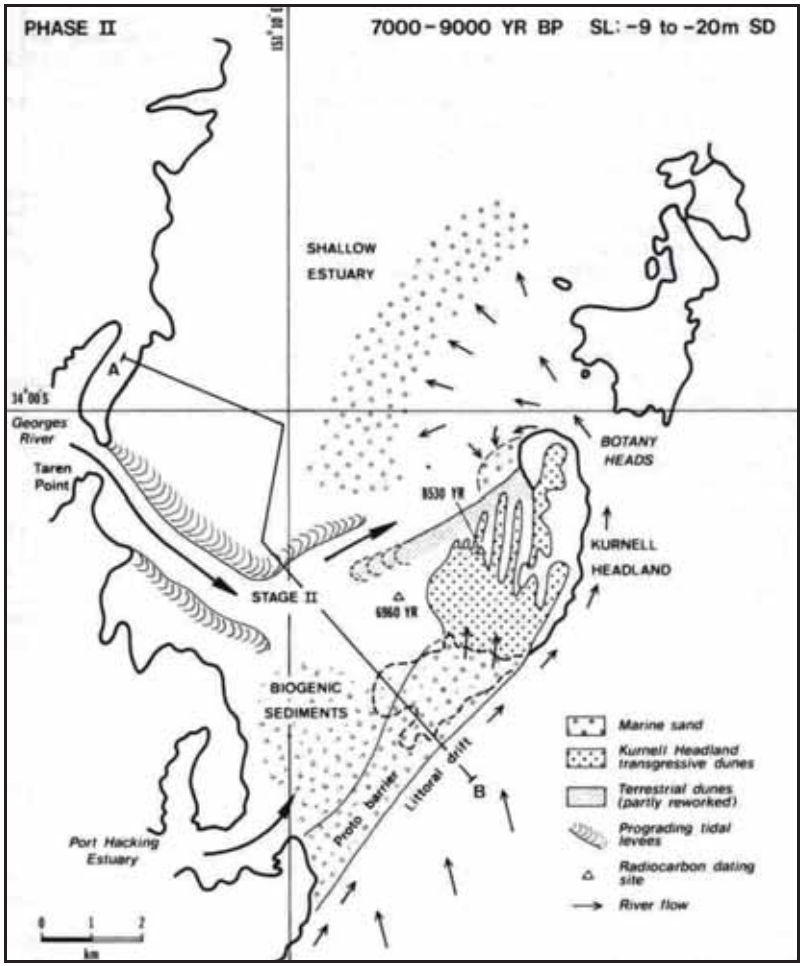
Since 1984 there have been a number of changes to the structure of Botany Bay and more are expected in the future:

- The construction of the third runway at Sydney Airport was completed in 1994. This construction claimed important migratory shorebird roosting and feeding habitat and little tern nesting site (NPWS 2001a), and decreased the tidal prism of Botany Bay. Significant seagrass meadows were destroyed by the changed wave and current patterns resulting from dredging the bay and extension of the runway and, despite recolonisation efforts, the seagrass *Posidonia australis* has not re-established on the northern side of the Bay (Watford and Williams 1998).
- Expansion of Port Botany was approved in 2005. Reclamation of 60 hectares of land and dredging 7.8 million cubic metres of Botany Bay are part of the expansion. This will change the shoreline of the bay and alter the hydrological flow regime of Penrhyn Estuary, an important shorebird site. Measures are in place to improve shorebird habitat and reduce disturbance at Penrhyn (URS



Source: Roy and Crawford (1979)

Figure 28: Botany Bay approximately 10,000 years ago



Source: Roy and Crawford (1979)

Figure 29: Botany Bay approximately 7,000–9,000 years ago

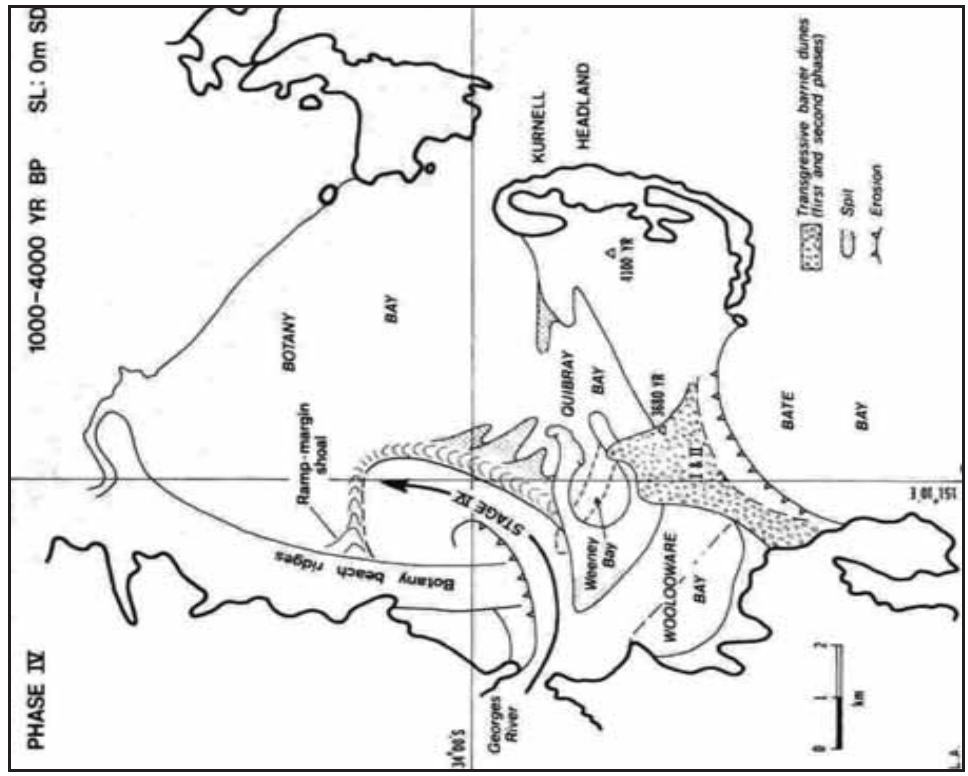


Figure 31: Botany Bay approximately 1,000–4,000 years ago

Source: Roy and Crawford (1979)

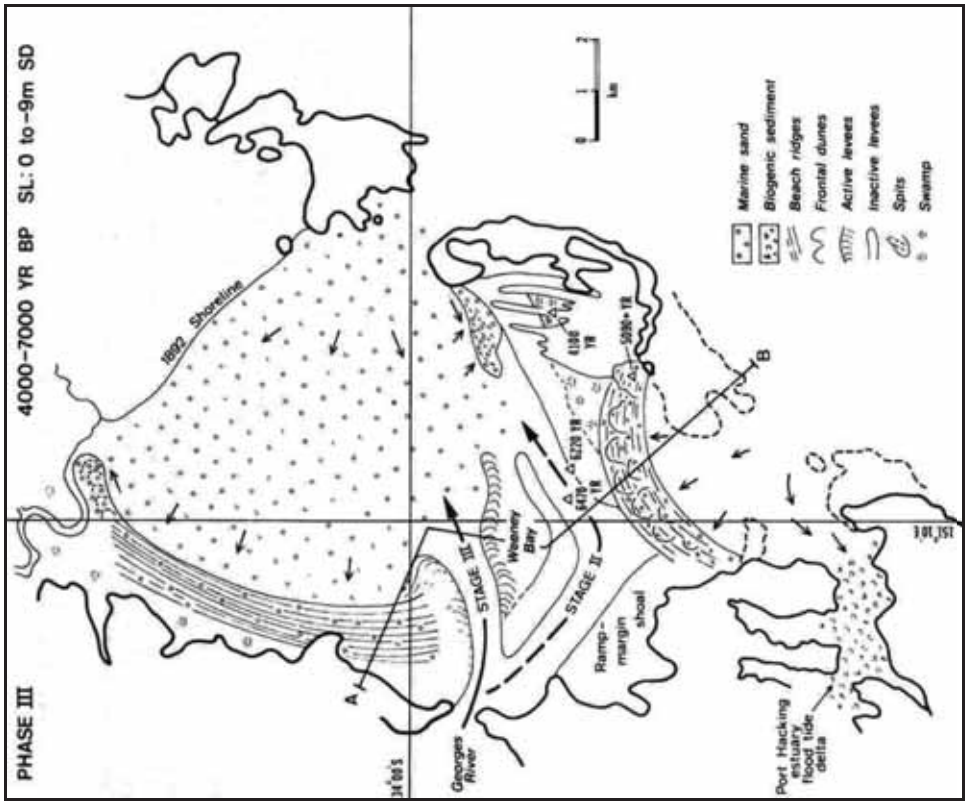


Figure 30: Botany Bay approximately 4,000–7,000 years ago

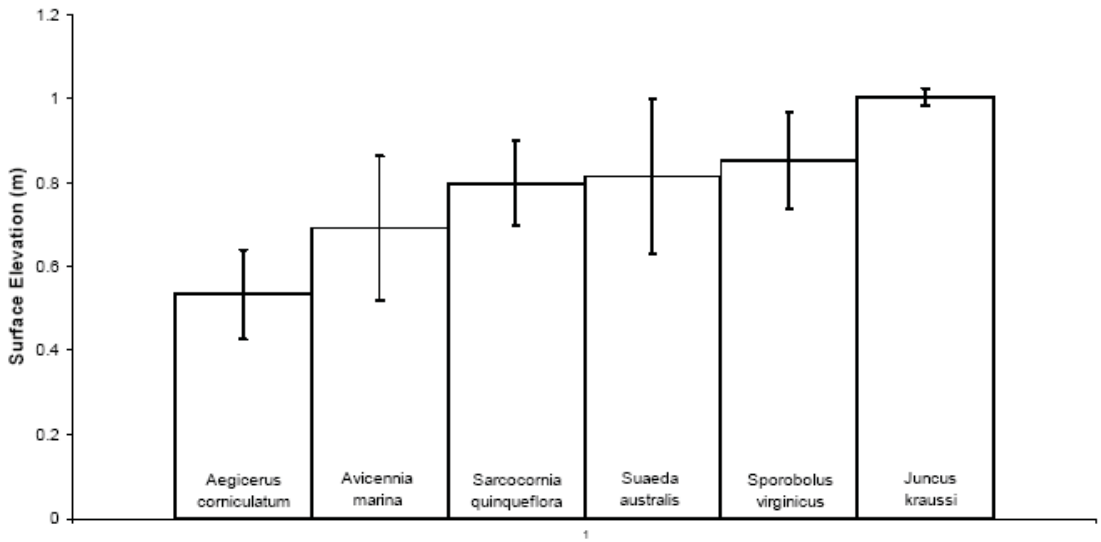
Source: Roy and Crawford (1979)

2003). However, it is largely unknown whether the site will maintain its biological diversity.

- Construction of a desalination plant on Kurnell Peninsula began in 2007. As part of this development a 7.9-kilometre long 1800-millimetre diameter pipeline will be buried in the seabed of Botany Bay for the distribution of desalinated water throughout Sydney. Environmental impact statements have stated that throughout the construction and ongoing maintenance of the pipeline, plumes of sediment generated along the pipeline path will cause loss of habitat including damage to seagrasses. Measures have been proposed to minimise impacts and monitor the site (CLT 2007; SWC 2007b).
- Energy Australia is proposing the construction and operation of two 132 kilovolt underground electrical cables to be buried in the seabed of Botany Bay to conduct electricity between the Kurnell and Bunnerong substations. An environmental assessment of the project stated that there are 82 threatened species, listed under the TSC Act and the EPBC Act, in the vicinity of the pipeline and construction will directly impact at least three of these species – black cod (Epinephelus daemelii), pipe fish (Festucalex cinctus) and seahorses. A seagrass management plan is to be prepared and implemented to minimise impacts to seagrasses (MS 2007).

5.2.2 Topography and microtopography

Towra Point is a low-lying land mass that is joined at its southern end to Kurnell Peninsula. Mangrove and saltmarsh communities fringe the area, which suggests that these areas receive regular tidal inundation (ALS 1977). Topography and microtopography are influential factors on the extent of tidal inundation; therefore these components play an important part in determining the species type and distribution at Towra Point. Saltmarsh and mangrove species can be differentiated by their elevation above sea level, which relates to their salinity tolerance. The landward progression of mangroves is limited by higher elevated areas with increased soil salinities due to less frequent tidal inundation (Clarke and Hannon 1969). Figure 32 shows the distribution of plant species at Towra Point according to topography.



Source: Hickey (2004)

Figure 32: Relationship between species distribution and surface elevation at Towra Point

There are three sections of dunes located in the interior of the northern part of Towra Point that reach a maximum height of five metres (ALS 1977). They surround an area of littoral rainforest and are listed as part of the endangered ecological community, Kurnell Dune Forest, under the TSC Act (WODEC 2007).

The shallow seabed adjacent to Towra Point, which was formed by deposition of marine and land sediment, provides a suitable environment for seagrass. Seagrass meadows occur to a maximum depth of three metres in Botany Bay; beyond this depth the growth of seagrasses is limited by reduced light penetration (Larkum 1976; ALS 1977).

Changes in topography and microtopography since 1984

Topography and microtopography are affected by the accretion and erosion of sediment. Little data is available on the change in topography of Towra Point as a whole since the time of listing as a Ramsar site. Continued erosion and sandmining of the Kurnell sand dunes south of Towra Point and erosion of Towra Beach have altered the topography of the area. While natural regimes of climate and hydrology will modify the topography and microtopography of the area, anthropogenic changes to Botany Bay will dictate the intensity and locations of these modifications.

The topography and microtopography of Towra Point are critical ecosystem components, as they define where a particular plant species can survive and influence habitat for fauna. Natural change usually occurs over a long period of time allowing species to adapt or natural processes of community succession to take place. Sudden anthropogenic change to topography and microtopography may result in a change in ecological character of the site and possible loss of species.

Sea level rise poses a significant threat as it will change the topography of the wetland. Surface Elevation Table and Marker Horizon technique is a useful method of measuring elevation trends of a wetland with respect to sea level and in determining the contributing factors of change (Rogers and Saintilan 2008). Surface elevation of Towra Point is a knowledge gap.

5.2.3 Sedimentation

Sediments in Botany Bay are of the Holocene period and predominantly consist of marine sand, mud and biogenic material (Roy and Crawford 1979):

- marine sand – fine to medium sized gains of quartz with very little stone fragments
- mud – silt and clay-sized particles derived from fluvial deposits and from the breakdown of organic matter from surrounding vegetation; typically dark grey, brown or black in colour
- biogenic material – calcareous material consisting of shells from molluscs, crustaceans and invertebrates as well as organic material.

Accretion and erosion of sediment is a critical process of Towra Point because it changes the geology, morphology and topography of the area and affects the distribution and abundance of plant and animal species. Wind, waves and currents are the natural processes that cause the movement of sediment from one area (erosion) to another (accretion) and the extent of movement and deposition is influenced by sediment type and size, water velocity, water depth and vegetation cover (Roy and Crawford 1979). Climate also has an influence on sedimentation; rainfall increases the sediment load entering from the catchment and storms increase the turbulence of the water (through waves and currents) causing greater movement

of sediment. Anthropogenic changes, such as urbanisation, throughout the catchment can also contribute significant volumes of sediment to the bay.

Towra Point was formed from the accretion of Aeolian sediment from Kurnell Peninsula and alluvial sediments from the Georges River, and continues to change on this basis. Since the 1860s, the once-large dune system on Kurnell Peninsula has been cleared of vegetation, and the exposed dunes were gradually blown into Quibray Bay and onto Towra Point (Bryant 1980; McGuinness 1988; Evans and Williams 2001). Tide and wave action has moved much of the sediment from Quibray Bay around Towra Point and towards the Elephants Trunk. Sediment from the Georges River flows into Botany Bay where it is mostly flushed out into the ocean. However, some sediment is deposited in the low-energy areas such as Woolooware and Weeney bays (ALS 1977).

Key processes in plant colonisation include accretion and erosion (Clarke and Hannon 1967). Some seagrass species colonise non-vegetated seabeds in low-energy areas (West 1983). They require sufficient light penetration for photosynthesis and are therefore found to a depth of three metres in Botany Bay (Larkum 1976). Seagrasses colonised Towra Point when geomorphological and light conditions became suitable and are highly productive species (they produce a large amount of organic material) (Connolly et al. 2005b), effective in trapping sediment (West 1983). The stabilisation of sediment formed tidal mudflats high in organic matter which provided favourable conditions for mangrove growth (Saintilan et al. 2009). Mangroves are also highly productive and trap sediment; over time, with natural tidal regimes and accretion from wind-blown sand, sediment accumulated on the landward side and elevated the land higher above sea level, which reduced the frequency of tidal inundation. These conditions subsequently provided a favourable habitat for saltmarsh colonisation (Saintilan et al. 2009). Accretion and erosion that have changed the topography and microtopography of Towra Point have a major influence on the distribution and abundance of flora species and consequently on the fauna species that occur.

Accretion and erosion are natural processes, however anthropogenic alterations to the area have changed the natural movement of sediment in the catchment both spatially and temporally (Bryant 1980). Prior to these alterations, natural sand transport in Botany Bay was in a south-easterly direction. Changes to the bathymetry and shorelines of the Botany Bay catchment have altered sand movement in a westerly direction (Roy and Crawford 1979). The following list describes the anthropogenic-induced changes to the natural sedimentation process before 1984.

- Urban expansion throughout the Botany Bay catchment, mainly along the Georges River, has increased the sedimentation rate and load entering the waterway via runoff from roads and other impermeable surfaces, sewer overflows, and runoff from rural lands and development.
- The increased accretion around Towra Point may have provided increased area for seagrass and mangroves to colonise.
- Dredging of parts of Botany Bay created deep sections where water flow has been decreased and suspended sediment settled. There is reduced tidal flushing in these areas and the sediments can be toxic due to the types of industries surrounding the catchment (SPCC 1979f).
- Dredging changed the light quality and hydrodynamic regime of the area, which caused changes in the types of aquatic organisms in Botany Bay. Seagrasses are strongly limited by light (Larkum 1976; West 1983) and are no longer found in the deep dredged areas. The change in sediments altered the species

composition and richness of the benthic organisms (SPCC 1979b; Jones and Candy 1981; Dexter 1984).

- Dredging in Botany Bay and the presence of hard surfaces on the northern side of the bay have changed the natural wave pattern by refracting wave energy. This has increased the erosion rate of Towra Beach on the eastern side (Figure 33) and increased the accretion rate of the Elephants Trunk on the western side of Towra Point (URS 2003). In the mid 1970s, following dredging and severe storms, the largest freshwater lagoon at Towra Point, Towra Lagoon, was inundated by sea water, changing the ecological character of that habitat. Dredging and structural changes to the bay have caused other areas, such as Lady Robinson's Beach at Brighton-le-Sands and Silver Beach at Kurnell, to be affected by increased rates of erosion (Bryant 1980).

Changes in sedimentation since 1984

The changes prior to 1984 have altered the natural sedimentation regime causing ongoing erosion of Towra Beach and the development of Towra Spit at the tip of the Elephant's Trunk (ALS 1977; Roy and Crawford 1979). In about 1990 the tip separated and formed Towra Spit Island (NPWS 1998; CW 2001).

The surrounding mudflats make Towra Spit Island a favourable feeding habitat for migratory shorebirds and its isolation from the mainland offers some protection as a nesting site for the endangered little tern. In 1997 increased accretion of sediment on the south-western side of the island formed a land bridge to Carters Island, which allowed foxes, cats and people to access this important shorebird site (NPWS 1998). The land bridge was dredged in 2004 to help restore Towra Beach and to make Towra Spit an island again.

The dynamics of the area suggest that Towra Spit Island will continue to migrate in a south-westerly direction. Between 1995 and 1999 the island moved at a rate of 25 metres per year (CW 2001). The altered wave patterns will continue to erode Towra

Photo: K. Brennan 2007

Figure 33: Erosion of Towra Beach

Beach, and intense storms, such as those in 1974, could cause up to 40 metres of beach recession (SMEC 2003). Renourishment of Towra Beach with sand will be an ongoing maintenance issue for the managers of Towra Point Nature Reserve in order to preserve Towra Beach and prevent further saltwater intrusion into Towra Lagoon.

Modelling of changes in land use in the upper catchment, such as in the Liverpool and Campbelltown areas, show a decrease in the sediment loads entering the Georges River since 1984, possibly due to a reduction of rural land use, better environmental management practices or changes in rainfall patterns (SMCMA 2007c). Throughout the Botany Bay catchment, Sydney Water is in the process of improving the quality of effluent and reducing the frequency of discharges from the various sewerage treatment plants, thereby reducing nutrient and sediment loads into the water (SWC 2007a). Sutherland Shire Council monitors sediment entering the sub-catchment, which influences Towra Point, and has installed a number of gross pollutant traps and stormwater quality improvement devices. Implementation of water sensitive urban design to residential and industrial areas will decrease sediment entering the water, thereby improving water quality.

Major future changes to Botany Bay include a pipeline across Botany Bay for the distribution of desalinated water for Sydney Water, two underground electrical cables from Silver Beach to La Perouse for Energy Australia, and dredging and reclamation for the extension of container port facilities for Sydney Ports. All three projects will affect the bathymetry of Botany Bay and alter the erosion and accretion patterns that influence Towra Point.

5.2.4 Limits of acceptable change for geomorphology

The natural processes of waves, currents, wind, sediment erosion and accretion in Botany Bay will continually change the geomorphology of Towra Point. Anthropogenic structures will also continue to expand and change as will sediment loads from the catchment due to increasing population pressure. The limits of acceptable change of geomorphology should aim to maintain the natural cycle of accretion and erosion, which is difficult because these processes are continually changing (Table 10). A hydrodynamic and geochemical model of the Georges River and Botany Bay system will give an indication of the effects of future changes to the structure of the estuary or changes in sediment loads and flow.

Table 10: Limits of acceptable change for geomorphology

Critical component or process	Baseline condition 1984 and 2010	Limits of acceptable change	Confidence in LAC
Geomorphology – Towra Spit Island	Towra Spit Island is an itinerant sand spit that remains isolated from the mainland except at low tide. The intertidal habitat is an important breeding site for the little tern and feeding and roosting sites for shorebirds. Annual management of western end of Towra Spit Island is undertaken so that it is not covered by high tides between September and April.	See LACs for little terns.	Low
Sedimentation *	Towra Point sub-catchment: 340 t/yr Kurnell sub-catchment: 300 t/yr Georges River catchment: 17,000 t/yr	Knowledge gap – no LACs identified.	

* Source: SMCMA (2007c, 2009) LAC: limit of acceptable change