3. Characteristics and current water resource development

This chapter provides information about the physical attributes, water use patterns and conservation values within the WRP amendment area. Although the amendment refers to all the islands within southern Moreton Bay, the information provided in this chapter concentrates on NSI because it contains the only substantial water resource within the area, and is therefore, is the main focus of the planning process.

3.1 Amendment area characteristics

The proposed amendment to the WRP area is the addition of NSI and SSI, known to the traditional owners as Minjerriba and Currigee, and the smaller southern Moreton Bay islands enclosed by NSI, SSI and the mainland to the previous WRP areas of Logan, Albert and Redlands subcatchments. NSI adds 267km^2, or about six per cent to the total Logan Basin WRP area of approximately 4800km^2. NSI is a large sand island that forms part of the eastern boundary of Moreton Bay. The island is located about 29km from the mainland at the northern end and is only about 4km at the southern end, with the intervening space occupied by a system of small islands and narrow channels (Specht 1979, Chen 2001).

SSI, Russell, Coochiemudlo, Macleay, Peel, Karragarra and Lamb islands, as well as a number of small and mostly uninhabited islands and mudflats between NSI, SSI and the mainland are included in the WRP amendment area.

3.1.1 Climate

Southern Moreton Bay experiences a subtropical climate with a moderate but seasonal and highly variable rainfall. Mean daily temperatures vary between 15-29^{o}C in summer, and 9-20^{o}C in winter.

Data records for NSI have both spatial and temporal limits which make it difficult to generate comprehensive and representative climate information.

Although Clifford and Specht (1979) report figures collected from Dunwich by the Bureau of Meteorology from 1913-1934, no modern pan evaporation sites exist within the WRP amendment area

Due to the lack of measured data, synthetic climate data was generated using the Department of Natural Resources and Water (NRW) SILO data drill facility, to provide reasonable monthly means. It should be noted that this data does not account for the probable spatial variation of actual climate data for NSI.

According to the synthetic climate record, rainfall follows the general seasonal patterns typical of SEQ, with 66 per cent falling during the warmer months of December to May. The wettest months are January to March, when 37 per cent of precipitation occurs. The synthesised long term rainfall record across NSI is displayed in Figure 3a and the monthly rainfall and pan evaporation in Figure3b.

Average annual rainfall over NSI is estimated as 1677 millimetres (mm) at Point Lookout (1947-1999), compared to an estimated pan evaporation of 1522 mm (based on Brisbane figures). Rainfall at Dunwich 1913-1934 was reasonably representative of the area at that time. This indicates that rainfall should exceed evapotranspiration over the long term, and significantly, over the wetter months, as shown on Figure 3b. These findings, in conjunction with the porous and permeable nature of the substrate, improve the potential for recharge to the groundwater (EHA 2005).

Figure 3a Monthly rainfall and pan evaporation for NSI derived from SILO data drill

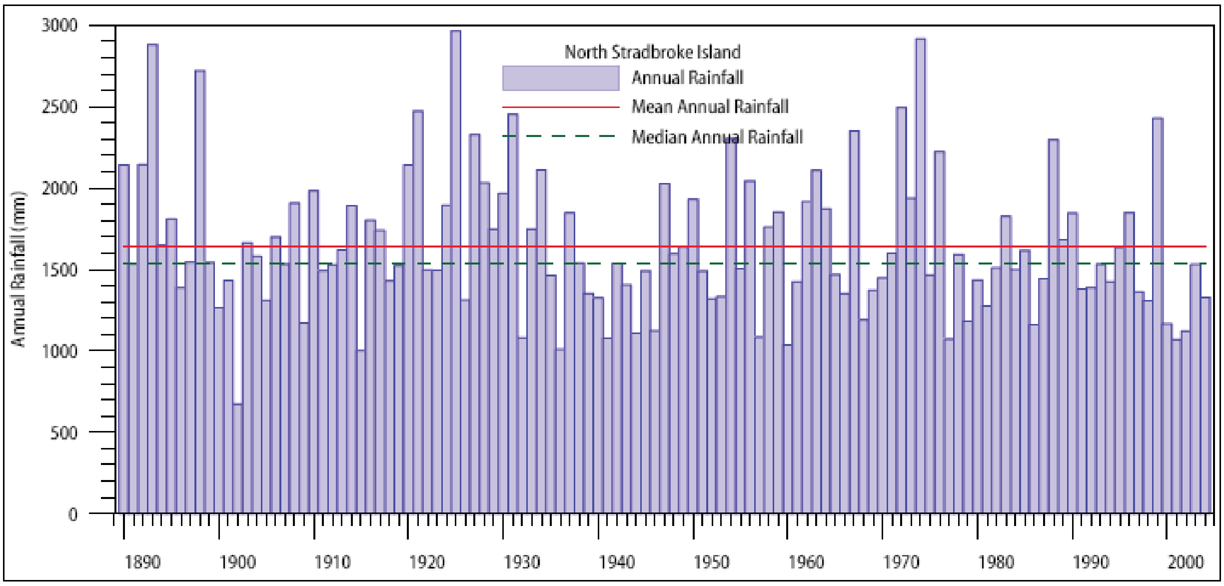
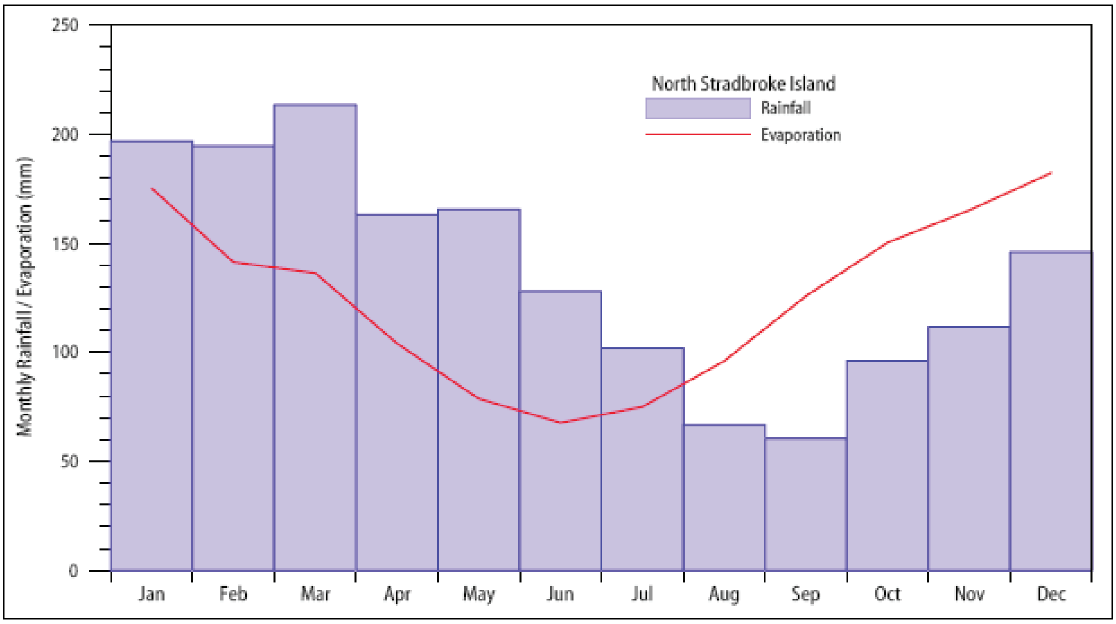


Figure 3b Average monthly rainfall and pan evaporation for NSI derived from SILO data drill



3.1.2 Topography and geology

Moreton Bay is a large, shallow expanse of water (maximum depth 30m), protected by a chain of islands forming its eastern boundary. Although the large outer islands are dominated by dune sands, others such as St Helena, Peel, Coochiemudlo, Macleay, Lamb, Karragarra and Russell represent the rocky tips of drowned hills. Other islands such as Mud, King and Bird are the remains of coral atolls (Davie 1998).

NSI was gradually separated from SSI at Jumpinpin Bar in the mid 1890s as a result of normal coastal erosion. The topography and geology of NSI have been reviewed by Laycock (1975), Chen (2001) and EHA (2005). The island is aligned north to north east, with a length of 37km and a width of 4km in the south. Increasing to a maximum of 11km near the northern end where it is separated from the mainland by about 29km. The southern end of NSI is only about 4km from the mainland, with the intervening distance occupied by a network of small islands separated by narrow channels.

The sand deposits on NSI and the other smaller islands are highly sensitive to the climatic and sea level fluctuations which shaped them. They have evolved as a result of world wide climate change associated with the glacial phases that occurred over recent geological times. In the warmer interglacial periods, Moreton Bay was below water and large quantities of sand were carried northwards along the coast by longshore currents, initially trapped between rocky outcrops. During the cooler glacial advances, sea levels in SEQ fell by up to 140m below present AHD. These events exposed large sand accumulations on the 40km wide continental shelf to the east of NSI and the accompanying arid climate with strong south easterly prevailing winds stripped the vegetation. Deprived of vegetation, the sands were blown into transgressive and parabolic dunes, which shifted towards the north west under the prevailing winds.

During the wetter interglacial periods leaching, erosion and revegetation modified the older dune profiles. Inland concentrations of the heavy minerals rutile, ilmenite and zircon were formed during the dune building process, providing the basis for the sand mining industry. These heavy minerals are naturally separated by wave action from the lighter silica sands to give the rich black sand strandline deposits observed on the beaches. Further concentration took place at the crests of high dunes due to wind action.

NSI is essentially a massive vegetated dune system, with the bedrock that forms the island's basement now only visible as isolated outcrops, forming rocky headlands that are the remnants of ancient hills. Such exposures occur at Point Lookout, Dunwich, south west of Ibis Lagoon near Cainiapa Passage, and to the south in the Fisherman's Road Quarry area. The dunes of NSI are arranged as north westerly trending ridges, reaching a maximum height of about 219m above AHD at Mount Hardgrave, near the centre of the island. Local topographic relief is often as much as 75m and in places the dune sands extend to a maximum depth of about 80m below AHD.

Three successive series of dune building took place on NSI between 300 000 and 20 000 years ago. The ancient dunes are the earliest and their eroded and truncated remains form the northern and central core of the island. The old dunes lie to the west of the ancient dunes and the recent dunes form the eastern third and southern tip of the island. A low escarpment and flat swampy area near Black Snake and Ibis Lagoons divides the island into a relatively high northern section, and a lower southern third, containing only younger dunes.

The dune sands are composed of fine-medium grained quartz, with patchy interbedded layers of carbonaceous sandrock and some ironstone bands. Swales between the dunes may form moist, protected depressions where organic debris accumulates and peat may form, rendering these depressions less permeable than the main sandmass. Such relatively impermeable layers form perched water tables well above the regional water table, allowing perched lakes and swamps to persist although sometimes ephemeral. Some of these features have been buried by progressive dunes in the past and their existence within the deeper sand mass may locally retard or occlude recharge to the regional aquifer.

In addition to perched lakes, dune lakes may form where an eroded depression has intersected the regional water table. Blue Lake is an example of such a window lake. Other topographic features of NSI include beaches, coastal freshwater swamps, mangroves and young unvegetated low sand dunes.

The most significant freshwater coastal feature on NSI is Eighteen Mile Swamp, a 26km long freshwater system composed of swamp and wetland, drained by Freshwater Creek. It lies parallel to the eastern coast just seaward of the truncated giant dunes of the main sand mass. It has formed from a coastal lagoon at the base of the main dune system. It is unique in SEQ, in that it is fed by groundwater seepage from the dunes rather than by surface water. The only features resembling it in the great sand masses further north are the much smaller swamps at Peregian (Everist 1975).

The swamp is bordered on the seaward side by the eastern beach ridge, and the inland edge is a vegetated wave cut escarpment, thought to be the shore line prior to the most recent sea level decline. The vegetation allows it to maintain a slope of 30-37 degrees, which is greater than the natural angle of repose of dry, fine grained sand. The side slopes of the main dune system are commonly between 15-20 degrees. The floor of Eighteen Mile Swamp consists of a layer of peat and grey plastic clay. It acts as a trap for the lateral groundwater seepage from the island dunes and diverts this water south via Freshwater Creek into Swan Bay.

The final event in the formation of NSI occurred about 6 500 years ago. A short period of slightly elevated sea level established a coastal platform around the island’s margin. Present day beaches form the margins of this platform and support the freshwater swamps at the edges of the main island aquifer.

3.1.3 Soils, vegetation and fauna

Southern Moreton Bay is part of one of Australia's premier wetlands, which continues to be rich in sea life despite being close to Brisbane's industrial and commercial developments and next to agricultural lands. It provides nursery environments for fish, prawns and crabs (the basis of important commercial and recreational fisheries), roosting sites for migratory birds, and seagrass beds which nurture dugong and turtles.

The dunes and coastal sand masses are characterised by wallum country, a term describing coastal heath, typified by communities of a few species of stunted trees and shrubs with a flowering heath understorey rich in biodiversity (Young 1948; Davie 1998; GHD 2002; EPA 2006).

NSI is an important holiday destination for SEQ residents and is unique in being an extensive, easily accessible, semi-wilderness area, close to urban centres of SEQ, with a diverse flora and fauna of enormous significance to the scientific community (Sparshott & Bostock 1993).

The extensive range of habitats on the island are characterised by dune sands of very low fertility, wallum vegetation and dystrophic lakes with peaty brown acidic water. The ecosystems are highly adapted, and there may be gradual recovery after major perturbation (Kikkawa 1975; Thatcher & Westman 1975; Clifford & Specht 1979). The dunes, lakes, surrounding swamps and sedgelands support a variety of plant and animal species, some rare and threatened and are an important seasonal refuge for migratory birds.

The soil types are controlled by their age, parent materials and the drainage conditions existing during their formation. The range of parent material is very limited; being mainly dune sands but the length and regimes of weathering, to which they have been exposed differs greatly. Many of the older soils have been severely eroded and in places covered by younger deposits. Drainage conditions have also been extremely variable, both spatially and temporally, during soil formation. They range from excessively dry on younger dunes, to permanently waterlogged in swamps and wetlands. The meagre soil nutrients have been derived from the small quantity of weatherable minerals in the sand, supplemented by salt spray. Most of the older soils have been leached to a great depth, so the bulk of remaining nutrients are contained within the living biomass (Thompson & Ward 1975) and may be depleted if the biomass is removed or severely disturbed. The dominant soil types on NSI are:

- podsols, the most common soil type, covering most of the dune country
- siliceous sand with no soil structure but some swampy depressions
- acid peat soils occupy low lying, swampy coastal plains
- salt marshes, consisting of saline mud, sand, peat and clay
- red earths and yellow duplex Lithosols on the rocky outcrops.

Everist (1975) reports most of the vegetation of NSI is typical of the wallum found on the other large sand islands and coastal sand masses. Most of the approximate 480 plant species on NSI are found in other parts of the Moreton region but there is an unusually high diversity of microhabitats. These result from frequent changes in topography, aspect and exposure to toxicity from salt spray across the island, as well as the extreme variation in water-holding capacities of the soil. Infiltration is so rapid in some areas of the dunes that most of the rainfall passes quickly beyond the depth of the root zone as deep drainage. Other soils are permanently waterlogged. The greatest variety of plant species occupy specialised ecological niches within these microhabitats.

There are several plant species which are listed as vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and the Queensland *Nature Conservation Act 1992*, which are the main legislation for protecting the environment and conserving biodiversity. Sparshott and Bostock (1993) recorded six species of plant which are currently considered, by the Queensland Herbarium, to be rare and threatened in the Flinders and Myora Swamps. These species are:

- *Acianthus amplexicaulis*, a small ground orchid
- *Durringtonia paludosa;* the Water Daisy
- *Olearia hygrophilas*; the Swamp Orchid
- *Phaius australis*; the Yellow Swamp Orchid
- *Phaius bernaysii*, and
- *Thelypteris confluens,* a semi-aquatic fern.

The shrub *Acacia baueri* and the tufted grass *Arthraxon hispidus*, which are presently listed under the above Acts as vulnerable, have also been recorded on NSI.

Of these vulnerable species, *Oleria hygrophila* and *Phaius. bernaysii* are both restricted to NSI, and *Phaius. australis*, the largest Australian orchid, is becoming rare in other localities. All three species are classified as endangered (Sparshott & Bostock 1993).

Fauna on NSI consists of 18 mammal species and at least 244 bird species. Possums are present in small numbers and gliders and koalas are also found on the island.

Macropods are common and include both the swamp wallaby *Wallabia bicolour*, which is inclined to show an unusual golden coloration, and the southern limit of the agile wallaby *Macropus agilis*. There is a conspicuous absence of Dasyurid marsupials (ie native cats and marsupial mice and rats) on NSI. Although rodents and bandicoots are numerous, they occupy almost exclusively the wetland/heath habitat. *Melomys littoralis* is the dominant species of rodent but other species include the False Water Rat *Xeromys myoides*, also known as the Water Mouse, which is listed as vulnerable (Kikkawa 1975; Covacevich 1984; Eyre et al.1998; Chen 2001).

None of the 34 species of terrestrial reptiles found on NSI are confined to the island, but the skink *Anomalopus truncates* has a limited distribution on the mainland (Covacevich & Ingram 1975, 1975; Kikkawa 1975).

The bird species diversity on the island may be considered high for an area of only 27 520 hectares (ha). Of the 244 species recorded from the island, 131 are land birds. Migrant birds include some of the rarest species recorded in Australia, as well as circumpolar species such as the Little Penguin *Eudyptula minor* at the northern limit of their range (Kikkawa 1975).

Seventeen species of frogs are presently known on NSI. Four of these, the Wallum Froglet *Crinia tinnula*, Cooloola Sedgefrog *Litoria cooloolensis*, Wallum Rocketfrog *Litoria freycineti* and Wallum Sedgefrog (or White Striped Frog) *Litoria olongburensis*, are termed acid frogs and are particularly susceptible to changes in water chemistry and water table disturbances. All are listed as vulnerable, apart from *Litoria cooloolensis,* which is listed as rare and endangered (Ingram & Corben 1975; EPA 2006).

The freshwater fish fauna of NSI are very sparse but include the soft-spined sunfish and vulnerable to endangered Oxleyan Pygmy Perch *Nannoperca oxleyana*. As well as the Mosquito Fish *Gambusia affinis*, an exotic pest which may have affected the abundance of native species (Arthington 1984; Leggett 1990; Arthington et al. 1996; EPA 2006). It has been reported by Thomson (1975) the lungfish *Neoceratodus foresteri* was introduced into Eighteen Mile Swamp during the early years of European settlement but there have been no reports of its survival.

The range of freshwater invertebrates is relatively small, although Stanisic (1984) has reported the occurrence of the freshwater sponge *Radiospongilla cantonensis* in Brown Lake.

Range of habitats

Marine and shoreline

Southern Moreton Bay is an area of overlap between the faunas of the tropical north and those, more typical of the warm temperate waters, to the south, resulting in a very varied shallow marine fish fauna. Both the Bottlenose and Indo-Pacific humpback dolphins frequent the waters around the islands. Also, humpback whales can be seen on their seasonal migrations from a number of vantage points on the north east coast around Point Lookout. On NSI, open marine habitats on the sandy beaches of the east coast contrast with the rocky headlands and fringing coral reefs to the north and east.

In the south of southern Moreton Bay, water circulation is reduced by a complex of channels, islands and sand bars between NSI, SSI and the mainland. The sheltered shorelines within this zone are protected from strong wave action, and the marine and intertidal communities experience almost estuarine conditions. The muddy foreshores support extensive mangrove woodlands, with seagrass meadows on the sandbanks and mudflats (Thompson & Ward 1975). All seven species of mangrove in the Moreton Bay area are present around NSI including the rare Black Mangrove (Clifford & Specht 1979; Sparshott & Bostock 1993; Davie et al 1998). Salt marshes have formed inshore of the mangroves, where freshwater seepage from the dunes limit the build-up of salinity brought in by spring tides. A variety of partially GDE types occur in this zone including sedgeland, salt-meadow and low shrubland. Swan Bay cuts deeply into the base of the NSI at the mouth of Eighteen Mile Swamp, providing shelter and shallow water (Thomson 1975; Abal et al. 2002; Finn 2006).

Although these shoreline habitats support relatively few plant species, they serve as fish nurseries that support commercial and recreational fishing. The seagrass beds stabilise the substrate and are also grazed by dugongs and three species of turtle (Covacevich 1984).

A community of birds strongly associated with the mangroves on NSI includes the Mangrove Heron *Butorides striatus*, Mangrove Kingfisher *Halcyon chloris*, Mangrove Warbler *Gerygone levigaster*, and Mangrove Honeyeater *Meliphaga versicolor*, with mudflats providing feeding grounds for four species of resident and at least 20 species of migratory waders (Kikkawa 1975).

An endangered mammal, the False Water Rat, depends on the coastal wetlands as well as mangrove communities for its survival. This creature builds large nests of mud and mangrove leaves up to 60 centimetresn height. It forages amongst the mangroves for crabs, shellfish and worms, returning to the adjacent sedgelands for shelter when the tide rises (Sparshott & Bostock 1993; Eyre et al. 1998).

Dunes

The younger coastal dunes on NSI, less than 15m above AHD, are composed of siliceous sand with some swampy depressions and sand blows. These include the modern dunes at the southern end of NSI and the northern strip from Amity Point along Flinders Beach. Vegetation is both sparse and low in biodiversity, with the most exposed trees and shrubs showing wind pruning (Clifford & Specht 1979).

The older dunes are characterised by podsols with a wide range of depth and age. Podsols form under warm temperatures, moderately high rainfall, and woodland to forest vegetation. They are characterised by three distinctive soil horizons:

- white siliceous sand (top few metres)
- siliceous sand 1-2m thick ,with organic material and some cemented layers
- deep, yellow or pale brown siliceous sand containing iron and aluminium compounds.

These older dunes support dry woodlands with or without a heath understorey. Ecosystems are zoned according to the depth and fertility of the podsol, as well as topography, exposure to wind and salt spray, and proximity to ground or surface water. Aspect may be particularly important because of its influence on rainfall. According to a study in a similar area, windward slopes may receive up to 10 per cent more rainfall than flatter areas and leeward slopes up to 10 per cent less. (Clifford & Specht 1979).

Giant podsols with thick soil profiles of up to 15-30m have formed on the crests and slopes of the most ancient dunes along the north-south axis of the island. They are characterised by a red/orange coloration in the lower part of the profile where iron compounds have been carried down by water and deposited. At lower elevations, layers of organic sand or coffee rock are sometimes exposed, probably representing locations of old freshwater swamps. Deep podsols are found around the edges of the giant podsol country, ranging to minimal podsols with weak soil horizons on the dunes and sand cliffs along the east coast and bordering Main Beach and Eighteen Mile Swamp.

The topsoil on the dunes is highly porous and low in organic content. This leads to a particularly poor capacity for holding nutrients. The dominant vegetation is open eucalypt forest, merging through zones of woodland with Melaleuca and mallee heath. In moister areas, humus podsols have formed in patches around lakes and swamps in the south western part of NSI, roughly parallel to the old dune system. These are characterised by grasses, sedges and the dominant shrub *Leptospermum liversidgei* (Clifford & Specht 1979).

Lakes and wetlands

The wetland ecosystems of NSI occupy a complex system of specialised groundwater dependent habitats, composed of heath and sedgelands, as well as low Melaleuca woodlands and wallum. There are two main types of these habitats; one occurs over perched water tables covered by acid peat soil and the other is the low lying freshwater marshes near the coast.

The coastal freshwater marshes were formed after the fronts of older dune systems were eroded by waves during a time of higher sea level. They are fed by seepage from the dunes, and include the floors of Eighteen Mile Swamp, Flinders wetlands, and the Welsby Lagoons area between Amity Point and Dunwich. Water tables are very close to the surface throughout the year (Everist 1975; Clifford & Specht 1979). Sparshott and Bostock (1993) recorded six species of plant which are currently considered by the Queensland Herbarium to be rare and threatened in the Flinders and Myora Swamps.

The perched lakes may be fringed, or invaded if shallow, by dense stands of sedges and rushes, particularly the grey sedge *(Lepironia articulate).* This species provides habitat for aquatic invertebrates and both food and shelter for higher order organisms such as fish, frogs and turtles. Where lake levels fluctuate significantly, as in Brown Lake, a sandy shoreline may be exposed during drier periods.

Blue Lake is a window into the water table. Its water level is more stable than of a perched lake, being controlled by the regional groundwater level, most of its margin is enclosed by a thick mat of vegetation and macrophytes with very little exposed shoreline (Bensink & Burton 1975; EPA 2006).

All of the lakes on NSI are relatively unproductive biologically. In their natural state they support both specialised ecosystems adapted to low nutrient, acidic and often highly coloured waters. They tend to be characterised by large populations of invertebrates, most notably the copepod *Calamoceia tasmanica*. Food chains are very simple, particularly where the lakes do not contain fish, so that aquatic insects are at the top of the food chain. Differences in species composition between lakes are due to their geographical isolation from each other and may occur opportunistically (Clifford & Specht 1979; EPA 2006).

Rock outcrops

The moderate slopes and steep bluffs of rocky headlands normally have a thin cover of soil, which sustains only stunted woodlands However, the solitary remaining occurrence of rainforest on NSI is an impoverished patch reported by Kikkawa (1975) and Sparshott and Bostock (1993) at Myora Point. It is characterised by a dense canopy containing a number of tree species such as lillypilly, corkwood and figs, laden with many large vines. The shrub and herb layers are both sparse and it supports only a few rainforest birds such as the Wonga Pigeon *Leucosarcia melanoleuca,* Noisy Pitta *Pitta versicolor*, Pale Yellow robin *Eopsaltria capito*, Rufous Shrike Thrush *Colluricincla megarhyncha*, and Lewin Honeyeater *Meliphaga lewiniiand,* as well as at least one species of rainforest snake.

Environmental threats

Erosion

Erosion is an integral component of coastal processes and sand islands are extremely vulnerable to its impacts. This was strongly demonstrated in the mid 1890s when Stradbroke Island was gradually severed in two with the breakthrough of the ocean at Jumpinpin. The passage generated still seems to be expanding. It is also possible Stradbroke Island may have been joined to Moreton Island in 1770, at the time when Captain James Cook mapped the eastern coastline of Australia. In any case there is anecdotal evidence quoted by Steele (1972) that the distance between the two islands may not have been as great then as now. Also, Robins (1984) mentions the southern end of Moreton Island has been subject to considerable erosion in recent history.

Kikkawa (1975) quotes an account of birds of Stradbroke Island in 1922, which describes an area of rain forest about 2km long and a few hundred metres wide at Porpoise Point, SSI. Apparently this area has since been eroded and disappeared entirely into the sea. Specht (1979) mentioned that the stability of the NSI shoreline seems well assured around most of the island, although considerable erosion has been observed around Amity since European settlement. For instance, a historic hut and a racecourse that hosted the Stradbroke Island Handicap have now been claimed by the sea.

One author quoted by Thompson (1967) wrote in approximately 1920, “To the best of my knowledge the inside part of Amity Point has gone some 600 or 700 yards since the sale of 1886, and the foreshores are still going.” More recently, Connor and Clifford (1972) observed that the clearing of the catchment area leading to Brown Lake caused erosion. Furthermore, sand was washed into the drainage channel, resulting in a deposit a few centimetres thick, which was soon invaded by a grass species new to this ecologically sensitive area.

The steeper slopes of NSI have been identified by Holt (2005) as being at some risk of landslides, particularly where there have been extensive cut/fill operations, increased water concentration into the slope, or removal of vegetation.

When a dune is forming, sand accumulates on the slope until it reaches its angle of repose, at which point the sand slips away. The angle of repose depends on a number of factors including particle size and moisture content. On densely vegetated slopes, tree roots probably enhance stability, with the roots contributing to soil strength and, to a minor extent, reinforcing the slope (Holt 2005).

Landslide events have been known to occur on NSI and generally occur during intense storm events. Two such events, the collapse of a 6m high costal sand cliff at Amity in 1936, and a 400m long landslide near a mine in 1998 were mentioned by Holt (2005). At particular risk is the western escarpment of Eighteen Mile Swamp, where the slope exceeds the angle of rest but is protected by vegetation. Main Beach is also a dynamic zone along the north-eastern shoreline where tidal activity influences foredune building and destruction. The foredune system is considered fragile and needs to be stabilised to an extent where pioneer plant communities can colonise. Mining for mineral sands in the foredunes took place in the early 1960s.

The frontal dunes are stabilised by vegetation on the landward side but often, due to fires or to an exceptionally high build-up of sand and strong winds, a blowout occurs. Blowout means, in a restricted area, the vegetation is destroyed or covered in sand and through this gap large amounts of sand are blown inland by the constant south easterly winds. The sand masses advance inland as wide parabolic dunes or narrow ridges (Benussi 1975). Such a blowout resulted in the separation of NSI and SSI.

Fire

Although moderate bushfires are common on NSI, the very intense fires, which may burn through swamps during drought seasons, can leave the peat smouldering for a number of weeks. This threatens both vulnerable plant species and their habitat. Specht et al.(1958) and Specht and Specht (1989) indicated heath and sclerophyll woodland would be expected to show either no long term change or a decrease in richness with time after burning.

Connor and Clifford (1972) observed an area around Brown Lake over four years, which was twice burned unevenly by bush fires. They concluded that much unexplained vegetation distribution could be the result of temporary colonisation by species which cannot tolerate the competition when the former vegetation recovers. Sparshott and Bostock (1993) also report changes which were still evident to native swamp vegetation a few years after a fire burned from the vicinity of point lookout, through Flinders Swamp, past Amity Point and down through Myora Swamp. Severe fires were also recorded on Stradbroke Island; one from August-October 1981, a bushfire in September 2003 burned on the Island for at least three days at the northern end of the island, and 2km^2 of dry swamp land between Amity and Point Lookout were burnt out in April 2006 by a fire started at Flinders Beach. Sparshott and Bostock (1993) reported damage to the woodland canopy in the Myora Springs region several years after a fire had burnt through the swamp. EPA (2006) point out increased sediment and nutrient loads can impact on dune lakes as a result from fires in adjacent areas.

In summary, it would seem most of the natural vegetation on NSI could be expected to recover fully from an occasional moderate fire but intense or widespread fires could cause a prolonged impact. Such fires would be more likely if the vegetation was recently established or severely stressed and dry. Under these circumstances, the effects of incipient erosion could be exacerbated.

Mining and infrastructure

Connor and Clifford (1979) point out the native vegetation of NSI is particularly sensitive to crushing and pedestrian/vehicular tracks may persist for several years with little traffic, exposing areas to wind erosion or initiate new drainage channels. Sparshott and Bostock (1993), when commenting on the proposed construction of a conveyor belt for loading silica sand onto barges, felt the use of heavy machinery in a swamp, and the possible laying of a hard base for the machinery to work on, would affect the hydrological dynamics of the swamp. This would sufficiently affect the species composition and probably encourage weeds whilst making the swamp less favourable for rare species.

In recent years, considerable attention has been given to the stabilisation and rehabilitation of mined areas and road cuttings. The results to date are promising but considerable work remains to be done. An account of a short-term study of the regeneration of native species following high-dune mining has been made by Thatcher and Westman (1975). From their studies it was estimated between 100-250 years would be required to re-establish the original community (Clifford & Specht 1979).

3.1.4 Hydrology

There is relatively little surface runoff on NSI because of the high rate of infiltration into the sand. Also, because of its diffuse nature it is difficult to accurately estimate. However, the outflow of surface water from NSI has been estimated to be between 52 925--71 175 ML/yr, and the peripheral outflow of groundwater to be 53 000--166 000 ML/yr, based of figures from Laycock (1975) and others. This infers a total annual discharge to the ocean of around 170 000 ML in an average year under natural conditions. However, this volume would vary significantly depending on temperatures, rainfall patterns and antecedent ground conditions. It would also have been permanently modified by ground and surface water extractions which are covered in more detail in Section 3.3 of this report.

The regional unconfined groundwater aquifer is the main water body on NSI, occurring as a lenticular freshwater mound, contained in sand extending through most of the island. The hydraulic conductivity of the sandmass and the available recharge is sufficiently high to enable lateral seepage from the freshwater mound to discharge regionally at the base of scarps around the island. This contributes to streams such as Capenbah Creek. It also feeds the marginal swamps and some lakes and seeps into the ocean through the dune sand barriers along the north and east. Because of the relatively shallow depth of the sand mass below sea level, the seawater may have only formed a short landward wedge under the perimeter of the island, rather than underlying the whole island as the base of a floating freshwater lens (EHA 2005). Figure 4 shows the locations of bores and surface water extraction points.

NSI is notable for its numerous and diverse lakes, swamps and lagoons, some of which are environmentally or culturally significant. Blue Lake is a water table window near the eastern coast, whilst most of the wetlands resulting from perched water tables are more to the east and may supply the sink to internal drainage areas. Another prominent type of wetland on NSI is the coastal fringing swamps. These include a series of small west coastal wetlands, the Flinders Beach wetland at the northern end of the island and Eighteen Mile Swamp, a major fringing wetland located on the eastern coast of the Island.

Eighteen Mile Swamp is traversed by Freshwater Creek, the only significant stream on NSI, which discharges into Swan Bay at the southern end of the island. A number of smaller streams are situated on the low lying island fringes, some receiving perennial flow from regional groundwater discharge, and possibly from perched water tables in the upper reaches. The main surface water bodies are listed in Table 1, with average annual discharge under natural conditions where estimated in Laycock (1975).

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Figure 4 Location of bores and surface water extraction points on NSI

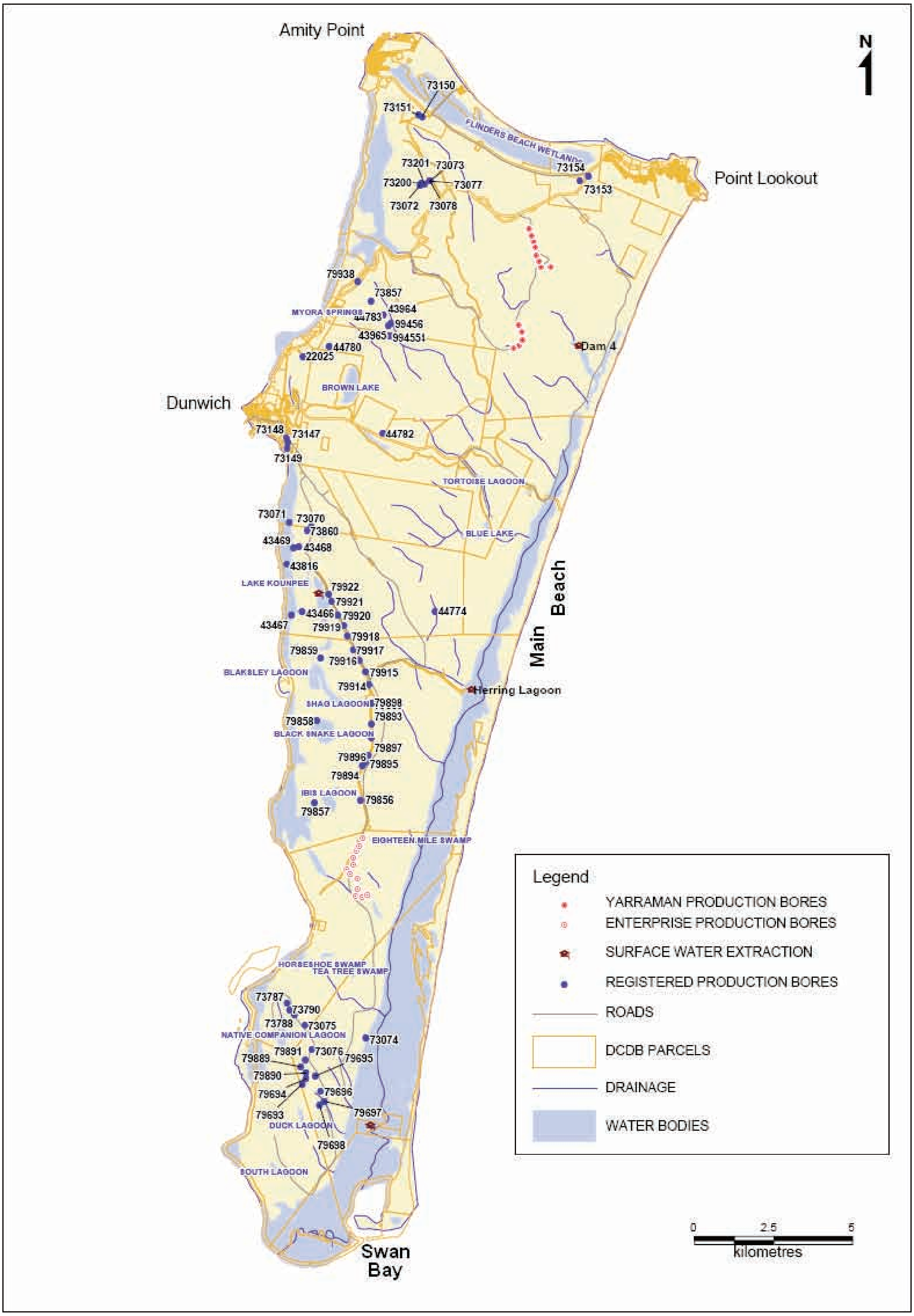


Table 1 Surface water bodies of NSI

Watercourse	Average annual flow (ML/yr)*	Notes
Amity Swamp and unnamed creek	4700	
Aranarawai Creek	2600	West coast north of Dunwich.
Black Snake Lagoon		Ephemeral perched water table lake in an internal drainage area.
Blakesley Lagoon		Perched water table.
Blue Lake	5500-6500	Permanent lake which is a water table window. GS 144003A at outflow to Herring Lagoon commenced 1990 with autosensors for EC, temperature, pH and about 4 water quality samples.
Brown Lake		Perched water table lake in an internal drainage area. Permanent but level fluctuates closely with rainfall.
Canalpin and Little Canalpin Creeks		Groundwater fed creeks on the west coast south of Dunwich,
Capenbah Creek	1300	West coast north of Dunwich. Regional groundwater flow.
Cooroon Cooroonpah Creek	800	West coast north of Dunwich.
Duck Lagoon		Perched water table.
Flinders Beach wetlands		Fringing swamp in the northern end of the Island, fed by groundwater and discharging to the beach via ephemeral springs.
Eighteen Mile Swamp upstream of Blue Lake outflow	7305	Freshwater Creek which runs through Eighteen Mile Swamp to Swan Bay is the dominant stream channel on NSI.
Eighteen Mile Swamp, Herring Lagoon	Discharge unmeasurable. estimated 32,000 ML/y r by Laycock (1975)	Artificial lake fed by groundwater, possibly from semi-perched water table. Gauging Station 144002A commenced 1973, record includes gauge levels, 20 water quality samples and autosensors for EC, temperature, pH.
Palm Lagoon (Eighteen Mile Swamp)		
Ibis Lagoon		Internal drainage area with perched water table.
Kounpee Swamp		Perched water table.
Lake Karboora		Perched water table.
Lake Kounpee		
Myora Springs	880	Groundwater spring on west coast north of Dunwich.
Native Companion Lagoon		
One Mile Creek		West coast north of Dunwich.
Shag Lagoon		
Swallow Lagoon		Perched water table
Tortoise Lagoon		Perched water table
The Keyhole Lakes		Groundwater fed lakes with associated unnamed water course and wetland located adjacent to the eastern coast at the CRL Yarraman Mine.
Welsby Lagoons		Perched water table
Yarraman Creek	3,500	GS 144004 at Dam 4 Yarraman Lakes commenced in 2000.
Yerrol Creek		West coast north of Dunwich.

* These figures are indicative only. (Sources: (Laycock 1975; Chen 2001; EHA 2005)

Groundwater modelling

NRW initiated hydrogeological modelling for the NSI regional aquifer in 2000, based on catchment characteristics, historical groundwater levels, rainfall data and water use. The modelling process is described in more detail in Section 3.5 of this report. NRW has further developed the hydrological models to simulate the historical groundwater level records, accounting for mining and extraction for urban supplies under various recharge conditions. These models will be used as a tool in the development of the WRP draft amendment and for testing the impacts of various development/management options on the groundwater levels, lakes, wetlands, GDEs and any risk to the aquifer from seawater intrusion. None of the other islands in the WRP draft amendment area have sufficient water resources for significant extraction to be considered.

Apart from NSI, the only other hydrological modelling carried out in the WRP draft amendment area has been the groundwater model for SSI commissioned by the Couran Cove Resort (Couran 2003).

3.2 Present water resource development and use

Present water usage within the WRP draft amendment area has been reviewed by EHA (2005).

3.2.1 Urban water use

Significant groundwater and surface water extraction from NSI is undertaken by Redland Shire Council to service both on-island and off-island communities with town water supply. Extraction is also undertaken by Consolidated Rutile Limited (CRL) and UNIMIN Australia Limited (UNIMIN), to support sand mining operations.

Redland Shire Council (RSC) derives its mainland water supplies from three sources, the bore field on NSI, Herring Lagoon (which are within the WRP draft amendment area) and Leslie Harrison Dam on the mainland. All of these sources are fed and replenished by rainfall; with the amount of water taken from them being altered to cater for variations in rainfall and water quality, to ensure environmental protection.

In addition to the groundwater extraction to support on-island communities, RSC has withdrawn approximately 21 ML/day since 1996 from a field of 15 large capacity production bores (located south of Dunwich) to support the needs of the wider Redland Shire. To ensure the sustainability of these extractions, RSC maintains a number of monitoring bores and carries out regular assessments of water levels. The ground and surface water extractions are treated at the NSI water treatment plant, then conveyed via a pipeline, which leaves the island in the vicinity of Canaipa Point to Heinemann Road reservoir on the mainland, with diversions supplying reticulated water to several islands including Russell, Macleay, Karragarra and Coochiemudlo.

RSC uses three small discrete bore fields to supply town water on NSI. There are three bores located at Dunwich (commencing in 1979), two located at Amity (since 1985) and three located at Point Lookout, close to Flinders Beach Wetland (since 1972). The total extraction from these bores is about 4 ML/day.

RSC is also authorised by NRW to pump about 15 ML of water per day from Herring Lagoon. Current extraction draws between 8-11 ML per day, depending on water quality and the level of water in the lagoon being above 3.2m AHD.

Table 2 is a summary of present water extractions in the WRP draft amendment area, which supply water primarily for mining, urban and residential purposes within and beyond the amendment area.

3.2.2 Mining industry water use

Apart from the RSC, the other significant water users on NSI are UNIMIN and CRL. UNIMIN uses about 2000 ML/yr to mine high quality silica sand and CRL is a partly owned subsidiary of Iluka Pty Ltd, which has mined sand on the island since 1966, although sand mining by other companies has been taking place since1949.

Currently, CRL operates two mines, Yarraman located at the northern end of the island and Enterprise in the southern section of the island. From these mines, CRL currently produces in the order of 70 000 tonnes of rutile, 45 000 tonnes of zircon, and up to 150 000 tonnes of ilmenite annually.

Groundwater is drawn by CRL from a series of production bores to support dredge mining and sand processing operations. Water is also drawn from a pump on Herring Lagoon and Kounpee Trench, a 4km long excavation, historically constructed using a dragline (Muller 1982).

The bulk of the water used by the mines is returned to the regional aquifer via direct seepage. This is done through the base and sides of the dredge ponds, via seepage through the sand tailings deposited away from the dredge pond. Some water, estimated by CRL to be around one per cent, is lost by evaporation from the dredge ponds and tailings dams.

It is important to note, despite the fact most of the water extracted for mining is returned to the aquifer, there is a spatial imbalance between the extraction of groundwater and its artificial replenishment points.

Any potential impacts of this imbalance must be taken into account when assessing the overall groundwater management of the island (EHA 2005).

3.2.3 Overall use

Apart from RSC and CRL, there are few water users on NSI or any of the other inhabited islands in the southern Moreton Bay area, apart from shallow bores of less than 6 m owned by householders for domestic supplies. Surface water is limited to lakes, wetlands, groundwater fed springs and short streams, none of which are significantly exploited. There are no artificial lakes apart from Kounpee Trench transitory mining ponds. Ground and surface water extraction on NSI are closely linked hydrologically, because the surface water is extracted from natural or artificial sources dependent on groundwater seepage. Table 2 lists the existing licensed water extractions from NSI from all sources, and for all uses.

Table 2 Summary of existing licensed water extraction draft amendment area.

Client	Location	Works type and number	Total annual use groundwater (ML)	Total annual use surface water (ML)
Industrial sand mining	Myora	3 Bores	2000	
Mineral sands mining	Yarraman	14 Bore	22 400	c
Mineral sands mining	Yarraman	Pump on watercourse		9600
Mineral sands mining	Herring Lagoon	Pump on watercourse		5475
Mineral sands mining	Kounpee Trench	seepage trench	12 775	c
Mineral sands mining	Amity area	1 Bore	1200	
Mineral sands mining	Gordon	16 Bores	11 420	
Mineral sands mining	Vance Mine	7 Bores	8240	
Urban use exported	Main Bore Field	15 Bores	14 850	
Urban use Dunwich	Dunwich	1 Bore	500	
Urban use Amity	Amity	1 Bore	200	
Urban use Point Lookout	Point Lookout	1 Bore	750	
Urban use exported	Herring Lagoon	Pump on watercourse		12 750
Others	Near Dunwich	2 bores	2	

3.3 Urban water entitlements

Redland Shire is the water service provider and main supplier of urban water in the WRP draft amendment area. It obtains a high proportion of its water supplies from within the WRP draft amendment area and is the owner and operator of infrastructure connected with the extraction, treatment and transport of ground and surface water from, and within, NSI.

There is a requirement under the Water Supply Emergency (SEQ provisions) Outcome 3 and Measure 9 in the *Water Regulation 2002* for the water service provider to:

- Maximise the sustainable take of groundwater from NSI and water from Leslie Harrison Dam. This is for the purpose of supplying water to Logan City Council by the Eastern Pipeline Inter-connector, without affecting existing water restrictions, if any imposed by Redland Shire Council on the residents of its local government area by 31 December 2008.
- Take all necessary steps to prepare for, and construct, the Eastern Pipeline Inter-connector to provide for a target of an additional 22 ML/day of water by 31 December 2008.

3.4 Unsupplemented water

Unsupplemented water is sourced from naturally occurring flows supplied by climatic and hydrologic factors alone, not impounded or regulated by a structure.

A water licence is required for the taking of, or interfering with, unsupplemented surface water, except when required for emergency public purposes (e.g. fire-fighting), domestic purposes or for watering stock on land adjacent to a watercourse, lake or spring. There are three main types of unsupplemented entitlements:

- area-based licences
- volumetric licences
- water harvesting licences.

There is one area-based licence within the WRP draft amendment area on NSI to irrigate 1.2ha. No further entitlements have been identified in the area as of April 2007.

3.5 Estimation of aquifer yields

The annual yield of a water resource is normally calculated as the maximum volume of water that can be taken from it in any one year, without compromising future supply or harming the environment. In addition, the yield generally comes with a defined probability of failure to supply. For example, a one per cent probability of failure means the full demand could not be supplied in one per cent of months over the calculation period. Such an annual yield and its level of certainty to supply can normally be estimated using a steady state hydrological model. However, a unique sustainable annual extraction rate cannot be ascribed to the dune aquifer system of NSI because of its highly variable climate, relatively short period of historical record and the regional complexity of the aquifer system with its delayed and cumulative response to stress.

The existing NRW model does not yet have a capacity to simulate changing conditions. However, in order to support long term sustainable management of the NSI aquifer, and provide a measure of certainty of supply, a more dynamic version of the groundwater model is being built. This will be supported by more comprehensive data and will simulate the impacts of extraction rates on the water table with more certainty during climatic fluctuations. Until this revised model is complete, the provisional annual yield for the aquifer will be determined through the results of the present NRW version of the hydrological model, with an adaptive management strategy in place to monitor hydrological and ecological stability, particularly with respect to GDEs. Management triggers will be activated through observed ecosystem responses.

3.5.1 Water balance for the NSI aquifer

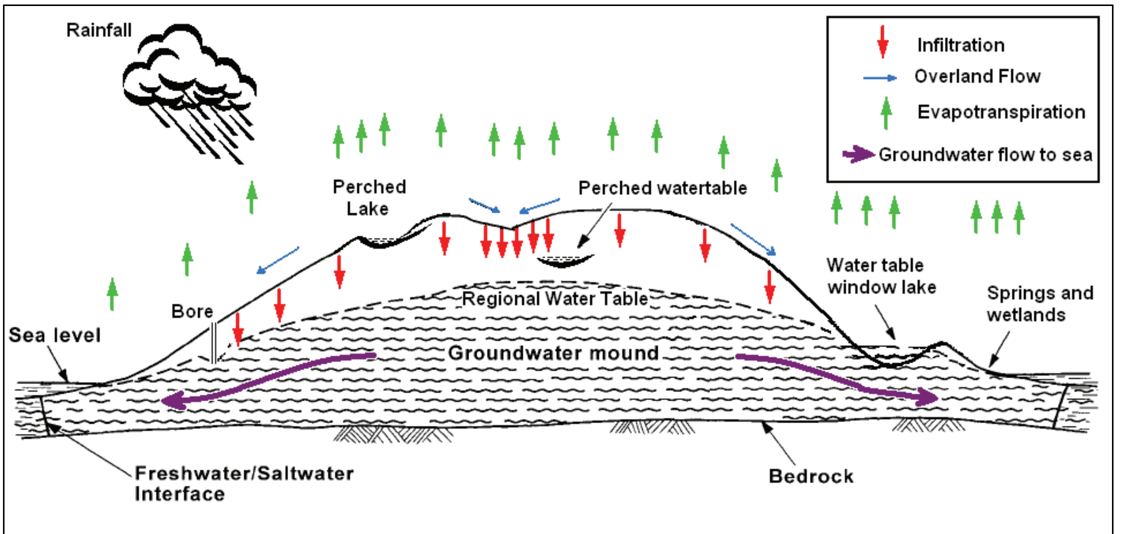
One of the key outcomes of the WRP draft amendment is to determine a management regime for how much water is available to be allocated from the NSI aquifer. This aquifer is the only significant water resource in the amendment area. This aim must be achieved while protecting the environment and the natural ecosystems dependant on this resource. This section gives a brief summary of how the available water from the NSI aquifer—the yield—is defined.

The yield of an aquifer is estimated by performing a water balance calculation on a hydrological system over a period of years, to ensure the outflows and extractions do not exceed the inflows or recharge. If such an imbalance were to occur over the long term, there would be a permanent declining trend in water levels. The water balance equation is:

Rainfall - Evapotranspiration - Groundwater outflow - Surface flow = Yield

The period of calculation should include an extended dry period to guarantee the yield estimate reflects the full range of climatic conditions. A diagram describing the NSI aquifer is shown in Figure 5. This diagram illustrates the mound of fresh groundwater that is maintained within the island sands, as a result of the balance of water entering and leaving the aquifer.

Figure 5 Diagram of water balance on a sand island



Generalised cross section of groundwater on North Stradbroke Island

The volume of extractable groundwater in a sand island aquifer is determined by the physical dimensions of the sand mass - these being its area and the depth between the water table and bedrock - and by a factor known as the specific yield. Put simply, the specific yield is the proportion of water that will drain from a specified volume of saturated aquifer material. It is closely linked to porosity, and commonly varies from 10-30 per cent for fine-medium sand but is known to be very variable on NSI. A potential volume of 2 300 000 ML freshwater has been calculated for the NSI aquifer. Although, in practice there are limitations on the extractable amount because of economically viable pumping depths, risk of salt water intrusion and the needs of the environment.

The smaller southern Moreton Bay islands do not have sufficient area, particularly height, to provide groundwater resources of more than local domestic use without serious risk of salt water intrusion. Therefore, it is not proposed to manage water resources on the smaller islands, although water conservation practices should be maintained to sustain the limited supplies.

Actual recharge to the aquifer is the most crucial aspect of the water balance but must be estimated indirectly as it is dependent on rainfall, evapotranspiration, and infiltration. These factors are all known to be variable spatially across the island. Water is contributed entirely by rainfall but before it can reach the aquifer it must infiltrate the soil. The proportion of the rainfall not lost to streams and overland flow becomes soil water and is subject to evaporation or evapotranspiration in the root zone.

The root zone is assumed to be up to 5m below the surface although Knight et al. (2002) observed roots of perennial trees and shrubs at a depth of 16 m below the surface in a Murray–Darling Basin study. Soil porosity, vegetation type and cover, rainfall intensity and topography all play a role in controlling the infiltration rate. Porosity is generally high on NSI, leading to a reasonably efficient infiltration rate overall. Vegetation loosens and protects the soil to increase infiltration but steep slopes lead to rapid runoff and overland flow.

The most suitable sites for infiltration are depressions where the water can accumulate on the surface and saturate the soil before eventually percolating as deep drainage through a considerable depth of dune sand (25-125m for over 60 per cent of the island) to recharge the aquifer. This process can be slow. The rate of seepage between two points in the aquifer system depends on their difference in height (for example, measured from sea level) and the hydraulic conductivity of the aquifer material – a property related to permeability.

The hydraulic conductivity determines the travel time of the water. In the NSI aquifer it probably ranges between 1-50 m/day for most of the sand mass but may vary considerably in both horizontal and vertical directions. This variability occurs because the wind that formed the dunes has sorted the sand into fine and coarse layers with different permeabilities. Subsequent rainwater has leached down cementing material such as iron or silica compounds in places, which can reduce pore spaces in some zones at previous water tables. In addition, the humic deposits formed under perched swamps and wetlands tend to have very low hydraulic conductivities of less than 1m/day. Finally, mining activities mix the sand layers, changing the hydraulic conductivity and making it more uniform. The locations of buried perched water tables within the dunes is not completely known at present but can prevent or greatly delay recharge above them from reaching the regional aquifer.

Figures for average annual rainfall and pan evaporation can only be approximately estimated from the existing records. There is some uncertainty in the estimation of evapotranspiration from pan evaporation because pan evaporation assumes water is actually available at all times and doesn't take into account evapotranspiration potentially influenced by slope, shade and vegetation. Evapotranspiration will be greatest over wetlands and open water and high where there are deep rooted plants but low on dry sand and recently revegetated areas. Because of these complexities, only a general estimate of between 400-800 mm/year long term recharge, contributing around 150 000 ± 50 000 ML/yr additional water to the aquifer can be made at the present time.

The main pathway by which groundwater leaves the system is by seepage into Moreton Bay or the ocean through dunes, swamps and groundwater fed streams. This situation occurs because, unlike most aquifer systems, a sand island aquifer is essentially a mound of water, constrained only by the rate at which the water can flow through the porous sand under the force of gravity. As in the case of recharge infiltration, the rate of outflow to the ocean around the shoreline is dependent on the hydraulic conductivity which may differ widely in all directions. It is estimated that the outflow averages about 155 000 ML/year (425ML/day), as compared to the total estimated surface water discharge of 72 000 ML/year (197ML/day).

Under natural conditions, without any extractions, the water table will decline during droughts because outflow is greater than recharge. However, a sequence of wet years raises the water table periodically and there is no overall trend. Although the present yield extracted from the aquifer is small in comparison to the natural water balance factors, it can be significant locally. When a bore is pumped, a depression forms in the water table around the bore because of the time it takes for replacement water to flow in from the aquifer. These cone shaped depressions may affect nearby users and GDEs or induce salt water intrusion from a local saline water body, even if the aquifer as a whole remains stable.

Despite the difficulties of measurement and limitations on the amount of data, the estimates of water balance factors are considered about 80 per cent accurate, generally adequate on the regional scale. From the point of view of modelling the main concerns are the uncertainty in the evapotranspiration rate and the need to include a range of possible hydraulic conductivities. The estimate of 400-800 mm/year, which was made by Laycock (1975), is considered reasonable in the light of more recently published literature (Chen 2001).

3.5.2 Constructing the groundwater model

The NRW groundwater model for NSI was built in 2001, based on the 'modular three-dimensional finite-difference ground-water model' package MODFLOW (McDonald & Harbaugh 1988).Some other groundwater modelling packages have also been included to enhance the NRW model's performance. Although models had previously been constructed to cover local areas, this was a first attempt to develop a whole-of-island model. It can simulate regional groundwater flow, including the impacts of pumping bores and water intensive sand mining activities, and can closely replicate water levels observed in most NRW bores. However, it is at present primarily operated as a steady state model, which means it can determine long term sustainability assuming an average recharge but cannot accurately predict local short term impacts of extraction at a small scale during periods of climatic stress. Neither can it, at present, fully predict the risk of seawater intrusion into the aquifer in response to long term pumping.

Since the 1980s MODFLOW, described by McDonald and Harbaugh (1988), has been the most widely used groundwater model internationally. It has the ability to simulate a wide variety of groundwater systems, has extensive publicly available documentation, and was rigorously peer reviewed. The NSI groundwater model divides the island into a grid of 15 000 square cells with 200m sides, whose depths are from surface to bedrock. This provides sufficient spatial detail to predict the effects of extraction on sensitive landscape features.

The simulation period for the model covered the 40 years between the beginning of 1960 and the end of 1999. As shown in Figure 3b, this period included significant dry periods during the 1960s, early 1970s, late 1970s, early 1980s and early 1990s. As well as exceptionally wet seasons in the mid 1970s. Recharge for the model was estimated through the series of daily rainfalls and estimated evapotranspiration, hydraulic conductivity and other soil and sand properties to allow for lags and attenuation of the rainfall events influencing the regional water table.

The model is calibrated by adjusting inputs such as the hydraulic conductivity for each cell, in the grid under several alternative recharge assumptions, until the observed water levels over the 40 year simulation period have been satisfactorily replicated. This model can be used to predict the effect of extraction on the average water table level over the long term. However, it is recognised some groundwater dependent wetlands and ecosystems of NSI may be subject to short term stress by extraction rates during dry periods. The risk of seawater intrusion would also be greater under such conditions. For this reason, an updated version of the model is presently being built, which will be able to simulate water table fluctuations under prolonged wet or dry conditions.

3.5.3 Concept of adaptive management

The department develops hydrological models to be used as a tool in the development of WRPs. These models can be used to test the impacts of development or management options on groundwater levels, lakes and wetlands, GDEs and any risk to the aquifer from seawater intrusion. However, as there is a degree of uncertainty in the existing model for the NSI aquifer (Chen pers. com. 2007), a newer, fully dynamic model is being constructed by NRW. This model will be gradually updated and calibrated over a period of at least two years. Until it is finalised, a cautious approach will be taken to managing the resource, using an adaptive management strategy to refine the yield estimate through close scrutiny of sustainability threats.

Adaptive management incorporates research into conservation action by integrating design, management and monitoring to systematically test assumptions, in order to adapt and learn. It is a suitable management approach to adopt where the hydrology, environmental systems and their interaction are complex, and to some extent unpredictable, but where short term actions are required (Salafsky et. al. 2001).

The steps required to enact adaptive management are to:

- establish a clear objective
- construct a model of the system
- develop a management plan based on the assumptions and results of the model
- develop a monitoring plan to test these assumptions
- implement both management and monitoring plans
- analyse the data and communicate the results
- use the results to adapt and fine tune the management plan through a regular review process.

Thus, it is proposed provisional yields be established through the WRP process, based on scenarios produced by the existing version of the model. However, these will be supported by a rigorous monitoring and review regime that will detect the incipient stages of any impacts from extraction, so remedial actions can be carried out. Water licence provisions may be adjusted to allow for the adaptive management approach during the period of development of the new dynamic model.

3.6 Overland flow water

Overland flow water is water which runs across the land after rainfall, either before it enters a watercourse or after it leaves a watercourse, as floodwater or after it rises to the surface naturally from underground.

Overland flow water intercepted while it is outside a watercourse will reduce the amount of water available downstream. Therefore, the construction of storages that capture overland flow water may impact on existing water users and ecosystems.

Available information does not indicate use of overland flow water is likely to affect existing entitlements because of the porosity of the soils throughout the WRP draft amendment area. However, the planning process may include a review of any areas where overland flow is significant and has potential for use.

3.7 Water quality

Water quality samples have been collected from NSI over a long period of time by NRW, RSC, CRL and various other parties. These samples indicate both ground and surface water are very fresh and negligible in nutrients but corrosive due to the low pH and carbonate levels and very low sodium chloride dominated salt content. The groundwater usually shows a high clarity, whereas some of the surface water tends to be highly coloured by tannin from the swampy soils. This water exceeds some Australian and New Zealand Environment Conservation Council (ANZECC) (2002) drinking and domestic guidelines and is treated by RSC before reticulation. However, the flora, fauna and aquatic ecosystems are adapted to this type of water quality and would be threatened if it were substantially altered.

Water quality problems, apart from the corrosiveness and colour, could potentially occur through salt water intrusion into the aquifer, metals and other toxins being dissolved, or kept in solution by the acidity or pollutants disturbing the naturally low nutrient levels in swamps and wetlands.

3.8 Conservation significance

Streams, lakes, wetlands and GDEs may be of conservation significance due to:

- their interconnection with surrounding ecosystems that are protected or regulated for conservation purposes
- the presence of rare or endangered species or inherent biodiversity within undisturbed aquatic habitats
- geomorphic features such as rare physical formations including dune systems and sand ridges
- the relative naturalness of a water body
- cultural, historical or heritage values associated with water bodies.

3.9 Conservation areas

There are many parts of the WRP draft amendment area which are of conservation significance, particularly lakes, wetlands and GDEs.

- **Moreton Bay Marine Park** was declared in 1993 and became one of Queensland's first Ramsar sites. It is run by the Queensland Parks and Wildlife Service, and now covers most of Moreton Bay's tidal lands and waters. Along the coast and around the islands, the boundary is the highest astronomical tide line (HAT). State leasehold land below HAT is generally included in the marine park, though freehold land is not included unless the owner has agreed. The marine park area is 340 000ha, its overall length is about 120km north to south.

  The Queensland Parks and Wildlife Service, with public input, has developed a zoning plan over the marine park. Most of the coastline of NSI is designated as habitat zone. These areas provide for reasonable use including fishing and boating but exclude activities such as shipping operations and mining. The north east coastline between Amity Point and Dunwich, as well as the southern tip including the Canaipa Passage, which separates NSI from adjoining islands, are conservation zones. Implying a greater level of protection but permitting recreational activities free from commercial trawling. Swan Bay, the outlet of Eighteen Mile Swamp at the south west tip of the island, is a protection zone, an area of high conservation value where all forms of fishing and extracting are prohibited. The zoning plan also contains specific provisions for managing shorebirds including provisions that shorebirds or their habitats must not be disturbed (EPA 2006).
- **Blue Lake National Park** protects coastal wallum and a freshwater lake of special significance to the local Quandamooka people. It includes Blue Lake (Karboora), a window lake formed within the island's water table and Tortoise Lagoon, a small seasonal swamp which is a perched above the regional water table. It provides habitat for the rare soft-spined sunfish.
- **Swan Bay Fish Sanctuary** at the southern end of NSI forms the outlet to Eighteen Mile Swamp, A unique geomorphic feature which is highly dependent on groundwater seepage both to maintain its ecosystems and to preserve its western boundary. This is a wave cut platform which is steeper than the angle of rest of dry sand but supported by the root structure of its vegetation. It has been identified as a landslide risk (Holt 2005). Deterioration in water flow , quality from Eighteen Mile Swamp or increase in sediments could impact on Swan Bay.
- **Brown Lake Conservation Area** on NSI is in an easily accessed area of wallum country. Brown Lake (Bummeira) is a culturally-significant perched lake and home to a variety of native flora and fauna including rare species. It has brownish water and shores bordered by reeds or sandy beaches.
- **Myora Springs Environmental Park and Myora Conservation Park** on NSI contains the only rainforest remnant on NSI. It supports the King fern, a large short trunked tree fern, and endangered phaius orchids, the largest species of orchids in Australia. It also supports a range of birds such as spoonbills and little egrets.
- **Scenic reserves** such as Aranerawei Creek and Flinders Beach Wetlands on NSI feature an assortment of habitats presenting a variety of flora and fauna, particularly wild flowers and small birds.
- **SSI Conservation Park**: a conservation estate comprising over 80 percent of SSI, supporting a range of flora and fauna representing lowland habitats now rare on the mainland. Examples are the swamp orchid, confined to Cabbage Palm closed forests, and the golden swamp wallaby.
- **Peel Island** (Tukrooar or Chercuba) has permanent heritage protection status under State legislation. Although too small to support a permanent tribe, it was frequently visited by the indigenous peoples to harvest marine life and contained a bora ring. A quarantine station was established there in 1874 and a segregated community for leprosy sufferers, known as a lazaret, operated from 1907-1950. The Queensland Parks and Wildlife Service is now acting as custodian of the island, pending a decision on a native title claim (Ludlow 2006).