Best practice management and wise use of the wetlands at Sydney Olympic Park

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Sydney Olympic Park is home for the largest cluster of estuarine wetlands in the Sydney Harbour system. These wetlands are now the jewel in the crown of the Parramatta River estuary, thanks to the reconstruction and restoration tasks undertaken over the past three decades. Leading to the Sydney 2000 Olympics, the then degraded and putrid wetlands were thoroughly restored. In addition, many new wetlands were constructed and some half-functioning wetlands were re-constructed. The monetary and other investments have been returning the dividends by a long way, as these wetlands now host high abundance and diversity of waterbirds and migratory shore birds, act as the sponge or kidney of the estuarine system by filtering much of the stormwater before it enters the River, play a pivotal role in the ongoing wetland education and tour program, a handy research site for academia, and most importantly, a magnificent cluster of functioning wetlands that not only thrive well but also act as model wetlands for others to manage theirs. The most useful aspect of the Authority's experience in managing these estuarine wetlands has been the ability to 'balance' the challenging management of the wetlands on the face of ever-increasing pressure from urbanisation, visitation, climate change and sea level rise. This presentation will highlight some of the values, vulnerability and volatility in managing estuarine wetlands at this site.

Introduction

Sydney Olympic Park (S 33° 50' 56.0872", E 151° 4' 3.7884") is situated in the greater Homebush Bay area and it is bounded by Homebush Bay itself on the eastern side, the Parramatta River on the north, the M4 Motorway on the west and Homebush Bay Drive on the south-east (Figure 1). It contains the largest coverage of wetlands in the Sydney Harbour-Parramatta River system. These wetlands are so invaluable that they are considered as the jewel in the crown of the Parramatta River system. These wetlands are listed on the national Directory of Important Wetlands in Australia as regionally significant (CoA 2020a).

The current diversity, extent and functionalities of these wetlands used to be quite different in the recent past (prior to the Sydney 2000 Olympics) and even in the longer past (prior to the establishment of the industrial estates in the mid-nineties) (OCA 1995). The presently existing wetlands are a heritage of the pre-European settlement, a legacy of the European settlement and a gift of the recent development activities particularly the Sydney 2000 Olympics. The transformations, modifications, moderations, rehabilitation, restoration and/or rejuvenation – every single episode have had made significant contributions towards what they are today: the make up of the collective presence, look, feel, functions, services, values, contributions and existence. Apart from their biodiversity and nature-serving functions these wetlands have been celebrated by Sydney-siders and beyond as places of connectivity, spirituality, culture, tradition, recreation, trade, commerce, science, education, research, refuge and many more. The extent of estuarine wetlands include Swamp Oak Floodplain Forest (8.64ha), coastal saltmarsh (28.5ha), mudflat (4.31ha), mangrove (69.56ha), estuarine lagoon (13.55) and estuarine creek (16.19ha). The Park does not have any substantial coverage of seagrass, except the presence of a few remnant plants in the NNR Wetland. Together, the estuarine wetlands makeup a total of approximately 140.75ha in the 205.0ha total wetlands in the Park. Figure 2 shows the diversity and spread of these wetland ecosystems. The ecological zonation of the estuarine ecosystems are in the same order of sequence mentioned earlier; with the estuarine creek at the lower-most elevation. The sheer diversity of these many ecosystems and the kind of ecotones that connect them are a rare occurrence in such a highly urban city.

Pre-Olympic Coverage and Conditions

There had been many wetlands in the area even prior to the Sydney 2000 Olympics. Figure 3 shows major transformational changes that the wetlands have had undergone over the millennia. These are also depicted sequentially listed in Tables 1 & 2.

The major activities that are listed in Table 1 and Table 2 have altered the physical character of the entire Homebush Bay area to such an extent that in most cases the landscape attributes are almost unrecognisable. Most noticeable changes meant a number of remarkable alternations and modifications, however, with a view to improving the functional and economic activities on the area. Some of the changes are listed below.

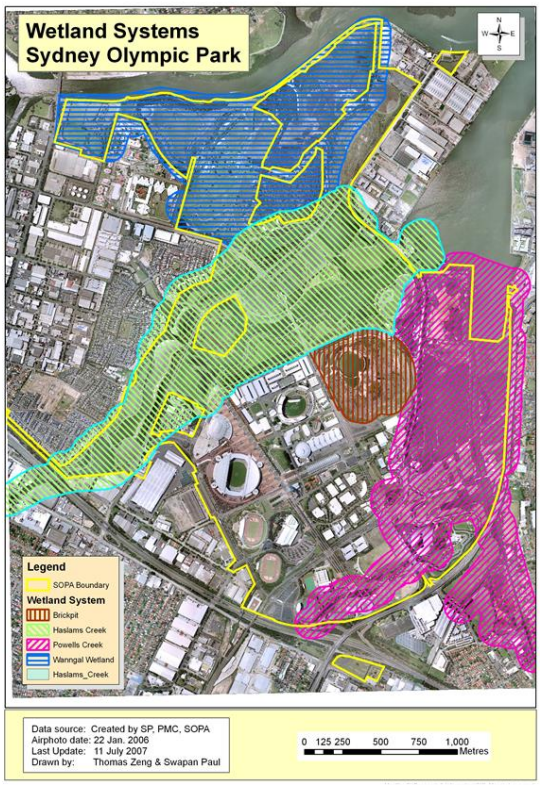

Figure 1. Estuarine Wetland Systems in Sydney Olympic Park

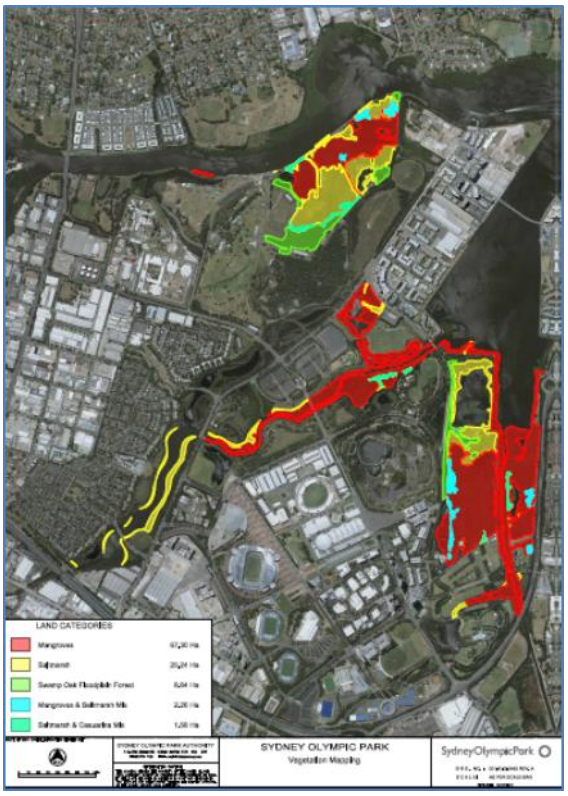

Figure 2. Spatial Distribution of Estuarine Wetlands.

- Massive pollution of the water, mudflats and sediment (OCA 1995);
- Up to 70% of the estuarine habitats, particularly coastal saltmarsh, were lost to development through land reclamation (Saintilan and Williams 2000);
- Fragmentation of ecosystems and habitats (OCA 1995);
- Displacement of fauna and flora (O'Meara and Darcovich 2014);
- Loss of biodiversity (Straw 2013);
- Introduction of pest and weed species, especially Mosquito Fish (*Gambusia* sp) (O'Meara and Darcovich 2014);
- Sedimentation and infilling of the natural water courses (McLoughlin 2000); and
- Obvious hardening of natural landscapes and alterations of the natural water courses.

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Table 1. Homebush Bay area Major Development Activities since 1788*

[Based primarily on literature review, other publications and examinations of aerial photos as well as site knowledge].

Period	Major events, structures and activities that have influenced mangrove, saltmarsh and other estuarine ecosystems within the greater Homebush Bay area
1788-1800s	No major activities other than traditional farming
	Initial Settlement Period
1810-1907	Homebush Estate formed and operated
1807-1860	Newington Estate formed and operated
1882-1996	RANAD (Royal Australian Naval Armament Depot (RANAD) established and operated.
1891-1960	Seawall construction in filling. This also involved conversion of the once mudflats and saltmarsh in to unexploded ordinance disposal site, which is now the Newington Nature Reserve Wetland
1907-1988	State Abattoirs operated, which used to discharge waste directly in to watercourse
1911-1988	State Brickpit operated, which required using Haslams Creek for transportation
1900-1930	Jetties formed and operated
1930-1940	Straightening of Powells Creek for stormwater discharge and sediment removals
1950-1970	Newington area landfilling for warehouse and Naval facilities
1960-1980	Landfilling of Bicentennial Park for waste disposal on waterways
	Industrial Era
1939-1970	Industrial establishments on Rhodes Peninsula and nearby areas and disposal of wastes in to the Bay
1950-1970	Reclamation of Wentworth Bay and banks of Haslams Creek through massive modifications
1919-1988	Industrial operations and chemical industries on Rhodes Peninsula, including discharge of toxic waste
1983-1988	Construction and establishment of Bicentennial Park as an environmental education facility
1995-1996	Various sporting venues were constructed
1988-today	Lidcombe Liquid Treatment Plant established and operated
1995-1998	Royal Ester Showground moved from Moore Park to the area, requiring hardening of the land surface
	Olympic Era
1995-2001	OCA formed and operated to stage the Sydney 2000 Olympics
1995-2000	OCA has undertook major clean-up and rehabilitation works, including wetland restoration and creation
	Post-Olympic Developments
2010-2012	Dioxin Clean-up from Homebush Bay bottom
2015-2016	Wentworth Bridge constructed over Homebush Bay and official opening on 22 May 2016
2000-today	Development for the Sydney 2000 Olympics and subsequently residential and commercial developments in the Olympic Peninsula and Sydney Olympic Park and Carter Street Precinct,

- Re-created after Cooper (2003) and based on site knowledge.

Table 2. Badu Mangrove Major Changes since 1930.
[Based primarily on examinations of aerial photos available from 1930 and site knowledge].

Year of Aerial Photo	Major events, structures and activities that have influenced mangrove, saltmarsh and other estuarine ecosystems within Powells Creek System
1930	Tramline present, which used to carry bricks from the Brickpit to the City of Sydney. Very small coverage of mangroves in the south; Bennelong Pond had no mangroves
1942	Some new stormwater channels visible; Powells Ck was still had its natural course
1943	Powells Ck straightened by excavations and a main drainage channel formed inside the present Badu Mangrove area. Excavated materials placed in Badu Mangrove area
1951	Mangrove colonising and area expanding to the north towards Badu Saltmarsh
1955	Mangrove areas further expanding slowly
1961	New bunds everywhere; WBR, Badu west & east showing bunds. Pipes that were used for transferring sediment by dredging Homebush Bay has been visible, laid from Homebush Bay to the flats in Badu Saltmarsh. Mangroves expanding and colonising in Bennelong Pond
1970	Badu Mangrove disconnected from Bicentennial Park by east-west pathway. East-west pathway visible from 1965) D onwards and dredging ceased possibly after 1961. Mangroves expanding; more in Bennelong Pond; massive dieback in the former course of Powells Creek, which is now Billabong
1978	Bennelong Parkway formed but with dirt; possibly from the Brickpit operations. Lots of mangroves expanding in Badu but also dieback in the area in front of the Education Centre; other areas were also struggling but expanding in Bennelong Pond. Park's workshop and compound area still not built.
1982	Colour photos available and 2SM Radio Tower in Badu Saltmarsh being built. Mangroves slowly recovering from dieback across the site but new dieback in Bennelong Pond
1986	More fill materials in the present Forebay Area in Bennelong Pond and further dieback in Bennelong Pond as the BiPark compound being built by infilling
1993	Boardwalk visible in the mangrove
1995	Mangroves closing in the ponded area left of the Tower; rest of mangroves looking ok and Forebay area colonised with Typha
2000	Mangroves in Badu east, west edge of Badu west and the area west of middle bund look poor; mangroves in Bennelong Pond sprouting and flourishing. Newly constructed channels in Badu west visible in the south-west corner and the Mangrove Classroom built in 1998 is also visible
2010	West of middle bund doing very well; isolated dieback areas recovering; Badu east showing some recovery and WBR looking better due to the automated SlipGate installed in 2006
2012	Ares closer to Benn Parkway, around the Boardwalk alignment and Badu east looking poor; area west of middle bund looking improved; Benn Pond trees looking ok; another pocket of small dieback on Badu east, perhaps from lightening
2014	Extensive area of new dieback at the upper end of Badu west; Benn Pond trees look stressed; Badu east looks poorer
2015	Parkview Precinct on the upper catchment has been developed and stormwater management system altered, that overflow through mangroves downstream
2016	Section of Badu Pathway and the bridge were raised by 600mm to avoid periodic tidal inundations due to the rising sea level
2017	A sedimentation basin was constructed inside Bennelong Pond to intercept sediment flowing from Parkview Precinct.
2020	A bypass channel was constructed in Badu Mangrove to alleviate the dieback that was caused in 2014

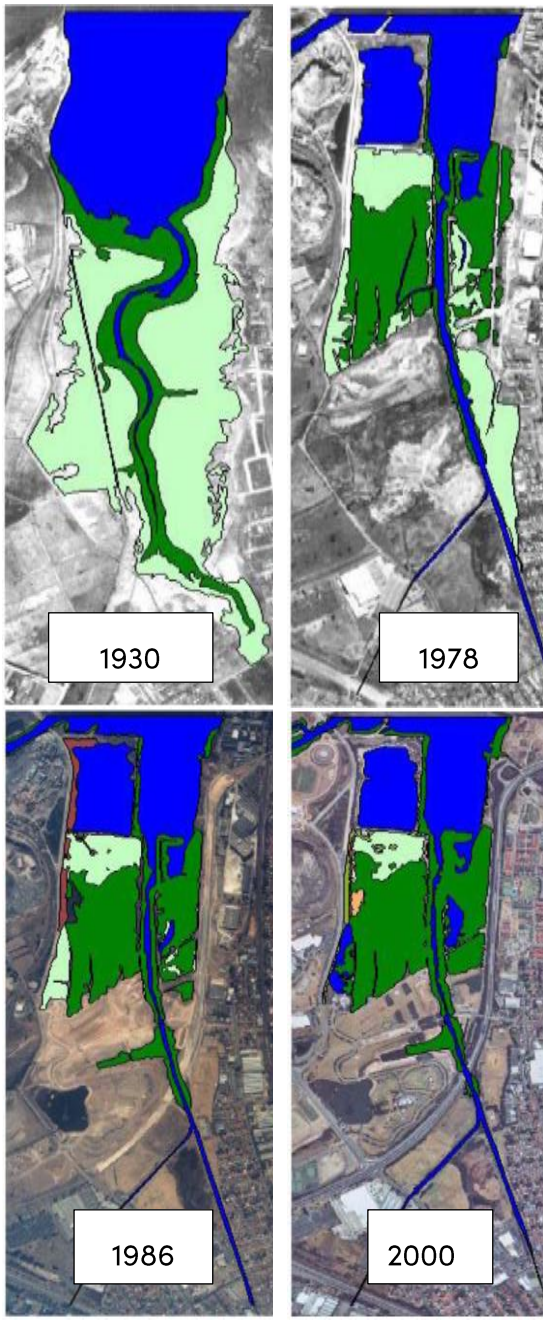


Figure 3. Noticeable changes in portion of Homebush Bay area (after Rogers 2004)

Figure 4. Major changes in the condition of the area that is now Newington Nature Reserve Wetland

Despite those changes some habitats and biodiversity thrived in the area due to the sheer resilience and natural ability to re-bounce. The ecological surveys that were undertaken immediately prior to the Sydney 2000 Olympics provides a comprehensive picture of the state of the ecology of Homebush Bay area (OCA 1995). Thanks to the Sydney 2000 Olympics that happened to be the single largest development activities in Australia in recent memory, which has also made remarkable contributions to the protection and conservation of wetlands, particularly estuarine wetlands, in the Homebush Bay area and Sydney Olympic Park. It can be claimed that if the Sydney 2000 Olympics did not take place and the size of the development activities were not undertaken, perhaps the degraded and derelict wetlands would have still remained a liability to the Sydney-siders and the nation as a whole. Some of these are illustrated below.

Wetland Reconstruction and Rehabilitation Efforts Leading to the Olympics

The most remarkable of all reconstruction activities that were undertaken leading to the Sydney 2000 Olympics (apart from the sporting venues and facilities) were the remediation of the heavily polluted site and reconstruction of the area. The remediation of past domestic, commercial and industrial waste sites at Sydney Olympic Park was the largest project of its kind in Australia and is one of the most significant environmental legacies of the Sydney 2000 Olympic and Paralympic Games. Approximately 160-hectares of the site was identified as containing wastes including power station ash, demolition rubble, asbestos, industrial hydrocarbons, domestic garbage, and dredging material from the Parramatta River. Between 1992 and 2000, the NSW Government spent $137 million for remedial action to clean up polluted areas (Pym 2001). The remediation policy at the time was to safely contain and where possible treat, waste on site, rather than relocating it to other places. Remedial action varied according to the type and location of the waste and local hydrological and soil conditions, and included the recovery, consolidation and containment of about 9.0 million cubic metres of waste. Approximately 400 tonnes of soil contaminated with hydrocarbons and classified under environmental legislation as 'scheduled chemical waste' was treated in a two-stage thermal desorption process. The majority of the buried waste was removed and relocated to designated waste containment mounds. These areas were capped, landscaped and turned into parkland. Leachate collection and transfer systems were built to prevent leachate from escaping into the environment.

Since every single one of the main waste dumping sites (landfills) and industrial polluted sites were in or near the waterways, which were developed by infilling former estuarine wetlands, as well by discharging polluted waste into watercourse, the largest beneficiary of the pollution containment and remediation was the ground water and the waterways by intercepting leachate from seeping in to wetlands and waterways. Below are brief examples of presently functioning wetlands that came about from repair, new creations, restoration, rehabilitation and or modification from the development works related to the Sydney 2000 Olympics.

a. Newington Nature Reserve (NNR) Wetland and River Walk

This wetland was reconnected to the adjacent Parramatta River after over 150 years of separation (Table 1). The new connectivity was established in 1997 and 2001 through construction of drainage and tidal flushing corridors (Figure 4). This has augmented drainage of the once stagnant water and facilitated tidal exchange. Because of the sudden drainage of the once stagnant water through the new corridors; those caused some abrupt changes in the wetland in the forms of acid sulfate release, stress on Swamp Oak Floodplain Forest (SOFF), change in the texture of the mud in the extensive mudflats that used to be heavily used as feeding grounds by migratory shorebirds, rapid expansion of coastal saltmarsh, salinity loss by the planted saltwater tolerant rare and threatened species on the upper marsh in the nursery area and stress on mangroves. Over time, those ecosystems have been undergoing fast adaptations and slowly but surely turning in to significantly beneficial habitats.

Also, the Riverwalk and the Sea Wall linear corridor was progressively restored by protecting the eroding sections of the river bank mainly due to the running of the River Cat ferry service.

b. Wilson Park and Kronos Hill remediation

These areas were two of the most polluted in the entire Homebush Bay area. These required most innovative and difficult remediation ever undertaken in Australia. In fact, it is perhaps the first attempt of remediation in the world by applying this technique. The toxic hydrocarbon, specifically tar (a polycyclic aromatic hydrocarbon compound), was buried underground from the gas conversion works in the early nineties. Tar would otherwise leach into Parramatta River and pollute the entire downstream-upstream course of the tidal river. A remediation technique was innovated, which involved containing the tar-contaminated leachate and then pumping to a mat populated with a specific type of bacteria. These bacteria would then breakdown the tar in to water and carbondioxide gas. As a result the river was no longer receiving polluted seep containing tar. Similarly, previously contaminated lands along Haslams Creek, particularly in Kronos Hill area, were contained, upgraded and landfills created. Together, these are now saving the estuarine waterways from leachate flows and pollution.

c. Haslams Creek enhancement

The entire upper section of Haslams Creek was completely reconstructed from vastly widening a previously existed concrete stormwater channel to a fully functional natural creek system. The widening has provided the much needed stormwater detention capacity to avoid flooding upstream. The works have constructed NSW's first ever large-scale creation of coastal saltmarsh. As a result, some 2.5ha of coastal saltmarsh was totally newly constructed on both edges of the Creek. The elevation was carefully maintained between 0.7mAHD and 1.1mAHD – a range that suits coastal saltmarsh in tidally open flats. Likewise, further lower section of the creek-line (Haslams Reach precinct) was also improved by undertaking various rehabilitation works. The Nuwi Wetland area was also upgraded by widening the stormwater-tidal exchange corridor and as well as created a small saltmarsh pocket (Pym 2001).

In this creek system also exists the Narawang Wetland cluster. This cluster of 22 freshwater ponds and three stormwater detention reservoirs were created to handle stormwater but most

importantly, as replacement habitats for Green and Golden Bell Frog and Latham's Snipe (Pym 2001). These ponds are separate from the Creek but at extremely high tides associated with storm events, the estuarine water can intrude in this wetland corridor.

Two other wetlands – Northern Water Feature and Eastern Water Quality Control Pond were also constructed to handle stormwater but to mainly provide stormwater storage and later used as interchanging capacity for the Australia's first ever large scale Water Recycling and Reclamation Scheme (WRAMS) for water commercial recycling and reuse.

d. Powells and Badu Mangrove area enhancement

Fortunately, much of the wetland areas that were once degraded and left derelict from the reclamation activities for landfill and industrial establishments in the early 1990s, many were already rectified and restored between 1983 and 1988 prior to the opening of the Bicentennial Park for environmental education and recreation. However, a few additional but minor rehabilitation works were undertaken during the Olympic development period, which primarily included widening the lower section of Boundary Creek, installation of a Fishway (Fish Passage) in this section and also elimination of water-logging and mosquito breeding habitats in a section of the Badu Mangrove precinct by constructing earthen channels.

Recent Initiatives and Present State of the Estuarine Wetlands

The present state is largely the result of the above-mentioned restoration and rehabilitation works undertaken leading to the Sydney 2000 Olympics. However, many new initiatives were also undertaken to complement some of the previous works and attend to new issues. As a result, the estuarine wetlands in the Park are generally overcoming any impacts from past changes, modifications and/or rehabilitation activities that were undertaken in relatively recent past; especially past two or so decades that were mainly linked to the Sydney 2000 Olympics. Since ecosystem restoration takes time and for a wetland to restore its full function as well as establish the complex network of overlapping and mutually connected functions take many years, it is relatively premature to expect major improvements in the wetland conditions. Nevertheless, the estuarine wetlands are fast adapting to the relatively stable habitat conditions and they are generally in a good state. A brief account of these wetland types are provided below.

a. Estuarine Creeks

Estuarine Creeks are significant corridors for flood mitigation through stormwater discharge and tidal exchange. The Creeks are also wonderful natural corridors for marine life as breeding, shelter, nursery, migration, (limited) emergency navigation and landmark features. Distinct Creeks that exist in the Park are Haslams Creek, Powells Creek (including the lower section of Boundary Creek) and Louise-Savage Creek. By far, the former two creeks play vital roles, as mentioned above.

Over time, the conditions of these creeks have fluctuated due to a variety of reasons. These include:

i. bank erosion from high intensity stormwater flows from extreme rain events induced by Climate Change;

ii. structures and utilities in the creek corridor;

iii. sewer overflows;

iv. flow of litter and sediment from upper catchments;

v. flow and settlement of water-borne weeds; and

vi. impacts of legacy modifications and changes.

One biggest physical change in the recent decades has been the widening of former Haslams Creek, from its concrete drainage channel structure to a many-time more natural creek, including construction of saltmarsh beds on the upper elevation of the creek line. This was undertaken immediately prior to the Sydney 2000 Olympics. On the other hand bank erosion and collapse has been a problem lately from two aspects: one, with the collapsing of the shores mangrove and saltmarsh also disappear with the collapse; two, the loss of sediment that has been so age-old, which trapped so much of organic carbon, have all but emitted to the atmosphere. In addition, if the shores keep collapsing at a greater rate then the integrity of some adjacent landfills may be under threat.

b. Estuarine Lagoons

There are four noticeable estuarine lagoons in the Park. These are the Waterbird Refuge (WBR), the Main Lagoon in the NNR Wetland, the Nuwi Wetland and Saltwater Billabong. These distinctly different habitats are characterised by direct links to the estuary and on receding tides they retain some tidal water in them. Because of their wetting-drying-retaining features, they attract a high diversity of birdlife and estuarine fauna and flora. They serve a variety of purposes including refuge, shelter, feeding, roosting, breeding, nursery and relaxing by many waterbirds and shorebirds; some of which travel from as far as the northern hemisphere (Straw 2013). Among these the WBR and the Main Lagoon in NNR Wetland are prominent. Marine life also uses them for many purposes.

The WBR used to be a 'black hole'; a dead and putrid water body for decades when it was disconnected from the nearby Homebush Bay in mid-1990s. Since it was re-connected in 2006 to the Bay with the help of construction of an innovative tidal weir (SmartGate), it has become a biodiversity hotspot. Migratory shorebirds, local waterbirds, marine life and coastal saltmarsh – all are now teeming with saturation and satisfaction. More details of these are seen in other chapters in this eBook.

Likewise, ever since the Main Lagoon in NNR Wetland was opened up to the nearby River in 1997 and 2000, the lagoon has slowly transformed from an algae-infested and mosquito-ridden waterbody into a highly interactive and diverse habitat. Various migratory shorebirds have recently started visiting the lagoon. Other two lagoons, Nuwi Wetland and Saltwater Billabong, are also slowly improving as useful habitats for marine life as well as waterbirds and local shorebirds.

c. Mangrove

The Park has only two out of some 78 species of mangroves that are globally available out of 41 species that are available in Australia (Duke 2006). These two species are Grey Mangrove (*Avicennia marina*) and River Mangrove (*Aegiceras corniculatum*). Since Grey Mangrove is the most dominating in the Park and River Mangrove has only a few trees scattered across the Park, 'mangroves' implies only Grey Mangrove. Mangroves reside at a specific elevation band in this part of the

Box 1. Tidal restoration in the WBR.

In the past, the Refuge was largely isolated from tidal exchange with the Parramatta estuary, which resulted in the wetland becoming stagnant; bird diversity and abundance declined, and algal blooms became common. A small pipe installed through the bund in the early 1990s allowed some tidal exchange, but conditions did not change for the better until a 2m wide automated, solar-powered tidal gate and weir was installed in 2007, allowing daily exchange of tides. Water flow can be adjusted seasonally and daily to account for tidal cycles and habitat needs. High tides flushed the wetlands of algae as well as discouraged new algal growths. The number and diversity of benthic invertebrate, an important component of migratory shorebirds' diet, increased. With no delays, a huge number of Bar-tailed Godwit made a comeback after decades of absence.

Box 2. Recent restoration of Badu Mangrove dieback area.

Grey Mangrove trees died in an area of approximately 7,000m2 within Badu Mangroves precinct during 2012 and 2013. Several investigations confirmed that the most likely cause was long-term water-logging. Following careful planning a bypass corridor was constructed by placing a box culvert and excavating two linking channels. The construction of the by-pass corridor has instantly removed the water-logging. Mangrove trees that were earlier stressed made a comeback and new seedlings are colonising. A scientific monitoring program has been in place to track the temporal changes.

east coast of Australia, with the most suitable band being 0.5mAHD to 0.9m AHD. Mangroves are a Protected Marine Vegetation under the NSW Fisheries Management Act 1994.

According to the condition assessment (included in Field 2013) undertaken over the period 2014 through 2019, approximately 48-61% of the overall coverage of the mangroves in the Park were in good condition, 22-44% in fair condition and 5-20% in poor condition. The relative scores of the condition changed from time to time due to various factors. The major contributing factors include:

i. sudden dieback of pockets of mangroves due to water logging (2013-14) and/or lightening (various years);

ii. mangrove canopy impacted by leaf-eating moth larvae (in 2003-04);

iii. slow dieback due to elevation changes from past landfilling works (continuous);

iv. slow dieback due to increased stormwater flows and resultant water-logging (2016-17) as well as sea level rise (recent);

v. deaths of trees from shore collapse due to stormwater and tidal flows from extreme rainfall events (recent years);

vi. canopy and trunk breakdown from overgrowth and loss of balance across creek-lines (various locations);

vii. establishment of boardwalk and other utility structures in the Park over a period of time;

viii. stormwater litter and debris settling on mangrove beds, especially along the creek-lines;

ix. stress and suppression from extreme weather events such as sudden rise in extreme ambient heat (2019) and shocks from sudden extreme cold (recent years);

x. shadow impacts from structures as bridges (1998) and buildings (1999);

xi. hydrocarbon (2002) and other pollution events in the past (various decades) that have caused genetic defects (Veldkornet *et al.* 2020) and other abnormalities (continuous); and

xii. stress and death of individual tree from undetected reasons, which could be linked to past pollution events.

Although the above-listed factors do impact on the health and condition of the mangroves in the Park, the sheer resilience and adaptation ability of the mangroves make them still stand out as one of the most thriving and flourishing ecosystems in the area. Actually, even though the mangroves have been undergoing various pressures in the recent decades, as listed above, due to other type of human-induced activities such as rise in the sediment bed from landfilling and upstream catchment earthworks that had been undertaken in the long past, mangroves have rapidly expanded in Homebush Bay area; compared to what existed prior to the industrial era (McLoughlin 2000, Saintilan and Williams 2000). This is purely because mangroves quickly colonise where conditions and habitats suit them.

Recent initiatives have improved the overall conditions of mangroves in the Park. A most recent example has been the installation of a bypass corridor to allow drainage of a waterlogged area and allow a natural regime of tidal exchange. Box 2 provides some more insights.

d. Estuarine Mudflats

Estuarine mudflats are spread across many wetlands in the Park. Some are exposed to daily tidal wetting-drying

regime yet others are inundated by either spring tides or stormwater discharge. These habitats are generally in excellent condition, therefore, attracting a relatively high diversity and abundance of migratory shorebirds, local shorebirds and resident waterbirds. Their conditions have been continually improving due to the improvements in the stormwater and tidal water qualities from lesser pollution. Estuarine life such as crabs, gastropod molluscs, polychaete and similar worms, algal films, seaweed as well as small fish and shrimp have been making these mudflats rich feeding grounds. As results of some carefully chosen improvement works, the texture and composition of the mudflats are gradually becoming more suitable for shorebirds and other creatures such as mud-dwellers, which are reflected by the increasing diversity and relative abundance.

e. Coastal Saltmarsh

Coastal saltmarsh resides mainly at the further higher tidal elevation than the mangroves. Coastal Saltmarsh is actually an ecological community, consisting of a number of signature plant species that are highly salt-tolerant and also other estuarine and semi-terrestrial biota. Coastal Saltmarsh is an Endangered Ecological Community in NSW under the *NSW Biodiversity Conservation Act 2016*. When referred to Coastal Saltmarsh, the assemblages of halophilic species that are represented include *Sarcocornia quinqueflora, Suaeda australis, Triglochin striata, Sporobolus virginicus*, and *Juncus kraussii*. It also has three other species that were introduced and by now these have been naturalised. These are *Wilsonia backhousei, Lamprathus tegens* and *Tecticornia pergranulata*. Among these, because of its rarity and special features, *Wilsonia backhousei* has been protected in NSW under the *NSW Biodiversity Conservation Act 2016* as a vulnerable species.

Like the mangrove conditions in the Park, condition assessment (Pacific Wetlands 2019) was also undertaken for Coastal Saltmarsh in the Park over the period 2008 through 2019. Approximately 51-66% of the overall coverage of the coastal saltmarsh in the Park was in good condition, 17-32% in fair condition and 13-17% in poor condition. The relative scores of the condition changed from time to time due to various factors. These factors include:

i. a decline in the extent of *Wilsonia backhousei* since 2014, most likely due to the overshadowing by trees and shrubs along the margin of the wetlands;

ii. terrestrial weeds expanding into the Saltmarsh Nursery area of NNR Wetland;

iii. stormwater litter and debris settling on saltmarsh beds, especially along the creek-lines;

iv. mangrove incursion due to sea level rise and bed slumping;

v. slow dieback due to elevation changes from past landfilling works (continuous);

vi. slow dieback due to increased stormwater flows and resultant water-logging (2016-17) as well as sea level rise (recent);

vii. losses of pockets from shore collapse due to stormwater and tidal flows from extreme rainfall events (recent years);

viii. establishment of boardwalk and other utility structures in the Park over a period of time;

ix. stress and suppression from extreme weather events such as sudden rise in extreme ambient heat (2003 and recent years);

x. shadow impacts from structures as bridges (1998) and buildings (1999);

xi. stress and death of small pockets from undetected reasons, which could be linked to past pollution events.

It has been widely claimed that over 70 per cent of coastal saltmarsh had been lost from Homebush Bay between 1930 and 1980 (Saintilan and Williams 2000). Losses have been also reported elsewhere along the Parramatta River (McLoughlin 2000). However, as an attempt to regain some of the lost saltmarshes, vast areas of the saltmarsh were reconstructed as part of the Sydney 2000 Olympic development and rehabilitation of wetlands. As a result, coastal saltmarsh area has more than doubled since late 1990s, mainly due to the creation of Haslams Creek Flats, additional saltmarsh in NNR Wetland and in the Waterbird Refuge. Not only the total area has been increased, the very quality of the saltmarsh areas has been also enhanced significantly by removing weedy plants and other measures, as below:

i. complete removal of Spiny Rush (*Juncus acutus*), a declared weed, from more than 7.0ha area of saltmarsh by employing a combination of techniques, including one that was developed through scientific trails (Paul and Young 2006; Paul *et al* 2007; Paul *et al* 2012);

ii. annual removal of Grey Mangrove seedlings from dedicated coastal saltmarsh areas under a permit from NSW Fisheries;

iii. continuous capture of stormwater-borne litter with the help of floating traps and booms, and hand-removals of litter from coastal saltmarsh beds by volunteers and SOPA staff; and

iv. careful handling and management of the tidal waters with the help of manually or automated weirs;

some of which measures are described later in this chapter.

The Authority's management approach and the successful conservation of the coastal saltmarsh have been used as demonstration examples by the NSW State Government.

f. SOFF (Swamp Oak Floodplain Forest)

SOFF (Swamp Oak Floodplain Forest), represented by *Casuarina glauca*, is an Endangered Ecological Community under the *NSW Biodiversity Conservation Act 2016*. The Authority's coverage of this community has been in three main precincts: NNR Wetland, Badu Mangrove and Badu Saltmarsh. According to the scientific monitoring conducted every two years since 2015, the condition of the NNR Wetland has been improving since it has had a setback from a dieback soon after the tidal modification in 2000 whereas other areas have been generally maintaining their conditions. So, in general, SOFF has been well protected and conserved in the Park.

g. Mosquito management

Mosquitoes, particularly those that use estuarine habitats as their primary breeding grounds, have been an integral feature of estuarine wetlands in the Park. Although their presence is a natural occurrence in habitats that suit them; their excessive populations are an indication of degrading conditions of wetlands and have been a nuisance and health issue for the Park visitors, residents and businesses. Pest mosquitoes, particularly *Aedes vigilax* (aka Vigilax mosquito), has been an estuarine specialist with coastal saltmarsh areas having semi-permanent tidal and/or rainwater impoundments being the most productive habitats for breeding of this species. But the trouble is that they breed, shelter and feed in more

Box 3. Saltmarsh reconstruction and rehabilitation in Haslams Flats.

Sydney Olympic Park has a long history of active management of saltmarsh. Remediation works in the 1990s included several major estuary restoration projects. Remnant coastal saltmarsh was conserved and a nursery established to provide local provenance seed and cuttings used in replanting programs. The concrete-lined channel of Haslams Creek was replaced with a new creek-bed and newly-built tidal mudflats were planted with saltmarsh. This was further rehabilitated in 2007.

than one habitat types – coastal saltmarsh, broken mangrove areas, water-pooled mudflats, drainage channels and crevices along creek-lines.

Therefore, any control measures often expanse across more than just coastal saltmarsh habitat or one particular estuarine habitat type.

A brief outline of the Authority's mosquito management program is illustrated in Box 4 & 5 below. However, the main approach to the mosquito problem has been two-fold: habitat enhancement measures so to eliminate actual and potential habitats for mosquito breeding, and, where this is not possible for technical, financial or other reasons, in those habitats a bacterial spore of the bacterium, Bti (*Bacillus thuringiensis* subspecies *israelensis*) is sprayed by helicopter and/or backpack spray kit (Webb 2013).

Principles of managing estuarine wetlands

Management of the complex mosaic of the estuarine wetlands has been a challenging task. In most cases the challenges have been unique, therefore, requiring innovative and creative interventions. The challenges arise from many directions and many of which were mentioned in the above sections. A summary of these include:

i. legal bindings and compliance;

ii. physical spread of the wetlands across various sub-catchments;

iii. wetlands that were attempted to be restored in the past but still taking their own time in the healing process;

iv. continued pollution from stormwater, particularly road runoff, litter, sediment and weed;

v. public usage of the site and increasing interest and presence of public with a sense of 'love to death'; and

vi. public events with potential disturbances to wildlife and habitats;

viii. development pressure, particularly light spill, noise and other pollutants; and

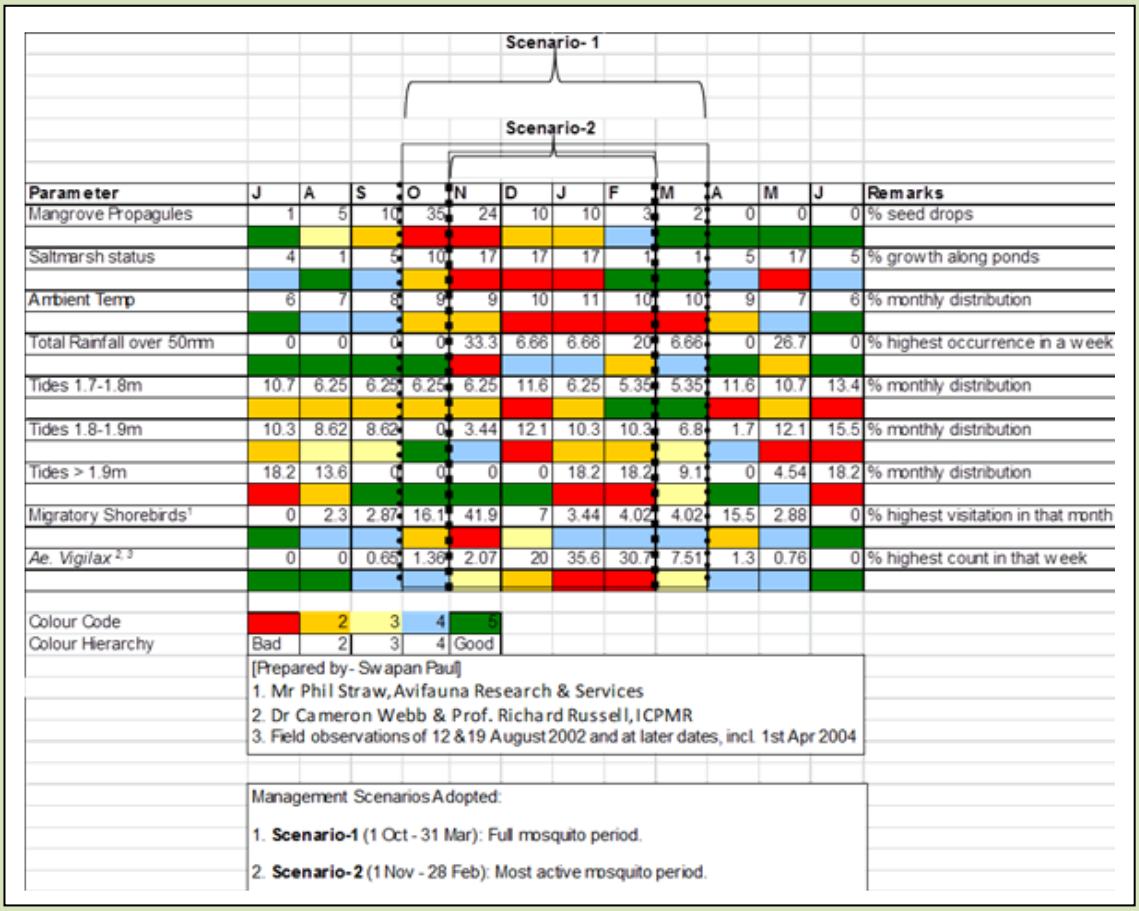
ix. climate change and sea level rise.

Box 4. A complex matrix, showing adaptive management of the NNR Wetland in managing the Authority Mosquito Program.

The wetland underwent many changes over the decades. The changes that were undertaken during 1993 to 2001 were aiming at fulfilling many management objectives. These include mosquito reduction, migratory shorebird optimisation, saltmarsh enhancement, mangrove protection but not encroaching in saltmarsh areas, less frequent algal growth and improved water quality.

After several iterative attempts a matrix was worked out by considering various abiotic, biotic and eco-hydrological factors that are known to have been playing direct roles in determining the success of the above objectives. Based on those factors a relative scoring was allocated, which was represented in colour codes. It is clear from the matrix that the most negative scoring (depicted by the greater concentration of red and orange colouration) was during two bands of periods. Those are periods when mosquito treatments are required. This matrix has helped determining the timing and magnitude of the efforts and at the same time to focus on managing the ecology of the wetland. As a result, by adjusting weir setting to 1.55m tide level, mosquito treatment events could be avoided during the less intense months of October and March (with less Red). However, this is possible only if there is not an associated rain event.

Adaptive Management principle helps in achieving this goal, which is primarily based on remaining focus on firm objectives but be flexible in reaching the objectives, however, based on good science. Consequently, the Authority's mosquito management program has been extremely effective, with a massive cost-saving when compared with the early days of this program.



Parameter	J	A	S	O	N	D	J	F	M	A	M	J	Remarks
Mangrove Propagules	1	5	10	35	24	10	10	3	2	0	0	0	% seed drops
Saltmarsh status	4	1	5	10	17	17	17	1	1	5	17	5	% growth along ponds
Ambient Temp	6	7	8	9	9	10	11	10	10	9	7	6	% monthly distribution
Total Rainfall over 50mm	0	0	0	0	33.3	6.66	6.66	20	6.66	0	26.7	0	% highest occurrence in a week
Tides 1.7-1.8m	10.7	6.25	6.25	6.25	6.25	11.6	6.25	5.35	5.35	11.6	10.7	13.4	% monthly distribution
Tides 1.8-1.9m	10.3	8.62	8.62	0	3.44	12.1	10.3	10.3	6.8	1.7	12.1	15.5	% monthly distribution
Tides > 1.9m	18.2	13.6	0	0	0	0	18.2	18.2	9.1	0	4.54	18.2	% monthly distribution
Migratory Shorebirds[1]	0	2.3	2.87	16.1	41.9	7	3.44	4.02	4.02	15.5	2.88	0	% highest visitation in that month
Ae. Vigilax[2,3]	0	0	0.65	1.36	2.07	20	35.6	30.7	7.51	1.3	0.76	0	% highest count in that week

Colour Code		2	3	4	5
Colour Hierarchy	Bad	2	3	4	Good

[Prepared by - Swapan Paul]
1. Mr Phil Straw, Avifauna Research & Services
2. Dr Cameron Webb & Prof. Richard Russell, ICPMR
3. Field observations of 12 & 19 August 2002 and at later dates, incl. 1st Apr 2004

Management Scenarios Adopted:

1. **Scenario-1** (1 Oct - 31 Mar): Full mosquito period.
2. **Scenario-2** (1 Nov - 28 Feb): Most active mosquito period.

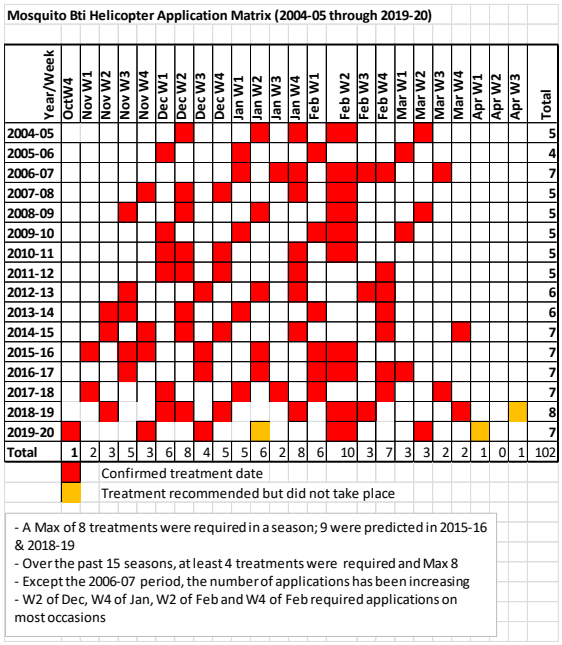


Figure 5. Mosquito helicopter treatment matrix in NNR Wetland.

So, to mitigate, manage, avoid and handle the challenges, the Authority has been undertaking many measures. The core principle of the measures and the management of the wetlands in the Park is Wise Use principle of Ramsar that the Australian Government follows (CoA 2020b). Wise Use advocates for four key pillars of wetland management: using an ecosystem approach, balancing uses, understanding and implementing sustainable use and using the best available information.

Since the values of these wetlands are in the end judged by humans – the ultimate users of these wetlands outside the wildlife and the nature - it is critical that a successful and lasting marriage takes place between human uses and sustainable functioning of these wetlands. That way nature conservation and human expectations are being balanced out on a regular basis (Paul 2018). The way the Authority fulfils the Wise Use guidelines are briefly outlined below.

a. Compliance and Due Diligence

The *Sydney Olympic Park Authority Act 2001*, (commonwealth) *Environment Protection and Biodiversity Conservation Act 1999*, *NSW Biodiversity Conservation Act 2016*, *NSW Fisheries Management Act 1994* and *NSW National Parks and Wildlife Act 1974* are the five main regulatory instruments that guide the conservation and management of the estuarine wetlands in the Park. To better manage, the Parklands Plan of Management (PoM), Biodiversity Management Plan (BMP) and Wetlands Operational Action Plan (WOAP) have been developed as guiding documents. To help undertake day-to-day activities and help maintain the site as well as undertake repair, renovation and restoration of the estuarine wetlands and ancillary lands and service structures, several other policies, procedures and protocols have been adopted. The Authority's various teams implement these procedures and guidelines, which help undertaking even a huge number of works simultaneously.

The other aspect of a balancing act has been development proposal that could otherwise influence and/or impact estuarine wetlands. This is looked at mainly under the direction of *NSW Environmental Planning and Assessment Act 1979* and the (commonwealth) *Environment Protection and Biodiversity Conservation Act 1999*. Whilst the need for more development activities in the precinct and in closer proximity to estuarine wetlands is well understood it is also given utmost priority to not encourage such developments at the expense of the ecological integrity of the wetlands. In fact, over the recent decades, the Authority has been able to strike that balance and by now it has been an exemplar in balanced urban development, as outlined above (Paul 2018).

b. Adaptive Management Framework

Realising that the natural systems have been continually evolving and so are the demands and aspirations of the Park users as well as the entire natural system is exposed to the influences of climate change and sea level rise, the Authority's management approach does have Adaptive Management principles well embedded. Accordingly, on one hand it remains firm in its conservation goals yet on the other it continually remains agile in making adjustments to its projects and programs so that ecosystems have the chance to adapt to changes. Figure 6 below shows an outline of the Adaptive Management framework.

Key steps that are always followed in the Adaptive Management are:

i. defining a management issue and drawing hypothesis that are based on scientific investigations and monitoring;

ii. undertaking risk analysis;

iii. setting management goals;

iv. undergoing genuine consultations with relevant stakeholders;

v. undertaking impact assessments and setting management actions;

vi. monitoring outcomes of management actions;

vii. evaluating the outcomes and re-setting goals (if needed);

viii. undertaking research and following the management loop.

In the above mix of steps, proper monitoring is critical to the success in achieving the conservation goals. Monitoring also helps identifying new issues and those are further challenged by employing hard science.

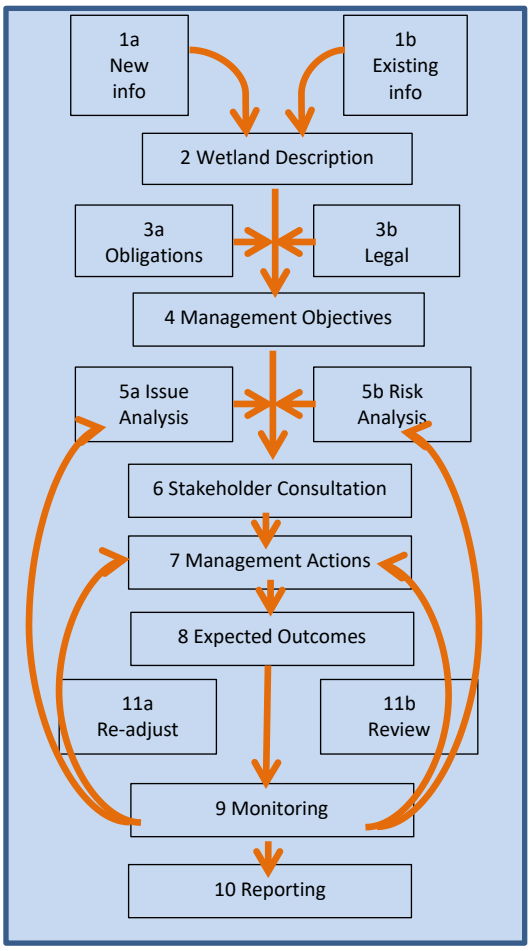


Figure 6. Adaptive Management Framework (re-constructed after SOPA 2006).

c. Innovation and Sustainability

Considering the limits in resources and funding as well as the time available for realising outcomes, it is always at the forefront of management ethos that innovative pursuit is always given the priority. In fact, by remaining open to new ideas and always challenging our own theories and hypotheses, the Authority has been able to develop numerous innovative management tools and prescriptions that are eventually replicable. Similarly, measures that will help reduce generation of wastes; reuse of materials as much as possible within the site so to reduce burden on transportation and disposal costs; recycle as much possible and use recycled

materials in as many cases as possible – these have been the Authority's core practices. As a result, the Authority has recently acclaimed as a world class sustainable operator and has been one of the few public sector agencies in NSW that is a Six-star Green Star Awardee.

As examples of innovation and sustainability practices, below is a list of tools and techniques that have been successfully developed and applied in the Park. These have now been widely applied by wetland managers across Australia and beyond. These include:

i. environmentally friendly control of *Juncus acutus* from the sensitive coastal saltmarsh areas;

ii. cost-effective and self-regeneration of coastal saltmarsh vegetation in Haslams Flats that saved a huge amount of cost from other options;

iii. development of a technique of undertaking contour maps of tidal exposure in mangrove and saltmarsh habitats;

iv. development of the concept and undertaking of channel construction in Badu Mangrove for alleviating perennial mosquito problem and improving mangrove health;

v. development of the concept and installation of a solar operated and fully automated tidal gate (SmartGate) in WBR;

vi. reuse of any mulch in estuarine areas that is generated from fallen or removed mangrove trees;

vii. any organic wastes generated from mangrove and saltmarsh areas are reused on site as much practicable;

viii. operations of automated tidal gauge and communication device with solar power;

ix. complete refurbishment and replacement of a 600m long boardwalk in the mangroves that used only recycled materials; and

x. replacement of bridges and structures in estuarine areas with recycled materials as a preferred choice.

d. Partnership and Collaboration

Partnership and collaboration have been two major drivers of seeking external support and engaging interested stakeholders in not only managing these wetlands but also offering the place for the partners and collaborators to make use of. Best examples of these are the Citizen Science volunteers, student researchers, higher degree research projects, industry research, international collaboration studies, and public agency and local government reference studies. As a result several dozens of studies have been undertaken in the estuarine wetlands, which help guiding the management of these wetlands. These also help other wetland managers to extract the information and make their wetlands good. Likewise, over the decades, more than a dozen of volunteer and philanthropic groups have also benefitted from and contributed to these wetlands.

The Cumberland Bird Observers Club provides dozens of volunteers every year for undertaking seasonal bird census, including birds using the estuarine wetlands.

Another big form of our collaborations and partnerships has been the running of the Wetland Education and Training (WET) Program. This program relies largely on the volunteered contributions from over a hundred of wetland professionals and academia, who give scholarly talks and field tutorials for wetland professionals. This program has

been running since 2002 and in this period of time several thousands of hours of volunteer hours were donated by these trainers and advisors to make this program successful. A large part of the program involves demonstration of tools and techniques that were successfully innovated and/or adopted in managing these wetlands. However, in running the program the estuarine wetlands also greatly benefit from the knowledge gained from the program.

Climate Change and Sea Level Rise

In the quest for innovation and sustainability and with a view to succeeding in Wise Use of wetlands, the Authority strives for up-to-date understanding in and looking out to projecting likely impacts of climate change and sea level rise on the estuarine wetlands.

The Authority's own studies, which are based on the data gathered by the NSW Manly Hydraulics Laboratory's tidal data from this site, have concluded that more than 7.00mm of average annual sea level rise in this site over the past 14 years, starting from 2002-03. This corroborates to that concluded in another independent study included in this eBook. In fact, in some years the rise was many-times higher and particularly in 2016-17 period, it rose by 55.0mm (Figure 7). The above rises mean that the estuarine wetlands are under tremendous pressure from the rising sea level. According to this trend line, the level in 2022 will reach 140mm above the 2002-03 level.

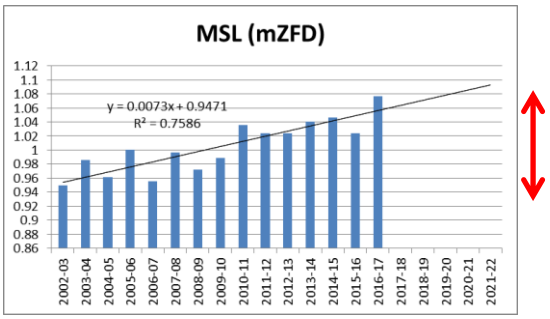


Figure 7. MSL and trend line in Sea Level Rise in Sydney Olympic Park.

To assesses the potential risks, vulnerability and adaptability, a study was undertaken in 2010 (Finlayson and Spiers 2011). According to the study, all estuarine wetlands within Sydney Olympic Park contained vulnerable components, based on an assessment of existing threats and risks and thence vulnerability to specific climate change and sea level rise impacts. However, some wetlands had more vulnerability than the others. The study suggested that the Authority's response to the changes in scenarios due to sea level rise and/or climate change would need to be reasonable, prompt and in most cases, pre-emptive. Proactive steps will help undertaking adaptation measures so to sustain conservation initiatives. Table 3 provides a summary of the outlook.

Other likely impacts of climate change (other than the sea level rise) on the estuarine wetlands are also being noticed heavily. A summary of the observations are listed below, many of which will require further detail studies. The observations include:

Table 3: Summary of major changes arising from sea level rise that are expected in main estuarine wetlands in Sydney Olympic Park.

1.075m AHD (average of high tides in 2000)	1.475m AHD (future average of high tides in 2050)	1.975m AHD (future average of high tides in 2100)
Parramatta River System: Newington Nature Reserve Wetland		
Under current tidal restrictions the entire mangrove area will be fully inundated; parts of the saltmarsh area in the Nursery section will remain un-inundated; the freshwater Wharf Pond will be partly inundated; the Swamp Oak will be partly inundated.	Under the same tidal restrictions the entire mangrove area will be fully inundated; only a very small part of the saltmarsh area in the Nursery section will be un-inundated; the freshwater Wharf Pond will be mostly inundated; the Swamp Oak will be mostly inundated; the Armory Creek will be flooded.	Under the same tidal restrictions the entire mangrove area will be more heavily inundated; all parts of the saltmarsh area including the Nursery section will be inundated; the freshwater Wharf Pond will be totally inundated; the Swamp Oak will be totally inundated; the Armory Creek will be completely flooded; many sections of pathways in the River Walk and the Armory will be flooded.
Powells Creek System: Badu Mangrove and Lake Belvedere		
With full tidal restrictions the WBR will be unaffected; Badu Saltmarsh ponds will be inundated; mangrove areas will be favourably inundated; the freshwater Bennelong Pond will not be inundated; pathways and walkways will not be flooded; freshwater Lake Belvedere will not be inundated.	With full tidal restrictions the WBR will be partly affected by water seepage through the bunds; Badu Saltmarsh and the ponds will be fully inundated; mangrove areas will be deeply inundated; the boardwalks will be more unstable; the freshwater Bennelong Pond will be inundated; most pathways and walkways will be flooded; freshwater Lake Belvedere will be fully inundated; pathways around the Lake will be flooded; leachate system may be infiltrated; portion of Oulton Ave pathway will be flooded.	Even with full tidal restrictions the WBR will be fully affected by flooding of the bunds; saltwater will infiltrate through WBR to the freshwater Triangle Pond; Badu Saltmarsh and the ponds will be fully inundated; mangrove areas will be deeply inundated; the boardwalks will be more unstable and unworkable; the freshwater Bennelong Pond will be fully inundated; all the pathways and walkways will be flooded; Lake Belvedere will be fully inundated; pathways around the Lake will be flooded; leachate system will be infiltrated and the Leachate Evaporative Pond will be infiltrated; Bennelong Parkway and the exit pathway of Bicentennial Park will be flooded; most sections of the Oulton Ave pathway will be fully flooded.
Haslams Creek System: Haslams Reach & Haslams Flats		
Tides will inundate all areas of mangroves and most areas of saltmarsh; Nuwi Wetland will be normally inundated by tides; the freshwater Northern Water Feature	Tides will inundate all areas of mangroves and all areas of saltmarsh; Nuwi Wetland will be more inundated by tides and if associated with storm events it will infiltrate the freshwater Narawang	Tides will inundate all areas of mangroves and all areas of saltmarsh; Nuwi Wetland will be more inundated by tides and even without associated storm events it will infiltrate the freshwater Narawang Wetland; the freshwater

and EWQCP will not receive tidal water; GGBF Ponds will not be inundated. Tides will inundate most areas of saltmarsh on Haslams Flats; the freshwater Teal Pond will not receive tidal water; GGBF Ponds will not be inundated.	Wetland; the freshwater Northern Water Feature will not receive tidal water but EWQCP will; GGBF Ponds will not be inundated. Tides will inundate all areas of saltmarsh on Haslams Flats; the freshwater Teal Pond will not receive tidal water; GGBF Ponds will not be inundated.	Northern Water Feature will not receive tidal water but EWQCP will be fully inundated; GGBF Ponds will not be inundated. Tides will inundate all areas of saltmarsh on Haslams Flats; the freshwater Teal Pond will receive tidal water; paths and walkways will be flooded; freshwater Narawang Wetland will be inundated by tides and GGBF Ponds will be severely affected.
Haslams Creek System: Narawang Wetland		
Freshwater Narawang Wetland will remain un-inundated.	Freshwater Narawang Wetland will remain un-inundated but if the tide heights rise due to associated storm events, the Wetland will receive tidal water.	Freshwater Narawang Wetland will be inundated with tides reaching above 1.475m AHD; internal pathways and walkways will be flooded.

i. droughts in 2003, 2013 and 2019 have burnt out mangrove canopy at places, burnt out mangrove seedlings in open pockets and burnt out saltmarsh vegetation, particularly *Wilsonia backhousei*;

ii. sudden extreme heat and rapid cold-shock are believed to have been causing failures in natural propagation success of Grey Mangrove;

iii. high intensity rain events associated with spring tides cause unprecedented flooding of estuarine and nearby public utility areas;

iv. high intensity rain events associated with spring tides create extreme flow events that naturalised estuarine creeks are unable to handle and cause bank erosions, mangrove falls and saltmarsh collapse;

v. unseasonal outbreak of filamentous algal blooms in estuarine lagoons;

vi. unexpectedly higher outbreaks of mosquito populations emanating from estuarine wetlands; and

vii. many more, which often go un-noticed.

Either in isolation and/or a combination or simultaneous effects of one or more of the above may mean that the task of managing the estuarine wetlands in the Park are likely to be much harder and more costly. To avoid remaining a helpless and silent observer of the damages taking place due to climate change and sea level rise, the Authority has been pro-active. It has prepared a Climate Change Adaptation Plan, developed in 2019 (SOPA 2019). But because of the lack of technically sound options to combat likely damage from impacts of climate change and and/or absence of timely and adequate resources, the adaptation abatement may become even more challenging.

Conclusions

The estuarine wetlands have enormous values. There have been legal imperatives; environmental and biodiversity conservation obligations; educational, recreational, aesthetic, spiritual and tourism demands; and international, regional and local drivers for which these wetlands require protection, enhancement and conservation. Over and above their usual ecosystem demands for protection and conservation, the sheer presence of these wetlands in a business hub that enjoys a high-profile economic significance, an extremely busy sporting precinct and an intensely urbanised city – the challenges in their effective management are enormous. Often these wetlands are loved to death; therefore often arise volatile situations that require urgent but thoughtful interventions. If left unattended, together those circumstances can leave the wetlands highly vulnerable to rapid, extensive and perhaps irreversible degradation and damage. It is pleasing that the Authority, with its continuous vigilance, presence of effective procedures and guidelines, and proactive interventions associated with the dedication of staff make the wetlands surviving and potentially sustaining into the future.

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