BOTANY BAY & CATCHMENT
WATER QUALITY IMPROVEMENT PLAN

With Support From

Australian Government

NSW GOVERNMENT | CMA Sydney Metropolitan CATCHMENT MANAGEMENT AUTHORITY

Cover Photo: Ramsar listed Towra Point Wetland with Sydney in the background *(John Dahlenburg)*

Principal Authors: Dr Rebecca Kelly (isNRM) and John Dahlenburg (SMCMA)

Contributing Authors (via specialist reports and/or models):
Tony Weber (BMT – WBM Pty Ltd)
Dr Joel Stewart (BMT – WBM Pty Ltd)
Greg Walkerden (Batkin – Walkerden Assoc)
Pam Batkin (Batkin – Walkerden Assoc)
Dr Peter Morison (Monash University)
Richard McManus (Equatica)
Katie Brookes (EDAW - AECOM)
Dr Alicia Loveless (DECCW)
Dr Peter Scanes (DECCW)
Geoff Coade (DECCW)
Assoc Prof Alberto Albani (University NSW)
Carl Tippler (GRCCC)

Reviewers/Advisors
Botany Bay Water Quality Improvement Program Reference Committee
Draft Botany Bay & Catchment Water Quality Improvement Plan was put out for public comment from November 2010 to February 2011.

Citation
Sydney Metropolitan Catchment Management Authority (2011). Botany Bay & Catchment Water Quality Improvement Plan. Sydney: Botany Bay Water Quality Improvement Program (BBWQIP)

Sydney Metropolitan Catchment
Management Authority
10 Valentine Ave
(PO Box 3720)
Parramatta NSW 2124
Phone: (02) 9895 7898
Email: sydney@cma.nsw.gov.au

CARING FOR OUR COUNTRY

This project was supported through funding from the Australian Government's Caring for our Country.

April 2011

Executive Summary

Introduction

This document is a Water Quality Improvement Plan developed for Botany Bay and its Catchment. It has been developed by the Sydney Metropolitan Catchment Management Authority, primarily with funding from the Australian Government through its Caring for Our Country Program.

The main objective of the Botany Bay & Catchment Water Quality Improvement Plan (WQIP) is to set targets for pollutant load reductions (in terms of total nitrogen [TN], total phosphorus [TP] and suspended sediment [TSS]) required to protect the condition of Botany Bay, its estuaries and waterways. In addition, it is expected that the Plan will be a tool for raising awareness and promoting behaviour changes amongst individuals and organisations. It is expected that the Plan will find an audience with Local, State and Federal Government agencies as well as with interested individuals, community groups and organisations. It has been developed with considerable input from the local community and other key stakeholders in the Catchment.

The Botany Bay Catchment consists of two major waterways: the Georges and Cook Rivers, as well as substantial foreshore areas to the Bay itself. The Catchment has a long history of human use, both Aboriginal and European and is substantially urbanised. Urbanisation is particularly prevalent in the Cooks River Catchment, Lower Georges River Catchment and areas of the foreshore. The Georges River Catchment still contains large areas of bushland that provide it buffering capacity and reduce the pressure on the Bay and the Georges River Estuary.

Botany Bay and its estuaries are associated with significant biodiversity and other environmental values as well as with community environmental and social values. The Bay and its Catchment are home to numerous endangered species and communities, a Ramsar listed wetland and migratory bird species, and Aboriginal and European heritage sites. There are also significant economic and social values attached to the Bay and its Catchment, through recreational use, ports, roads and the airports. Community environmental values for the waterways of the Catchment have been set using a community based process.

Ecological Condition and Pollutant Load Reduction Targets

The community environmental values set by the community have then been used along with scientific information to set ecological condition targets for the Georges and Cooks River estuaries and for the Bay itself.

Reduction in chlorophyll-A (Chl-A) and turbidity levels required to meet these targets.

Area	Reductions needed	
	Chl-A	Turbidity
Upper Georges River Estuary	44%	91%
Middle Georges River Estuary	38%	74%
Lower Georges River Estuary	19%	38%
Lower Cooks River Estuary	42%	52%
Botany Bay	Target met	Target met

To reduce the stormwater pollution loads coming from urban development to the waterways in the Botany Bay Catchment, it is recommended that all new development and/or redevelopment meet the stormwater pollution reduction targets shown below. These reduction targets can be achieved by incorporating WSUD into urban development and renewal. These stormwater reduction targets will need to be included in local and state government planning policies such as development control plans (DCPs).

Stormwater reduction targets recommended for urban development in the Botany Bay Catchment.

Stormwater Pollutant	Greenfield Developments Large re-developments	Multi-unit dwellings. Commercial developments. Industrial developments. Small re-developments.
Gross pollutants	90%	90%
Total suspended solids (TSS)	85%	80%
Total phosphorus (TP)	60%	55%
Total nitrogen (TN)	45%	40%

Scenarios to Improve Water Quality in the Botany Bay Catchment

The Plan explores 'best' and 'worst' case scenario options for the Catchment, in line with expected population growth (as described in the Sydney Metropolitan Strategy). The **'best' case** involving application of water sensitive urban design (WSUD) to infill redevelopment areas to meet growing population needs and rehabilitation of some riparian areas could lead to r**eductions of stormwater pollutants** delivered to the Bay **by 2030** of: **TSS (turbidity) 17%**, **TP 13%**, **TN 9%** (reductions in TP and TN will reduce the amount of nutrients available in the water and hence reduce Chl-A levels). These reductions in turbidity and nutrients will lead to improved local waterway conditions throughout the Botany Bay Catchment.

The **'worst' case** involving greenfield development without WSUD to meet growing population needs could lead to **increases of stormwater pollutants** delivered to the Bay **by 2030** of **TSS (turbidity) of 10%, TP 10% and TN 12%** respectively. These changes are also associated with significant local declines in river condition, particularly in the Georges River Catchment.

The Plan explores 31 different WSUD "treatment train" options that could feasibly meet the pollutant reductions implied by the 'best' case or preferred Plan scenario. These treatment trains are combinations of 7 basic WSUD devices: bioretention; next generation bioretention; buffers; gross pollutant traps; vegetated swales; rainwater tanks; and wetlands. The Plan shows the different costs and load reductions associated with each treatment train option (see table below for a summary of 8 of the least costly options). The costs and effects of riparian rehabilitation are also explored. It is stressed that in choosing a treatment train option, lowest cost may not be the best option and that several factors should be considered in choosing treatment train options with which to implement this water quality improvement plan (WQIP):

- The area available in which to place WSUD devices and the relative area of land that needs to be treated to achieve targeted load reductions.
- Physical constraints of the site which limit the treatment trains that can be applied.
- The total cost of options and balance between upfront and on-going maintenance costs, and consideration of how these are to be funded.
- The reductions over and above targeted load reductions that could be achieved through application of different treatment train options.

The 31 WSUD options were run through the Botany Bay CAPER Decision Support System (DSS) that was developed specifically to test a range of scenarios for the development of this WQIP. The Botany Bay CAPER DSS was used to provide an estimate of the impacts of the various WSUD options on nutrient and sediment delivery as well as the costs of their implementation throughout the

Botany Bay Catchment. The options shown below were chosen because they could achieve target load reductions within the infill redevelopment area. It should be noted when considering these results that the full costs shown here would not be experienced until 2030. Costs would be incrementally incurred as areas were developed/redeveloped and WSUD treatment options implemented. It should also be noted that many of these costs will already be included in the costs of redeveloping these urban areas with more advanced and environmentally sensitive stormwater systems. Councils in the Catchment have always, and will continue to, undertake improvements to their own infrastructure which are also included in the costs shown below. It is therefore likely that the "gap" or additional funds needed each year to achieve these reductions will not be high over the 20 year period. The eight least costly scenarios tested are shown below in the table (the full list of all 31 options can be found in section 4.1of the report). The costs have also been further broken down into subcatchment areas in section 4.2and LGA areas in Appendix 2.

Results of the top eight WSUD scenarios for the urbanised area of the Botany Bay Catchment sorted from least cost to highest cost

		Reduction in stormwater pollutant (%)					
WSUD Scenario	**Proportion of infill area treated by 2030**	**TSS**	**TP**	**TN**	**Annuatised lifecycle cost in 2030 $millions**	**Upfront cost in 2030 $millions**	**Annual Maintenance cost in 2030 $millions**
Next generation bioretention	89%	-15.2	-12.2	-6.9	$25.4	$278.1	$52.7
Bioretention	91%	-15.8	-12.7	-6.9	$26.0	$284.4	$53.9
GPT and Bioretention	91%	-16.5	-12.7	-6.9	$35.6	$580.2	$62.4
Swale and Bioretention	87%	-15.7	-12.5	-6.9	$43.2	$431.8	$92.4
Swale, GPT and Bioretention	87%	-16.0	-12.5	-6.9	$52.4	$714.8	$100.5
GPT and Wetland	100%	-16.7	-12.5	-6.9	$54.8	$1,944.1	$33.1
Bioretention and Wetland	87%	-15.5	-12.5	-7.8	$63.2	$1,679.5	$72.2
Swale and Wetland	98%	-16.6	-13.1	-6.9	$63.6	$1,758.5	$68.9

Recommendations

To be effective, the Plan needs to be owned and implemented by all levels of government as well as by individuals and organisations within the Catchment. The Plan provides direction on how each of these groups could act to implement its recommendations. This Plan needs to be reviewed and adopted by the various levels of government as well as the wider community living in the Catchment.

Some of the key recommended actions by the various groups that operate within this Catchment (taken from section 5 of the Plan) are listed below.

It is recommended that the **Australian Government**:

- Reviews and endorses the Botany Bay & Catchment WQIP,
- Sets up a specific funding program to implement actions listed in the Botany Bay & Catchment WQIP, possibly via a devolved grants program,

- Ensures all grants or funding allocated in the Botany Bay Catchment are consistent with and/or support the implementation of this Plan,
- Ensures that land/infrastructure/facilities under its control (including airports and military facilities) minimise its negative impacts on water quality,
- Provides long-term protection to the bushland in the Holsworthy Military Area to ensure it continues to provide buffering capacity to the Georges River and Botany Bay.

It is recommended that the **NSW Government**:

- Reviews and endorses/adopts the Botany Bay & Catchment WQIP,
- Incorporates the stormwater load reduction targets proposed in the Plan into the following regional planning policies: the Metropolitan Strategy and its sub-regional plans, the Metropolitan Water Plan, the SMCMA Catchment Action Plan and any other NSW Government policies that could have an impact on waterways in the Botany Bay Catchment,
- Ensures any new government policies or plans developed for, or that will have an impact on, the Botany Bay Catchment meet the Plan's water quality targets and are consistent with its objectives,
- Ensures that land/infrastructure/facilities under its control (including ports, roads and rail) minimise their negative impacts on water quality,
- Ensures the SMCMA has sufficient funding to continue to support the implementation of this Plan and to maintain and update the Botany Bay CAPER DSS and other catchment models developed,
- Ensures Sydney Water continues to improve the overflow performance of its sewer systems throughout the Catchment. Particular attention should be given to the sensitive waterways of the Upper Cooks River Catchment and the Upper Georges River Estuary,
- Continues to fund water quality improvement devices in the Botany Bay Catchment that are consistent with this Plan via a devolved grants scheme.

It is recommended that the **local councils in the Botany Bay Catchment**:

- Review and endorse/adopt the Botany Bay & Catchment WQIP,
- Use the Botany Bay CAPER DSS to test a range of scenarios and identify the most effective scenario(s) that will enable the LGA to meet their load reduction targets,
- Develop a short LGA-scale WQIP using the Botany Bay CAPER DSS,
- Include the stormwater/WSUD clause developed by the SMCMA (or similar) into the LGA's Local Environment Plan (LEP) (SMCMA 2008f),
- Prepare or update the LGA's Development Control Plan(s) to include WSUD and the stormwater pollutant load reduction and flow control targets identified in section 3.4,
- Ensure all new development or redevelopment minimises its impacts on the waterways (flow, water quality, riparian condition),
- Ensure new or renewed local council infrastructure (i.e. roads, drainage, car parks, buildings, footpaths, bike paths, etc.) are designed from a WSUD perspective and meet the stormwater pollutant load reduction targets, to minimise impacts on waterways,
- Engage with and support local communities implementing actions consistent with the Botany Bay & Catchment WQIP.

It is recommended that the **regional groups of councils and/or Regional Organisations of Councils** (ROCs) that operate in the Botany Bay Catchment:

- Review and endorse/adopt the Botany Bay & Catchment WQIP,

- Promote the Botany Bay & Catchment WQIP to members of the group and local communities,
- Coordinate and/or seek funding for regional-scale projects to support the implementation of the Botany Bay & Catchment WQIP,
- Ensure any regional projects, plans or programs, such as estuary management plans, are supportive of the objectives outlined in the WQIP.

It is recommended that the **community groups or NGOs** that operate within the Botany Bay Catchment:

- Continue, or undertake new works, to improve bushland and riparian zones within their subcatchments,
- Seek funding to undertake local-scale projects of interest that will support the objectives of the Botany Bay & Catchment WQIP,
- Promote the Botany Bay & Catchment WQIP to members of the group and their local communities.

It is recommended that the **households and businesses** in the Botany Bay Catchment:

- Take actions on their own properties that support the load reduction targets for the Catchment. These might include things like installing rainwater tanks, permeable paving, rain gardens (small household-scale bioretention systems) etc.,
- Private certifiers, and local councils, should ensure only best practice sediment and erosion control plans are approved for developments and ensure they are complied with,
- Let their friends, neighbours and/or customers know what actions they are taking to reduce stormwater pollution and improve the local waterways.

Local Community Acceptance, Support and Compatibility

To facilitate the implementation of the recommended actions contained in the Botany Bay and Catchment WQIP the Botany Bay CAPER Decision Support System (DSS) has been developed. This DSS has been designed so that it can be downscaled to the subcatchment and/or local government area scales. This will enable councils, ROCs and NGOs to test scenarios and determine the best ways for them to meet the stormwater pollutant reduction targets required to protect the environmental and social values as well as the ecological conditions of the waterways of the Botany Bay Catchment.

Implementation of the Plan is expected to lead to substantial benefits to the community. Cleaner waterways and healthier environments in the Catchment will increase the community’s ability to use Botany Bay and its estuaries and rivers. It can be expected that this will contribute to improvements in community health, leading to tangible long-term benefits, consistent with National and State policies.

Table of Contents

List of Figures

List of Tables

Acronyms / Abbreviations

BASIX	Building and Sustainability Index (NSW Department of Planning & Infrastructure)
BBCCI	Botany Bay Coastal Catchments Initiative
BBWQIP	Botany Bay Water Quality Improvement Program
CAPER	Catchment Planning and Estuary Response (CAPER) Tool
Chl-A	Chlorophyll A (measure of amount of microalgae in the water)
CRA	Cooks River Alliance (Replacing CRFWG from July 2011)
CRFWG	Cooks River Foreshores Working Group
CRVA	Cooks River Valley Association
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DCP	Development Control Plan (Council Planning Policy)
DEM	Digital Elevation Map
DECCW	Department of Environment Climate Change and Water
DO	Dissolved Oxygen
DSS	Decision Support System/Tool
EPA	Environment Protection Authority
ERM	Ecological Response Model
EV	Environmental Vales
GRCCC	Georges River Combined Councils Committee
LEP	Local Environment Plan (Council Planning Policy)
LGA	Local Government Area
NGO	Non Government Organisation
NRM	Natural Resource Management
MUSIC	Model for Urban Stormwater Improvement Conceptualisation (used to calculate stormwater pollution reduction and costs of using various treatment devices)
PAR	Photosynthetically Active Radiation (measure of available light)
Ramsar	Called Ramsar Convention (agreed in Ramsar, Iran, 1971) an intergovernmental treaty to maintain the ecological character of internationally important wetlands
ROC	Regional Organisation of Councils
SCCG	Sydney Coastal Councils Group
SMCMA	Sydney Metropolitan Catchment Management Authority
SSROC	Southern Sydney Regional Organisation of Councils
TN	Total Nitrogen
TP	Total Phosphorous
TSS	Total Suspended Solids (measure of sediment load)
UNSW	University of New South Wales
UTS	University of Technology Sydney
WQIP	Water Quality Improvement Plan
WQOs	Water Quality Objectives
WSROC	Western Sydney Regional Organisation of Councils
WSUD	Water Sensitive Urban Design

1 Introduction

This document is a Water Quality Improvement Plan developed for Botany Bay and its Catchment. It has been developed by the Sydney Metropolitan Catchment Management Authority (SMCMA), primarily funded by the Australian Government's Caring for Our Country Program, through the Botany Bay Water Quality Improvement Program (BBWQIP).

The BBWQIP is seeking to achieve long-term protection of the surface waters of Botany Bay, its estuaries and Catchment.

- It is primarily focused on the pollutants washing off the hard surfaces in the Catchment (suspended solids [sediments], nitrogen and phosphorus [nutrients]).
- It will also continue to engage with councils and key stakeholders in the Botany Bay Catchment so they can participate in finding and implementing innovative solutions to improve water quality in the Bay and its Catchment.
- It has produced a scientifically derived ecological response model of Botany Bay and its estuaries and a water quality decision support system, which can be used to model the impacts changes in the Catchment are likely to have on the Bay's water quality and ecological communities.

Botany Bay and its estuaries are associated with significant biodiversity and other environmental values as well as with community environmental and social values. The Bay and its Catchment are home to numerous endangered species and communities, a RAMSAR listed wetland and migratory bird species and Aboriginal and European heritage sites. There are also significant economic and social values attached to the Bay and its Catchment, through recreational use, aquaculture, ports, roads and the airports.

This Plan is an agreed Water Quality Improvement Plan that builds on research and engagement undertaken as part of the Botany Bay Water Quality Improvement Program (BBWQIP), to provide direction to future land use and water quality management decisions in the Botany Bay Catchment. It also supports five of the thirteen state-wide natural resource management targets contained in the NSW Government's State Plan. Likewise this Plan supports a number of the targets set in the SMCMA's Catchment Action Plan and is consistent with objectives set in the Metropolitan Strategy and the Metropolitan Water Plan. This Plan presents community values for the Bay and its Catchment, and considers the feasibility and cost of achieving these objectives over a 20 to 60 year period.

1.1 Catchment description

The Catchment of Botany Bay is approximately 1,165km^2 in area. It is bounded to the north by the Parramatta River and Sydney Harbour Catchments, to the west by the Hawkesbury-Nepean Catchment and the south by the Hacking River Catchment. This area is the traditional homelands of the Dharug, Dharawal and Gandangara Aboriginal language groups (Goodall and Cadzow, 2009). There are now approximately 2 million people who live within the Catchment.

The two major waterways in the Botany Bay Catchment are the Georges River (84% of land area) and the Cooks River (9% of land area), both of which have significant estuarine sections linking to Botany Bay (see Figure 1). The Woronora River is also located in this Catchment and flows into the Georges River before it reaches Botany Bay. It is the only regulated river in the Catchment, due to its drinking water storage dam of around 72,000 megalitres. The dam is located 24 kms upstream of its junction with the Georges River, was completed in 1941 and primarily supplies water to residents in the Sutherland Shire.

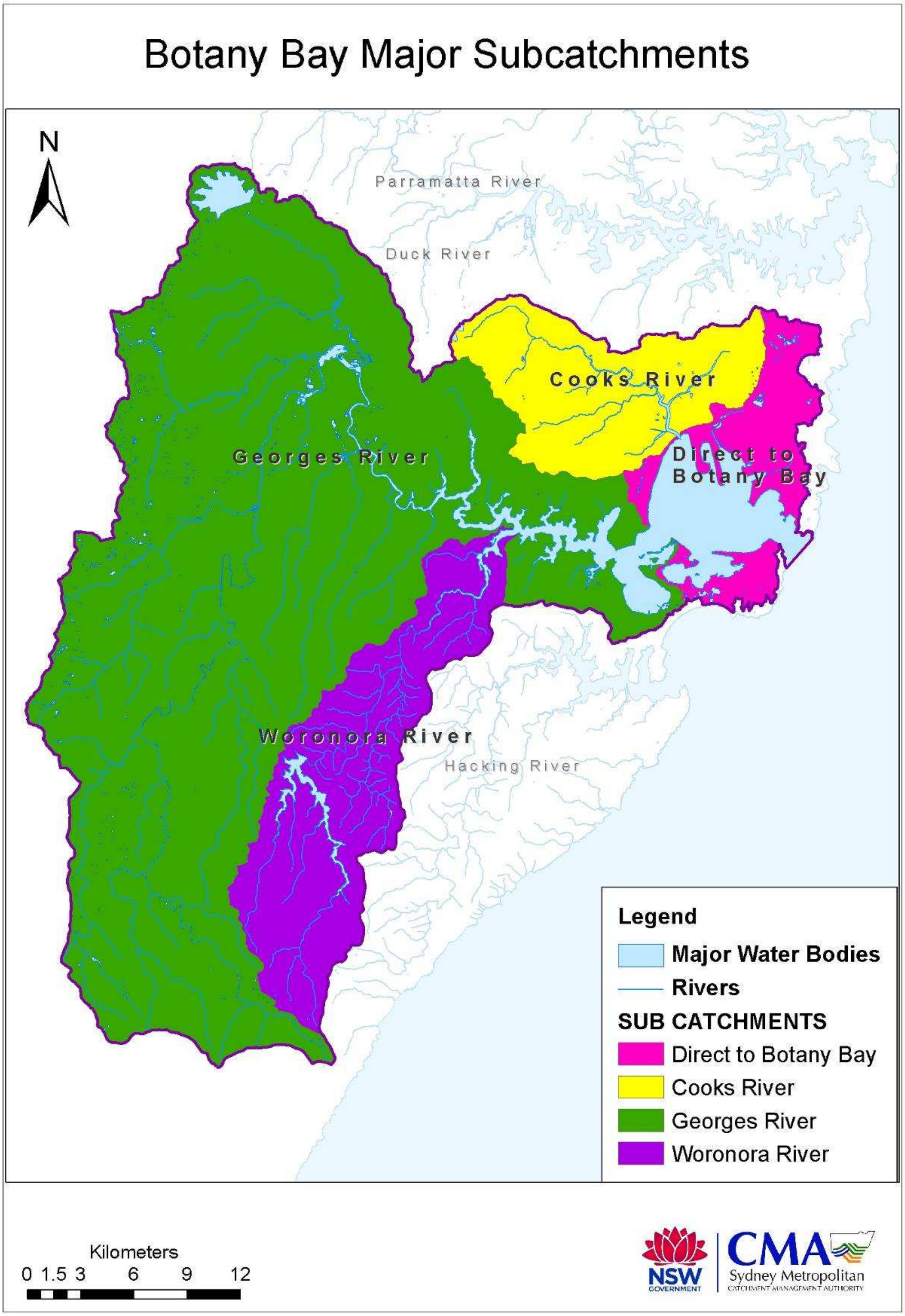


Figure 1. Major subcatchments of Botany Bay

As can be seen in the 3D view of the digital elevation model (DEM) for the Catchment (Figure 2), the southern part of the Catchment, consisting of the headwaters of the Georges and Woronora River has the highest elevation in the Catchment. The Cooks River Catchment is generally lower lying.

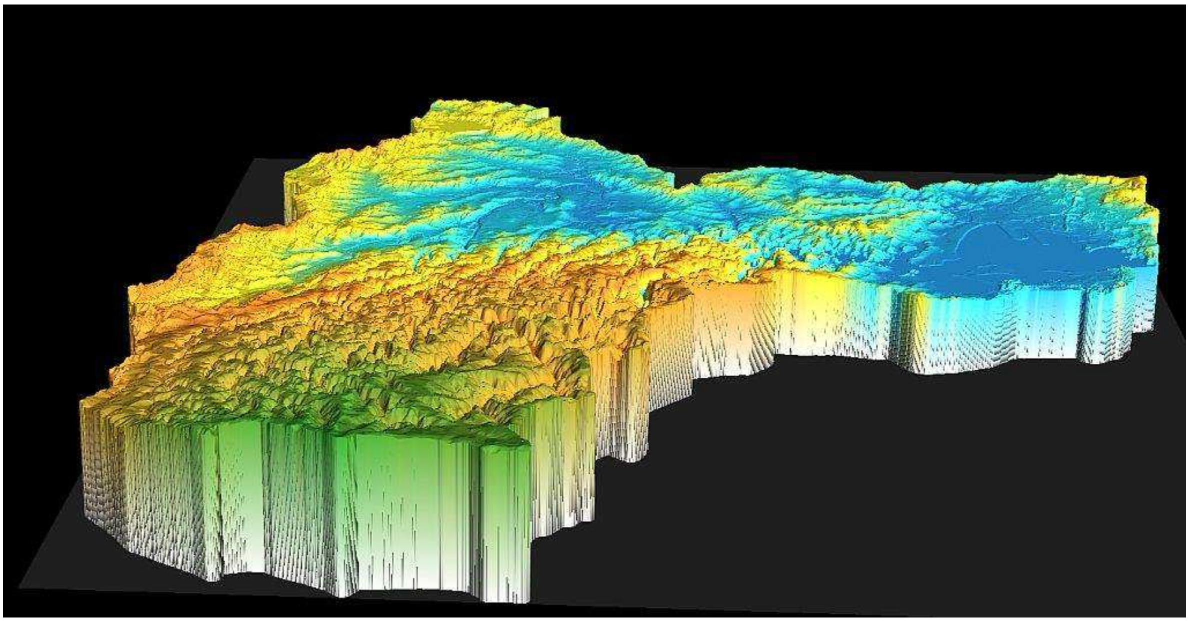


Figure 2. 3D view of DEM for Botany Bay Catchment

Overall, the Georges River Catchment accounts for 94% of mapped stream reaches in the Botany Bay Catchment (21% in the Woronora River Catchment), with the Cooks River Catchment accounting for only 4% (due in part to many smaller streams in the Cooks River Catchment being piped and therefore absorbed into stormwater infrastructure). Stream reaches in the Cooks River are largely modified with 89% being artificially constructed structures such as open concrete channels, metal sheet piling channels, rocked channels or underground concrete pipes. The Georges River Catchment also has a substantial length of constructed reaches with 19% of the Georges River Catchment, excluding the Woronora River, being artificially constructed. The Woronora River itself is largely unmodified with only 3% of the stream length being made up of constructed channels (EarthTech 2007).

Vegetation mapping in the Catchment shows that 52% of stream reaches (by length) are intact either inside or outside reserves (see Figure 3). These reaches largely occur in the Georges and Woronora River Catchments. 10% of the reaches in the Catchment have no vegetation or are used for flood control consisting of most of the stream reaches in the Cooks River Catchment (71%) and a small proportion of reaches in the Georges (8% of area excluding Woronora) and Woronora River (1%) Catchments. The majority of the Cooks River Catchment reaches are in a degraded ecological condition (23%). More than half of these have good to moderate vegetation cover. By comparison 15% of the Georges River Catchment, excluding Woronora River, is in a degraded ecological condition, almost all with little or no vegetation cover (EarthTech 2007).

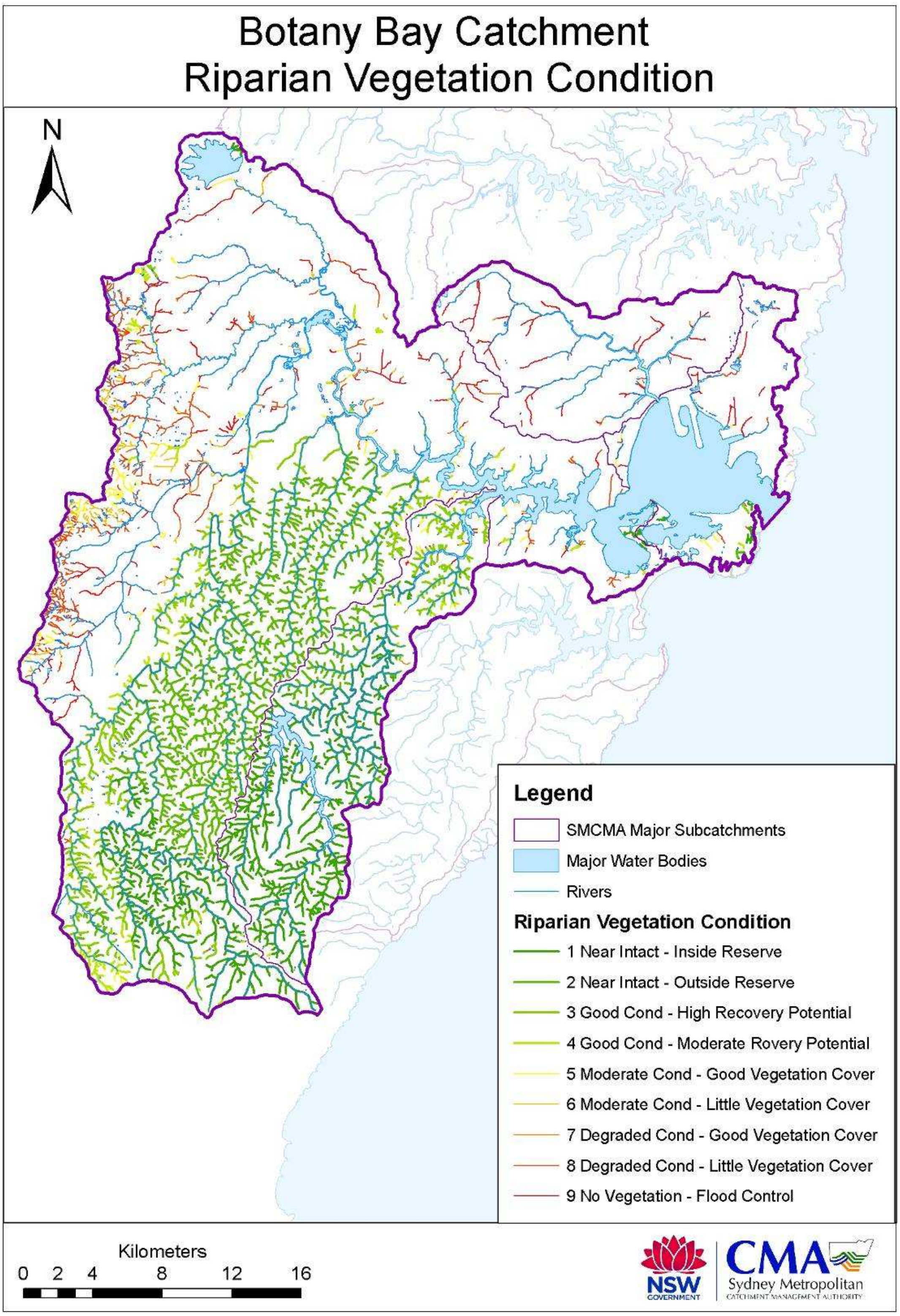


Figure 3. Riparian vegetation cover on stream reaches in the Botany Bay Catchment (from EarthTech 2007)

One way of considering the values the community attaches to waterways is to consider the types of access available to the community on different stream reaches. Overall most of the stream reaches in the Botany Bay Catchment have no access (52%), or limited access (such as pedestrian only access 31%). Only a very small length (3% of the total catchment) can be accessed for boating and fishing and 14% is accessible to pedestrians and bicycles. A substantial proportion of the Cooks River

Catchment stream reaches are accessible, with 47% being pedestrian/cycle accessible and 7% accessible for boating and fishing. 40% are categorised as having no access. The Woronora River Catchment has very limited access, with nearly 60% having no access, and only 3% being accessible for pedestrian/cycle and boating and fishing. A large proportion of the Georges River Catchment, excluding Woronora also has limited (31%) or no access (51%), with only 3% accessible for boating and fishing and 16% for pedestrian/cycle.

There are 24 Local Government Areas that have land within the Catchment. The largest areas of land are attributed to Campbelltown (26%), Sutherland (15%) and Liverpool (14%) Council's. Other Councils covering a substantial proportion of the total Catchment area are Bankstown, Botany Bay, Canterbury, Fairfield, Holroyd, Hurstville, Marrickville, Randwick, Rockdale, Strathfield, Wollondilly and Wollongong Those councils with only very small areas in the Catchment are shown in faded text (see Figure 4 below).

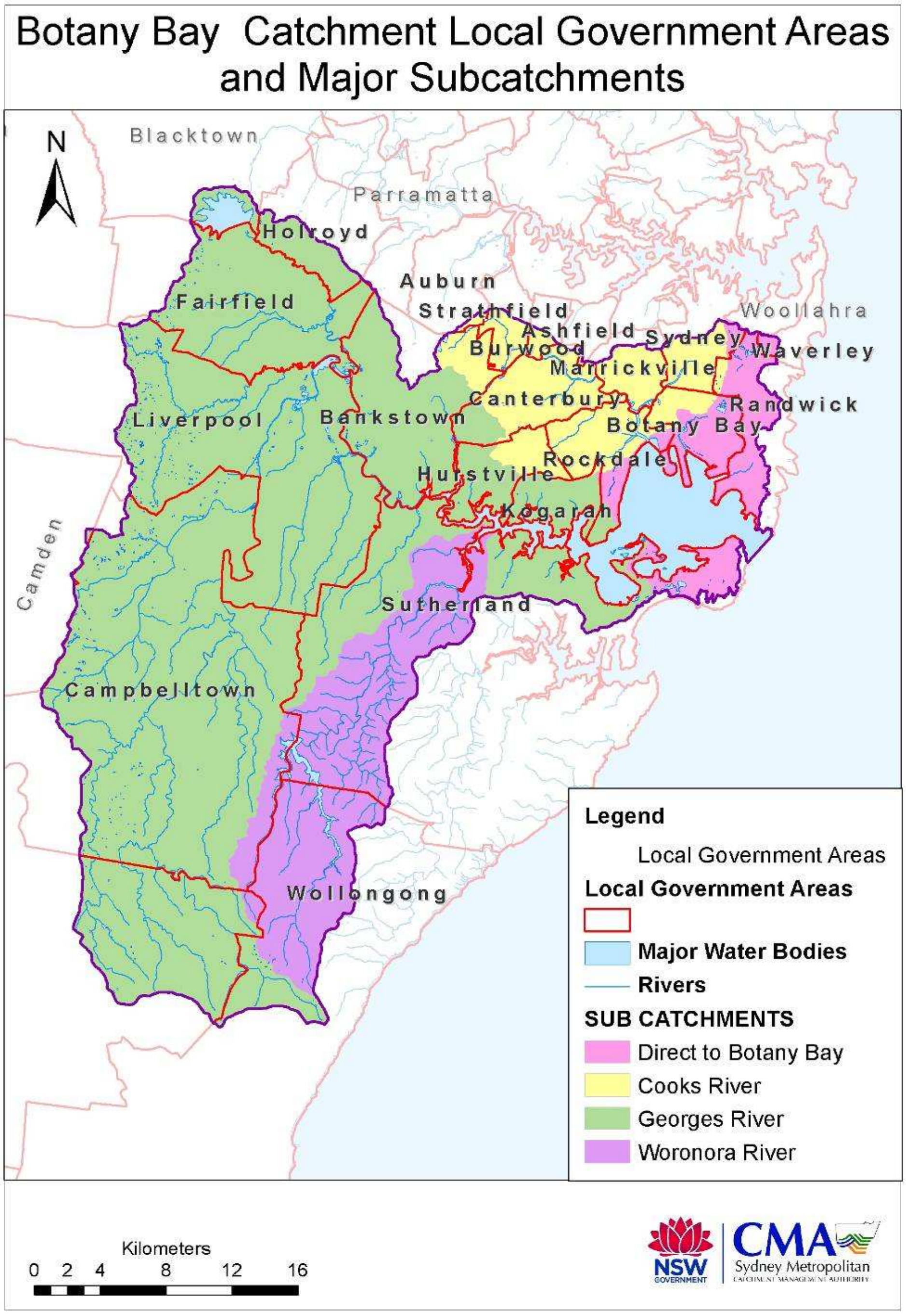


Figure 4. LGAs in the Botany Bay Catchment

1.2 Past activities in the Botany Bay Catchment

Aboriginal people have lived in the area around Botany Bay for thousands of years, living off the land, hunting, fishing and gathering food from plants. Botany Bay was first described by European explorers in 1770 and then settled by European settlers arriving with the First Fleet in 1788. Shortly after the arrival of the First Fleet, soldiers, convicts and free immigrants were granted land in the area. Early uses consisted of timber extraction, farming and lime extraction from oyster shells left by the Aboriginal people. In 1815 the first privately run woollen mill was established on a stream close to Botany Bay and shortly after a flour mill was also opened.

In the 1830's the area around the Bay was used for market gardens, and fishing villages sprung up around the Bay. From 1859 to 1886 the Botany Bay swamps supplied water to the city and surrounding suburbs. Many industries were opened in the area during this time. By 1869 the area was no longer considered to be a reliable source of water as the natural swamp had been drained by the many industries using the area.

In the early 1900's many factories were built in the Cooks River and Botany Bay Catchment areas. These often discharged pollutants directly into the waterways. During this time water and air quality in the area substantially declined. In 1921 Mascot was chosen as the site for Sydney International Airport. Port Botany was also used from 1930 and further expanded in the 1970's. Over this period the Botany Bay Catchment was also under increasing pressure from residential developments, with residential areas extending in all directions from the Bay.

More development of Port Botany is currently underway and planned to be finished shortly. These major industrial areas bring a large volume of boat, rail, truck and car traffic into the foreshore area of Botany Bay. Land use and industrial development is now more strictly controlled.

Information in this section has been summarised from City of Botany Bay (2010).

Cup and Saucer Creek 1901

Courtesy of City of Canterbury local history photograph collection

Rowing on the Cooks River, Hurlstone Park circa 1895

Courtesy of City of Canterbury local history photograph collection

1.3 Status of current land use

The Botany Bay Catchment contains a mix of bushland and rural areas, largely to the south western side of the Catchment and urban areas, including commercial, industrial and residential areas, primarily focused in the Lower Georges River Catchment, the Cooks River Catchment and areas draining directly into the Bay. Overall a large proportion of the Catchment is still bushland (42%) and parkland (5%). Most of this occurs in the Georges River Catchment and the areas to the south of the Bay. The Georges River Catchment is 48% bushland and 4% parkland. The value and buffering capacity of this bushland is vital to the health of the Georges River. Its benefits in terms of water quality are very apparent after rainfall events. In addition, this subcatchment also has substantial rural areas (13%). Urban areas take up roughly a third of this subcatchment, with commercial and industrial areas covering 6% and residential areas covering 28% of the Georges River Catchment respectively.

By contrast the Cooks River subcatchment only has one small area of bushland within the Wolli Creek tributary, no significant rural lands and only 8% parkland. The rest of the subcatchment is divided between commercial and industrial land uses (20%) and residential areas (72%). Urban areas are largely focused on the areas of the Catchment draining directly to the Cooks River Estuary (these areas are 81% urban).

While the areas of the Botany Bay Catchment draining directly into the Bay retain substantial areas of bushland (14%) and parkland (17%), they are largely devoted to urban land uses. In these areas of the Catchment, commercial and industrial areas account for 30% and residential areas for 39%. Figure 5 shows a map of major land uses in the Catchment. The proportion of the Catchment devoted to major land uses is given in Table 1 and Figure 6.

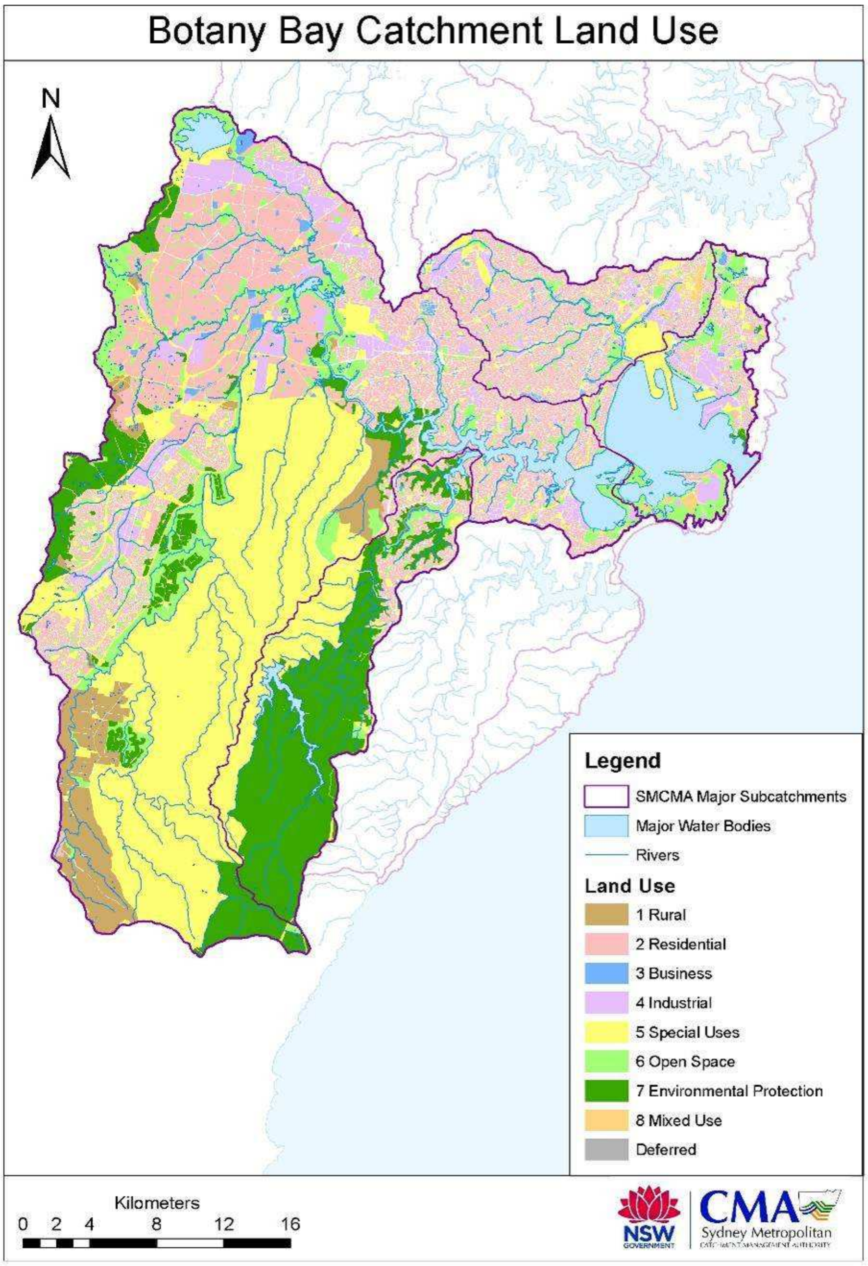


Figure 5. Major land uses in the Botany Bay Catchment

Table 1. Land use classes and areas for Botany Bay Catchment

Land Use Class	*% Catchment Area*	*Area (km²)*
Parkland	4.9	57.2
Airport	1.0	12.0
Industrial	0.9	10.2
Commercial	6.5	75.4
Residential	30.2	352.8
Bushland	40.3	469.2
Waterbody	6.0	70.1
Rural	10.2	118.6
Totals	100	1165.5

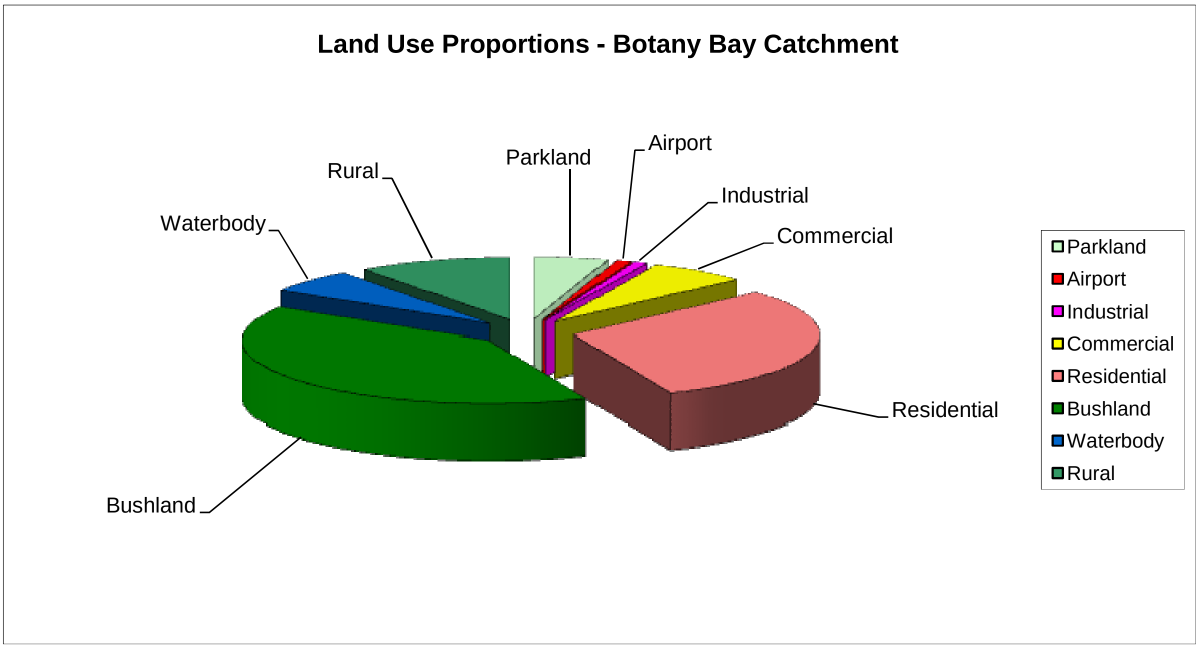


Figure 6. Major land use proportions in the Botany Bay Catchment

1.4 The economic values of waterways in the Botany Bay Catchment

Despite the urbanisation of the Catchment, there are significant direct economic/commercial values associated with the natural state of the waterways that could be jeopardised by water quality deterioration and conversely, potentially increased should there be an improvement in the future.

In the upper reaches of the Georges River Catchment there are several fruit orchards that draw water directly from the river. Oyster farming has continued since the outbreak of QX disease in 1995 with the introduction of the Pacific Oyster and new strains of the Sydney Rock Oyster. Currently there are about 10 ha under oyster leases in Botany Bay and the Georges River Estuary. There are currently several applications for an expansion of leases in the near future (NSW I&I 2010).

Despite the lack of an operational commercial fishery in the Bay, the health and availability of fish habitat in the estuary is significant for other fish stocks on the east coast of Australia. Studies at Towra Point showed the importance of mangroves and saltmarsh habitat in providing food and nursery areas for juvenile commercial fish species (Mazumber et al. 2006). The Georges River and Towra Point support significant areas of estuarine vegetation, whilst in the Cooks River there have been several successful projects to re-instate areas of estuarine vegetation including constructed salt marshes, with more planned in the future (Eco Logical 2009).

Apart from the primary productive nature of the estuaries, recreation in the Catchment has significant economic value to the communities and businesses of greater Sydney. Recreational fishing, boating, canoeing, and other direct recreational activities are extremely popular. There are swimming locations on the Georges River and in Botany Bay, and other locations in the Cooks River have recently been investigated by DECCW and the Department of Health in response to community interest in the health risks associated with recreational use of the River (DECCW pers comm. 2010). A residential survey in 2001 found that on average, each respondent household values an improvement in water quality to make it safe for swimming along the length of a River at over $75 (Bennett & Morrison 2001). This gives some idea of the value and importance of water quality for recreational activities in this area.

Finally, there are various indirect values to residents that can be negatively impacted by water quality. Although there is currently no local data available, real estate value has been shown to correlate to water quality in studies conducted overseas (Phaneuf et al 2008). It is logical to assume that a similar relationship exists in the Catchment, especially with many properties in the lower sections clearly taking greater advantage of waterway views and access in recent years, as river health and foreshore amenity has improved.

1.5 Botany Bay and its estuaries

The Catchment area drains into the Cooks River and Georges River estuaries before entering Botany Bay. Estuarine vegetation communities in Botany Bay, Georges and Cooks Rivers are shown in Figure 7 below and are categorised as seagrass, saltmarsh and mangroves. These communities tend to provide an indication of good ecological condition. Seagrass communities are adversely affected by decreases in light associated with elevated nutrient and sediment levels in the water. Mangroves and saltmarsh are more resilient to elevated levels of nutrients and sediments.

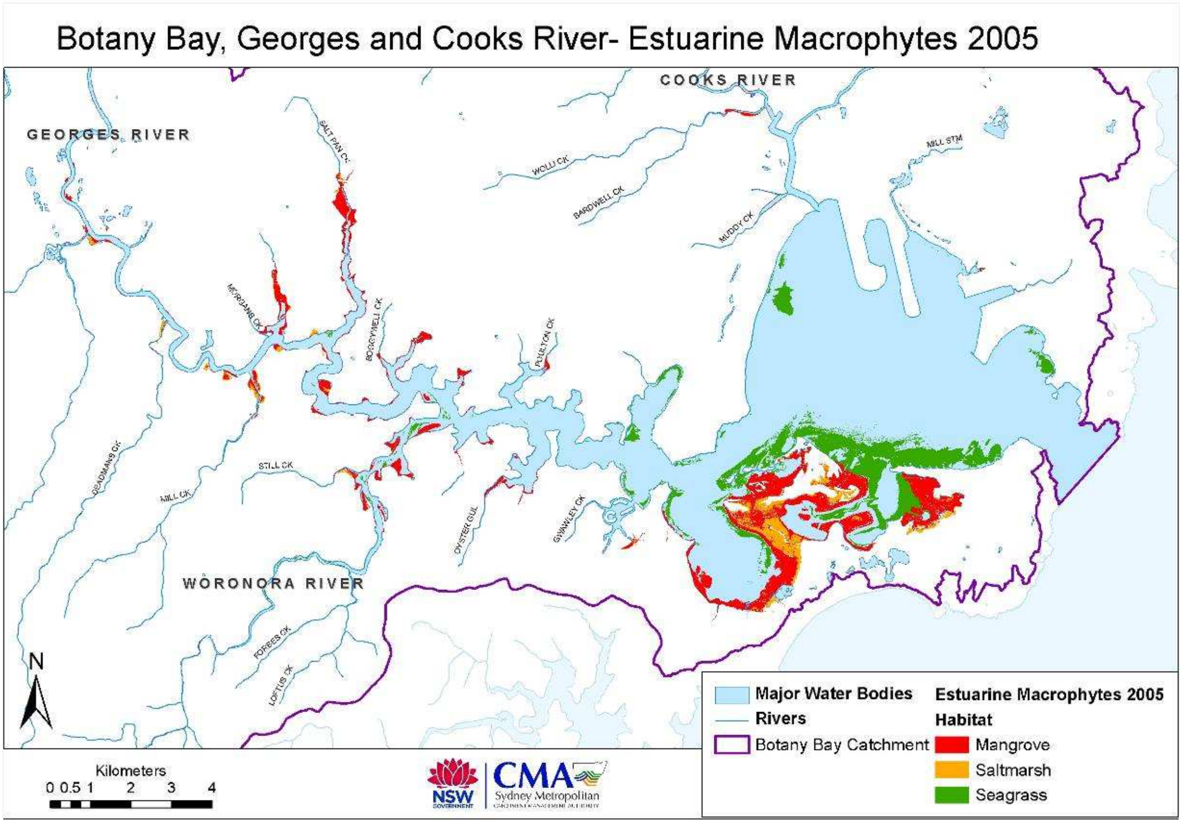


Figure 7 Mapped macrophytes in Botany Bay and its estuaries

Given the long history of channel modification, the filling of lowlands and urban development in the Cooks River Estuary, it is generally in a poorer condition than the Bay and the Georges River Estuary. It does contain some small remnant areas of saltmarsh and mangroves but these are very isolated. However, mangroves are colonising many sections of the river and councils have recreated saltmarsh areas in conjunction with bank naturalisation, stabilisation and revegetation works. Currently there is no seagrass in the Cooks River Estuary (Cooks River Estuarine Vegetation Management Plan 2009).

The Georges River Catchment has not been as heavily developed as the Cooks River Catchment and generally has better water quality. This estuary still contains substantial areas of saltmarsh, seagrass and mangrove, although it is likely that the extent of these communities in the estuary has declined as a result of past land use and management actions.

Botany Bay also has areas of saltmarsh, seagrass and mangrove, particularly around the Towra Point Wetland, which is Ramsar listed. It contains 40% of Sydney's remaining mangrove communities and 60% of its remaining saltmarsh communities (DECCW & SMCMA, 2010). It is also host to many important bird species, including many listed in international migratory bird agreements.

Past activities in the Botany Bay Catchment have affected the health of these waterways. Further uncontrolled development is likely to lead to deterioration of the condition of these estuaries and of the Bay itself. At particular risk are the Georges River Estuary and the southern parts of Botany Bay, including the Towra Point Wetlands. This is because of the relatively large areas of bushland still in the Georges River Catchment and the potential increases in pollutant levels which could occur if this part of the Catchment were developed in an uncontrolled way.

1.6 Managing water in urbanised catchments

The urbanisation of the Botany Bay Catchment has fundamentally changed the way water, and pollutants are carried in it, flows through the Catchment. Figure 8 shows the pervious and impervious areas of the Catchment. Before the Catchment was settled by Europeans, it was largely pervious – that is, rainwater falling on the land surface was absorbed by soils and evaporated back into the atmosphere by the plants. Water was generally filtered through the soil before reaching a waterway, however during high rainfall events water still ran off the land surface, but not much of the time. These processes reduced the sediments and nutrients reaching the streams. The groundcover provided by grasses and trees also meant much smaller rates of sediment was eroded, and a greater uptake of nutrients occurred in the Catchment itself.

Increased urbanisation has made large areas of the Catchment impervious and has connected these areas directly to waterways via stormwater infrastructure. This means water regularly runs directly off the land surface and quickly makes its way into the waterways, instead of being filtered through the soil and vegetation (see Figure 8). Stormwater systems very effectively move water from urban areas into waterways, quickly transporting not only the water, but also any pollutants in that water, straight into streams, estuaries and the Bay. These fundamental changes in Catchment hydrology mean that in urban areas storm hydrographs rise and fall much more rapidly than in undeveloped catchments, with higher peaks and greater volumes of water. This poses significant problems to the waterways of the Catchment.

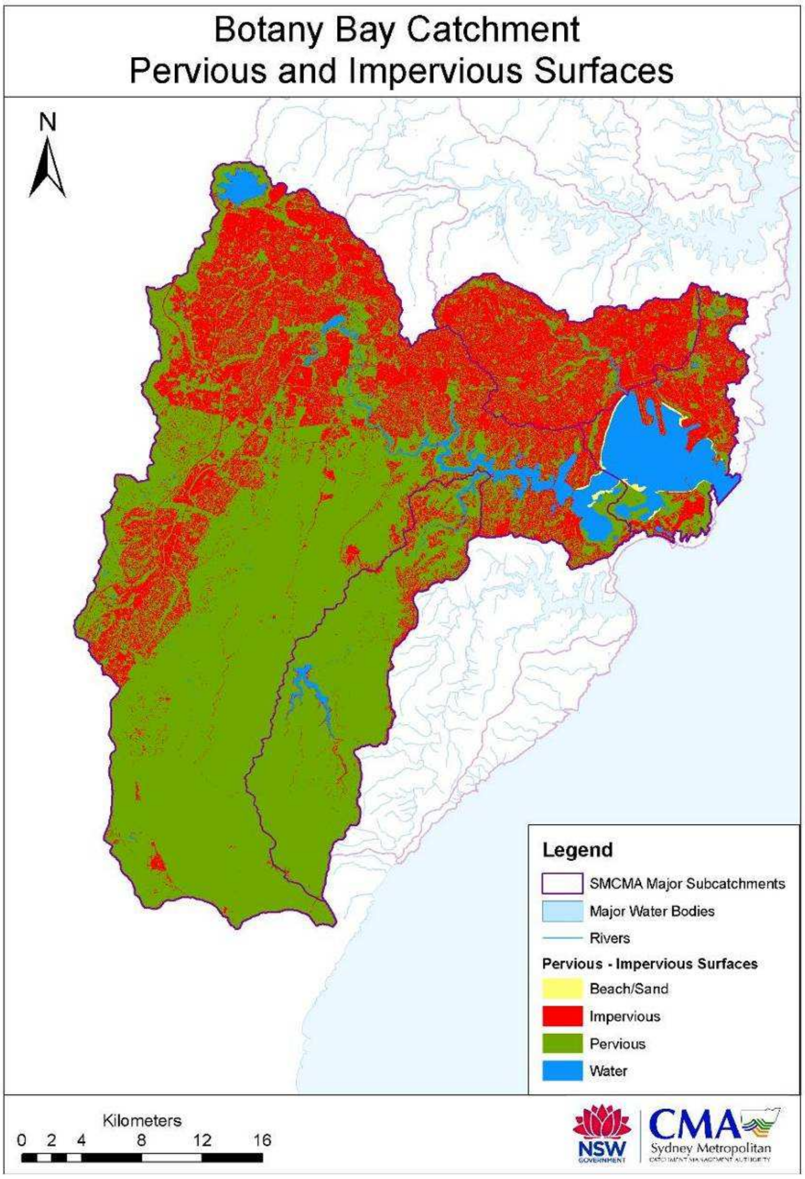


Figure 8. Pervious and impervious areas in the Botany Bay Catchment

Management options in urban areas rely on several mechanisms: reducing the volume of water available to runoff the impervious land surfaces; filtering flows before they reach the stream; or, harvesting stormwater before it makes its way to the streams (decreasing the direct connectedness of the impervious parts of the Catchment to waterways). These actions all aim to reduce the effects of increased imperviousness caused by urbanisation. In urban areas these management actions are referred to by the general term 'water sensitive urban design' or WSUD.

WSUD seeks to ensure that development is designed, constructed and maintained so as to minimise impacts on the natural water cycle. It focuses on the interactions between the urban built form (including urban landscapes) and the urban water cycle, incorporating the three urban water streams of potable water, wastewater, and stormwater. Interventions in any one or more of these water streams, illustrated in Figure 9, can have synergistic benefits for the others.

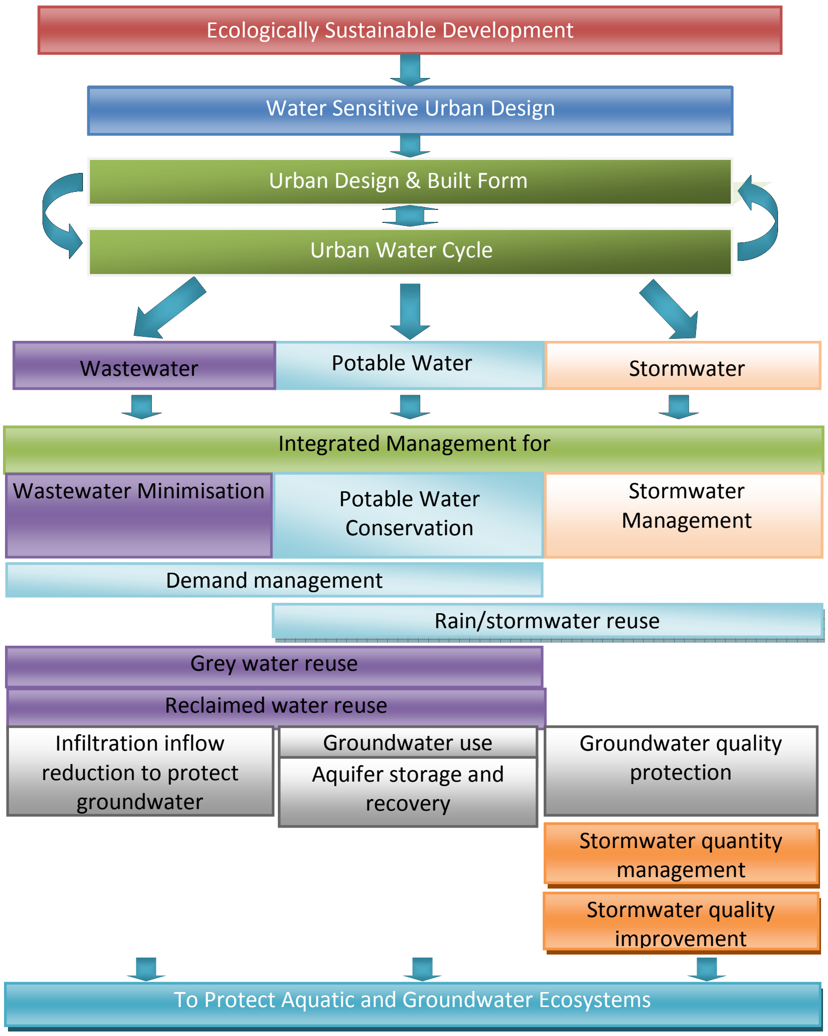


Figure 9. WSUD Framework (after Engineers Australia 2006).

In addition to reducing stormwater pollution in the Botany Bay Catchment there needs to be reductions in pollution from dry and wet weather sewer overflows. Sewer overflows also contribute significant amounts of nutrients and sediments as well as pathogens to the waterways of the Botany Bay Catchment.

1.7 Current monitoring of the Catchment and estuaries

There are currently a number of monitoring programs underway in the Botany Bay Catchment that relate to water quality. These include:

- A network of five real-time water quality monitoring stations measuring Chl-A, turbidity, dissolved oxygen, temperature, salinity and light (PAR). These monitoring stations were funded by the Australian Government and are being maintained by the SMCMA with support from the GRCCC. The Cooks River Estuary and the Georges River Estuary both have two monitoring stations and one is located in Botany Bay. The data collected is available live from the BBWQIP website at: www.sydney.cma.nsw.gov.au/bbcci/monitoring-network.html
- The GRCCC with funding from the Australian Government and support from local councils and the community has been undertaking a Community River Health Monitoring Program in the Georges River Catchment. They have secured funding to expand this Program into the Cooks River Catchment. They are monitoring macroinvertebrates, water quality and riparian vegetation at more than 40 sites. A "Report Card" is produced twice a year showing the results of the monitoring. More information about the Program and copies of the report cards are available at: www.georgesriver.org.au/River-Health-Monitoring-Program.html
- The Cooks River Valley Association (CRVA) is a community organisation that has a water quality monitoring group, who have been testing water quality since 2007 at a number of sites along the Cooks River. More information and results can be found at: www.crva.org.au
- The NSW Government Beachwatch programs were set up in 1989 to provide regular and reliable information on beach water quality, to enable people to make informed decisions about where and when to swim. Beachwatch monitors water at swimming locations to assess the level of faecal contamination and currently monitors 15 sites in the Botany Bay Catchment (4 on the Georges River and 11 sites around Botany Bay). Monitoring reports and more information can be found at: www.environment.nsw.gov.au/beachapp/default.aspx
- Sydney Water Corporation monitors a number of sites throughout the Botany Bay Catchment as part of its licence requirements. It also runs an extensive Streamwatch program with schools and the community. A number of their monitoring sites are located within the Botany Bay Catchment. More information can be found at: www.sydneywater.com.au/Education/streamwatch.cfm

  Sydney Water also runs a Dry Weather Leakage Reduction Program and does surveillance monitoring of water quality, to detect leakage from sewers at about 72 stormwater outlets across the Botany Bay Catchment. If the level of the faecal contamination is detected at a level in excess of 5,000 cfu/100mL, then a catchment investigation is carried out to determine if the source of the contamination is the public sewer.
  In addition, they also run a Dry Weather Overflow Reduction Program that inspects and repairs Sydney Water sewers that have a high risk of discharge to waterways due to blockage. The main cause of blockage is tree root intrusion; with oil, grease and debris build up and pipe collapse also important causes. The Program commenced in 2005 and is prioritised by the public health and environmental sensitivity of the receiving waters for discharges. There are about 1,300 kilometres of high risk sewers in the Botany Bay Catchment and about 10% of these have been inspected and repaired. Over the next 5 years Sydney Water aims to inspect and repair a further 30%.
- The NSW Food Authority also undertakes regular microbial monitoring in the Botany Bay and Lower Georges River area to support the oyster industry that operates in this area. More details can be found at: www.foodauthority.nsw.gov.au/industry/industry-sector-requirements/shellfish

- Many of the local councils in the Botany Bay Catchment undertake water quality monitoring in some of their waterways. For example Marrickville Council has a RiverScience ecological monitoring program.
- Several universities have also periodically monitored parts of the Botany Bay Catchment. SMCMA are currently working with Macquarie University and monitoring a number of water quality improvement devices that have been installed in the Botany Bay Catchment to check their efficacy. The SMCMA also engaged UNSW to undertake detailed benthic sediment and foraminifera analysis around Botany Bay and the Georges River Estuary (see Albani & Rickwood 2010, Albani 2008 and 2005).

This list is not exhaustive and more site specific monitoring is undertaken by individual organisations for a variety of site specific and/or licensing requirements. Ideally it would be good if all the various monitoring being undertaken was linked and made available from a centralised point.

1.8 Existing approaches to improving water quality in the Botany Bay Catchment

Existing approaches to improving water quality in the Botany Bay Catchment are very fragmented and ad hoc, and often rely on the efforts of individual councils and/or regional groups of councils such as:

- Georges River Combined Councils Committee (GRCCC),
- Cooks River Foreshores Working Group (CRFWG) (to be replaced by the Cooks River Alliance (CRA) from July 2011),
- Southern Sydney Regional Organisation of Councils (SSROC),
- Western Sydney Regional Organisation of Councils (WSROC), and
- Sydney Coastal Councils Group (SCCG).

There are also NSW Government-funded urban sustainability projects being delivered in this Catchment through sub-regional groupings of between two and eight councils that in many cases involve improving water quality and engaging their communities in the process.

The efforts of these groups and of individual local governments in the Catchment are to be commended, as they have taken a proactive approach to improving their local waterways in the absence of a comprehensive State-endorsed plan for the Botany Bay Catchment.

When the SMCMA was established, one of the NSW Government's requirements for it was to implement a Botany Bay Strategy. It was only with official creation of the SMCMA in 2007 and funding from the Australian Government for the BBCCI that catchment-scale research and planning for this WQIP commenced.

Over the years there have been numerous calls by regional groups and the community for the development of a "plan" to improve and protect the waterways of Botany Bay and its Catchment. It is timely then, that the Australian Government has provided funding through its Caring for Our Country Program to develop a WQIP for the Botany Bay Catchment, based on a robust scientifically derived framework. It is largely through the persistence and efforts of these regional groups, individual councils, community environmental groups and the general community, who have continually advocated for Botany Bay and its waterways, that the development of the Botany Bay WQIP occurred.

While sewer overflows are not explicitly dealt with in this Plan it is worth noting efforts currently being undertaken by Sydney Water to reduce pollution from sewer overflows and leaks including:

- Major sewerage treatment plant upgrades and wastewater transfers out of the Catchment that have occurred to improve the water quality of the Upper Georges River and Upper

Georges River Estuary; and,

- Active monitoring of waterways to locate and rectify sewer leaks and to identify illegal sewer connections to the stormwater system.

The Botany Bay WQIP will set a clear framework for the Catchment that will help to coordinate and maximise the benefits from any local and/or regional policy, planning and on-ground works undertaken in the Catchment.

1.9 The Water Quality Improvement Plan

The Botany Bay Water Quality Improvement Plan (WQIP) is the result of a huge effort by the SMCMA, Australian Government, Local Government, DECCW scientists, modellers, regional NRM groups, community environmental groups, consultants, local Aboriginal groups and the general community.

The main objective of the Plan is to set targets for pollutant load reductions (in terms of total nitrogen, total phosphorus [nutrients] and suspended sediment [turbidity]) required to protect the condition of the Bay, its estuaries and waterways. In addition, it is expected that the Plan will be a tool for raising awareness and promoting behaviour changes amongst individuals and organisations. It is expected that the Plan will find an audience with Local, State and Federal Government agencies as well as with interested individuals, community groups and organisations.

The WQIP is designed to give focus and direction to water quality policy development and on-ground implementation throughout the Botany Bay Catchment. It will help guide more localised or subcatchment planning and policy development by local councils and regional groups of councils. It should also help guide regional planning policies such as: The Sydney Metropolitan Strategy and its sub-regional strategies, Metropolitan Water Strategy etc., being developed and implemented by the NSW Government.

Everyone's actions have the potential to affect water quality. Choices that households, businesses, developers, councils and state government make, will all have an effect on the levels of nutrients and sediments exported from the Catchment into the creeks, rivers, estuaries and Bay. To be effective the Plan needs to be owned and implemented by all levels of government as well as by individuals and organisations. The Plan provides direction on how each of these groups could act to implement its recommendations.

Implementation of this Plan is expected to lead to substantial benefits to the community. The Plan is designed to lead to reductions in the amount of nutrients and sediments entering the waterways. While the effect of the Plan on pathogens, including faecal contaminants has not been quantified, it can be expected that the reduction in nutrient and sediment pollution would be linked to reduced faecal contamination. Cleaner waterways and healthier environments in the Catchment will increase the community's ability to use the Bay and its waterways. Access to the natural environment is particularly important for good health. A growing body of research is showing that contact with natural environments provides social, health and psychological benefits. It is particularly important to the healthy physical and social development of children (NSW Health 2009). It can be expected that this use will improve community health leading to tangible long-term benefits consistent with national and state policies (pers. comm. G. Burges, NSW Health).

The objective of this Plan is to reduce future pollutant loads to Botany Bay and its waterways. It does not provide direction on dealing with specific pollution problems arising from past activities, for example issues with toxic sediments derived from past industrial activities in the Catchment and on the Bay foreshore.

The Plan does not specifically deal with sewer overflows other than highlighting the need to reduce their impacts, particularly in sensitive areas of the Cooks River and the Upper Georges River Estuary that are already under pressure from significant stormwater pollution. It notes the actions Sydney Water are taking to reduce sewer overflows and leaks. While not dealt with here, private sewer connections are also potentially a significant source of pollution and need to be comprehensively addressed.

Environmental flows have also not been addressed by this Plan. While they are an important issue in parts of the Catchment, they are not generally an issue across the Botany Bay Catchment and are being addressed by water sharing plans administered by the NSW Office of Water.

1.10 Consultation processes used in developing this Plan

Both the Botany Bay CCI project (2007 - 2008) and the Water Quality Improvement Program (2009 onwards) have relied upon significant input from key stakeholders and the community. The major consultation activities undertaken are summarized below.

1.10.1 Reference Committee

The BBWQIP Reference Committee meets quarterly, with the objective 'to engage key sections of the Catchment community on progress and status of the Botany Bay Water Quality Improvement Program (BBWQIP)'.

The scope outlined for the Committee is to facilitate the exchange of information with those undertaking the various aspects of the Botany Bay Water Quality Improvement Program, including Commonwealth, State and Local government, and the community, regarding the following:

- Supporting the development of a Water Quality Improvement Plan for the Botany Bay Catchment,
- The set up of a water quality monitoring network in the Botany Bay Catchment,
- The nature and timing of inputs to the BBWQIP development and implementation process,
- Stakeholder engagement and communication,
- Modelling and data acquisition/generation activities associated with the development of a Decision Support System/Tool for the Botany Bay Catchment,
- The role of Water Sensitive Urban Design (WSUD) in the Catchment,
- WSUD and the planning process,
- Useful information, contacts and resources to support the program,
- Possible synergies or integration with non-BBWQIP activities,
- Additional sources of funding for the extension of BBWQIP related activities, and
- Engaging senior management of the government agencies and organisations represented on the Reference Committee.

Members of the BBWQIP Reference Committee are listed below.

Table 2. BBWQIP Reference Committee Members (2009-2011)

Name	Affiliation(s)
Philip Sansom (Chair)	Sydney Metropolitan Catchment Management Authority (SMCMA), Southern Sydney Regional Organisation of Councils (SSROC), Georges River Combined Councils Committee (GRCCC)
Kaia Hodge	Sydney Water Corporation (SWC)
Jim Colman	Community Representative, ex-Botany Bay Program
Judy Pincus	Cooks River Foreshores Working Group (CRFWG)
Lew Solberg	Community Indigenous Representative
Robert Kolano	Department of Defence – Holsworthy

Name	Affiliation(s)
Helen Sloan	SSROC
Lisa Teasdale	Department of Sustainability, Environment, Water, Population and Communities
Mardie Kearns / Kate Gowland	Department of Sustainability, Environment, Water, Population and Communities (Caring for our Country Facilitators – NSW & ACT)
Carla Ganassin	Department of Primary Industries - Fisheries (previously Department of Industry and Investment)
Ian Curtis	Hurstville Council (Council Staff Representative)
Sharyn Cullis	Community Representative, Georges River Environment Education Centre (DET), ex- South Sydney Catchment Management Board
Alison Hanlon	GRCCC
Simon Rowe	Ocean Watch Australia (Commercial Fishing Industry Rep)
Peter Scanes	Office of Environment & Heritage (Previously Department of Climate Change & Water (DECCW)
Owen Graham	SMCMA
John Dahlenburg	SMCMA

1.10.2 Development of Environmental Values and Water Quality Objectives

A series of workshops were held throughout the Botany Bay Catchment from September 2007 to March 2008. These were designed to inform Catchment residents and stakeholders, and to seek their opinions on the Catchment's environmental values via a survey questionnaire and a workshop. The results of the survey questionnaire (SMCMA 2008) can be found at www.sydney.cma.nsw.gov.au/bbcci/ValuesObjectives.html The results of the workshops can be found in Table 3 and Table 4 below.

1.10.3 Scoping workshop for the Botany Bay Decision Support System (DSS)

A workshop was held with key stakeholders in December 2009, to identify needs and wants relating to the DSS, potential end-users, potential uses and ideas for presentation of outputs in the DSS. A summary of the feedback from this workshop along with a response outlining what would be possible within the DSS can be found at www.sydney.cma.nsw.gov.au/bbcci/publications/Botany_Bay_DSS_Workshop_Feeback_Dec_09.PDF. This feedback has provided significant direction to the development of the Botany Bay Catchment Planning and Estuary Response (CAPER) DSS and its interface. In turn this DSS has been used to run the scenario options considered in this Plan.

1.10.4 Scoping workshop for the WQIP

A scoping workshop for the Water Quality Improvement Plan was also held in December 2009. Attendees were given a potential Table of Contents for a WQIP and were asked to nominate additional sections they thought needed to be added to the WQIP. They were also asked to write a brief description of the contents of their suggested sections using individual form based feedback. After doing this they moved into four groups for a more detailed discussion of WQIP sections needed. Each group was given several copies of a "Discussion Paper for the Development of a Water Quality Improvement Plan for the Botany Bay Catchment" (SMCMA 2009) to give the group members more details on what might be included in different sections of a Botany Bay WQIP. A summary of these discussions can be found at www.sydney.cma.nsw.gov.au/bbcci/publications/WQIP_Workshop_Stakeholder_Feedback_Feb_10.PDF.

The feedback from the scoping workshop and comments received on the "Discussion Paper for the Development of a Water Quality Improvement Plan for the Botany Bay Catchment" (SMCMA 2009), which was released for public comment in March 2010, have been used as the basis for the development of this WQIP.

1.10.5 Feedback on possible scenarios at Botany Bay CAPER DSS workshops

A decision support system, the Botany Bay CAPER DSS was developed to support development of the Botany Bay WQIP and to allow the multitude of scientific and modelling work carried out on the Catchment to be aggregated and used (see SMCMA 2007a-b, 2008 a-e, 2009a-b). Training workshops in the use of this DSS were held for Council staff and other key stakeholders. A brief discussion on scenarios to be run and used in the Plan was held as a part of these workshops.

1.10.6 Feedback on Draft Botany Bay & Catchment WQIP

A Draft Botany Bay & Catchment WQIP was developed based on the Discussion Paper for the Development of a Water Quality Improvement Plan and the scoping workshop referred to in section 1.10.4 . The Draft WQIP was first reviewed by the Reference Committee and updated based on their feedback prior to being released for public comment. It was put out for public comment from November 2010 until February 2011. The public exhibition was promoted via the BBWQIP eNewsletter and website as well via letters written to key stakeholders and government departments. An online feedback form was used along with traditional methods. Several feedback workshops were also held with community groups during the exhibition period.

The feedback and comments received via all means was then collated and presented to the BBWQIP Reference Committee for review prior to its incorporation in the final WQIP.

2 Water Quality Issues and Environmental Values

In order to develop an appropriate plan for managing water quality in the Botany Bay Catchment it was first necessary to understand current water quality issues and the values that the community place on their local waterways. This section outlines current water quality issues before summarising community values and aspirations for water quality uncovered by the community engagement process described in section 1.10.2.

2.1 Summary of key water quality issues

Degradation of water quality has been rated by Botany Bay Catchment stakeholders as their key concern for the Bay and its Catchment. Declining water quality can lead to impacts on recreational uses of the Bay, environmental and ecological values associated with the Bay and its waterways as well as other uses and non-use values. Changes in water quality in the Bay and its tributaries are generally caused by catchment runoff, which may be characterised by elevated nutrients and sediments as a result of changed land use practices, sewage discharge and urban runoff.

In urban areas, pervious surfaces (e.g. forests and grassland) have been replaced by impervious surfaces (e.g. roads and buildings). Surfaces that in the past would have filtered nutrients from the rainfall are now impervious and collect and transport pollutants directly into waterways via stormwater systems. In general, urban activities generate large amounts of nutrients and sediments in the long term, especially during construction phases. Sediment delivered during construction activity can have critical long-term impacts on ecological health of waterways.

Urban development also has infrastructure such as sewer systems that contribute nutrients, sediment and pathogens to the waterways. Sydney Water has two major sewerage systems within the Botany Bay Catchment. The Malabar system provides service to about 1.34 million people, collecting wastewater from the Cooks River and the Western and Northern sides of the Georges River and Botany Bay areas and transporting it to the Malabar Sewerage Treatment Plant for treatment and discharge to the ocean. The Cronulla system provides service to about 0.23 million people by collecting wastewater from the southern side of the Georges River and Botany Bay and transporting it to the Cronulla Sewerage Treatment Plant for treatment and discharge to the ocean.

These extensive sewer systems can leak and are designed to overflow into stormwater systems and waterways under certain circumstances. The leakage of sewers can come about because of many causes, but failure of old pipes and intrusion of tree roots are common causes of sewer leaks or overflows. The main sewer infrastructure is the responsibility of Sydney Water, but a significant proportion of the sewer system is privately owned and maintained. The connection between the main sewer system and private homes and businesses is the responsibility of property owners. Many of these connections are very old and have had little or no maintenance done on them; as property owners are often unaware that they are responsible for their maintenance. This “privately owned” portion of the sewer system contributes significant nutrients and pathogens to the waterways in the Botany Bay Catchment.

Water quality can also be degraded through incorrect use of foreshore/open areas and riparian vegetation in urban areas. Destruction of riparian vegetation compromises the water filtering capacity and sediment stabilisation of these areas, thus impacting on water quality. A number of activities have been identified as increasing the pressure on significant foreshore vegetation within these natural urban areas, including: inappropriate use of riparian areas, trampling, clearing of vegetation and weed infestation, clearing vegetation for views, boat moorings, residential encroachment landscaping, fertiliser use, disposal of green waste, rubbish, and stormwater pollution.

Rural activities also have the potential to generate excess amounts of nutrients and sediments. Some rural activities can expose soils to erosion, resulting in large amounts of sediment and attached nutrients being transported into waterways. Other activities (e.g. intensive farming, cattle access to streams, inappropriate fertiliser use), if inappropriately managed, have the potential to generate an increased source of pollutants that can be washed off into drains, creeks and rivers. Sediments can also be eroded from stream banks and delivered to waterways during runoff events.

Seagrasses and other bottom-growing plants and animals are extremely important components of estuarine ecosystems, providing food and shelter to a wide range of fish and other organisms including – for seagrasses – protected seahorses and pipe fishes. There is a well-established relationship between water clarity and the depth that seagrass can grow to (and hence, the area of seagrass that can grow in the estuary). This relationship exists because as more sediments are washed into waterways, the water becomes more murky (turbid) and transmits less light to the seagrasses that grow on the floor of the Bay or estuary. If the seagrasses do not receive enough light to grow, they die. This can also happen if light is reduced by other factors such as: excessive algal growth in the water, which creates turbidity; or macroalgal (seaweed) growth on the seagrass leaves, which directly blocks light. Similarly, if seagrasses are physically covered by sediments washed into the water as a result of eroded soils, they are smothered and die.

Excess nutrients entering the Bay and its estuaries from catchments can have a number of consequences for their ecology. The amount of algae that can grow is a direct consequence of the amount of nutrients brought into the Bay from its Catchment and other sources. The growth of algae occurs in two phases: an initial very high level (bloom) when nutrients are washed in following rain and a reduced ongoing bloom from recycled nutrients. The major bloom can rapidly consume all the available nutrients in the water, and then slowly die and reduce in intensity. As they die, the algal cells with their absorbed nutrients fall to the estuary/Bay floor and are recycled by microbes in the sediment. Over time, this store of nutrients in the sediments increases, and the nutrients recycled into the water column from sediments can sustain a relatively high level (but smaller amount than the bloom) of algae between rainfall events.

The main water quality impacts for contact recreation come from pathogens, with secondary concerns about abundance of algae – particularly harmful species and by reductions in water clarity.

2.2 Environmental values of Botany Bay and its waterways

To obtain the views of Catchment residents and stakeholders on the environmental values of the Botany Bay Catchment, a series of local workshops were held throughout the Catchment from September 2007 to March 2008 and a survey was undertaken. A background paper was prepared prior to the workshops that outlined information on Environmental Values (EV) and Water Quality Objectives (WQOs) and provided a brief summary of previously determined environmental values and water quality objectives for Botany Bay and its Catchments.

Responses to the questionnaire and workshops were summarised to provide preferred ecological conditions for rivers and creeks, estuaries, the Towra Point Wetland and Botany Bay itself. Preferred recreational uses of these waterways as well as other values, such as use for drinking water, cultural activities, industrial and primary industry activities were also indicated. Table 3 shows the proportion of respondents from these workshops who indicated each of the specified values for their local rivers and creeks. Environmental values for the estuaries, Bay and Towra Point Wetland are provided in Table 3 and Table 4 below.

Table 3. Community preferences for environmental values and water quality objectives for rivers and creeks in the Botany Bay Catchment[1]

Subcatchment	Desired Ecological Condition Target			Recreational Water Quality Objectives/Goals						
	High Conservation or Ecological Value System	Slightly to Moderately Disturbed System	Highly Disturbed Systems	Primary Contact	Secondary Contact	Visual	Drinking	Cultural	Industrial	Primary Industry
Alexandra Canal	0%	37%	63%	8%	58%	34%	0%	46%	42%	8%
Bow Bowing Creek	0%	33%	67%	0%	67%	33%	0%	50%	33%	17%
Deadmans Creek	100%	0%	0%	100%	0%	0%	83%	67%	0%	17%
Harris Creek	100%	0%	0%	100%	0%	0%	100%	60%	0%	20%
Lime Kiln Creek	50%	50%	0%	38%	50%	12%	0%	25%	13%	50%
Lower Cabramatta Creek	0%	88%	12%	12%	88%	0%	0%	100%	0%	13%
Lower Prospect Creek	0%	86%	14%	14%	86%	0%	0%	86%	0%	0%
Lower Woronora River	44%	56%	0%	100%	0%	0%	0%	67%	0%	11%
Mid Georges River	33%	67%	0%	33%	67%	0%	0%	50%	0%	17%
Mill Creek	75%	25%	0%	88%	12%	0%	38%	75%	0%	0%
North Botany Bay Area Waterways	6%	47%	47%	33%	67%	0%	7%	73%	40%	47%
O'Hares Creek	100%	0%	0%	83%	0%	17%	50%	67%	0%	33%
Punchbowl Creek	100%	0%	0%	83%	0%	17%	50%	67%	0%	33%
Salt Pan Creek	67%	33%	0%	83%	17%	0%	0%	50%	17%	17%
Upper Cabramatta Creek	12%	88%	0%	13%	74%	13%	0%	88%	0%	13%
Upper Cooks River	15%	78%	7%	33%	63%	4%	15%	70%	15%	7%
Upper Georges River	83%	17%	0%	66%	17%	17%	17%	50%	33%	50%
Upper Prospect Creek	0%	86%	14%	29%	57%	14%	0%	86%	14%	14%
Upper Woronora River	100%	0%	0%	100%	0%	0%	63%	63%	0%	0%
Williams Creek	80%	20%	0%	100%	0%	0%	100%	60%	0%	20%

[1] Blue highlighting in table shows majority response (where only one choice could be selected).

Table 4. Community preferences for environmental values in Botany Bay, its estuaries and Towra Point Wetland[2]

Subcatchment	Desired Ecological Condition Target			Recreational Water Quality Objectives/Goals						
	High Conservation or Ecological Value System	Slightly to Moderately Disturbed System	Highly Disturbed Systems	Primary Contact	Secondary Contact	Visual	Drinking	Cultural	Industrial	Primary Industry
North Botany Bay	44%	56%	0%	85%	13%	2%	3%	78%	21%	49%
Cooks River Estuary	32%	58%	10%	48%	50%	2%	0%	78%	8%	13%
Lower Georges River Estuary	0%	100%	0%	82%	9%	9%	0%	55%	9%	64%
South Botany Bay	57%	43%	0%	100%	0%	0%	0%	86%	0%	0%
Towra Point Wetland Area	81%	19%	0%	72%	14%	14%	0%	81%	6%	35%
Upper Georges River Estuary	100%	0%	0%	100%	0%	0%	40%	60%	0%	20%

[2] Blue highlighting in table shows majority response (where only one choice could be selected).

These tables show a strong community preference for the estuaries and Botany Bay to be managed to a level which allows primary contact activities to occur and that maintains ecological condition either at a high conservation value level or for some areas in the Bay and Cooks River Estuary to a slight to moderately disturbed level. Community preferences for rivers vary more widely and depend on their location and current condition. There is a greater acceptance of some rivers and creeks being managed to achieve a highly disturbed condition. This is generally the case where rivers and creeks are associated with industrial and primary industry uses, and have been heavily modified for a long time because of past development practices. In other cases the community shows a strong preference to maintain rivers and creeks in a high conservation state, maintaining primary recreation values and values associated with drinking water. Almost all rivers and creeks have a large proportion of community indicating they associate these waterways with cultural values.

3 Water quality – objectives and loads

This section summarises current waterway pollutant loads and the reductions of pollutant loads required to deliver the environmental values outlined in Section 2. A plan for achieving pollutant load reductions is outlined in Section 4.

3.1 Current Catchment loads and estuary condition

Catchment loads of nutrients and sediments and the current condition of Botany Bay and its estuaries have been estimated using models and data sets developed as part of the Botany Bay Coastal Catchments Initiative and Botany Bay Water Quality Improvement Program. This section first describes estimated catchment loads then describes estuary condition relative to target levels of chlorophyll-A (Chl-A) and turbidity that have been developed.

3.1.1 Catchment loads

Catchment loads of total nitrogen (TN), total phosphorus (TP) and total suspended sediments (TSS) have been estimated using the Source Catchments Model (eWater 2010, SMCMA 2007) and the Botany Bay CAPER DSS. Loads associated with major subcatchments of the Botany Bay Catchment are provided in Table 5.

Table 5. Current catchment export loads of sediment and nutrients by subcatchment[3]

Subcatchment	Area (ha)	Flow (ML/year)	TSS (T/year)	TN (kg/yr)	TP (kg/yr)
Cooks River Catchment					
Alexandra Canal	1,567	6,576	782	12,179	1,495
Cook River Estuary	6,381	23,583	2,779	43,336	5,313
Upper Cooks River	1,770	5,714	660	10,342	1,264
Total	***9,718***	***35,873***	***4,221***	***65,857***	***8,072***
Georges River Catchment					
Bow Bowing Creek	11,546	19,777	1,960	34,255	3,406
Cabramatta Ck / Prospect Ck Junction	904	2,186	211	3,434	408
Cabramatta Creek	7,623	14,250	1,379	24,869	2,299
Deadmans Creek	1,827	3,488	116	2,680	247
Georges/O'Hare/Punchbowl Junction	3,886	5,443	245	5,317	454
Harris Creek	2,543	3,919	161	3,442	329
Lower Georges River Estuary	5,350	20,137	2,372	37,014	4,538
Mills Creek	2,203	5,463	370	6,696	716
O'Hares Creek	9,603	27,943	998	23,620	1,930
Orphan School Creek	3,919	10,222	1,187	18,570	2,273
Prospect Creek	5,132	13,617	1,470	23,448	2,817
Punchbowl Creek	5,455	10,891	341	8,126	732
Upper Georges River	4,806	8,257	409	9,320	643
Upper Georges River Estuary	8,399	22,180	2,370	37,741	4,549
Williams Creek	2,752	5,134	192	4,222	404
Woronora River: Above Dam	6,941	27,229	912	21,463	1,900
Woronora River: Below Dam	8,089	26,499	1,527	28,684	3,041
Total	***90,978***	***226,635***	***16,220***	***292,901***	***30,684***
Other Botany Bay Catchment areas					
North Botany Bay	4,966	21,579	2,319	36,870	4,455
South Botany Bay	2,143	8,348	685	11,586	1,333
Total	***7,109***	***29,927***	***3,003***	***48,456***	***5,788***
Total for entire Catchment	**107,805**	**292,435**	**23,445**	**407,213**	**44,545**

[3] Areas, loads and flows are for additional contributing subcatchment areas only (i.e. the subcatchment area not including areas included in upstream subcatchments) not for the entire subcatchment. Total loads for a subcatchment would be the sum of contributing area loads to the catchment outlet.

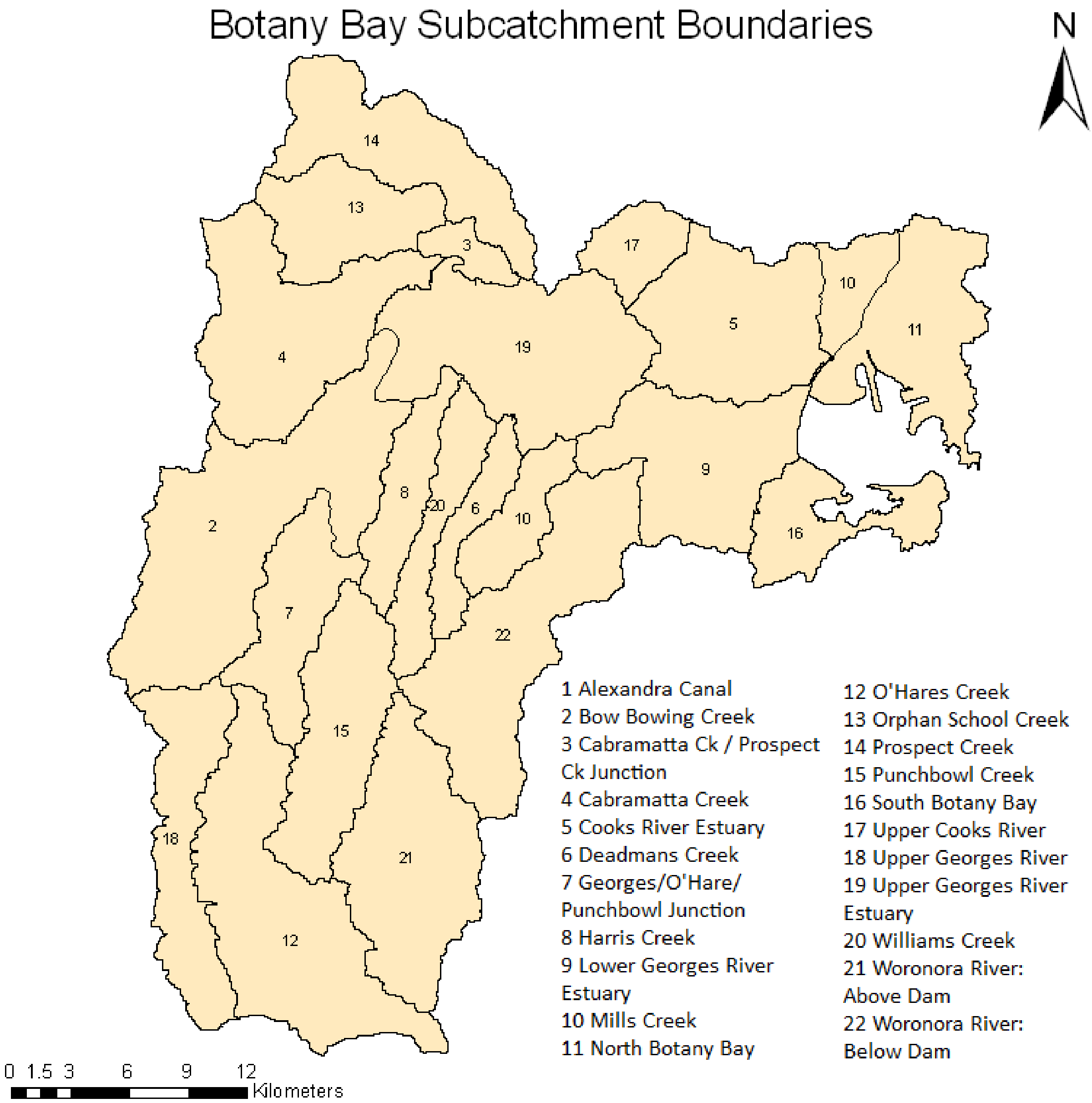


Figure 10. Map of subcatchment areas referred to in Table 5

3.1.2 Estuary condition and levels of protection

The National Water Quality Management Strategy (ANZECC 2000) is the basis for the majority of decisions about water quality management in NSW. ANZECC provides for three “levels of protection” for Aquatic Ecosystems:

1. High Conservation Value: systems that have a high ecological and/or conservation value and are systems that are largely unmodified or have undergone little change. They are often found within national parks, conservation reserves or inaccessible locations.
2. Slight to Moderate Disturbance: systems that have undergone some changes but are not considered so degraded as to be highly disturbed. Aquatic biological diversity may have been affected to some degree but the natural communities are still largely intact and functioning.
3. Highly Disturbed: systems that have undergone considerable degradation. Natural communities are largely not functional and nuisance species such as algae may be present in large volumes.

Estuaries and coastal lakes can be simply thought of as having two zones: the shallow margins and the deeper central basin. The margin ecosystems are structured by the substratum available (rocky or sand/mud), along with the presence of large attached plants such as large algae and seagrasses and other rooted plants. The extent of the attached plant communities is governed by physical factors such as sediment stability, resulting from wave and current erosion and by the availability of light for photosynthesis. Rooted plants also bind sediments and protect them from erosion.

The habitat provided by the large attached plants encourages the presence of a wide range of invertebrates (molluscs, crustaceans, worms etc) which support diverse fish assemblages, including the protected seahorses and pipe fish. Research has shown that the protection and food sources provided by seagrass and other rooted plants is essential for the survival of most of these types of invertebrates and fish. It has also been shown that seagrass provides essential protection and feeding grounds for juvenile stages of many fish species, even ones who do not spend their adult lives associated with seagrass.

Healthy riparian vegetation, including salt marshes, provides benefits for shallow margin ecosystems. In turn, on natural shores when the “wrack” of shed seagrass material (that develops naturally as seagrass grows) is pushed above the high water line by wave action, the wrack provides nutrition and desiccation protection for saltmarsh plants.

Human impacts on waterway ecosystems result from physical destruction (dredging, reclamation, hardening shorelines), changes to light penetration, addition of nutrients, and the addition of toxins.

As catchments are developed, more sediments are washed into waterways. These sediments make the water murky (turbid) and reduce the depth that light can penetrate through the water. If the seagrasses and other plants that live on the bottom can no longer get sufficient light, they die. If the seagrasses die, then all the invertebrates and fish associated with the seagrasses have nowhere to live and their abundance is also reduced. The turbid runoff from catchments may also contain excessive nutrients. These nutrients can stimulate the excessive growth of planktonic algae, and in shallow water the excessive growth of nuisance macroalgae in and around seagrass beds. The macroalgal growth also shades seagrass, adding an additional growth stress for the seagrass. The stimulated growth of nuisance algae and the accelerated loss of seagrass results in large build-ups of decaying plant matter in the water. In areas where the natural shoreline shape has been altered (usually made more vertical) this decaying matter accumulates in large amounts. A small amount of decaying seagrass is natural and forms an essential nutrient-recycling pathway. Excessive decaying plant matter, however, strips oxygen from the water and sediments and may exclude the majority of animal life.

Figure 11 shows a stylised view of coastal estuary/Bay ecosystems in good to poor condition. A brief description of the characteristics of systems at each of the levels of protection follows.

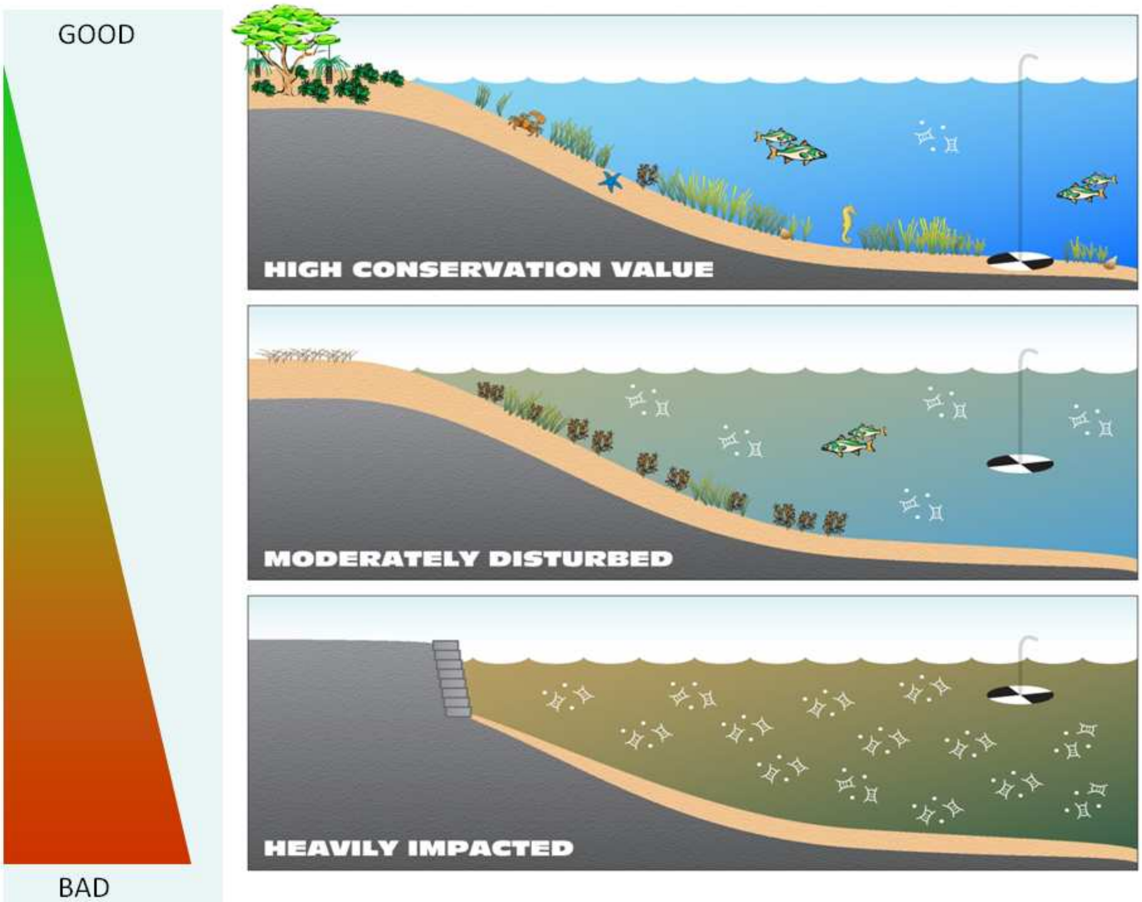


Figure 11. Ecological features of coastal lakes moving from good to poor condition (Source: Peter Scanes, DECCW)

High Conservation Value

The waterway edge and those parts of the waterway bed that receive sufficient light support well developed seagrass (or macrophyte) beds with a small amount of large macroalgae. Associated with the seagrass are a wide variety of invertebrates including crabs, prawns, worms, molluscs, starfish and small zooplankton. This rich food source supports a high diversity of juvenile and adult fish species, including protected seahorses and pipe fishes. Clear water allows the seagrass or macrophyte beds to extend to deep waters, often all the way to the waterway floor, thus substantially increasing their area. Healthy riparian vegetation, including saltmarsh communities, complements the aquatic biodiversity. The clear, low nutrient, open waters support a naturally moderate level of planktonic algae.

Indicators of good ecosystem quality would be high water clarity, low chlorophyll concentrations and very small amounts of green nuisance macroalgae among the seagrass.

Moderately Disturbed

Catchment disturbance has resulted in increased water turbidity and nutrient runoff. This has resulted in decreased light penetration. The seagrass or macrophytes in deeper waters no longer receive sufficient light and have died off, substantially reducing the area of plant habitat. High nutrient inputs have resulted in increased levels of planktonic algae in open water and excessive growth of green nuisance macroalgae which is further suppressing growth of seagrass. Fish and invertebrate diversity is reduced as a result of the loss of seagrass habitat and smothering by macroalgae.

Indicators of disturbed condition would be poor water clarity, moderate chlorophyll concentrations and obvious to large amounts of green nuisance macroalgae among the seagrass.

Highly Disturbed

Catchment disturbance has increased to the point where water clarity is so poor that seagrass or macrophytes cannot survive, or if they do, it is only as a narrow strip near the waterway margin. Large input loads of nutrients sustain large biomasses of planktonic algae. Fish and invertebrate diversity is substantially reduced due to the absence of seagrass and other habitat and the presence of such large amounts of phytoplankton. Changes to the shoreline result in the accumulation of decaying plant matter, leading to low oxygen concentrations in near-shore waters.

Indicators of a highly disturbed condition would be very poor water clarity, high concentrations of chlorophyll, masses of macroalgal wrack and absence of seagrass or macrophytes.

3.1.3 Thresholds used for levels of Protection in Botany Bay

A set of thresholds to indicate transition between these different levels of protection have been developed by DECCW for Botany Bay and its estuaries based on chlorophyll-A (Chl-A) concentrations and turbidity. While these thresholds are used as specific values it should be noted that the transition between states is more continuous, so that condition declines or improves incrementally as these thresholds are approached. Thresholds are given in Table 6.

Table 6. Thresholds of Chl-A (mg.L-1) and turbidity (NTU) for levels of protection for Botany Bay (Source: pers. comm. Peter Scanes, DECCW; Scanes, 2009).[4]

	Chl-A (mg.L-1)		Turbidity (ntu)	
	High conservation value (HCV)	Slight to moderate disturbance (SMD)	High conservation value (HCV)	Slight to moderate disturbance (SMD)
Upper estuary	3.5	5.3	1.9	2.9
Middle estuary	2.2	3.3	1.9	2.9
Lower estuary	2.1	3.2	1.9	2.9
Bay	1.9	2.9	2.2	3.3

3.2 Ecological targets for Botany Bay and its estuaries

The community preferences for environmental values defined through the community consultation process (see Table 4, Section 2.2) have been used to define the conservation status target for estuaries and the Bay. Using the thresholds in Table 6, ecological target levels of Chl-A and turbidity have been set. These targets along with current (modelled) values are given in Table 7.

[4] Thresholds for HCV are based on trigger values developed by DECCW using the 80th percentile value from a set of relatively pristine estuaries in NSW. No good value for turbidity in the upper estuary is available so the middle estuary value has been used in this case. SMD thresholds are set at 1.5 times the HCV value based on advice from Peter Scanes (DECCW). Ideally these values should be compared against a long-term data set, in terms of a probability of exceedence or failing this a median value. In most cases such a long term data set is not available and so comparison with an average value is acceptable.

Table 7. Ecological targets for Botany Bay and its estuaries

Location	Conservation status	Chl-A (mg.L-1)		Turbidity (ntu)	
		Current Modelled (annual average)	Target	Current Modelled (annual average)	Target
Upper Georges River Estuary	HCV	6.3	3.5	20	1.9
Middle Georges River Estuary	SMD	4.7	2.9	11	2.9
Lower Georges River Estuary	SMD	3.6	2.9	4.7	2.9
Lower Cooks River Estuary	SMD	5	2.9	6.1	2.9
Botany Bay	HCV	1.9	1.9	1.3	2.2

From this table it can be seen that in most cases substantial reductions in Chl-A and turbidity levels are required to meet the ecological condition targets that have been put in place. Relative changes required for turbidity are generally much higher than those required for Chl-A. Botany Bay itself currently meets condition thresholds for both Chl-A and turbidity although for Chl-A the current value sits exactly on the threshold, indicating the system is at best close to transitioning to slight to moderately disturbed state.

It should be noted that Water Quality Guidelines have also been set for oyster aquaculture areas (see NSW DPI 2006). These involve thresholds of faecal coliforms, pH, salinity, suspended sediments, aluminium and iron. These thresholds are relevant to oyster growing areas in the Mid and Lower Georges River Estuary and in the southern part of Botany Bay. These guideline values have not been explicitly addressed in this Plan as the impact of scenarios on the constituents considered by the guidelines could not be quantified. However it could be expected that many of the actions that improve water quality in terms of turbidity and Chl-A could also be expected to lead to improved levels of these other constituents.

3.3 Approaches to reducing pollutant loads

The Botany Bay Catchment is home to more than 2 million people and this high level of urbanisation has had an impact on water quality. One of the major ways to improve the water quality in urbanised areas is to ensure new developments as well as infill and redevelopments reduce pollutant loads (both nutrients and erosive flows) by implementing Water Sensitive Urban Design (WSUD). WSUD devices should be designed for normal flood conditions and will have little or no impact on large floods. They will however, if designed appropriately, have an impact on reducing smaller and more frequent storm events including those that are likely to contribute to erosion in natural streams. The term WSUD refers to many different possible actions (new devices, management interventions and practices and are under constant development). In this plan, seven main types of WSUD devices are considered in more detail:

- constructed wetlands,
- bioretention systems/raingardens,
- gross pollutant traps,

- vegetated swales,
- rainwater tanks,
- buffers, and
- riparian revegetation.

These are described in more detail below.

Note that other potentially effective WSUD options such as permeable paving, sediment basins and sand filters are also available but the effects of these have not been quantified in this Plan.

3.3.1 Constructed Wetland

A constructed wetland is essentially a shallow, densely vegetated pond or series of ponds into which stormwater flows before it reaches either a waterway or the stormwater system. These ponds are designed to help sediments and other pollutants settle out from the stormwater and contain plants and biofilms that use nutrients in the water column. They effectively provide a filter for the water before it passes into the stormwater system or waterway. A constructed wetland is generally a fairly large WSUD device capable of treating a relatively large area of a catchment. They provide habitat for aquatic flora and fauna and contribute to the amenity of public open spaces. They can also be designed to flows from smaller rainfall events.

3.3.2 Bioretention System/Raingardens

Bioretention is a site-based system for using the physical, chemical and biological properties of plants, soil and microbes to filter stormwater. Bioretention systems can typically be used close to the source of urban runoff. Rainfall-runoff is captured and filtered through a planted out soil medium before being conveyed to a waterway, stormwater system or storage device for reuse. Water begins to pond on the surface once the capacity of the soil medium is reached and they can be designed to detain runoff from smaller events. The water is only allowed to pond for short periods and small depths. The bioretention system contains vegetation that takes up nutrients and traps sediments. These systems operate in a similar way to an ephemeral wetland.

3.3.3 Next Generation Bioretention system (with submerged zone)

Bioretention systems have been further developed to incorporate a submerged or wet zone in their base. Typically some stormwater is trapped in a zone that is up to 45cm deep and made up of gravel or sand in the presence of a small amount of carbon (5% by volume). Because this zone becomes anaerobic it promotes denitrification. This significantly improves the nitrogen removal of the bioretention system. The process also improves copper and zinc removal rates (can meet ANZECC targets), and improves plant survival during long dry periods. Several of these systems have already been constructed in Sydney and South East Queensland. One is currently operational in the Botany Bay Catchment.

3.3.4 Vegetated/Grassed Swale

Vegetated/grassed swales are constructed open channel drainage ways, vegetated with native or exotic grasses, trees and shrubs and are used to treat and convey stormwater runoff. Filtered stormwater is generally collected in slotted pipes at the base of the swale where it can be conveyed to a drainage system or waterway or even a storage device for reuse. Water is not allowed to pond for any long period of time. Vegetated swales generally have gentle side slopes and can be roughly trapezoidal or parabolic in shape. There are many examples in the Botany Bay Catchment including the one shown in the picture opposite.

3.3.5 Gross Pollutant Trap (GPT)

A gross pollutant trap is a device designed to trap litter, coarse sediments and organic matter from runoff entering the stormwater system. They are generally thought to be inefficient at trapping nutrients.

3.3.6 Rainwater tank

A rainwater tank is a water storage system designed to be installed on individual houses or businesses to catch rainfall falling on a roof surface. These tanks can provide water for domestic use, such as for flushing toilets, watering gardens, washing clothes, or hot water systems. These systems reduce the amount of water running off the site and entering the stormwater system. In general the more things the rainwater is used for the greater the reduction in stormwater leaving the site.

3.3.7 Buffer Strip

A buffer strip is a relatively narrow area of land adjacent to, say a road or river, which is vegetated. This is intended to filter surface runoff before it reaches the stormwater system or stream.

3.3.8 Riparian revegetation

Riparian revegetation as a management action involves creation of vegetated buffers along the edge of waterways. Vegetation can consist of large woody vegetation such as trees and shrubs, or smaller vegetation such as grasses. This vegetation acts to filter overland flow before it reaches the stream, removing some of the sediments and nutrients before they end up in the waterway. It can also help stabilise the banks of waterways and hence reduce erosion during storm events.

The management of such vegetated riparian zones is different in rural areas to urban areas. In rural areas it is necessary to exclude stock from the buffer for the water quality benefits to be realised which usually means that riparian zones must be fenced off. In urban areas riparian vegetation needs to be protected from human interference, such as removal of trees to open up water views. In both cases the water quality benefits will depend on the length of the waterway that is revegetated, the width of the buffer and the extent and age of vegetation making up the buffer. Riparian vegetation can also offer other benefits to stream health through the provision of shade to the waterway which reduces algal growth and improves stream habitat.

3.3.9 Other WSUD Devices

There are other WSUD devices such as sediment basins, sand filters and permeable paving that can also be used in urban developments. If they are designed and maintained correctly they will each have a positive impact on water quality. They have not been modelled or considered in detail for this Plan.

3.4 Scenarios and trajectories of potential future water quality

This section explores the possible changes in water quality under a range of future circumstances. The recommended stormwater pollution reduction targets that have been used for these scenarios are shown below in Table 8. The scenarios have been tested using the Botany Bay Catchment and Planning Estuary Response Decision Support System (Botany Bay CAPER DSS [see Appendix 3]).

3.4.1 Stormwater Pollution Reduction Targets

Stormwater Quality

The stormwater reduction targets for greenfield and large redevelopments, as shown in Table 8, are based on those developed for the Growth Centres Commission in 2006 and by DECC (2007). These targets have been used in scenario testing in this Plan and are recommended as the targets that should be implemented in the Botany Bay Catchment. These stormwater pollution reduction targets were used to test scenarios in this Plan.

Table 8. Recommended stormwater quality reduction targets used to test scenarios in the Plan

Stormwater Pollutant	Greenfield developments Large redevelopments	Multi-unit dwellings. Commercial developments. Industrial developments. Small redevelopments.
Gross pollutants	90%	90%
Total suspended solids (TSS)	85%	80%
Total phosphorus (TP)	60%	55%
Total nitrogen (TN)	45%	40%

Stormwater Flows

Urban development has significantly altered the flow/hydrology of the Botany Bay Catchment. This is particularly important in areas were urban stormwater flows into sensitive and/or natural waterways. Flow regimes are considered to be equally important to water quality in determining the level of ecosystem health of streams and wetlands in urban areas.

Urban development increases the frequency, duration, peak flows and volume of stormwater runoff, due to the increase in impervious area in urban catchments. Pipe and constructed channel drainage systems deliver flows more rapidly, and directly, to receiving waters, and concentrate flows at a single point. An important consequence of these effects is the potential for increased erosion of natural waterways downstream of urbanising areas (which also contributes to declines in water quality). It is recommended that all new urban development be designed to minimise the impacts of erosive flows on sensitive waterways. It is anticipated that the NSW Office of Environment and Heritage will shortly release guidance on appropriate targets for a NSW Stream Erosion Index.

Stream flow regimes in urban catchments also have a significant deleterious effect on the ecosystem health of waterways. Investigations have found that the impact of urban development on stream ecosystem health is directly related to the 'effective' (or 'directly connected') impervious area in the Catchment, and it is postulated that this reflects the impact of significantly increased frequency of flow (and therefore habitat disturbance) in urban streams. This conclusion is based on the observation that comparable areas (or proportions) of catchment imperviousness do not significantly affect stream health where no formal (piped/lined) drainage systems exist which 'directly connect' those impervious areas to the waterway (Ladson, Walsh et. al. 2004). Implementing WSUD throughout the Botany Bay Catchment will help increase the area of hard surfaces that are not directly connected to the stream network and so will help improve ecosystem health and reduce erosive flows in sensitive waterways.

Natural wetlands are particularly susceptible to the impacts of urban stormwater flow regimes upon their wetting and drying cycles. For catchments above natural wetlands, it may be necessary to address in more detail the hydrologic change associated with catchment urbanisation beyond typical flow attenuation strategies. An investigation undertaken by the Hunter Councils Group (Hunter Councils, 2007) has recommended the adoption of flow management objectives for minimising the impacts of catchment urbanisation upon wetlands, based on the definition of the wetland inundation and drying characteristics of different wetland types. This investigation report (Hunter Councils 2007) also provides guidance on the classification of wetlands for the purposes of setting catchment stormwater management objectives.

3.4.2 Scenarios Modelled for the Botany Bay Catchment

The Botany Bay Catchment and Planning Estuary Response Decision Support System (Botany Bay CAPER DSS – see Appendix 3) has been developed and used to consider several alternative future scenarios or trajectories for catchment water quality. These provide a glimpse at alternative possible future options, both good and bad, and provide an indication of what is achievable in terms of water quality improvement. These scenarios are described in Table 9.

Table 9. Scenarios of future development and remediation for the Botany Bay Catchment

Scenario name	Details	Type
Infill development using WSUD and rehabilitation of riparian corridors	Expansion of residential and commercial/industrial areas occurs through infill redevelopment only with WSUD applied to reach reduction TN/TP/TSS reduction targets in Table 8. Growth rates assumed based on Sydney Metropolitan Subregional Strategies (2005). Rates applied out to 2070. Riparian corridors: 1.61 km of riparian frontage revegetated with mixed grass and trees each year (corresponds to 10% of available length by 2030 and 30% by 2070)	'Best' case improvement – referred to as 'preferred Plan scenario'
Infill development using WSUD	Same urban infill assumptions as above. No riparian remediation/revegetation undertaken	'Good' improvement
Base case	Current land use and generation of pollutants continues into the future. Note: this does not account for potential increases in pollutants through increased density of existing urban areas (reduced perviousness)	Status quo
Greenfield development in Campbelltown/Liverpool (no WSUD)[5]	Urban growth through major greenfield development in Campbelltown and Liverpool area without WSUD. Equivalent area of rural lands developed by 2030 as for urban infill scenario above. Growth in pollutants past 2030 projected at same rate for comparison.	'Worst' case

The total base case (current) pollutant load of TN, TP and TSS flowing into the Bay from its Catchment is provided in Table 5, section 3.1. Table 10 provides the percentage change in loads for the total catchment (see also Figure 12) expected under the scenarios of future development and remediation assuming current climate (as described in Table 9). Results have also been summarised for the Cooks River (Figure 13), Upper Georges (Figure 14) and Lower Georges (Figure 15) River and for subcatchments flowing directly into Botany Bay (Figure 16). Note that these results refer to the loads generated within these areas rather than the total river loads in the river at the end of each section. For example, impacts for the Lower Georges River refer to changes in the load being generated by subcatchments in the Lower Georges River area only. Changes in river load for the Lower Georges River would also need to consider changes in loads being generated in the Upper Georges River subcatchment. All results shown in these figures assume current climate conditions continue. Appendix 1 provides results using climate change projections for 2030 and 2070. Appendix 2 provides a summary of scenario results by LGA.

[5] This scenario assumes that greenfield development occurs on rural (i.e. agricultural) lands. For this scenario it does not occur on bushland or on land that is currently part of the Holsworthy site.

Table 10. Percentage change in nutrient and sediment export loads from base case for future development/remediation scenarios

Pollutant and Scenario[6]	Total Catchment		Cooks River subcatchment		Upper Georges River subcatchment		Lower Georges River subcatchment		Bay foreshore subcatchments	
	2030	2070	2030	2070	2030	2070	2030	2070	2030	2070
TN										
Greenfield development in Campbelltown/Liverpool	6%	19%	0%	0%	10%	31%	0%	0%	0%	0%
Expansion through infill redevelopment using WSUD	-7%	-17%	-7%	-18%	-7%	-18%	-5%	-14%	-6%	-15%
Infill redevelopment using WSUD and rehabilitation of riparian corridors	-9%	-21%	-8%	-20%	-9%	-22%	-7%	-18%	-9%	-23%
TP										
Greenfield development in Campbelltown/Liverpool	12%	36%	0%	0%	21%	62%	0%	0%	0%	0%
Expansion through infill redevelopment using WSUD	-11%	-26%	-10%	-25%	-12%	-29%	-7%	-20%	-9%	-22%
Infill redevelopment using WSUD and rehabilitation of riparian corridors	-13%	-31%	-11%	-27%	-14%	-34%	-9%	-25%	-13%	-31%
TSS (sediment)										
Greenfield development in Campbelltown/Liverpool	10%	29%	0%	0%	17%	50%	0%	0%	0%	0%
Expansion through infill redevelopment using WSUD	-15%	-38%	-14%	-37%	-17%	-42%	-11%	-29%	-13%	-32%
Infill redevelopment using WSUD and rehabilitation of riparian corridors	-17%	-42%	-15%	-38%	-19%	-45%	-12%	-33%	-16%	-39%

[6] Preferred Plan scenario results are highlighted in blue.

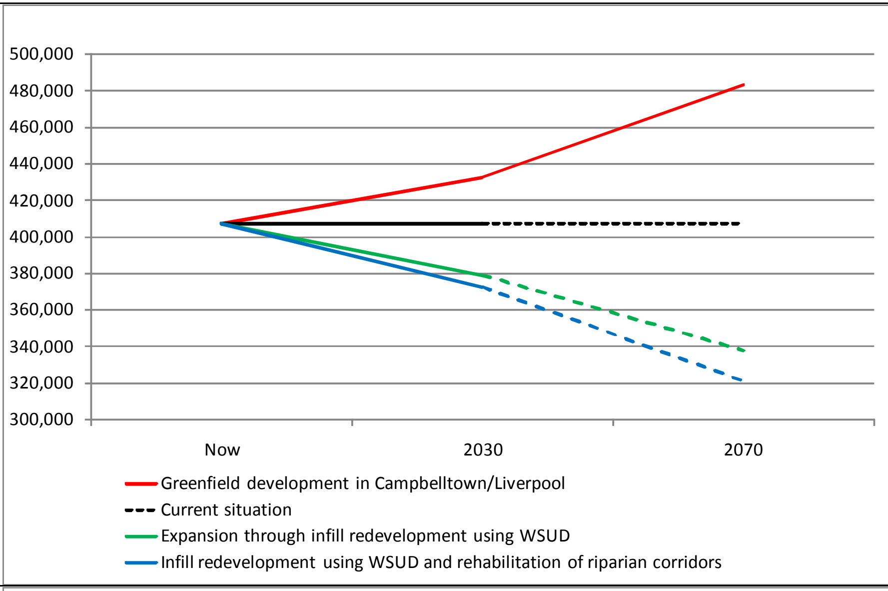
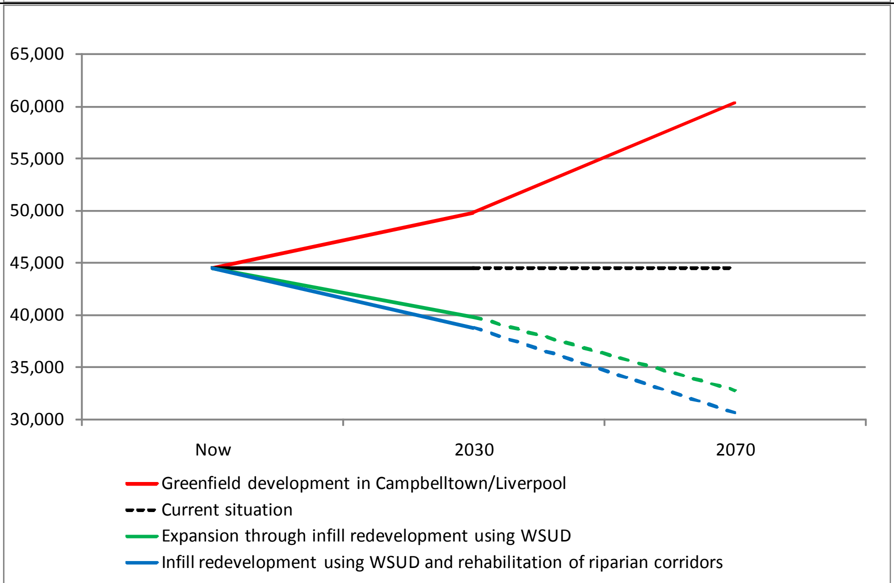
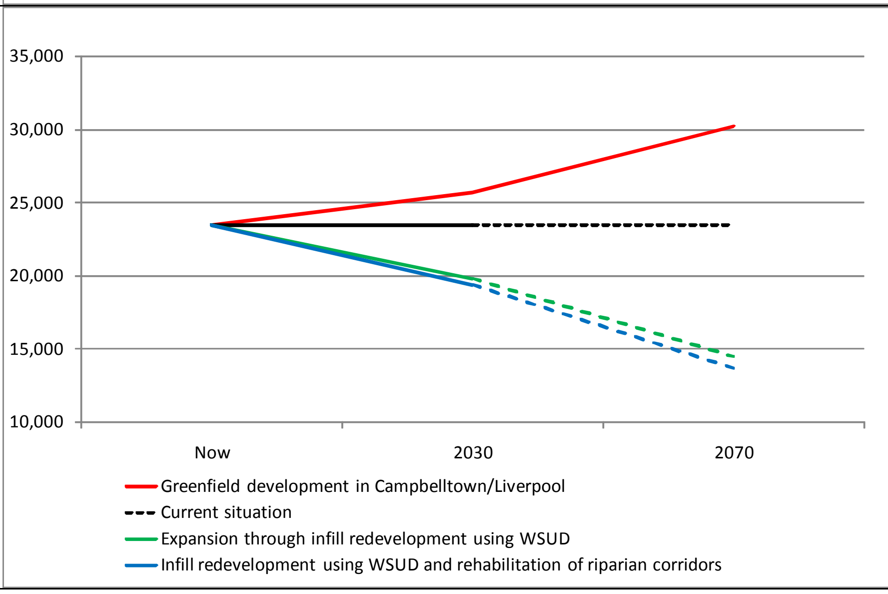
TN **Kg/Y**	
TP **Kg/Y**	
TSS **Tonnes/Y**	

Figure 12. Trajectories of future pollutant loads for scenario options described in Table 9: Total Catchment

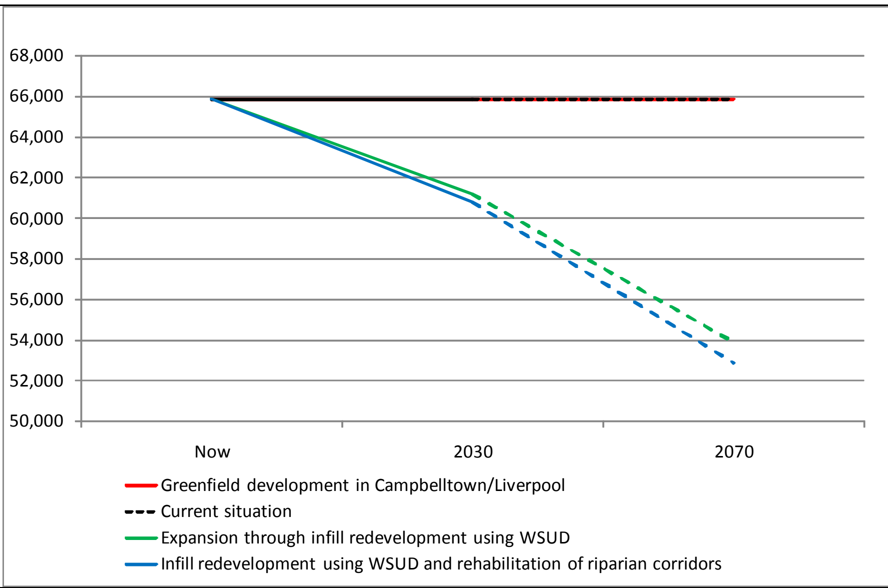
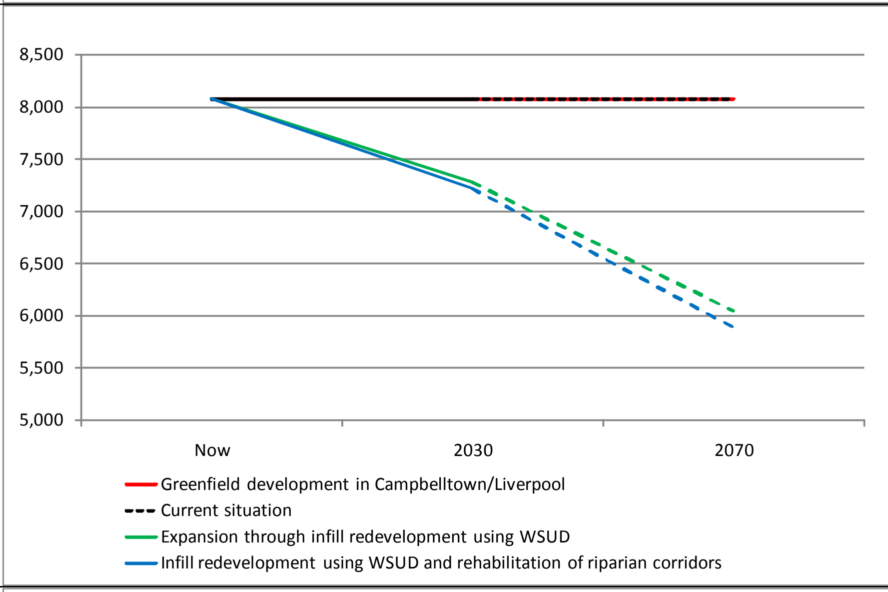
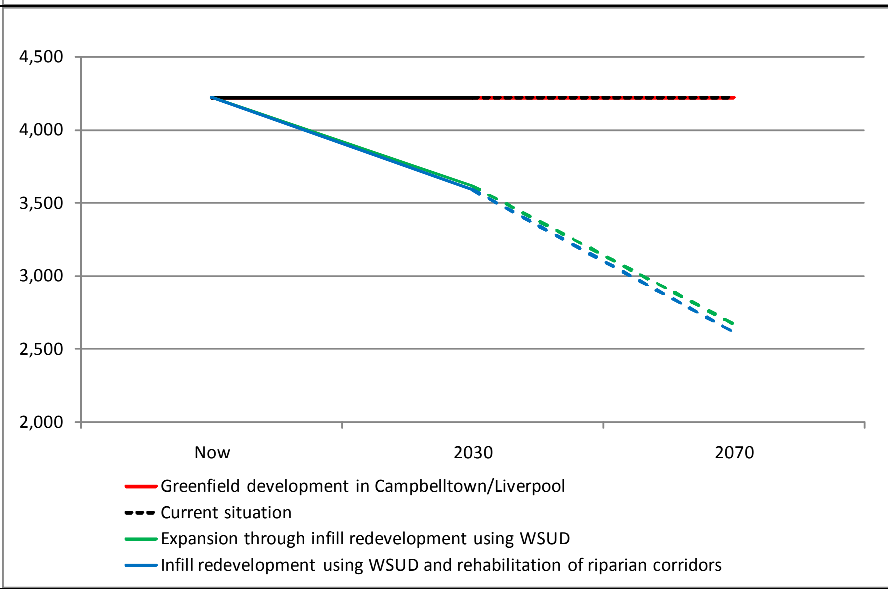
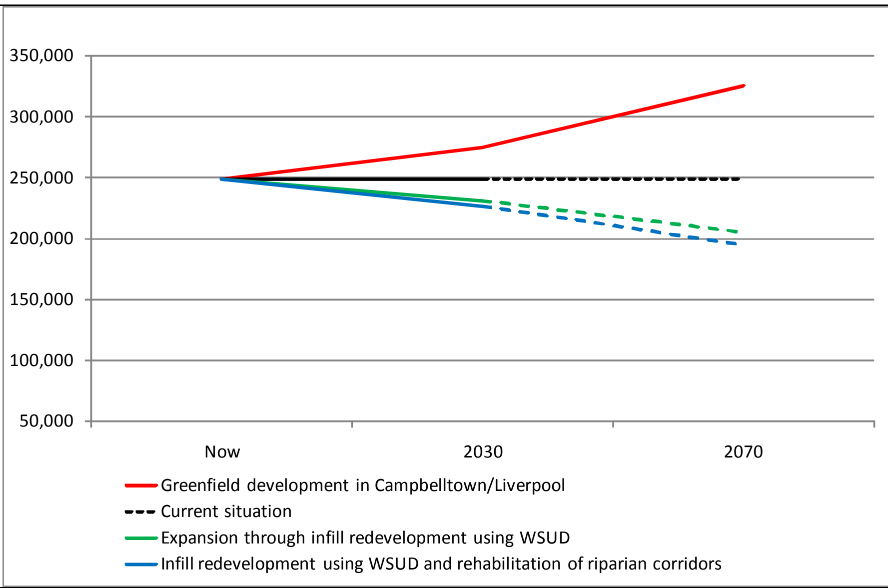
TN **Kg/Y**	
TP **Kg/Y**	
TSS **Tonnes/Y**	

Figure 13. Trajectories of future pollutant loads for scenario options described in Table 9: Cooks River subcatchment

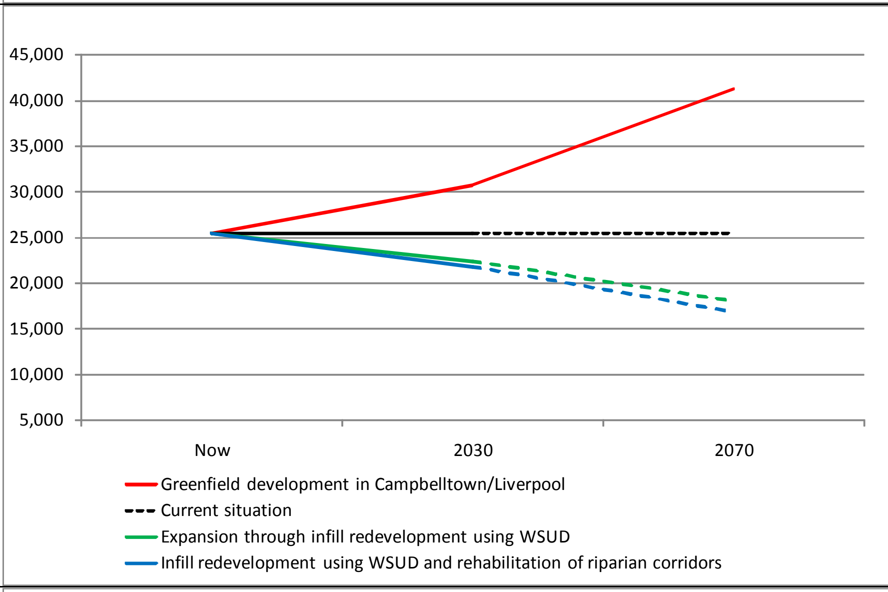
TN

Kg/Y



TP

Kg/Y



TSS

Tonnes/Y

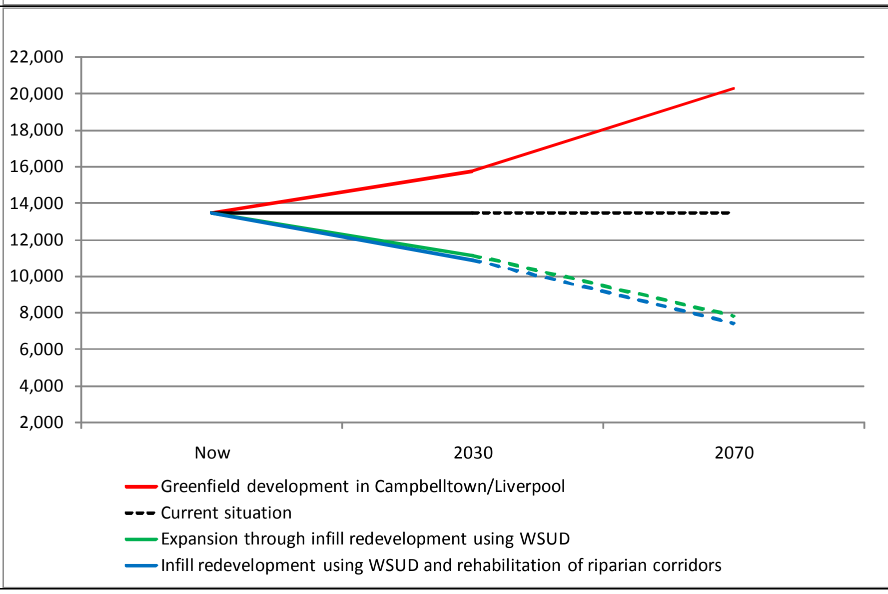
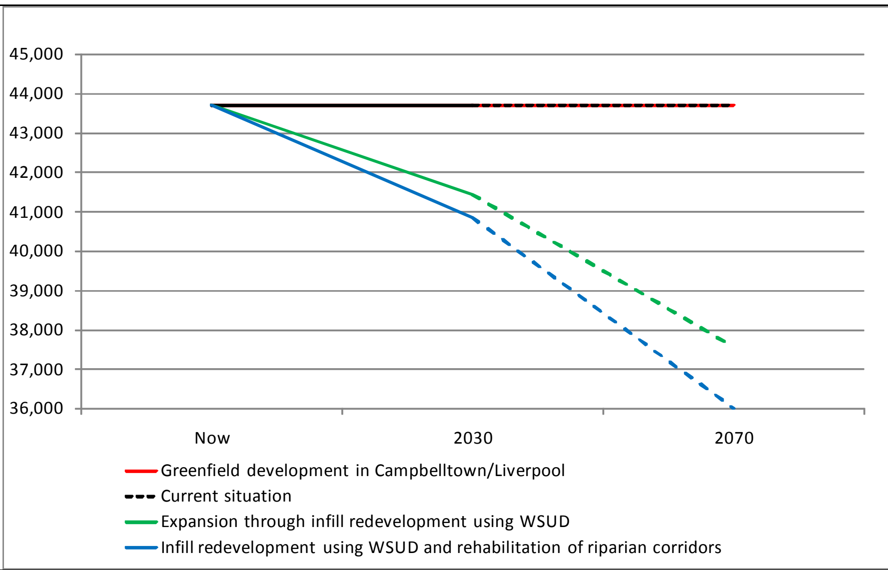


Figure 14. Trajectories of future pollutant loads for scenario options described in Table 9: Upper Georges River subcatchment

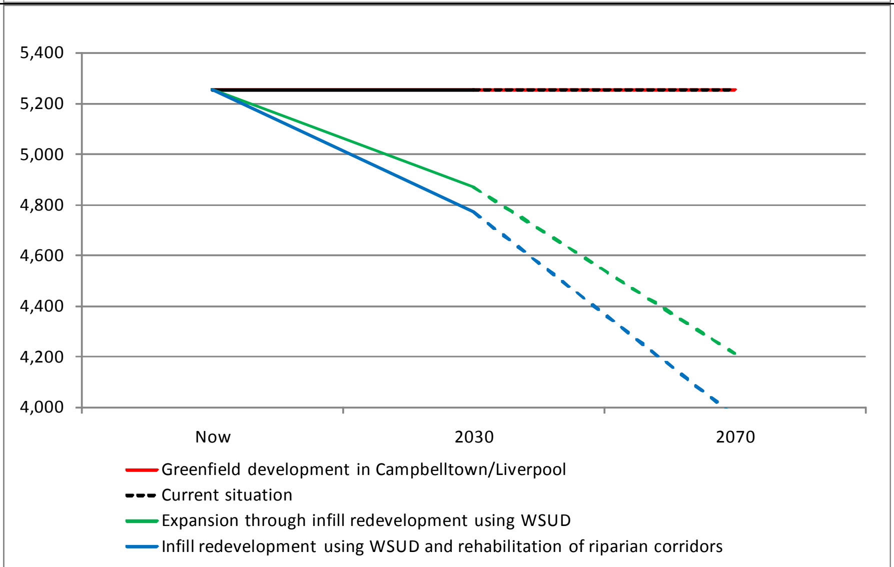
TN

Kg/Y



TP

Kg/Y



TSS

Tonnes/Y

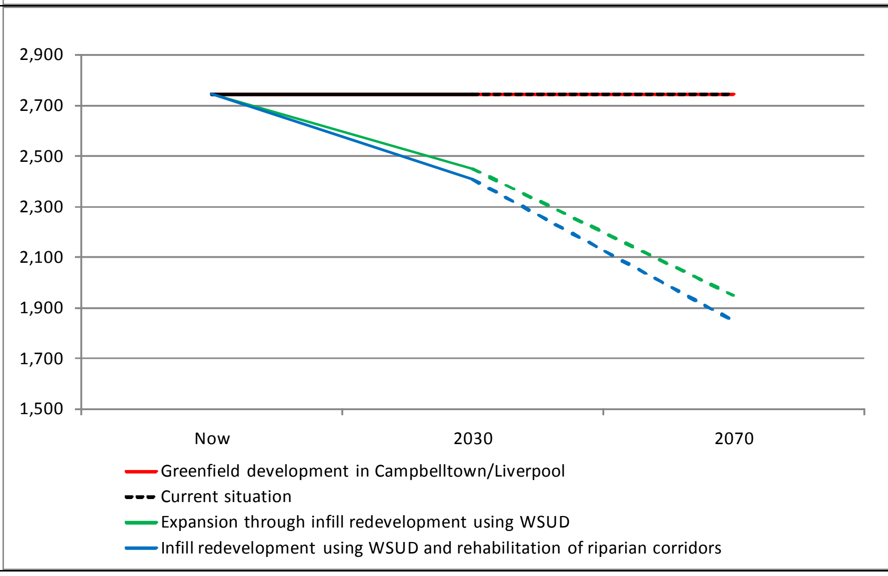


Figure 15. Trajectories of future pollutant loads for scenario options described in Table 9: Lower Georges River subcatchment

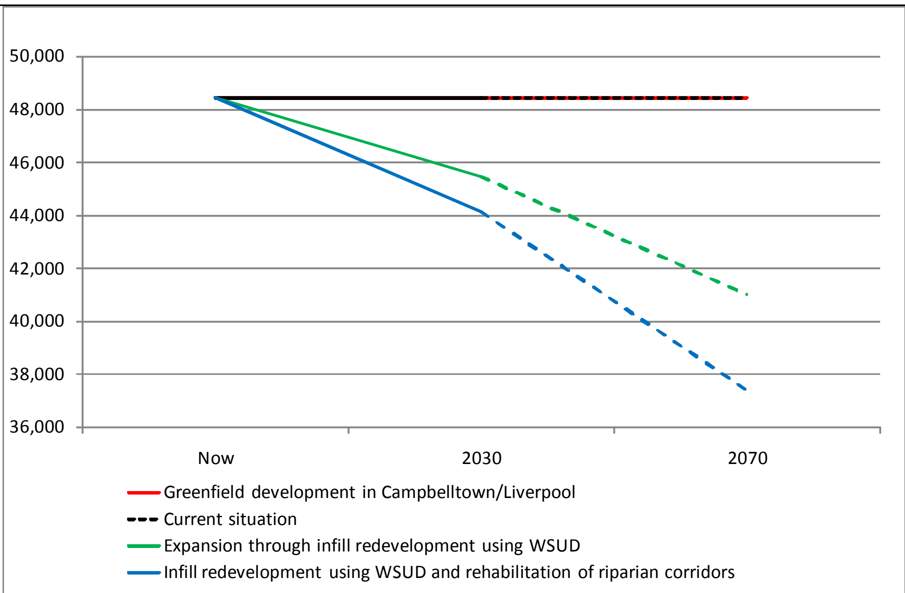
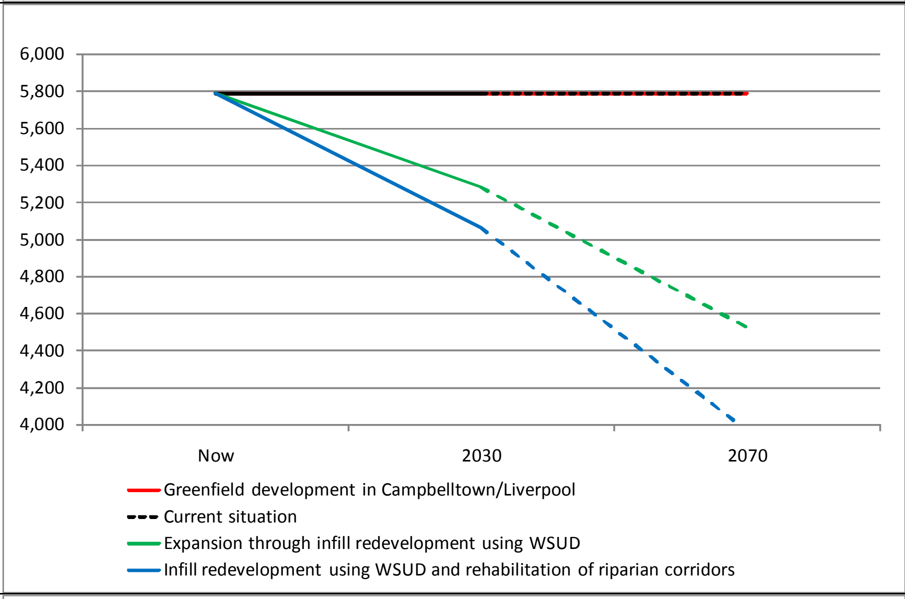
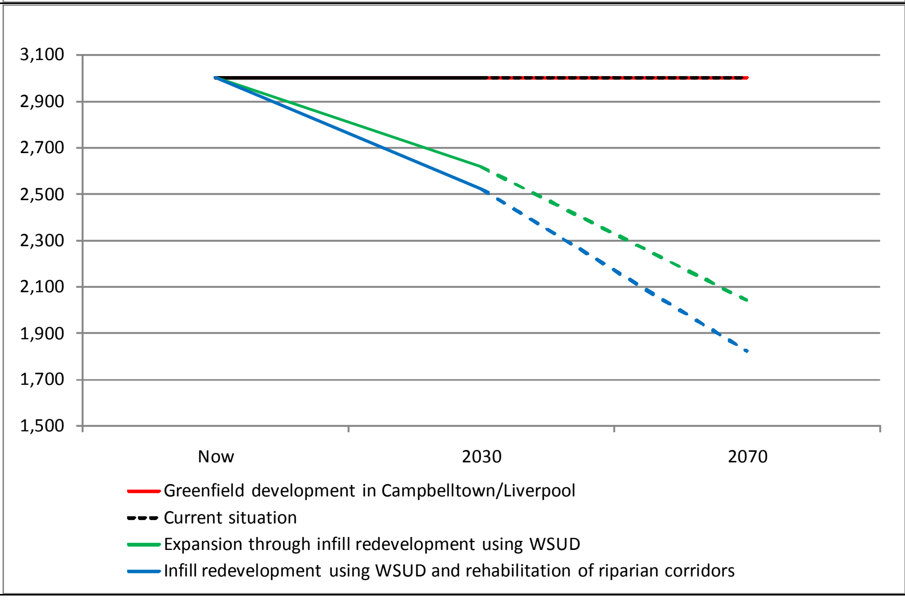
TN **Kg/Y**	
TP **Kg/Y**	
TSS **Tonnes/Y**	

Figure 16. Trajectories of future pollutant loads for scenario options described in Table 9: Botany Bay foreshore subcatchments

These figures show:

- By 2030:
  - The best case, or preferred, scenario based on infill development with WSUD and riparian rehabilitation could see **decreases** of 9% of TN, 13% TP and 17% TSS from current (base case) levels.
  - WSUD is responsible for most of the change with a 2% change from current levels in all pollutants due to rehabilitation of riparian corridors.
  - The worst case scenario would lead to **increases** of 6% of TN, 12% of TP and 10% of TSS from current levels.
- These trends continue such that by 2070 the best case, or preferred, scenario could see falls in pollutants of between 21 and 42% from current levels.
- All of the impact of the worst case scenario is seen in loads from the Upper Georges River subcatchment due to the assumed placement of greenfield development in the Campbelltown and Liverpool areas. Loads from these subcatchments increase by 10% (TN), 21% (TP) and 17% (TSS) by 2030. By 2070 the increases would range from over 30% to 60% of current nutrient and sediment levels. While there is no change in loads generated by Lower Georges River subcatchments (as seen in Figure 13), the total load generated to the end of the Lower Georges River would increase by 9% (TN), 17% (TP) and 14% (TSS) by 2030 and by 26 to 52% by 2070.
- The best case scenario has very similar relative impacts on loads generated for all the subcatchment areas. Decreases in TN range from 7% in the Lower Georges, 8% in the Cooks to 9% in all other subcatchment areas. A slightly greater range of impacts is seen for TP and TSS, with the lowest decreases (9%, 12%) seen for the Lower Georges and the highest decreases seen for the Upper Georges River (14%, 19%).

Overall these results show that fairly sizeable decreases in nutrient and sediment loads are possible for all major subcatchment areas of the Bay. In addition the implications of not acting could also be very severe with substantial increases in nutrient and sediment delivery being quite likely.

Section 4 shows some ways in which these decreases in pollutant generation could be achieved and explores the cost implications of several alternatives.

The following sections explore what these changes in water quality might mean for Botany Bay and its estuaries and river condition and pollutant loads.

3.5 Estuary impacts of load reduction scenarios

Target levels of Chl-A and turbidity for Botany Bay and its estuaries were described in Table 7, section 3.2. This table showed that to meet the target levels decreases, in both Chl-A and turbidity, were required in all the estuaries. The exception to this was for Chl-A and turbidity in the Bay itself, although with the current Chl-A level being at the target, arguably reductions in this are required to ensure the Bay stays in a desired high conservation value state in the longer term. The percentage reductions from current levels of these condition indicators required to meet targets is given in Table 11.

Table 11. Percentage reductions in Chl-A and turbidity required to meet ecological targets

Area	Chl-A	Turbidity
Upper Georges River Estuary	44%	91%
Middle Georges River Estuary	38%	74%
Lower Georges River Estuary	19%	38%
Lower Cooks River Estuary	42%	52%
Botany Bay	Target met	Target met

A direct comparison of load reductions achieved in TN, TP and TSS using a scenario of infill redevelopment and riparian rehabilitation is given in Table 12. This table shows that by 2070 load reductions can be expected to be similar to the changes required in Chl-A and turbidity to meet the target levels in the Lower Georges River Estuary. Nutrient changes in the Upper and Middle Georges River Estuary and the Lower Cooks Estuary are likely to be roughly 50% of the change required in Chl-A. For the Bay, both turbidity and Chl-A target levels are already met so expected reductions in sediment would reduce pressure on these areas and most likely bring them further under the target level.

Note that this simple comparison does not take into account the non-linearities in the estuary and Bay systems which mean changes in Chl-A and turbidity may not be the same as changes in nutrients and sediments being delivered to the system. Some reasons for this include the cycling of nutrients and sediments within the estuaries and marine sediments and nutrients being fed into the system. In some cases reducing turbidity can lead to slight increases in Chl-A because the clearer water allows for greater penetration of light into the water column. It is however a useful first comparison to see whether these changes are of a similar magnitude.

Table 12. Load changes achieved by the preferred Plan scenario (infill redevelopment with WSUD and riparian rehabilitation)[7]

Area	2030			2070		
	TN	TP	TSS	TN	TP	TSS
Upper Georges River Estuary	-9%	-14%	-18%	-21%	-32%	-43%
Middle Georges River Estuary	-9%	-14%	-18%	-21%	-32%	-43%
Lower Georges River Estuary	-9%	-14%	-18%	-21%	-32%	-43%
Lower Cooks Estuary	-8%	-11%	-15%	-20%	-27%	-38%
Botany Bay	-9%	-13%	-17%	-21%	-31%	-42%

The Botany Bay CAPER DSS also includes a metamodel of a receiving water quality model developed by DECCW for the Botany Bay CCI project. Results from the metamodel for this scenario are given in Table 13. Figure 17 provides a map of estuary zones, as described in this table.

[7] Results from the DSS have been grouped for the whole of the Georges River Estuary only, rather than for the Upper, Middle and Lower estuary.

Table 13. Modelled changes (from the current situation) in median Chl-A due to infill redevelopment with WSUD and riparian rehabilitation

Estuary zone	2030	2070
Upper Georges	5.8%	12.1%
Mid Georges	-2.3%	-6.2%
Lower Georges	-2.1%	-6.0%
Upper Cooks	-1.4%	-8.6%
Lower Cooks	-0.2%	-0.5%
North West Botany Bay	-0.2%	-0.4%
North East Botany Bay	-0.3%	-0.6%
South Botany Bay	-1.1%	-2.4%
Towra Point	-0.6%	-1.9%

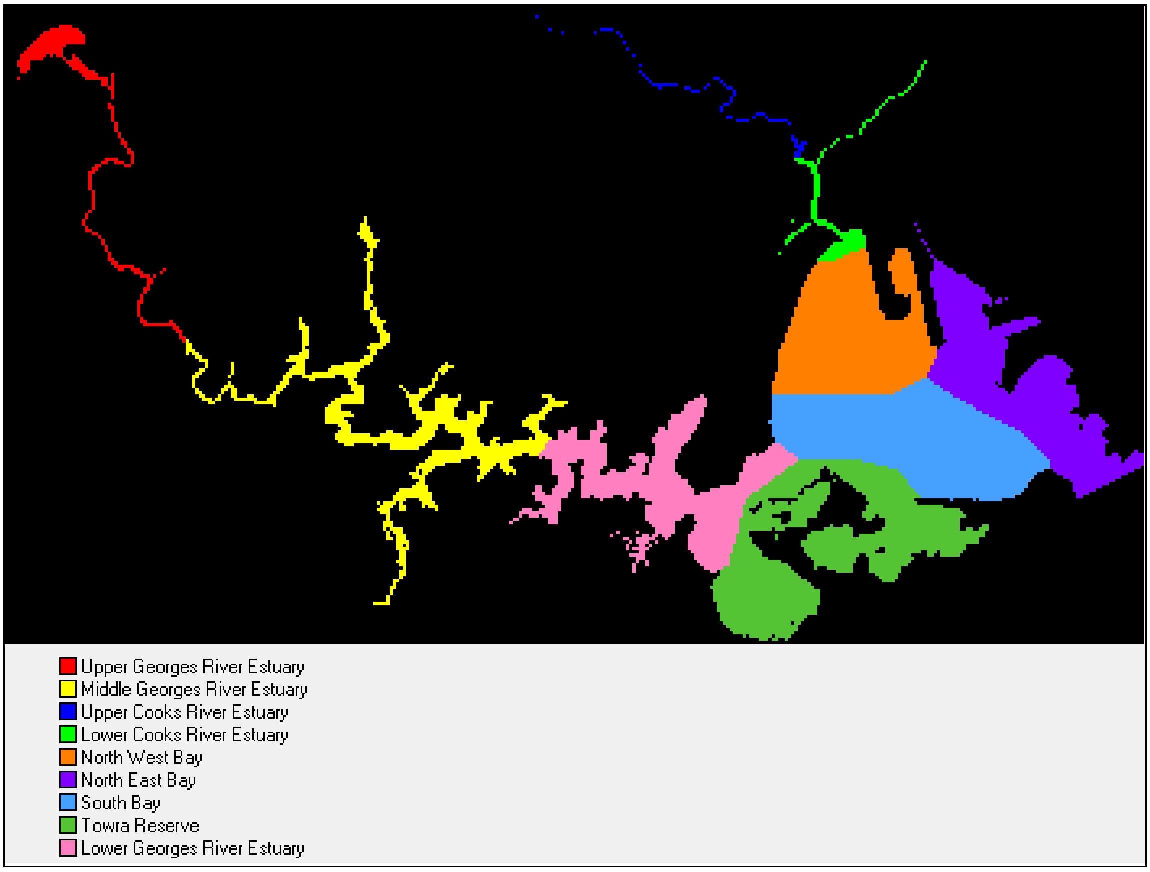


Figure 17. Estuary zones used in the analysis of Plan scenarios

This table shows that the model predicts small improvements in median Chl-A levels as a result of this scenario for all areas except the Upper Georges River Estuary. The greatest change is predicted for the Upper Cooks Estuary with an 8.6% decrease in Chl-A by 2070. Changes in the Bay and Lower Cooks are predicted to be much lower, below 1%. For the Lower Cooks River estuary these changes are well below those required to meet the target levels, while for the Bay targets are currently met (although only just in the case of Chl-A so a small decrease is still useful in reducing the pressure on this system).

There are several reasons that can be suggested for these results:

- There may be problems with the model calibration and set up which mean that it is insensitive to changes in incoming nutrient loads. Further work is currently being undertaken to test whether this may be the case.
- The model might be accurately estimating impacts on the estuary. It may be that there are sufficient nutrients and sediments currently in the system that even with large changes in load there would be relatively small changes in estuary condition in the medium term.
- It's possible that as sediment (turbidity) is removed from the system, light penetration increases causing increases in Chl-A. This could be brought about as reductions in nutrients (particularly nitrogen) are typically expected to be lower than decreases in turbidity.

Given these issues it's not possible to conclusively say whether the scenario option of infill redevelopment and riparian rehabilitation will be sufficient to return the Bay and its estuaries to target ecological conditions by 2070. What is clear is that declines in estuary condition took place over a long time frame and that moving back to improved conditions will also take a long time. The preferred Plan scenario is an important step in reducing catchment pollutants and improving the estuary condition. In any case changes required will be at least as great as those described by the preferred Plan scenario.

It is likely that meeting the Catchment load targets presented in this Plan will be a substantial step towards meeting the ecological condition targets that have been set for the Bay and its estuaries. Changes in nutrient and sediment loads are a similar magnitude as reductions in Chl-A and turbidity required in the estuary. Further decreases may be necessary from 2070 onwards to fully achieve these estuary condition targets. However, estuary condition changes continuously with decreases in pollutant loads such that significant ecological benefits will be accrued even before ecological condition targets are met.

CASE STUDY: What would happen if we met population growth needs through greenfield developments?

The Plan scenario assumes that increased housing stock for a growing population is met through infill redevelopment which employs water sensitive urban design. Another commonly suggested alternative would be to build a greater housing stock through greenfield development. There are two options for the placement of such greenfield sites: development of rural lands that fringe the city, or clearing and development of bushland areas (for example if areas of Holsworthy were released for development). Two obvious questions are: what would happen to water quality if these types of options were allowed; and, what effect might water sensitive urban design in these areas make? To answer these questions 4 different scenario options were considered:

- Greenfield development on existing *rural* land *without* WSUD (i.e. our 'worst' case scenario above)
- Greenfield development on existing *rural* land *with* WSUD
- Greenfield development on existing *bush* land *without* WSUD
- Greenfield development on existing *bush* land *with* WSUD

The size of these developments is the same in all cases, although their placement is slightly different due to the different types of land they are assumed to occur on. Table 14 shows the impacts of these scenario options on sediment and nutrient loads delivered to the Bay and rivers.

Table 14. Impact of greenfield development options with and without WSUD and nutrient and sediment loads (% change from base case loads) by 2030

	Rural land, No WSUD	Rural land, With WSUD	Bushland, No WSUD	Bushland, With WSUD
TN				
Total catchment	6.23	0.63	10.69	4.12
Georges River Catchment	8.67	0.87	14.86	5.73
TP				
Total catchment	11.84	3.41	12.95	3.37
Georges River Catchment	17.19	4.94	18.81	4.89
TSS				
Total catchment	9.64	-2.27	13.18	-0.15
Georges River Catchment	13.94	-3.28	19.05	-0.22

This table shows that all options without WSUD would lead to substantial increases in pollutant loads. Developing on bushland would increase loads by a greater extent than developing rural lands, as these generally have higher than natural loads. Even where WSUD is applied all scenarios lead to an increase in nutrient loads. Small decreases in TSS are estimated where WSUD is applied – these changes are very small and particularly in the case of bushland, are not significantly greater than zero.

At a localised level all these scenarios are associated with very substantial declines in the water quality of affected rivers and creeks. If bushland is developed with no WSUD, localised impacts can range from a 130% to 480% increase in TSS, 100-300% increase in TN and 120-420% increase in TP. Even if WSUD were employed, localised impacts for TN and TP would still range from increases of 40-120% and 30-110% respectively. If rural areas are to be developed with WSUD, the greatest local impact is still a 36% increase in TP. These are all very substantial increases in river loads, and indicate that under these options not only would the health of the Bay and Georges River Estuary decline, but rivers and creeks in the affected areas would also be very substantially affected.

3.6 Subcatchment targets and impacts on river condition

The preferred scenario to reduce nutrient and sediment delivery to the Bay through infill redevelopment using water sensitive urban design and rehabilitation of riparian corridors is expected to have significant impacts on the rivers and streams of the Catchment, not only the estuaries and Bay. The percentage nutrient and sediment load reductions associated with this scenario option for 2030 for key streams and subcatchment areas in the Catchment are given in Table 15.

Table 15. Percentage change in TSS, TP and TN for the preferred Plan scenario (infill redevelopment with WSUD and riparian rehabilitation) for 2030 for rivers and creeks

River/Creek	TN	TP	TSS
Cooks River			
Alexandra Canal	-8%	-11%	-16%
Upper Cooks River	-13%	-18%	-25%
Cook River Estuary	-8%	-11%	-15%
Georges River			
Bow Bowing Creek	-14%	-23%	-29%
Cabramatta Creek	-12%	-21%	-24%
Deadmans Creek	0%	-1%	-1%
Harris Creek	-4%	-8%	-12%
Mill Creek	-3%	-5%	-8%
Orphan School Creek	-19%	-26%	-35%
Prospect Creek	-15%	-20%	-27%
Williams Creek	-3%	-6%	-9%
Woronora River	-2%	-3%	-4%
Upper Georges River Estuary	-11%	-17%	-23%
Lower Georges River Estuary	-9%	-14%	-18%
Botany Bay foreshore areas			
North Botany Bay	-10%	-14%	-17%
South Botany Bay	-6%	-8%	-11%

As can be seen in Table 15, even by 2030, this option is expected to significantly decrease the pollutant loads of streams in the Catchment. Streams feeding into the Cooks River Estuary would see decreases of up to 8-25% of pollutant loads (the highest reductions are for suspended sediment entering the Upper Cooks River). Many creeks flowing into the Georges River Estuary would see similar or even greater reductions of pollutant loads. Orphan School Creek would experience reductions of 19-35%, while Bow Bowing, Prospect and Cabramatta Creeks and the Upper Georges River Estuary would see reduction in TSS of 24 to 29% and in nitrogen of 12 to 15%.

For some creeks and rivers flowing into the Georges River Estuary it is possible to estimate not just the change in pollutant load associated with this scenario but also the change in condition that this could be expected to lead to. Using the rating method employed by the Community River Health Monitoring Program (GRCCC 2010) run by the Georges River Combined Councils' Committee (GRCCC), changes in condition associated with these pollutant load reductions that could be expected are shown in Table 16. The condition for the worst case scenario of greenfield development without WSUD is also included along with the current condition. Note that only a few areas were able to be considered in this analysis. These were areas where the GRCCC monitoring sites overlapped with areas being modelled for the Botany Bay & Catchment WQIP. Green cells highlighted in Table 16 are those where condition would be expected to improve from the current condition, while cells highlighted red show an expected decline in condition.

Table 16. River condition (grade for TN and TP) associated with base case, preferred Plan scenario and worst case scenario (Georges River subcatchments only) (after GRCCC 2010)[8]

River/Creek	TN		
	Current grade	Preferred Plan scenario-Infill redevelopment and riparian rehabilitation	Worst case scenario - Major greenfield development without WSUD
Lower Cabramatta Ck	F-	F-	F-
Georges River Woolwash	B+	B+	B-
Mill Ck	A+	A+	A+
Woolwash O'Hares Ck	A+	A+	A+
Lower Orphan School Ck	B+	A+	B+
Lower Prospect Ck	B	A	B
Georges River Cambridge Ave	A+	A+	C+
	TP		
	Current grade	Plan scenario - Infill redevelopment and riparian rehabilitation	Worst case scenario - Major greenfield development without WSUD
Lower Cabramatta Ck	F-	F-	F-
Georges River Woolwash	A+	A+	A+
Mill Ck	E+	D-	E+
Woolwash O'Hares Ck	A+	A+	A+
Lower Orphan School Ck	A+	A+	A+
Lower Prospect Ck	F-	F+	F-
Georges River Cambridge Ave	A	A	C-

As can be seen in this table, the preferred Plan scenario can be expected to lead to real improvements in river condition in many of the rivers and creeks in terms of TN and TP. For Lower Orphan School Creek this improvement could take the creek back to the reference condition and for Prospect Creek could return nitrogen levels from being at a moderately impacted level to a minor departure from the reference condition. These changes don't consider the impact of changed riparian revegetation on river condition. Any scenario to improve riparian vegetation on a natural waterway would also be expected to have significant localised benefits for macroinvertebrates due the shading and improved habitat it would provide.

Importantly the preferred Plan scenario also averts the declining condition that would be expected under the worst case scenario. In the worst case scenario TN would likely result in the Georges River at Woolwash declining from a minor departure from the reference condition to being moderately impacted. At Cambridge Avenue the decline would be even greater with the river currently at reference condition, expected to decline to being moderately impacted. A similar impact would be expected for TP at Cambridge Avenue, with a decline from a minor departure from the reference condition to being in a moderately impacted state.

[8] Grades can be interpreted as: A+ is excellent; A to B- is good; B to C- is fair; and, D+ to F- is poor. These are calculated based on a score related to how far the TN and TP concentration is from a guideline level.

CASE STUDY: What could we achieve if we focused all our works on the areas with the highest pollutant generation?

The preferred Plan scenario assumes infill redevelopment with water sensitive urban design in line with the Sydney Metropolitan Subregional Strategies. What would be possible if, instead of this, we focused our efforts on redeveloping areas with the highest pollutant loads?

These areas are the Alexandra Canal, Cooks River Estuary, Lower Georges River Estuary (excluding Hurstville), North Botany Bay, and parts of the Upper Cooks River (Bankstown and Strathfield) and Upper Georges River (Canterbury). They all have nitrogen loads of greater than 6kg/ha and sediment loads of greater than 380 kg/ha (up to 530kg/ha in parts of the Alexandra Canal subcatchment). Focusing on these areas with infill redevelopment would see load reductions as shown in Table 17.

Table 17. Comparison of load reductions for preferred Plan scenario vs. targeted infill redevelopment with WSUD (% change from base case)

Area	TSS		TP		TN	
	Plan scenario	Targeted redevelopment	Plan scenario	Targeted redevelopment	Plan scenario	Targeted redevelopment
Total catchment	-15.5%	-20.3%	-10.7%	-14.0%	-6.9%	-9.0%
Bay foreshore	-12.9%	-31.5%	-8.8%	-21.4%	-6.2%	-15.1%
Georges River	-16.3%	-9.2%	-11.3%	-6.4%	-7.0%	-4.0%
Cooks River	-14.4%	-54.8%	-9.9%	-37.6%	-7.1%	-27.1%

As this table shows, it would be possible to reduce sediments and nutrients delivered to the Bay by an even greater amount if infill redevelopment with WSUD were to be targeted to occur in only the areas which are the greatest generation areas. Doing this would however make it less likely that the condition targets for the Georges River Estuary would be met, and would mean that some of the big improvements in river condition under the preferred Plan scenario would not be achieved – for example improvements in Orphan School, Prospect, Mill and Williams Creeks expected under the preferred Plan scenario would not be expected if only the highest pollutant load producing areas (Alexandra Canal, Cooks River Estuary, North Botany Bay, Upper Cooks River (Bankstown and Strathfield), Upper Georges River (Canterbury) and the Lower Georges River Estuary subcatchments) were targeted.

The preferred Plan scenario also implies targets in load reduction for each of the Local Government Areas in the Botany Bay Catchment. The equivalent target load reduction for each LGA for 2030 is given in Table 18.

Table 18. Target changes in TSS, TP and TN for preferred Plan scenario (infill redevelopment and riparian rehabilitation) for LGAs by 2030

LGA	TSS	TP	TN
Ashfield	-25%	-17%	-13%
Auburn	-14%	-13%	-9%
Bankstown	-29%	-21%	-15%
Botany Bay	-15%	-12%	-9%
Burwood	-25%	-17%	-13%
Campbelltown	-19%	-15%	-8%
Canterbury	-12%	-9%	-7%
Fairfield	-32%	-24%	-17%
Holroyd	-27%	-21%	-15%
Hurstville	-11%	-8%	-6%
Kogarah	-13%	-10%	-7%
Liverpool	-25%	-20%	-12%
Marrickville	-11%	-8%	-6%
Randwick	-16%	-13%	-9%
Rockdale	-11%	-8%	-6%
Strathfield	-21%	-15%	-11%
Sutherland	-9%	-7%	-4%
Sydney	-28%	-20%	-14%
Waverley	-15%	-11%	-8%

Note: no targets have been set for Wollongong and Wollondilly given their negligible areas of urbanised land in the Catchment. Within the Catchment boundary these LGA's generally have bushland areas for which load reduction targets cannot be sensibly set. These areas have the potential to be major contributors to nutrient and sediment loads however if population pressures mean that this bushland is targeted for greenfield development, particularly if no WSUD is applied to any developments. A target of 'no net increase' from these areas should be aimed for. Targets have been set for Ashfield and Auburn. Even though these LGAs only occupy a small area in the Catchment, the majority of this area is urbanised.

Table 18 above shows that the targets for sediment reduction range from 9 to 32%, while for nitrogen the range is from 4 to 17%. Sutherland has the lowest targets while Fairfield targets are the highest. These differences are due to the mix of urban and rural/bushland land uses and the extent to which an LGA is expected to be targeted for infill redevelopment.

4 Implementation – Water Quality Management & Control Actions

The Botany Bay CAPER DSS has been used to consider several alternative water sensitive urban design options for achieving these load reductions. These alternatives are presented here as potential pathways capable of achieving the required load reductions to allow the costs and potential benefits of alternatives to be explored. They are not intended to be exhaustive – there may be many other ways of achieving the same reductions in load. Also the feasibility of constructing such devices on-ground has not been considered. Councils would need to consider the physical and other constraints of their circumstances to determine the best mix of actions. The Botany Bay CAPER DSS has been developed so individual councils and/or groups of councils can develop and test a range of implementation scenarios to determine the best mix of options for their circumstances.

4.1 Management and control actions

In the urban environment of the Botany Bay Catchment, management and control actions available for controlling pollutants generally consist of WSUD devices, either implemented in isolation or in a treatment train of two or more devices. In total, 43 alternative treatment train options have been considered. These involved combinations of six basic WSUD devices:

- wetland;
- bioretention system;
- gross pollutant trap;
- vegetated swale;
- rainwater tank, and;
- buffer.

A seventh WSUD option – a next generation bioretention system – was also considered in isolation.

These treatment trains were first passed through a simple test to determine which should be further considered by the DSS: the area of residential and commercial/industrial land which would need to be treated in each subcatchment to achieve the reductions needed to meet state-wide targets for infill redevelopment had to be less than or equal to the area for infill redevelopment. If this area was greater than the available residential and commercial/industrial land area then the option was discarded. This is not to say that such options would not be useful as part of a strategy to reduce nutrient and sediment exports to Botany Bay, merely that in a simplified way broadscale rollout of such options would not be enough to achieve targeted reductions. The results of this simple filtering exercise are given in Table 19.

Table 19. Treatment train options categorised by feasibility to achieve target reductions within available land area.

Infeasible treatment train options	Feasible treatment train options (ordered by least cost (1) to highest cost to achieve target levels (31))	
Rainwater tank	1- Next generation bioretention	20- Rainwater tank, Swale, GPT and Bioretention
GPT	2- Bioretention	21- Rainwater tank and Wetland
Buffer	3- GPT and Bioretention	22- Rainwater tank, GPT and Wetland
Swale	4- Swale and Bioretention	23- Buffer, GPT, Bioretention and Wetland
Wetland	5- Swale, GPT and Bioretention	24- Rainwater tank, Swale and Wetland
Rainwater tank and Buffer	6- GPT and Wetland	25- Rainwater tank, Bioretention and Wetland
Rainwater tank and GPT	7- Bioretention and Wetland	26- Rainwater tank, Buffer and Bioretention
Rainwater tank and Swale	8- Swale and Wetland	27- Rainwater tank, Swale, GPT and Wetland
Buffer and GPT	9- Buffer and Bioretention	28- Rainwater tank, GPT, Bioretention and Wetland
Rainwater tank, GPT and Buffer	10- GPT, Bioretention and Wetland	29- Rainwater tank, Buffer and Wetland
Swale and GPT	11- Swale, GPT and Wetland	30- Rainwater tank, Buffer, GPT and Wetland
Rainwater tank, Swale and GPT	12- Buffer, GPT and Bioretention	31- Rainwater tank, Buffer, GPT, Bioretention and Wetland
	13- Swale, Bioretention and Wetland	
	14- Rainwater tank and Bioretention	
	15- Buffer and Wetland	
	16- Rainwater tank, GPT and Bioretention	
	17- Buffer, GPT and Wetland	
	18- Rainwater tank, Swale and Bioretention	
	19- Buffer, Bioretention and Wetland	

All feasible options were then run to determine the pollutant reductions they could achieve and costs involved in meeting targeted load reductions.

The riparian remediation option included in the load reductions scenarios was also costed. Results from this analysis are provided in the section 4.2.2.

4.2 Impacts and costs of planned water quality improvement scenarios

Two types of scenarios have been considered to improve water quality – WSUD options to be implemented with infill redevelopment and riparian remediation. This section provides results on the impacts and costs of these options.

4.2.1 Water Sensitive Urban Design

Thirty-one WSUD combinations were run through the Botany Bay CAPER DSS to provide an estimate of their impacts on nutrient and sediment delivery as well as the costs of their implementation (based on MUSIC). These combinations were chosen because they could achieve target load reductions within the infill redevelopment area. These combinations/scenarios were all applied to different land areas. The proportion of the area of residential and commercial/industrial land that each needed to be applied to, to meet the state-wide load reduction targets was estimated based on their influence on nitrogen, phosphorus and sediment generation rates. The area that the scenario was applied to was the smallest area that allowed all three target reductions to be met in all subcatchments.

Table 20 shows the area each treatment train option needs to be applied to, in hectares and as a proportion of the infill area, along with the pollutant load reductions and costs across the entire Catchment for each WSUD scenario.

Three different measures of cost are provided with these results:

- The annuatised lifecycle cost at 2030 (assumes full implementation of the management option by 2030). This considers the total cost stream attributable to a WSUD option (including upfront costs and annual maintenance costs) and determines an annual equivalent payment over the lifecycle of the device.
- The upfront cost at 2030. This is the sum of all upfront costs paid out by 2030 to implement the management scenario. Note that these would not fall in any single year but would be distributed over time.
- The annual maintenance cost by 2030. This is the sum of all annual maintenance costs once the scenario is fully implemented.

It should be noted when considering these results, that the full costs shown here would not be experienced until 2030. Costs would be incurred incrementally as areas are developed and WSUD treatment options implemented. In the absence of further information on the pattern of infill development expected, it has been assumed here that this will occur evenly each year, such that $1/20^{th}$ of the cost increase is incrementally experienced each year. These scenarios have been sorted from least cost to highest cost scenarios.

It is important to remember that these costs do not take into consideration the considerable budget allocations councils in the Botany Bay Catchment make each year to improve water quality and their local environment. Local councils will also renew their assets over time and they can incorporate WSUD into these infrastructure renewal projects at little or no cost. Significant funds are also contributed by the NSW and Australian Government towards environmental projects. For example there are currently five urban sustainability grants underway within this Catchment that all have substantial water quality improvement components. Likewise Sydney Water has made, and will continue to make, significant investments within the Catchment to improve sewer systems, install and maintain water quality improvement devices and naturalise concrete channels.

The private sector will also contribute a significant proportion of the funds needed because new developments and redevelopments of land will continue to need to meet council planning policy requirements. This will mean lot or even street and precinct scale WSUD; such as rainwater tanks, raingardens, vegetated swales, constructed wetlands and permeable paving will often be privately funded and installed as part of new or redevelopments.

The likely proportional breakdown of funds has not been done as changes in planning policy at the State and local scales will impact funding breakdown significantly. This means the “additional” funds needed to implement the Botany Bay & Catchment WQIP will only be a fraction of those costs shown in the tables below.

Table 20. Area each treatment train was applied to and estimated pollutant load reductions and costs ($',000,000) for entire Botany Bay Catchment by 2030

Option No.	WSUD Scenario	Area treated (ha)	Proportion of infill area treated	TSS	TP	TN	Annuatised lifecycle cost(/yr) in 2030	Upfront cost in 2030	Maintenance cost (/yr) in 2030
1	Next generation bioretention	10,936	89%	-15.2	-12.2	-6.9	$25.4	$278.1	$52.7
2	Bioretention	11,184	91%	-15.8	-12.7	-6.9	$26.0	$284.4	$53.9
3	GPT and Bioretention	11,184	91%	-16.5	-12.7	-6.9	$35.6	$580.2	$62.4
4	Swale and Bioretention	10,698	87%	-15.7	-12.5	-6.9	$43.2	$431.8	$92.4
5	Swale, GPT and Bioretention	10,698	87%	-16.0	-12.5	-6.9	$52.4	$714.8	$100.5
6	GPT and Wetland	12,303	100%	-16.7	-12.5	-6.9	$54.8	$1,944.1	$33.1
7	Bioretention and Wetland	10,698	87%	-15.5	-12.5	-7.8	$63.2	$1,679.5	$72.2
8	Swale and Wetland	12,003	98%	-16.6	-13.1	-6.9	$63.6	$1,758.5	$68.9
9	Buffer and Bioretention	10,936	89%	-15.8	-12.6	-6.9	$66.7	$837.5	$124.5
10	GPT, Bioretention and Wetland	10,471	85%	-15.5	-12.3	-7.6	$70.9	$1,920.8	$78.6
11	Swale, GPT and Wetland	12,003	98%	-17.2	-13.1	-6.9	$74.0	$2,076.0	$78.0
12	Buffer, GPT and Bioretention	10,936	89%	-16.2	-12.6	-6.9	$76.1	$1,126.8	$132.8
13	Swale, Bioretention and Wetland	10,471	85%	-15.5	-12.4	-7.8	$79.8	$1,800.2	$110.6
14	Rainwater tank and Bioretention	10,698	87%	-15.5	-12.7	-7.9	$81.3	$1,237.1	$84.0
15	Buffer and Wetland	12,003	98%	-15.5	-12.3	-7.1	$88.4	$2,193.2	$101.9
16	Rainwater tank, GPT and Bioretention	10,471	85%	-15.5	-12.6	-7.8	$88.6	$1,487.8	$90.2
17	Buffer, GPT and Wetland	11,717	95%	-16.0	-12.0	-6.9	$96.4	$2,451.0	$108.4
18	Rainwater tank, Swale and Bioretention	10,360	84%	-15.5	-12.8	-7.8	$96.5	$1,352.8	$120.9
19	Buffer, Bioretention and Wetland	10,583	86%	-15.5	-12.6	-7.7	$102.5	$2,202.9	$140.9
20	Rainwater tank, Swale, GPT and	10,360	84%	-16.0	-13.2	-8.1	$105.5	$1,626.9	$128.7

Option No.	WSUD Scenario	Area treated (ha)	Proportion of infill area treated	TSS	TP	TN	Annuatised lifecycle cost(/yr) in 2030	Upfront cost in 2030	Maintenance cost (/yr) in 2030
	Bioretention								
21	Rainwater tank and Wetland	12,303	100%	-15.5	-13.0	-8.6	$109.1	$2,728.5	$61.0
22	Rainwater tank, GPT and Wetland	11,313	92%	-15.5	-12.0	-7.9	$110.1	$2,808.2	$64.7
23	Buffer, GPT, Bioretention and Wetland	10,471	85%	-15.5	-12.4	-7.6	$110.5	$2,456.5	$147.3
24	Rainwater tank, Swale and Wetland	10,816	88%	-15.5	-12.5	-7.7	$114.5	$2,560.2	$94.9
25	Rainwater tank, Bioretention and Wetland	10,583	86%	-15.5	-13.1	-8.9	$118.4	$2,616.2	$103.5
26	Rainwater tank, Buffer and Bioretention	10,471	85%	-15.5	-12.9	-8.1	$119.2	$1,746.5	$150.9
27	Rainwater tank, Swale, GPT and Wetland	10,698	87%	-15.5	-12.5	-12.5	$122.5	$2,815.4	$102.0
28	Rainwater tank, GPT, Bioretention and Wetland	10,360	84%	-15.5	-12.8	-8.7	$124.9	$2,835.2	$109.2
29	Rainwater tank, Buffer and Wetland	11,445	93%	-15.5	-12.9	-8.3	$144.8	$3,123.6	$131.8
30	Rainwater tank, Buffer, GPT and Wetland	11,059	90%	-15.5	-12.4	-8.1	$149.4	$3,310.9	$135.8
31	Rainwater tank, Buffer, GPT, Bioretention and Wetland	10,360	84%	-15.5	-12.9	-8.9	$164.0	$3,365.2	$177.2

Table 20 shows that these options need to be applied to a large proportion (84 – 100%) of the infill area to achieve the targeted load reductions. This corresponds to treating between 10,000ha and 12,500 ha, or 19 - 27% of urban lands in the Catchment.

While all these scenarios meet the basic State-wide targets for pollutant load reductions in infill redevelopment areas (80:55:40 for TSS:TP:TN) there are considerable differences in the pollutant load reductions that they achieve. For example a treatment train involving rainwater tanks, swales, GPTs and wetlands (option 27) can achieve over 1.5 times as much reduction in TN (12.5%) as some other options while achieving very similar reductions in TSS. Costs also differ substantially. Some options have higher overall costs than others. Some have a different emphasis on upfront over ongoing maintenance costs.

When considering the best option to implement in any situation it is important to realise that the lowest cost option may not be the best option. Some things that should be considered when choosing treatment train options with to implement this water quality improvement plan are:

- The area available in which to place WSUD devices and the relative area of land that needs to be treated to achieve targeted load reductions.
- Physical constraints of the site which limit the treatment trains that can be applied.
- The total cost of options and balance between upfront and on-going maintenance costs, and consideration of how these are to be funded.
- The reductions over and above targeted load reductions that could be achieved through application of different treatment train options.
- Community acceptance and compatibility.

Results for the WSUD options/scenarios on major subcatchment areas are provided in Table 21 to Table 23. Results for each LGA are provided in Appendix 2.

The best mix of options to achieve the targeted load reductions for a given site will depend on the physical, social, economic and other constraints and opportunities relevant to the site. It is important that these, and other results derived using the Botany Bay CAPER DSS, be used for strategic planning purposes only and that more detailed assessments of the feasibility and likely impacts of specific WSUD options be made before they are implemented. It is possible that the best option in a specific circumstance won't be the lowest cost or highest efficiency option shown here. A treatment train must be designed for the specific circumstances into which it is to be placed and will need to meet the specific requirements such as the physical constraints of the site, the nature of the runoff to be treated, the funding and resources available and other mechanisms available to encourage uptake, and so on. Detailed MUSIC or other model analysis of proposed schemes can be entered into the Botany Bay CAPER DSS to estimate the contribution these would make to meeting Catchment load targets outlined in this Plan.

Councils, developers, the Sydney Metropolitan CMA and other government agencies are already undertaking substantial investments in WSUD. These scenarios do not try to capture the works already being done. The work already undertaken to improve water quality will help contribute to the achievement of load reduction targets. These results are simply included here to assist in strategic planning of future actions.

Table 21. Pollutant load reductions and costs ($',000,000) for Georges River Catchment to 2030

Option No.	WSUD Scenario	TSS	TP	TN	Annuatised lifecycle cost (/yr) in 2030	Upfront cost in 2030	Maintenance cost (/yr) in 2030
1	Next generation bioretention	-15.9	-12.9	-7	$20.2	$221.8	$42.1
2	Bioretention	-16.6	-13.4	-7	$20.7	$226.9	$43.0
3	GPT and Bioretention	-17.4	-13.4	-7	$28.4	$462.9	$49.8
4	Swale and Bioretention	-16.4	-13.2	-7	$34.4	$344.5	$73.7
5	Swale, GPT and Bioretention	-16.8	-13.2	-7	$41.8	$570.2	$80.2
6	GPT and Wetland	-17.5	-13.1	-7	$43.7	$1,550.8	$26.4
7	Bioretention and Wetland	-16.3	-13.2	-7.9	$50.4	$1,339.8	$57.6
8	Swale and Wetland	-17.5	-13.8	-7	$50.8	$1,402.7	$55.0
9	Buffer and Bioretention	-16.6	-13.3	-7	$53.2	$668.1	$99.3
10	GPT, Bioretention and Wetland	-16.3	-12.9	-7.7	$56.6	$1,532.2	$62.7
11	Swale, GPT and Wetland	-18.1	-13.8	-7	$59.0	$1,656.0	$62.2
12	Buffer, GPT and Bioretention	-17	-13.3	-7	$60.7	$898.9	$106.0
13	Swale, Bioretention and Wetland	-16.3	-13.1	-7.9	$63.7	$1,436.0	$88.2
14	Rainwater tank and Bioretention	-16.3	-13.4	-8	$64.9	$986.8	$67.0
15	Buffer and Wetland	-16.3	-13	-7.1	$70.5	$1,749.5	$81.3
16	Rainwater tank, GPT and Bioretention	-16.3	-13.3	-7.9	$70.7	$1,186.8	$71.9
17	Buffer, GPT and Wetland	-16.9	-12.7	-7	$76.9	$1,955.1	$86.5
18	Rainwater tank, Swale and Bioretention	-16.3	-13.5	-7.9	$77.0	$1,079.1	$96.4
19	Buffer, Bioretention and Wetland	-16.3	-13.2	-7.8	$81.8	$1,757.3	$112.4
20	Rainwater tank, Swale, GPT and Bioretention	-16.8	-13.9	-8.2	$84.1	$1,297.8	$102.7
21	Rainwater tank and Wetland	-16.3	-13.8	-8.7	$87.1	$2,176.5	$48.6
22	Rainwater tank, GPT and Wetland	-16.3	-12.6	-8	$87.8	$2,240.1	$51.6
23	Buffer, GPT, Bioretention and Wetland	-16.3	-13.1	-7.7	$88.1	$1,959.5	$117.5
24	Rainwater tank, Swale and Wetland	-16.3	-13.2	-7.8	$91.3	$2,042.3	$75.7

Option No.	WSUD Scenario	TSS	TP	TN	Annuatised lifecycle cost (/yr) in 2030	Upfront cost in 2030	Maintenance cost (/yr) in 2030
25	Rainwater tank, Bioretention and Wetland	-16.3	-13.8	-9	$94.5	$2,086.9	$82.5
26	Rainwater tank, Buffer and Bioretention	-16.3	-13.6	-8.2	$95.1	$1,393.1	$120.4
27	Rainwater tank, Swale, GPT and Wetland	-16.3	-13.2	-13.2	$97.7	$2,245.9	$81.3
28	Rainwater tank, GPT, Bioretention and Wetland	-16.3	-13.5	-8.8	$99.6	$2,261.6	$87.1
29	Rainwater tank, Buffer and Wetland	-16.3	-13.6	-8.4	$115.5	$2,491.7	$105.2
30	Rainwater tank, Buffer, GPT and Wetland	-16.3	-13.1	-8.1	$119.2	$2,641.1	$108.3
31	Rainwater tank, Buffer, GPT, Bioretention and Wetland	-16.3	-13.7	-9	$130.8	$2,684.4	$141.3

Table 22. Pollutant load reductions (%) and costs ($',000,000) for Cook River Catchment to 2030

Option No.	WSUD Scenario	TSS	TP	TN	Annuatised lifecycle cost (/yr) in 2030	Upfront cost in 2030	Maintenance cost (/yr) in 2030
1	Next generation bioretention	-14.7	-11.7	-7.1	$3.4	$37.0	$7.0
2	Bioretention	-14.1	-11.2	-7.1	$3.5	$37.8	$7.2
3	GPT and Bioretention	-14.4	-11.7	-8.2	$4.7	$77.1	$8.3
4	Swale and Bioretention	-14.4	-12	-8.9	$5.7	$57.4	$12.3
5	Swale, GPT and Bioretention	-14.7	-11.6	-7.1	$7.0	$95.0	$13.4
6	GPT and Wetland	-14.4	-11.4	-7.3	$7.3	$258.5	$4.4
7	Bioretention and Wetland	-14.4	-11.6	-8	$8.4	$223.3	$9.6
8	Swale and Wetland	-15	-11.6	-7.1	$8.5	$233.8	$9.2
9	Buffer and Bioretention	-14.9	-11.1	-7.1	$8.9	$111.3	$16.6
10	GPT, Bioretention and Wetland	-14.4	-11.4	-7.9	$9.4	$255.4	$10.5
11	Swale, GPT and Wetland	-14.4	-11.9	-8.3	$9.8	$276.0	$10.4
12	Buffer, GPT and Bioretention	-14.4	-11.8	-8.6	$10.1	$149.8	$17.7
13	Swale, Bioretention and Wetland	-14.4	-11.4	-8.3	$10.6	$239.3	$14.7
14	Rainwater tank and Bioretention	-14.4	-11.9	-9.1	$10.8	$164.5	$11.2
15	Buffer and Wetland	-15.4	-12.1	-7.1	$11.8	$291.6	$13.5
16	Rainwater tank, GPT and Bioretention	-14.5	-11.5	-7.1	$11.8	$197.8	$12.0
17	Buffer, GPT and Wetland	-14.4	-11.4	-8	$12.8	$325.8	$14.4
18	Rainwater tank, Swale and Bioretention	-15.9	-12.1	-7.1	$12.8	$179.8	$16.1
19	Buffer, Bioretention and Wetland	-14.8	-11.5	-7.1	$13.6	$292.9	$18.7
20	Rainwater tank, Swale, GPT and Bioretention	-14.4	-11.5	-8	$14.0	$216.3	$17.1
21	Rainwater tank and Wetland	-14.4	-11.5	-11.5	$14.5	$362.7	$8.1
22	Rainwater tank, GPT and Wetland	-14.4	-11.8	-8.1	$14.6	$373.3	$8.6
23	Buffer, GPT, Bioretention and Wetland	-14.8	-12.2	-8.4	$14.7	$326.6	$19.6
24	Rainwater tank, Swale and Wetland	-15.3	-11.7	-7.1	$15.2	$340.4	$12.6
25	Rainwater tank, Bioretention and Wetland	-15.4	-11.5	-7.1	$15.7	$347.8	$13.8

Option No.	WSUD Scenario	TSS	TP	TN	Annuatised lifecycle cost (/yr) in 2030	Upfront cost in 2030	Maintenance cost (/yr) in 2030
26	Rainwater tank, Buffer and Bioretention	-14.4	-11.3	-7.9	$15.8	$232.2	$20.1
27	Rainwater tank, Swale, GPT and Wetland	-14.4	-11.5	-8	$16.3	$374.3	$13.6
28	Rainwater tank, GPT, Bioretention and Wetland	-14.4	-11.6	-8	$16.6	$376.9	$14.5
29	Rainwater tank, Buffer and Wetland	-14.4	-11	-8.2	$19.2	$415.3	$17.5
30	Rainwater tank, Buffer, GPT and Wetland	-14.4	-11.8	-9	$19.9	$440.2	$18.1
31	Rainwater tank, Buffer, GPT, Bioretention and Wetland	-14.4	-12	-9.2	$21.8	$447.4	$23.6

Table 23. Pollutant load reductions and costs ($',000,000) for the Botany Bay foreshore Catchments to 2030

Option No.	WSUD Scenario	TSS	TP	TN	Annuatised lifecycle cost (/yr) in 2030	Upfront cost in 2030	Maintenance cost (/yr) in 2030
1	Next generation bioretention	-13.2	-10.4	-6.2	$1.8	$19.3	$3.7
2	Bioretention	-12.6	-10	-6.2	$1.8	$19.7	$3.7
3	GPT and Bioretention	-12.9	-10.4	-7.1	$2.5	$40.2	$4.3
4	Swale and Bioretention	-12.9	-10.7	-7.7	$3.0	$30.0	$6.4
5	Swale, GPT and Bioretention	-13.1	-10.3	-6.2	$3.6	$49.6	$7.0
6	GPT and Wetland	-12.9	-10.1	-6.3	$3.8	$134.8	$2.3
7	Bioretention and Wetland	-12.9	-10.3	-6.9	$4.4	$116.5	$5.0
8	Swale and Wetland	-13.4	-10.3	-6.2	$4.4	$122.0	$4.8
9	Buffer and Bioretention	-13.3	-9.9	-6.2	$4.6	$58.1	$8.6
10	GPT, Bioretention and Wetland	-12.9	-10.2	-6.8	$4.9	$133.2	$5.5
11	Swale, GPT and Wetland	-12.9	-10.6	-7.2	$5.1	$144.0	$5.4
12	Buffer, GPT and Bioretention	-12.9	-10.5	-7.5	$5.3	$78.2	$9.2
13	Swale, Bioretention and Wetland	-12.9	-10.2	-7.2	$5.5	$124.9	$7.7
14	Rainwater tank and Bioretention	-12.9	-10.6	-7.9	$5.6	$85.8	$5.8
15	Buffer and Wetland	-13.8	-10.7	-6.2	$6.1	$152.1	$7.1
16	Rainwater tank, GPT and Bioretention	-13	-10.3	-6.2	$6.1	$103.2	$6.3
17	Buffer, GPT and Wetland	-12.9	-10.2	-7	$6.7	$170.0	$7.5
18	Rainwater tank, Swale and Bioretention	-14.3	-10.7	-6.2	$6.7	$93.8	$8.4
19	Buffer, Bioretention and Wetland	-13.3	-10.3	-6.2	$7.1	$152.8	$9.8
20	Rainwater tank, Swale, GPT and Bioretention	-12.9	-10.2	-6.9	$7.3	$112.8	$8.9
21	Rainwater tank and Wetland	-12.9	-10.3	-10.3	$7.6	$189.2	$4.2
22	Rainwater tank, GPT and Wetland	-12.9	-10.5	-7	$7.6	$194.8	$4.5
23	Buffer, GPT, Bioretention and Wetland	-13.3	-10.8	-7.2	$7.7	$170.4	$10.2
24	Rainwater tank, Swale and Wetland	-13.7	-10.4	-6.2	$7.9	$177.6	$6.6
25	Rainwater tank, Bioretention and Wetland	-13.8	-10.2	-6.2	$8.2	$181.5	$7.2

Option No.	WSUD Scenario	TSS	TP	TN	Annuatised lifecycle cost (/yr) in 2030	Upfront cost in 2030	Maintenance cost (/yr) in 2030
26	Rainwater tank, Buffer and Bioretention	-12.9	-10	-6.8	$8.3	$121.1	$10.5
27	Rainwater tank, Swale, GPT and Wetland	-12.9	-10.3	-7	$8.5	$195.3	$7.1
28	Rainwater tank, GPT, Bioretention and Wetland	-12.9	-10.3	-7	$8.7	$196.6	$7.6
29	Rainwater tank, Buffer and Wetland	-12.9	-9.8	-7.1	$10.0	$216.6	$9.1
30	Rainwater tank, Buffer, GPT and Wetland	-12.9	-10.5	-7.8	$10.4	$229.6	$9.4
31	Rainwater tank, Buffer, GPT, Bioretention and Wetland	-12.9	-10.7	-8	$11.4	$233.4	$12.3

4.2.2 Remediation of riparian corridors

The load reduction scenarios include a component of remediation of riparian corridors throughout the Catchment. The impacts and estimated costs of these activities to 2030 are summarised in Table 24. Cost types are the same as for the WSUD scenarios above.

Table 24. Impacts and costs of riparian remediation scenario to 2030

	TN	TP	TSS	Annuatised lifecycle cost in 2030 ($/yr)	Upfront cost in 2030 ($)	Maintenance cost in 2030 ($/yr)
Cooks River	1%	1%	1%	$691	$17,893	$895
Upper Georges River	2%	3%	3%	$23,691	$613,526	$30,676
Lower Georges River	1%	2%	2%	$717	$18,559	$928
Botany Bay	3%	4%	4%	$1,213	$31,422	$1,571
Total	**2%**	**3%**	**2%**	**$26,312**	**$681,400**	**$34,070**

These results show that the main opportunities for riparian remediation occur in the Upper Georges River Catchment and in areas of the Catchment draining directly into Botany Bay. The cost of this remediation is substantially less than for most WSUD options. However impacts are also less and are focused in less developed areas of the Catchment, rather than in the Cooks River and Lower Georges River areas.

Undertaking both riparian remediation and WSUD of infill redevelopment areas would substantially reduce pollutant delivery throughout the Catchment and would improve not only outcomes in Botany Bay but also in the rivers and streams of the Catchment.

5 Recommended Implementation Actions

To ensure water quality improves in Botany Bay and its Catchment actions will need to be implemented at different levels of government as well as by the community. Below is a list of recommended actions each group should undertake to support the Botany Bay & Catchment WQIP. Those considered to be of highest priority are shown in bold.

5.1.1 Australian Government

It is recommended that the Australian Government:

5.1.1.1 Reviews and endorses the Botany Bay & Catchment WQIP,

5.1.1.2 Sets up a specific funding program to implement actions listed in the Botany Bay & Catchment WQIP, possibly via a devolved grants program,

5.1.1.3 Ensures all grants or funding allocated in the Botany Bay Catchment are consistent with and/or support the implementation of this Plan,

5.1.1.4 Continues to fund water quality improvement devices in the Botany Bay Catchment that are consistent with this Plan,

5.1.1.5 Uses the Botany Bay CAPER DSS to model the impacts of large scale projects proposed in the Botany Bay Catchment and use the results to determine the appropriateness of funding those projects,

5.1.1.6 Ensures that land/infrastructure/facilities under its control (including airports and military facilities) minimise their negative impacts on water quality,

5.1.1.7 Provides long-term protection to the bushland in the Holsworthy Military Area to ensure it continues to provide buffering capacity to the Georges River and Botany Bay,

5.1.1.8 Considers funding a pilot program that uses economic incentives/instruments for private landholders to install water quality improvement and runoff attenuation devices,

5.1.1.9 Considers funding a project to consolidate and harmonise the ecological and environmental monitoring being undertaken in the Catchment so that they can be accessed from a single site,

5.1.1.10 Considers funding the development of a framework that allows the collation and development of an extensive “State of the Catchment” report that can be repeated every two years.

5.1.2 NSW Government

It is recommended that the NSW Government:

5.1.2.1 Reviews and endorses/adopts the Botany Bay & Catchment WQIP,

5.1.2.2 Incorporates the stormwater load reduction targets proposed in the Plan into the

following regional planning policies: the Metropolitan Strategy and its sub-regional plans, the Metropolitan Water Plan, the SMCMA Catchment Action Plan and any other NSW Government policies that could have an impact on waterways in the Botany Bay Catchment,

5.1.2.3 The Department of Planning and Infrastructure consider including water quality and erosive flow targets into BASIX,

5.1.2.4 Ensures any new government policies or plans developed for, or that will have an impact on, the Botany Bay Catchment meet the Plan's water quality targets and are consistent with its objectives,

5.1.2.5 Ensures that land/infrastructure/facilities under its control (including ports, roads and rail) minimise their negative impacts on water quality,

5.1.2.6 The Department of Planning and Infrastructure, SMCMA, DECCW and Sydney Water use the Botany Bay CAPER DSS to test catchment-scale interventions or land use changes proposed in the Botany Bay Catchment,

5.1.2.7 The Department of Planning and Infrastructure, DECCW and SMCMA use the Botany Bay CAPER DSS to model the impacts of large scale projects proposed for the Botany Bay Catchment before allocating funding and/or giving approval,

5.1.2.8 The SMCMA and Department of Planning and Infrastructure undertakes a project to identify parcels of land that have the potential to be developed in the Botany Bay Catchment in the future and set specific targets for these areas,

5.1.2.9 The SMCMA seeks endorsement of the Plan from the NSW Government Senior Officers Group,

5.1.2.10 Ensures the SMCMA has sufficient funding to continue to support the implementation of this Plan and to maintain and update the Botany Bay CAPER DSS and other catchment models developed,

5.1.2.11 Ensures Sydney Water continues to improve the overflow performance of its sewer systems throughout the Catchment. Particular attention should be given to the sensitive waterways of the Upper Cooks River Catchment and the Upper Georges River Estuary,

5.1.2.12 Continues to fund water quality improvement devices in the Botany Bay Catchment that are consistent with this Plan via a devolved grants scheme,

5.1.2.13 Promotes the Botany Bay & Catchment WQIP to local councils, government agencies and the community,

5.1.2.14 Considers introducing legislation that requires private sewers to be checked and certified when properties are sold,

5.1.2.15 Considers amending or introducing legislation to enable councils and private certifiers to have more powers to enforce compliance with sediment and erosion control during construction activities,

5.1.2.16 Considers funding a pilot program that uses economic incentives/instruments for private landholders to install water quality improvement and runoff attenuation devices,

5.1.2.17 Considers funding a project to consolidate and harmonise the ecological and environmental monitoring being undertaken in the Catchment so that they can be accessed from a single site,

5.1.2.18 Considers funding the development of a framework that allows the collation and development of an extensive "State of the Catchment" report that can be repeated every two years.

5.1.3 Local Government

It is recommended that the local councils in the Botany Bay Catchment:

5.1.3.1 Review and endorse/adopt the Botany Bay & Catchment WQIP,

5.1.3.2 Use the Botany Bay CAPER DSS to test a range of scenarios and identify the most effective scenario(s) that will enable the LGA to meet their load reduction targets,

5.1.3.3 Develop a short LGA-scale WQIP using the Botany Bay CAPER DSS,

5.1.3.4 Use the MUSIC model, or similar programs, for evaluating and designing smaller scale WSUD projects,

5.1.3.5 Include the stormwater/WSUD clause developed by the SMCMA (or similar) into the LGA's Local Environment Plan (LEP) (SMCMA 2008f),

5.1.3.6 Prepare or update the LGA's Development Control Plan(s) to include WSUD and the stormwater pollutant load reduction and flow control targets identified in section 3.4,

5.1.3.7 Ensure all new development or redevelopment minimises its impacts on the waterways (flow, water quality, riparian condition),

5.1.3.8 **Ensure new or renewed local council infrastructure (i.e. roads, drainage, car parks, buildings, footpaths, bike paths, etc.) are designed from a WSUD perspective and meet the stormwater pollutant load reduction targets, to minimise impacts on waterways**,

5.1.3.9 Review and optimise Council street sweeping schedules/routes to ensure protection of waterways from sediments and nutrients are maximised,

5.1.3.10 Ensure best practice sediment and erosion control plans are approved and complied with for all development/construction sites,

5.1.3.11 Ensure local NRM projects planned or implemented are consistent with the Botany Bay & Catchment WQIP and are helping to meet LGA load reduction targets,

5.1.3.12 Review and ensure that other local council policies or practices don't reduce the LGA's ability to implement the load reduction targets,

5.1.3.13 Engage with and support local communities implementing actions consistent with the Botany Bay & Catchment WQIP,

5.1.3.14 Promote the Botany Bay & Catchment WQIP and downscaled LGA-scale version of the WQIP to their local communities,

5.1.3.15 Promote the Botany Bay & Catchment WQIP to local commercial and industrial organisations or groups,

5.1.3.16 Ensure internal and externally funded works programs or projects are consistent with the Botany Bay & Catchment WQIP.

5.1.4 Regional Groups of Councils and/or ROCs

It is recommended that the regional groups or Regional Organisations of Councils (ROCs) that operate in the Botany Bay Catchment:

5.1.4.1 Review and endorse/adopt the Botany Bay & Catchment WQIP,

5.1.4.2 Promote the Botany Bay & Catchment WQIP to members of the group and local communities,

5.1.4.3 Coordinate and/or seek funding for regional-scale projects to support the implementation of the Botany Bay & Catchment WQIP,

5.1.4.4 Advocate for member councils to align their works programs with the WQIP objectives,

5.1.4.5 Support members of the group with the development, or updating of, local planning policies,

5.1.4.6 Ensure any regional projects, plans or programs, such as estuary management plans, are supportive of the objectives outlined in the WQIP.

5.1.5 Community Natural Resource Management (NRM) Groups and/or NGOs

It is recommended that the community groups or NGOs that operate within the Botany Bay Catchment:

5.1.5.1 Continue or undertake new works to improve bushland and riparian zones within their subcatchments,

5.1.5.2 Seek funding to undertake local-scale projects of interest that will support the objectives of the Botany Bay & Catchment WQIP,

5.1.5.3 Let their members/volunteers, friends and neighbours know what actions they are taking to reduce stormwater pollution and improve the local waterways,

5.1.5.4 Promote the Botany Bay & Catchment WQIP to members of the group and their local communities,

5.1.5.5 Advocate for the Botany Bay & Catchment WQIP to local councillors and/or local members of parliament.

5.1.6 Private Households and Businesses

It is recommended that the households and businesses in the Botany Bay Catchment:

5.1.6.1 Businesses that have big impacts on, or derive significant benefits from, the Botany Bay

Catchment meet the stormwater reduction targets identified in the Plan. If these targets cannot be met then these businesses should consider funding works in other parts of the Catchment to offset their impacts,

5.1.6.2 Private certifiers, and local councils, should ensure only best practice sediment and erosion control plans are approved for developments and ensure they are complied with,

5.1.6.3 Take actions on their own properties that support the load reduction targets for the Catchment. These might include things like installing rainwater tanks, permeable paving, rain gardens (small household-scale bioretention systems) etc.,

5.1.6.4 Remove litter, plant material and sediment from paths and gutters in theirs and areas adjoining their properties. Take steps to reduce the chance of these materials accumulating and/or being washed off hard surfaces of their property into the stormwater system when it rains,

5.1.6.5 Get involved in a local bushcare group working on improving wetlands or the riparian zones of waterways,

5.1.6.6 Let their friends, neighbours and/or customers know what actions they are taking to reduce stormwater pollution and improve the local waterways,

5.1.6.7 Let their local councillor or local parliamentarian know that improving the local waterways and improving water quality in the Botany Bay Catchment is important to them,

5.1.6.8 Talk to their local school and/or work place about things they might be able to do to minimise their impacts on local waterways.

5.1.7 Other recommendations

The modelling results presented in this Plan are of a general nature and are only intended to provide a useful starting point for councils in managing pollutants in runoff. Modelling at the scale required for preparation of this Plan cannot incorporate all the detail necessary for planning implementation of specific treatment trains. It is recommended, therefore, that more detailed analysis of options be undertaken on a case-by-case basis before implementing any of the WSUD options or treatment trains described here for infill redevelopment areas. This analysis should include assessment of physical and other relevant constraints, as well as detailed MUSIC modelling, or a similar program, of treatment train designs.

As implementation of this plan progresses, it is recommended that interventions and projects undertaken be reviewed, and that detailed MUSIC modelling results be incorporated into the Botany Bay CAPER DSS (using the user-defined WSUD option) to estimate the total catchment effect of these management actions.

6 Monitoring of the recommendations and activities of the WQIP

6.1 Introduction

It is important that the research and monitoring undertaken for preparation of the Botany Bay & Catchment Water Quality Improvement Plan be continued over the long term. Over the long-term, these will enable changes in water quality resulting from improvements and changes in land use in the Catchment to be measured. In the short-term, the monitoring results will help refine and validate the Botany Bay Ecological Response Model (ERM) that has been developed for Botany Bay and its estuaries (SMCMA 2009a). Furthermore, publication on the internet of water quality monitoring data from the real-time water quality monitoring network that has been put in place is likely to play a powerful educational role for both the councils and the community.

6.2 Monitoring strategy

A component of the BBWQIP has been to establish a network of five real-time water quality monitoring stations throughout the estuaries. Two stations are on the Cooks River Estuary (near Ewan Park and near Sydney's International Airport); two are also on the Georges River Estuary (just below Prospect Creek and just below Salt Pan Creek) and one is located in Botany Bay near Woolooware Bay. These stations are monitoring salinity, temperature, chlorophyll-A (Chl-A), turbidity, dissolved oxygen (DO) and light (PAR) in real-time. They commenced collecting data in July 2010, which is available live from www.sydney.cma.nsw.gov.au/bbcci/monitoring-network.html

In the short-term these monitoring stations will enable us to better understand how water quality changes in the estuaries under a range of climatic conditions. The data being gathered will also allow for better calibration of the Botany Bay ERM. In the longer-term the monitoring stations will provide the data needed to assess the efficacy of the policies and on-ground works implemented in response to the Botany Bay & Catchment WQIP.

The GRCCC has a community river health monitoring program which is run twice a year (spring and autumn) with the support of community volunteers. It has been funded primarily by the Australian Government. This program currently monitors 42 sites on the Georges River for macroinvertebrates, water quality and riparian vegetation. The data is then aggregated analysised and put into a "report card" that is released twice a year. This program is currently being expanded to include sites on the Cooks River. The monitoring program provides results that are easily understood by the community and complements the real-time water quality monitoring data being collected. This monitoring program has enabled pollution "hot spots" to be identified and localised management interventions proposed. Over the longer-term this monitoring program will provide valuable data on the ecological efficacy of policies and on-ground works implemented both locally and more broadly throughout the Catchment.

Several scientific studies undertaken as part of the BBCCI, the BBWQIP and for the CRFWG have provided baseline data on aquatic sediment distribution, sediment geochemistry and foraminifera (distribution and total populations) (Albani & Rickwood 2010, Albani 2008, Albani & Kollias 2005). The data provided by these studies will enable the process to be repeated in 10 to 15 years time to look at changes in condition over this period.

To ensure the effectiveness of the interventions and recommendations contained in the Botany Bay & Catchment WQIP are monitored and reported, it is recommended that:

- the five real-time water quality monitoring stations be maintained and that the data is collected is made public via the BBWQIP and/or SMCMA,

- the community river health monitoring program continue to be run in spring and autumn and be expanded to include the Cooks River, as well as areas of Botany Bay and the results be reported at least annually to the community,
- the aquatic sediment distribution, sediment geochemistry and foraminifera (distribution and density) be measured using the same methodology by 2025, and
- the potential for a centralised site for describing projects and accessing monitoring data in the Catchment and estuary be explored.

6.3 Modelling strategy

This Water Quality Improvement Plan is based on substantial new science and modelling. In particular a catchment water quality model and receiving water quality model were developed. The results from these models have then been captured in the Botany Bay CAPER DSS, along with additional MUSIC modelling of WSUD devices and data on the effects of riparian remediation. While the modelling that underpins the WQIP is best practice and a substantial improvement on previous knowledge there are several improvements that could be made to further improve the knowledge underpinning the WQIP:

- The receiving water quality model should be recalibrated and possibly reconfigured as the real-time water quality monitoring station data for the Bay and its estuaries becomes available.
- The catchment water quality model should be recalibrated and verified as additional pollutant concentration data becomes available.
- New treatment train options should be modelled using the MUSIC model.

All of these improvements should be incorporated into the Botany Bay CAPER DSS when available. The modelling undertaken to support the Botany Bay & Catchment WQIP has also been undertaken to provide information for catchment-scale planning and management. It is intended to provide general information to councils and other organisations on the effects of potential management options. It is recommended that planning for substantial treatments or other management interventions be supported by more detailed modelling work. This may, for example, involve the development of detailed MUSIC models for individual developments, including treatment trains of WSUD devices.

With the cooperation of local councils the SMCMA should maintain a database of WSUD treatment train (devices), locations and catchment areas, that have been implemented in the Catchment and detailed modelling results (MUSIC modelling) and/or other monitoring information on their effectiveness at removing pollutants and their cost. It is recommended that this information be used to update the Botany Bay CAPER DSS and assess the effectiveness of actions undertaken in response to this Plan when it is reviewed.

6.4 Botany Bay CAPER DSS

The Botany Bay CAPER DSS has been created to support the development of this Water Quality Improvement Plan. It has been designed to use the catchment and receiving water quality models that have been developed and also includes additional MUSIC modelling and literature-based information. It is recommended that the Botany Bay CAPER DSS be maintained by the Sydney Metropolitan CMA for use by the SMCMA, local governments and other organisations involved in planning and management activities for the Bay and its Catchment. The DSS should be provided to users free of charge. It will need to be updated when major improvements are made to the science, or modelling, that underpins it. For example, if the catchment water quality or receiving water quality model are updated then the ideally the DSS should also be updated to reflect these changes.

Updating of the DSS may best happen in line with major planning timelines, such as the review of the Botany Bay & Catchment WQIP.

7 Review and reporting

7.1 Introduction

It is import that progress on implementing the Botany Bay & Catchment WQIP is reviewed at specified times and that the results of the reviews are reported back to key stakeholders and the community. The Botany Bay & Catchment WQIP has to operate in a very dynamic environment that has a multitude of players whose policies impact on urban development and hence water quality. With this in mind it will be important to continue to promote and support adoption of the WQIP by all levels of government, key stakeholders and the community well after its release.

7.2 WQIP reporting and review processes

Both the BBCCI and the BBWQIP have used a variety of reporting and review processes that have helped make both programs successful. These processes should continue to be used and should be supplemented by new ones developed specifically for the Botany Bay & Catchment WQIP. Following are recommendations for the ongoing and future review and reporting relating to the implementation of the Botany Bay & Catchment WQIP:

- Continue to support the BBWQIP website and monitor website usage,
- Continue to prepare and distribute at least two eNewsletters per year to report on WQIP progress, and maintain a database of contacts,
- Continue to meet with the BBWQIP Reference Committee at least on an annual basis,
- Maintain a database of users of the Botany Bay CAPER DSS and monitor its adoption and usage throughout the Catchment,
- Prepare an annual review and brief report on the adoption rate or uptake of the WQIP by key stakeholders. This report should be presented to the BBWQIP Reference Committee for review/comment,
- Undertake a review of the WQIP two years after its release via a workshop and web survey and prepare a short report, which should be presented to the Reference Committee and then released publically,
- Update the WQIP after the two year review based on its findings,
- Conduct a thorough review of the WQIP after five years, including scientific and modelling data as well as pollutant load reduction targets. This review should be completed within one year and the updated WQIP put out for public comment/exhibition for at least 3 months and released by the end of 2017.

8 Glossary

Annuatised Costs	Refers to the annual average cost whose sum is equivalent to the net present cost over the life of the asset. That is, it is the sum of the annual cost stream into the future, discounted in each year to account for the opportunity cost of money spent this year as opposed to delaying a cost until next year (i.e. the interest rate you could earn on the money) divided by the number of years over which the sum is conducted. It is commonly used by economists to account for a stream of costs into the future.
Biofilms	Biofilms are layers of a variety of microorganisms growing on the surface of plants or hard surfaces that are submerged or wet often.
Brownfield Development / Urban Renewal	Refers to land that has previously been developed but is abandoned or underused, usually considered as a potential site for redevelopment. It may or may not be environmentally contaminated.
Foraminifera	Small marine unicellular protozoa that that secrete a shell. They can be found in bottom sediments in marine and estuarine environments.
Greenfield Development	Development on land that has not been previously developed.
Infill Development	Any development occurring within the existing urban area is considered infill. This includes both detached and attached housing, development on vacant land or redevelopment of an existing site to increase density or change the land use.
Riparian	The area on the bank/adjacent to a waterway (River, Creek, Stream, Wetland, Estuary)
Water Sensitive Urban Design (WSUD)	Water Sensitive Urban Design/Development is a new way of planning, designing and constructing urban environments that is sensitive to the issues of water sustainability and environmental protection

9 References

Albani, A.D. and Rickwood, P.C. 2010 An Environmental Assessment of the Georges River: *The Bottom Sediments of the Georges River and its Bays and Tributaries.* For SMCMA: Botany Bay Water Quality Improvement Program (BBWQIP) www.sydney.cma.nsw.gov.au/bbcci/Publications.html

Albani, A.D. 2008 Environmental Assessment of Botany Bay: *Sediments, Sediment Geochemistry & Foraminifera.* For SMCMA: Botany Bay Coastal Catchments Initiative (BBCCI) www.sydney.cma.nsw.gov.au/bbcci/Publications.html

Albani, A. D and Kollias, G 2005 Cooks River Survey, Prepared for Marrickville Council www.sydney.cma.nsw.gov.au/bbcci/Publications.html

ANZECC 2000 National Water Quality Management Strategy: Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Section 3.1.3.1)

Bennett, J. & Morrison, M. 2001 Valuing the environmental attributes of NSW Rivers: Draft Report Prepared for the Environment Protection Authority. March 2001. –Charles Sturt University

City of Botany Bay 2010 'History', City of Botany Bay website, www.botanybay.nsw.gov.au

Department of Environment and Climate Change 2007 Managing urban stormwater: environmental targets Consultation Draft – October 2007.

Department of Environment, Climate Change & Water and SMCMA 2010 Towra Point Nature Reserve Ramsar Site *Ecological Character Description.* For SMCMA: Botany Bay Coastal Catchments Initiative (BBCCI)

Earth Tech. 2007. Sydney Metropolitan CMA Waterways Health Strategy. Earth Tech Pty. Ltd. for Sydney Metropolitan CMA, Sydney, NSW.

Eco Logical Australia (2009) Cooks River Estuarine Vegetation Management Plan. Commissioned by the Cooks River Foreshore Working Group.

Engineers Australia (2006). *Australian Runoff Quality,* Institution of Engineers, Australia.

eWater 2010 www.ewater.com.au/products/ewater-source/for-catchments / Accessed September 2010

Goodall, H. and Cadzow, A. 2009 Rivers and Resilience. Aboriginal People on Sydney's Georges River, UNSW Press, Sydney.

Georges River Combined Councils Committee (GRCCC) 2010 Community River Health Monitoring Program: Report Card – Autumn 2010

Hunter Councils (2007). Water Sensitive Urban Design Solutions for Catchments above Wetlands, available online www.hccrems.com.au/RESOURCES/HCCREMS-Publications.aspx

Ladson, A. R., Walsh, C. J., Fletcher, T. D., & Horton, P. (2004). Improving stream health by reducing the connection between impervious surfaces and waterways. Paper presented at the International Conference on Water Sensitive Urban Design, Adelaide, Australia.

Mazumder, D., Saintilan, N., Williams, R., 2006. Trophic relationship between itinerant fish and crab larvae in a temperate Australian saltmarsh. Marine Freshwater Research 57, 1–7.

NSW Department of Health 2009, Healthy Urban Development Checklist: *A guide for health services when commenting on development policies, plans and proposals*

NSW Department of Primary Industries, 2006. NSW Oyster Industry Sustainable Aquaculture Strategy.

NSW Industry and Investment (NSW I & I), 2010 Innovation in the NSW aquaculture industry - video series – Bob Drake video. Viewed November 2010 at www.dpi.nsw.gov.au/fisheries/aquaculture/starting-up/innovation

Phaneuf, D.J., Smith, V.K., Palmquist, R.B. and J.C. Pope (2008) "Integrating property value and local recreation models to value ecosystem services in urban watersheds", Land Economics 84(3): 361-381.

Scanes, P. 2009. Draft Chlorophyll / Turbidity Trigger Values for NSW, October 2009. Unpublished report, NSW Department of Environment, Climate Change and Water (DECCW).

Sydney Metropolitan Catchment Management Authority (SMCMA) 2007a Modelling the Catchments of Botany Bay. Sydney: Botany Bay Coastal Catchments Initiative (BBCCI)

Sydney Metropolitan Catchment Management Authority (SMCMA) 2007b Barriers and Opportunities to WUSD Adoption in the Botany Bay Catchment. Sydney: BBCCI

Sydney Metropolitan Catchment Management Authority (SMCMA), 2008a Determining the Environmental Values of Botany Bay and its Catchments "A Descriptive Analysis of the Botany Bay Catchment Environmental Values Questionnaire". Sydney: BBCCI

Sydney Metropolitan Catchment Management Authority (SMCMA), 2008b Modelling the Catchments of Botany Bay. Council Pollutant Loads E2 Modelling Results. BBCCI

Sydney Metropolitan Catchment Management Authority (SMCMA) 2008c Modelling the Catchments of Botany Bay: Predicted Future Landuse Changes (2030 & 2070) E2 Modelling Results. Sydney: BBCCI

Sydney Metropolitan Catchment Management Authority (SMCMA) 2008d. Water Sensitive Urban Design Adoption Strategy for the Botany Bay Catchment. Sydney: BBCCI

Sydney Metropolitan Catchment Management Authority (SMCMA) 2008e Review of the Statutory and Institutional Arrangements relating to protecting water quality in Botany Bay and its estuaries and catchments. Sydney: BBCCI

Sydney Metropolitan Catchment Management Authority (SMCMA) 2008f Incorporating Appropriate Stormwater Management/WSUD Requirements in Local Environment Plans (LEPs). Sydney: BBCCI

Sydney Metropolitan Catchment Management Authority (SMCMA) 2009a. Results of a multi-dimensional receiving water quality model for Botany Bay (Sydney, Australia). Sydney: BBCCI

Sydney Metropolitan Catchment Management Authority (SMCMA) 2009b Discussion Paper for the Development of a Botany Bay Water Quality Improvement Plan. Sydney: Botany Bay Water Quality Improvement Program (BBWQIP)

Zhang, X. Liu, X., Zhang, M., Dahlgren, R.A., Eitzel, M. (2010) Review of vegetated buffers and a meta-analysis of their mitigation efficiency in reducing non-point source pollution, Journal of Environmental Quality, 39:76-84.

Botany Bay & Catchment Water Quality Improvement Plan

Appendices

Appendix 1. WQIP scenario projections using climate change assumptions

This Appendix provides catchment load results for 2030 and 2070 development and remediation scenarios using climate change projections for this period. This analysis includes an assessment of the possible changes in rainfall and temperature which could result by 2030 and 2070 due to climate change. These simulated time series have been run through the Botany Bay Catchment Hydrological Model to see what difference they might make to rainfall-runoff and thus to nutrient and sediment delivery to the estuaries and Bay. These results should be used with extreme caution as there are many factors that have not been included or considered in this analysis. For example:

- The basic rainfall-runoff model has been used as is – changes in the period of dry spells and the severity of storms could change the way in which rainfall is intercepted and transported in the Catchment. For example, drier soils may not allow as much infiltration and may cause a higher proportion of flows to runoff during rainfall events. This could be exacerbated by more intense storm events.
- Changes in sea level associated with climate change could be expected to have many different effects on the estuary and the Bay. Some areas of urbanised land may become unviable due to flooding. Changes in water levels and temperature could change the way basic chemical, physical and biological processes work in the estuary. This might mean, for example, a quicker response to elevated nutrient levels as algae grow faster in response to increased nutrients.

These results have been provided as a starting point to get people thinking about the possible impacts of climate change and the way it may affect our ability to make changes and to monitor for the effects of those changes.

Table 25 provides the projected impacts of the preferred Plan scenario (infill redevelopment and riparian rehabilitation) and worst case scenario (greenfield development in Campbelltown and Liverpool without WSUD). Note the effect of climate projections on TN, TP and TSS loads using the base case land use mix has also been provided for reference. Projections are given for 2030 and 2070.

Table 25. Changes in Catchment load using climate change projections for 2030 and 2070

	2030 climate predictions			2070 climate predictions		
Area	**Current situation**	**Infill redevelopment and riparian rehabilitation**	**Greenfield development in Campbelltown/ Liverpool**	**Current situation**	**Infill redevelopment and riparian rehabilitation**	**Greenfield development in Campbelltown/ Liverpool**
TN						
Cooks	-6%	-13%	-6%	-16%	-20%	-16%
Upper Georges	-8%	-16%	2%	-20%	-22%	-11%
Lower Georges	-6%	-12%	-6%	-17%	-18%	-17%
Bay	-6%	-15%	-6%	-17%	-23%	-17%
Total	**-7%**	**-15%**	**-1%**	**-19%**	**-21%**	**-13%**

	2030 climate predictions			2070 climate predictions		
Area	**Current situation**	**Infill redevelopment and riparian rehabilitation**	**Greenfield development in Campbelltown/ Liverpool**	**Current situation**	**Infill redevelopment and riparian rehabilitation**	**Greenfield development in Campbelltown/ Liverpool**
TP						
Cooks	-6%	-16%	-6%	-16%	-27%	-16%
Upper Georges	-7%	-21%	12%	-19%	-34%	-1%
Lower Georges	-6%	-15%	-6%	-17%	-25%	-17%
Bay	-6%	-18%	-6%	-17%	-31%	-17%
Total	**-7%**	**-19%**	**4%**	**-18%**	**-31%**	**-8%**
TSS						
Cooks	-6%	-20%	-6%	-16%	-38%	-16%
Upper Georges	-7%	-26%	9%	-19%	-45%	-5%
Lower Georges	-6%	-18%	-6%	-17%	-33%	-17%
Bay	-6%	-21%	-6%	-17%	-39%	-17%
Total	**-7%**	**-23%**	**2%**	**-18%**	**-42%**	**-10%**

These projections show that the current situation (land use mix) is projected to be associated with declining TN, TP and TSS loads under the climate change scenarios. This is generally due to the drier climate and lower levels of rainfall expected to result from climate change. The relative changes in these pollutants are almost identical for each area. This is because the rainfall-runoff driver has changed identically in each case, and it is the only driver of change assumed in the model. Those small differences seen (i.e. for the Upper Georges) are likely to be due to rounding differences in the model. The preferred Plan scenario is associated with much greater reductions in TN, TP and TSS than the base case or the worst case scenarios (as expected). These reductions are greater also than would be expected under the current climate assumption used throughout the Plan. This is also as expected due to the drier climate. The worst case scenario is associated with both small increases and small to moderate decreases in pollutant loads. The projection for 2030 is for a very small improvement in TN for the whole Catchment, with small increases in TP and TSS. By 2070, the projection is for decreases in pollutant loads for all pollutants and areas of the Catchment (although in the case of TP in the Upper Georges this improvement is very slight). As mentioned above, these results should be used as indicative and as a starting point for further discussion, investigation and analysis due to their known short-comings.

Estuary results are not provided for these scenario options. This is because it is felt that changes in the estuary due to sea level rise and the effects of increased temperature in the estuary are likely to have effects at least as strong as those caused by changes in rainfall and catchment load. These effects are not able to be estimated at this time so analysis of impacts of projected load changes on the estuaries and Bay have been excluded because of their greater potential to be misleading.

Appendix 2. Impacts and WSUD scenario results by LGA

This appendix provides results for each LGA for scenarios described in Sections 3.4 and 4.2 of this Plan. For context a map of the subcatchments in the Botany Bay Catchment is given in Figure 18 below.

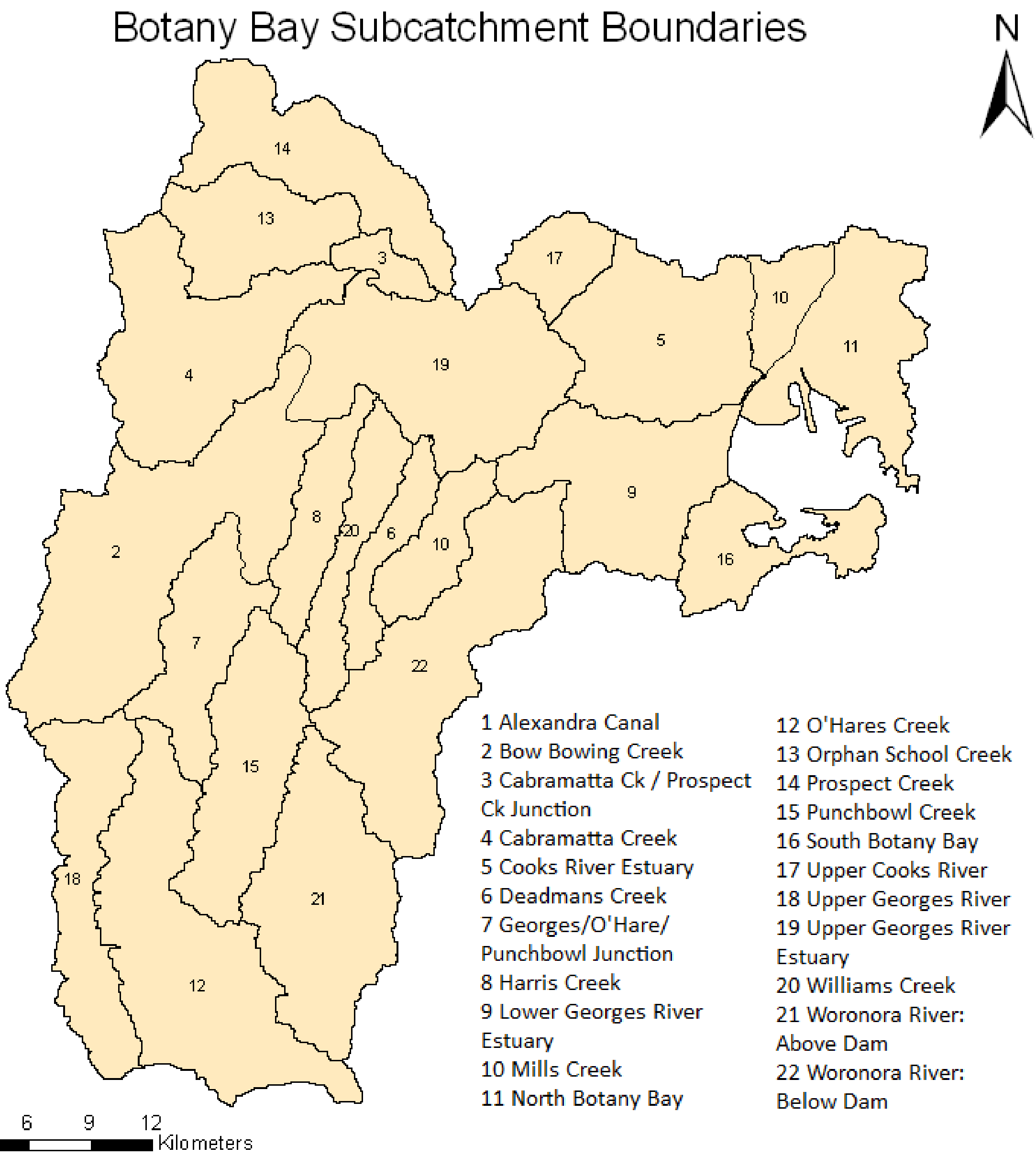


Figure 18. Map of subcatchment boundaries in the Botany Bay Catchment

Planned water quality improvements

Table 26 to Table 28 provide loads and percentage changes in catchment loads of TN, TP and TSS from the base case (current situation) for the development options described in Section 3.2 of this Plan.

Table 26. Loads (kg) and percentage impacts from the base case (current situation) of TN for development scenarios

LGA	Current situation	Greenfield development in Campbelltown/ Liverpool		Expansion through infill redevelopment using WSUD		Infill redevelopment using WSUD and rehabilitation of riparian corridors[9]	
	Load	Load	Change from base case	Load	Change from base case	Load	Change from base case
Ashfield	155	155	0%	136	-13%	136	-13%
Auburn	194	194	0%	190	-2%	177	-9%
Bankstown	33,261	33,261	0%	28,784	-13%	28,319	-15%
Botany Bay	21,972	21,972	0%	20,811	-5%	20,028	-9%
Burwood	1,421	1,421	0%	1,242	-13%	1,242	-13%
Campbelltown	58,770	75,170	28%	54,968	-6%	53,924	-8%
Canterbury	21,788	21,788	0%	20,575	-6%	20,369	-7%
Fairfield	34,771	34,771	0%	29,885	-14%	28,734	-17%
Holroyd	6,489	6,489	0%	5,755	-11%	5,513	-15%
Hurstville	14,775	14,775	0%	13,960	-6%	13,915	-6%
Kogarah	11,159	11,159	0%	10,534	-6%	10,330	-7%
Liverpool	41,708	50,691	22%	37,828	-9%	36,528	-12%
Marrickville	8,013	8,013	0%	7,568	-6%	7,556	-6%
Randwick	10,243	10,243	0%	9,652	-6%	9,274	-9%
Rockdale	18,797	18,797	0%	17,886	-5%	17,643	-6%
Strathfield	4,425	4,425	0%	4,006	-9%	3,948	-11%
Sutherland	65,811	65,811	0%	63,363	-4%	62,979	-4%
Sydney	10,298	10,298	0%	8,880	-14%	8,850	-14%
Waverly	1,091	1,091	0%	1,027	-6%	1,001	-8%
Wollondilly	16,584	16,584	0%	16,584	0%	16,572	0%
Wollongong	25,487	25,487	0%	25,487	0%	25,487	0%
Grand Total	**407,213**	**432,595**	**6%**	**379,121**	**-7%**	**372,527**	**-9%**

[9] Preferred Plan scenario is highlighted in blue

Table 27. Loads (kg) and percentage impacts from the base case (current situation) of TP for development scenarios

LGA	Current situation	Greenfield development in Campbelltown/ Liverpool		Expansion through infill redevelopment using WSUD		Infill redevelopment using WSUD and rehabilitation of riparian corridors[10]	
	Load	Load	Change from base case	Load	Change from base case	Load	Change from base case
Ashfield	19	19	0%	16	-17%	16	-17%
Auburn	19	19	0%	19	-4%	17	-13%
Bankstown	4,049	4,049	0%	3,290	-19%	3,217	-21%
Botany Bay	2,681	2,681	0%	2,484	-7%	2,356	-12%
Burwood	175	175	0%	145	-17%	145	-17%
Campbelltown	5,239	8,615	64%	4,594	-12%	4,465	-15%
Canterbury	2,676	2,676	0%	2,470	-8%	2,436	-9%
Fairfield	4,190	4,190	0%	3,362	-20%	3,183	-24%
Holroyd	791	791	0%	666	-16%	628	-21%
Hurstville	1,811	1,811	0%	1,672	-8%	1,665	-8%
Kogarah	1,374	1,374	0%	1,268	-8%	1,234	-10%
Liverpool	4,125	6,023	46%	3,467	-16%	3,305	-20%
Marrickville	982	982	0%	906	-8%	904	-8%
Randwick	1,216	1,216	0%	1,116	-8%	1,056	-13%
Rockdale	2,294	2,294	0%	2,140	-7%	2,100	-8%
Strathfield	541	541	0%	470	-13%	461	-15%
Sutherland	7,320	7,320	0%	6,905	-6%	6,843	-7%
Sydney	1,254	1,254	0%	1,013	-19%	1,008	-20%
Waverly	130	130	0%	120	-8%	115	-11%
Wollondilly	1,505	1,505	0%	1,505	0%	1,503	0%
Wollongong	2,152	2,152	0%	2,152	0%	2,152	0%
Grand Total	**44,545**	**49,819**	**12%**	**39,779**	**-11%**	**38,810**	**-13%**

[10] Preferred Plan scenario is highlighted in blue.

Table 28. Loads (tonnes) and percentage impacts from the base case (current situation) of TSS for development scenarios

LGA	Current situation	Greenfield development in Campbelltown/ Liverpool		Expansion through infill redevelopment using WSUD		Infill redevelopment using WSUD and rehabilitation of riparian corridors[11]	
	Load	Load	Change from base case	Load	Change from base case	Load	Change from base case
Ashfield	10	10	0%	8	-25%	8	-25%
Auburn	9	9	0%	9	-6%	8	-14%
Bankstown	2,110	2,110	0%	1,532	-27%	1,502	-29%
Botany Bay	1,398	1,398	0%	1,249	-11%	1,192	-15%
Burwood	92	92	0%	69	-25%	69	-25%
Campbelltown	2,958	4,411	49%	2,466	-17%	2,406	-19%
Canterbury	1,400	1,400	0%	1,243	-11%	1,228	-12%
Fairfield	2,187	2,187	0%	1,556	-29%	1,483	-32%
Holroyd	412	412	0%	317	-23%	301	-27%
Hurstville	947	947	0%	841	-11%	838	-11%
Kogarah	719	719	0%	638	-11%	623	-13%
Liverpool	2,311	3,119	35%	1,809	-22%	1,733	-25%
Marrickville	514	514	0%	456	-11%	455	-11%
Randwick	630	630	0%	554	-12%	527	-16%
Rockdale	1,198	1,198	0%	1,080	-10%	1,062	-11%
Strathfield	283	283	0%	229	-19%	225	-21%
Sutherland	3,735	3,735	0%	3,419	-8%	3,392	-9%
Sydney	655	655	0%	471	-28%	469	-28%
Waverly	68	68	0%	59	-12%	58	-15%
Wollondilly	725	725	0%	725	0%	724	0%
Wollongong	1,084	1,084	0%	1,084	0%	1,084	0%
Grand Total	**23,445**	**25,705**	**10%**	**19,814**	**-15%**	**19,388**	**-17%**

As could be expected these tables show that the impact of the Greenfield expansion scenario is limited to the Campbelltown and Liverpool LGAs. This option would lead to a nearly 50% increase in TSS leaving Campbelltown, and a 35% increase leaving Liverpool. Phosphorus loads from these LGAs is expected to increase by an even greater amount, 64% for Campbelltown and 46% for Liverpool. The increase in nitrogen loads would be smaller but still substantial at 28% and 22% respectively.

The scenarios considering expansion through infill redevelopment with and without riparian rehabilitation give similar results, although as expected the improvements with riparian rehabilitation are slightly greater than without it. All LGAs have some improvement except Wollondilly and Wollongong, which did not contain any of the assumed infill redevelopment or riparian rehabilitation. Fairfield experiences the largest reduction in pollutants with decreases in TSS, TP and TN of 32%, 24% and 17% respectively. The smallest decreases outside Wollongong and Wollondilly are for Sutherland, with reductions of 9%, 7% and 4% respectively.

[11] Preferred Plan scenario is highlighted in blue.

WSUD option scenarios

This section provides the results by LGA for WSUD treatment train scenarios described in section 4.1. Table 29 to Table 37 provide results for TN, TP and TSS load reductions (%) respectively when fully implemented in 2030. Please note Wollongong and Wollondilly have been left out because the values are zero. Table 41 to Table 52 provide annuatised lifecycle costs, upfront costs and annual maintenance costs (in $1,000,000's) for each LGA. Note option numbers corresponding to each option are in brackets after the option name in the table.

Table 29 Load reductions (%) for TN of selected WSUD scenario options by LGA in 2030: Part 1

	Bioretention (2)	Next generation bioretention (1)	Rainwater tank & Bioretention (14)	Rainwater tank & Wetland (21)	Buffer & Bioretention (9)	Buffer and Wetland (15)	Buffer, bioretention & Wetland (19)
Ashfield	-12.7	-17.9	-14.6	-15.8	-12.7	-13.0	-14.2
Auburn	-2.2	-3.1	-2.5	-2.7	-2.2	-2.2	-2.5
Bankstown	-13.5	-19.0	-15.5	-16.8	-13.5	-13.8	-15.1
Botany Bay	-5.3	-7.5	-6.1	-6.6	-5.3	-5.4	-5.9
Burwood	-12.6	-17.9	-14.6	-15.8	-12.6	-12.9	-14.1
Campbelltown	-6.5	-9.1	-7.5	-8.1	-6.5	-6.6	-7.2
Canterbury	-5.6	-7.9	-6.4	-7.0	-5.6	-5.7	-6.2
Fairfield	-14.1	-19.9	-16.2	-17.6	-14.1	-14.4	-15.7
Holroyd	-11.3	-16.0	-13.0	-14.1	-11.3	-11.6	-12.7
Hurstville	-5.5	-7.8	-6.4	-6.9	-5.5	-5.6	-6.2
Kogarah	-5.6	-7.9	-6.5	-7.0	-5.6	-5.7	-6.3
Liverpool	-9.3	-13.2	-10.7	-11.6	-9.3	-9.5	-10.4
Marrickville	-5.6	-7.8	-6.4	-6.9	-5.6	-5.7	-6.2
Randwick	-5.8	-8.2	-6.6	-7.2	-5.8	-5.9	-6.5
Rockdale	-4.8	-6.8	-5.6	-6.1	-4.8	-5.0	-5.4
Strathfield	-9.5	-13.4	-10.9	-11.8	-9.5	-9.7	-10.6
Sutherland	-3.7	-5.3	-4.3	-4.7	-3.7	-3.8	-4.2
Sydney	-13.8	-19.5	-15.9	-17.2	-13.8	-14.1	-15.4
Waverley	-5.9	-8.3	-6.8	-7.4	-5.9	-6.0	-6.6

Table 30 Load reductions (%) for TN of selected WSUD scenario options by LGA in 2030: Part 2

	Buffer, GPT and Bioretention (12)	Buffer, GPT and Wetland (17)	Rainwater tank, Buffer and Bioretention (26)	Rainwater tank, Buffer and Wetland (29)	Rainwater tank, Buffer, GPT and Wetland (30)	Rainwater tank, Buffer, GPT, Bioretention & Wetland (31)	Swale and Wetland (8)	Swale and Bioretention (4)	Swale, Bioretention and Wetland (13)
Ashfield	-12.7	-12.7	-14.8	-15.3	-14.8	-16.3	-12.7	-12.7	-14.3
Auburn	-2.2	-2.2	-2.6	-2.7	-2.6	-2.8	-2.2	-2.2	-2.5
Bankstown	-13.5	-13.5	-15.8	-16.3	-15.7	-17.3	-13.5	-13.5	-15.2
Botany Bay	-5.3	-5.3	-6.2	-6.4	-6.2	-6.8	-5.3	-5.3	-6.0
Burwood	-12.6	-12.6	-14.8	-15.3	-14.8	-16.2	-12.6	-12.6	-14.3
Campbelltown	-6.5	-6.5	-7.6	-7.8	-7.6	-8.3	-6.5	-6.5	-7.3
Canterbury	-5.6	-5.6	-6.5	-6.7	-6.5	-7.1	-5.6	-5.6	-6.3
Fairfield	-14.1	-14.1	-16.4	-17.0	-16.4	-18.0	-14.1	-14.1	-15.8
Holroyd	-11.3	-11.3	-13.2	-13.7	-13.2	-14.5	-11.3	-11.3	-12.8
Hurstville	-5.5	-5.5	-6.5	-6.7	-6.4	-7.1	-5.5	-5.5	-6.2
Kogarah	-5.6	-5.6	-6.6	-6.8	-6.6	-7.2	-5.6	-5.6	-6.3
Liverpool	-9.3	-9.3	-10.9	-11.3	-10.9	-12.0	-9.3	-9.3	-10.5
Marrickville	-5.6	-5.6	-6.5	-6.7	-6.5	-7.1	-5.6	-5.6	-6.3
Randwick	-5.8	-5.8	-6.8	-7.0	-6.7	-7.4	-5.8	-5.8	-6.5
Rockdale	-4.8	-4.8	-5.7	-5.9	-5.7	-6.2	-4.8	-4.8	-5.5
Strathfield	-9.5	-9.5	-11.1	-11.5	-11.1	-12.2	-9.5	-9.5	-10.7
Sutherland	-3.7	-3.7	-4.4	-4.5	-4.3	-4.8	-3.7	-3.7	-4.2
Sydney	-13.8	-13.8	-16.1	-16.7	-16.1	-17.7	-13.8	-13.8	-15.5
Waverley	-5.9	-5.9	-6.9	-7.1	-6.9	-7.6	-5.9	-5.9	-6.6

Table 31 Load reductions (%) for TN of selected WSUD scenario options by LGA in 2030: Part 3

	Swale, GPT and Wetland (11)	Swale, GPT and Bioretention (5)	Rainwater tank, Swale and Wetland (24)	Rainwater tank, Swale, GPT and Wetland (27)	Rainwater tank, Swale and Bioretention (18)	Rainwater tank, Swale, GPT and Bioretention (20)	GPT and Bioretention (3)	GPT and Wetland (6)
Ashfield	-12.7	-12.7	-14.2	-14.0	-14.4	-14.9	-12.7	-12.7
Auburn	-2.2	-2.2	-2.5	-2.4	-2.5	-2.6	-2.2	-2.2
Bankstown	-13.5	-13.5	-15.1	-14.9	-15.3	-15.8	-13.5	-13.5
Botany Bay	-5.3	-5.3	-5.9	-5.9	-6.0	-6.2	-5.3	-5.3
Burwood	-12.6	-12.6	-14.2	-14.0	-14.4	-14.8	-12.6	-12.6
Campbelltown	-6.5	-6.5	-7.3	-7.2	-7.4	-7.6	-6.5	-6.5
Canterbury	-5.6	-5.6	-6.2	-6.2	-6.3	-6.5	-5.6	-5.6
Fairfield	-14.1	-14.1	-15.8	-15.6	-16.0	-16.5	-14.1	-14.1
Holroyd	-11.3	-11.3	-12.7	-12.5	-12.9	-13.3	-11.3	-11.3
Hurstville	-5.5	-5.5	-6.2	-6.1	-6.3	-6.5	-5.5	-5.5
Kogarah	-5.6	-5.6	-6.3	-6.2	-6.4	-6.6	-5.6	-5.6
Liverpool	-9.3	-9.3	-10.4	-10.3	-10.6	-10.9	-9.3	-9.3
Marrickville	-5.6	-5.6	-6.2	-6.2	-6.3	-6.5	-5.6	-5.6
Randwick	-5.8	-5.8	-6.5	-6.4	-6.6	-6.8	-5.8	-5.8
Rockdale	-4.8	-4.8	-5.4	-5.4	-5.5	-5.7	-4.8	-4.8
Strathfield	-9.5	-9.5	-10.6	-10.5	-10.8	-11.1	-9.5	-9.5
Sutherland	-3.7	-3.7	-4.2	-4.1	-4.2	-4.4	-3.7	-3.7
Sydney	-13.8	-13.8	-15.4	-15.3	-15.7	-16.2	-13.8	-13.8
Waverley	-5.9	-5.9	-6.6	-6.5	-6.7	-6.9	-5.9	-5.9

Table 32 Load reductions (%) for TN of selected WSUD scenario options by LGA in 2030: Part 4

	GPT, Bioretention and Wetland (10)	Bioretention and Wetland (7)	Rainwater tank, GPT and Bioretention (16)	Rainwater tank, GPT and Wetland (22)	Rainwater tank, GPT, Bioretention and Wetland (28)	Rainwater tank, Bioretention and Wetland (25)
Ashfield	-14.0	-14.3	-14.3	-14.5	-16.0	-16.3
Auburn	-2.4	-2.5	-2.5	-2.5	-2.8	-2.8
Bankstown	-14.9	-15.2	-15.2	-15.5	-17.0	-17.4
Botany Bay	-5.8	-6.0	-6.0	-6.1	-6.7	-6.8
Burwood	-14.0	-14.3	-14.3	-14.5	-16.0	-16.3
Campbelltown	-7.2	-7.3	-7.3	-7.4	-8.2	-8.3
Canterbury	-6.2	-6.3	-6.3	-6.4	-7.0	-7.2
Fairfield	-15.6	-15.9	-15.8	-16.2	-17.8	-18.1
Holroyd	-12.5	-12.8	-12.8	-13.0	-14.3	-14.6
Hurstville	-6.1	-6.2	-6.2	-6.3	-7.0	-7.1
Kogarah	-6.2	-6.3	-6.3	-6.4	-7.1	-7.2
Liverpool	-10.3	-10.5	-10.5	-10.7	-11.8	-12.0
Marrickville	-6.1	-6.3	-6.3	-6.4	-7.0	-7.2
Randwick	-6.4	-6.5	-6.5	-6.6	-7.3	-7.4
Rockdale	-5.4	-5.5	-5.5	-5.6	-6.1	-6.3
Strathfield	-10.5	-10.7	-10.7	-10.9	-12.0	-12.2
Sutherland	-4.1	-4.2	-4.2	-4.3	-4.7	-4.8
Sydney	-15.2	-15.6	-15.5	-15.8	-17.4	-17.8
Waverley	-6.5	-6.6	-6.6	-6.8	-7.4	-7.6

Table 33 Load reductions (%) for TP of selected WSUD scenario options by LGA in 2030 in 2030: Part 1

	Bioretention (2)	Next generation bioretention (1)	Rainwater tank and Bioretention (14)	Rainwater tank and Wetland (21)	Buffer and Bioretention (9)	Buffer and Wetland (15)	Buffer, Bioretention and Wetland (19)	Buffer, GPT and Bioretention
Ashfield	-20.7	-19.8	-20.9	-21.2	-20.5	-20.1	-20.4	-20.5
Auburn	-4.5	-4.3	-4.5	-4.6	-4.4	-4.3	-4.4	-4.4
Bankstown	-22.3	-21.4	-22.5	-22.9	-22.1	-21.6	-22.0	-22.1
Botany Bay	-8.7	-8.4	-8.8	-8.9	-8.7	-8.5	-8.6	-8.7
Burwood	-20.7	-19.8	-20.9	-21.2	-20.5	-20.0	-20.4	-20.5
Campbelltown	-14.7	-14.0	-14.8	-15.0	-14.5	-14.2	-14.4	-14.5
Canterbury	-9.1	-8.8	-9.2	-9.4	-9.1	-8.9	-9.0	-9.1
Fairfield	-23.5	-22.5	-23.8	-24.1	-23.3	-22.8	-23.2	-23.3
Holroyd	-18.7	-17.9	-18.9	-19.2	-18.6	-18.2	-18.5	-18.6
Hurstville	-9.1	-8.7	-9.2	-9.3	-9.0	-8.8	-9.0	-9.0
Kogarah	-9.2	-8.8	-9.3	-9.4	-9.1	-8.9	-9.1	-9.1
Liverpool	-19.0	-18.2	-19.2	-19.5	-18.8	-18.4	-18.7	-18.8
Marrickville	-9.1	-8.8	-9.2	-9.4	-9.1	-8.9	-9.0	-9.1
Randwick	-9.8	-9.4	-9.9	-10.0	-9.7	-9.5	-9.7	-9.7
Rockdale	-8.0	-7.7	-8.1	-8.2	-7.9	-7.8	-7.9	-7.9
Strathfield	-15.6	-15.0	-15.8	-16.0	-15.5	-15.1	-15.4	-15.5
Sutherland	-6.8	-6.5	-6.8	-6.9	-6.7	-6.5	-6.7	-6.7
Sydney	-22.8	-21.9	-23.1	-23.4	-22.7	-22.1	-22.5	-22.7
Waverley	-9.9	-9.5	-10.0	-10.2	-9.8	-9.6	-9.8	-9.8

Table 34 Load reductions (%) for TP of selected WSUD scenario options by LGA in 2030: Part 2

	Buffer, GPT and Bioretention (12)	Buffer, GPT and Wetland (17)	Rainwater tank, Buffer and Bioretention (26)	Rainwater tank, Buffer and Wetland (29)	Rainwater tank, Buffer, GPT and Wetland (30)	Rainwater tank, Buffer, GPT, Bioretention & Wetland (31)	Swale and Wetland (8)	Swale and Bioretention (4)	Swale, Bioretention and Wetland (13)
Ashfield	-19.6	-20.2	-21.0	-20.9	-20.2	-21.1	-21.3	-20.4	-20.2
Auburn	-4.2	-4.3	-4.5	-4.5	-4.3	-4.5	-4.6	-4.4	-4.3
Bankstown	-21.1	-21.8	-22.6	-22.5	-21.8	-22.7	-23.0	-21.9	-21.8
Botany Bay	-8.3	-8.5	-8.9	-8.8	-8.5	-8.9	-9.0	-8.6	-8.5
Burwood	-19.6	-20.2	-21.0	-20.9	-20.2	-21.0	-21.3	-20.3	-20.2
Campbelltown	-13.9	-14.3	-14.9	-14.8	-14.3	-14.9	-15.1	-14.4	-14.3
Canterbury	-8.7	-8.9	-9.3	-9.2	-8.9	-9.3	-9.4	-9.0	-8.9
Fairfield	-22.3	-23.0	-23.9	-23.8	-23.0	-23.9	-24.2	-23.1	-23.0
Holroyd	-17.7	-18.3	-19.0	-18.9	-18.3	-19.0	-19.3	-18.4	-18.3
Hurstville	-8.6	-8.9	-9.2	-9.2	-8.9	-9.2	-9.3	-8.9	-8.9
Kogarah	-8.7	-9.0	-9.3	-9.3	-9.0	-9.3	-9.5	-9.0	-9.0
Liverpool	-18.0	-18.5	-19.3	-19.2	-18.5	-19.3	-19.5	-18.7	-18.5
Marrickville	-8.7	-8.9	-9.3	-9.2	-8.9	-9.3	-9.4	-9.0	-8.9
Randwick	-9.3	-9.6	-10.0	-9.9	-9.6	-10.0	-10.1	-9.6	-9.6
Rockdale	-7.6	-7.8	-8.1	-8.1	-7.8	-8.1	-8.2	-7.9	-7.8
Strathfield	-14.8	-15.2	-15.9	-15.8	-15.2	-15.9	-16.1	-15.4	-15.2
Sutherland	-6.4	-6.6	-6.8	-6.8	-6.6	-6.9	-6.9	-6.6	-6.6
Sydney	-21.6	-22.3	-23.2	-23.1	-22.3	-23.2	-23.5	-22.5	-22.3
Waverley	-9.4	-9.7	-10.1	-10.0	-9.7	-10.1	-10.2	-9.8	-9.7

Table 35 Load reductions (%) for TP of selected WSUD scenario options by LGA in 2030: Part 3

	Swale, GPT and Wetland (11)	Swale, GPT and Bioretention (5)	Rainwater tank, Swale and Wetland (24)	Rainwater tank, Swale, GPT and Wetland (27)	Rainwater tank, Swale and Bioretention (18)	Rainwater tank, Swale, GPT and Bioretention (20)	GPT and Bioretention (3)	GPT and Wetland (6)
Ashfield	-21.3	-20.4	-20.3	-20.4	-20.8	-21.5	-20.7	-20.3
Auburn	-4.6	-4.4	-4.4	-4.4	-4.5	-4.6	-4.5	-4.4
Bankstown	-23.0	-21.9	-21.9	-21.9	-22.4	-23.1	-22.3	-21.8
Botany Bay	-9.0	-8.6	-8.6	-8.6	-8.8	-9.1	-8.7	-8.5
Burwood	-21.3	-20.3	-20.3	-20.3	-20.8	-21.4	-20.7	-20.2
Campbelltown	-15.1	-14.4	-14.4	-14.4	-14.7	-15.2	-14.7	-14.3
Canterbury	-9.4	-9.0	-9.0	-9.0	-9.2	-9.5	-9.1	-8.9
Fairfield	-24.2	-23.1	-23.1	-23.1	-23.6	-24.4	-23.5	-23.0
Holroyd	-19.3	-18.4	-18.4	-18.4	-18.8	-19.4	-18.7	-18.3
Hurstville	-9.3	-8.9	-8.9	-8.9	-9.1	-9.4	-9.1	-8.9
Kogarah	-9.5	-9.0	-9.0	-9.0	-9.2	-9.5	-9.2	-9.0
Liverpool	-19.5	-18.7	-18.6	-18.7	-19.1	-19.7	-19.0	-18.6
Marrickville	-9.4	-9.0	-9.0	-9.0	-9.2	-9.5	-9.1	-8.9
Randwick	-10.1	-9.6	-9.6	-9.6	-9.8	-10.2	-9.8	-9.6
Rockdale	-8.2	-7.9	-7.9	-7.9	-8.0	-8.3	-8.0	-7.8
Strathfield	-16.1	-15.4	-15.3	-15.4	-15.7	-16.2	-15.6	-15.3
Sutherland	-6.9	-6.6	-6.6	-6.6	-6.8	-7.0	-6.8	-6.6
Sydney	-23.5	-22.5	-22.4	-22.5	-22.9	-23.7	-22.8	-22.3
Waverley	-10.2	-9.8	-9.7	-9.8	-10.0	-10.3	-9.9	-9.7

Table 36 Load reductions (%) for TP of selected WSUD scenario options by LGA in 2030: Part 4

	GPT, Bioretention and Wetland (10)	Bioretention and Wetland (7)	Rainwater tank, GPT and Bioretention (16)	Rainwater tank, GPT and Wetland (22)	Rainwater tank, GPT, Bioretention and Wetland (28)	Rainwater tank, Bioretention and Wetland (25)
Ashfield	-19.9	-20.4	-20.5	-19.5	-20.8	-21.2
Auburn	-4.3	-4.4	-4.4	-4.2	-4.5	-4.6
Bankstown	-21.5	-21.9	-22.1	-21.0	-22.4	-22.9
Botany Bay	-8.4	-8.6	-8.6	-8.2	-8.8	-9.0
Burwood	-19.9	-20.3	-20.4	-19.5	-20.8	-21.2
Campbelltown	-14.1	-14.4	-14.5	-13.8	-14.7	-15.0
Canterbury	-8.8	-9.0	-9.0	-8.6	-9.2	-9.4
Fairfield	-22.7	-23.1	-23.3	-22.2	-23.6	-24.1
Holroyd	-18.0	-18.4	-18.5	-17.6	-18.8	-19.2
Hurstville	-8.7	-8.9	-9.0	-8.6	-9.1	-9.3
Kogarah	-8.8	-9.0	-9.1	-8.7	-9.2	-9.4
Liverpool	-18.3	-18.7	-18.8	-17.9	-19.1	-19.5
Marrickville	-8.8	-9.0	-9.0	-8.6	-9.2	-9.4
Randwick	-9.4	-9.6	-9.7	-9.2	-9.8	-10.1
Rockdale	-7.7	-7.9	-7.9	-7.5	-8.0	-8.2
Strathfield	-15.0	-15.4	-15.5	-14.7	-15.7	-16.0
Sutherland	-6.5	-6.6	-6.7	-6.4	-6.8	-6.9
Sydney	-22.0	-22.5	-22.6	-21.5	-22.9	-23.4
Waverley	-9.6	-9.8	-9.8	-9.3	-10.0	-10.2

Table 37 Load reductions (%) for TSS of selected WSUD scenario options by LGA in 2030: Part 1

	Bioretention (2)	Next generation bioretention (1)	Rainwater tank and Bioretention (14)	Rainwater tank and Wetland (21)	Buffer and Bioretention (9)	Buffer and Wetland (15)	Buffer, Bioretention and Wetland (19)	Buffer, GPT and Bioretention
Ashfield	-25.9	-24.8	-25.3	-25.3	-25.9	-25.3	-25.3	-26.4
Auburn	-6.0	-5.7	-5.9	-5.9	-6.0	-5.9	-5.9	-6.1
Bankstown	-28.0	-26.8	-27.4	-27.4	-28.0	-27.4	-27.4	-28.6
Botany Bay	-11.0	-10.5	-10.7	-10.7	-11.0	-10.7	-10.7	-11.2
Burwood	-25.9	-24.7	-25.3	-25.3	-25.8	-25.3	-25.3	-26.4
Campbelltown	-17.0	-16.3	-16.6	-16.6	-17.0	-16.6	-16.6	-17.4
Canterbury	-11.5	-11.0	-11.2	-11.2	-11.4	-11.2	-11.2	-11.7
Fairfield	-29.5	-28.2	-28.9	-28.9	-29.5	-28.9	-28.9	-30.1
Holroyd	-23.5	-22.5	-23.0	-23.0	-23.5	-23.0	-23.0	-24.0
Hurstville	-11.4	-10.9	-11.1	-11.1	-11.4	-11.1	-11.1	-11.6
Kogarah	-11.5	-11.0	-11.2	-11.2	-11.5	-11.2	-11.2	-11.7
Liverpool	-22.2	-21.3	-21.7	-21.7	-22.2	-21.7	-21.7	-22.7
Marrickville	-11.5	-11.0	-11.2	-11.2	-11.5	-11.2	-11.2	-11.7
Randwick	-12.4	-11.9	-12.1	-12.1	-12.4	-12.1	-12.1	-12.7
Rockdale	-10.1	-9.6	-9.8	-9.8	-10.1	-9.8	-9.8	-10.3
Strathfield	-19.6	-18.7	-19.2	-19.2	-19.6	-19.2	-19.2	-20.0
Sutherland	-8.7	-8.3	-8.5	-8.5	-8.7	-8.5	-8.5	-8.9
Sydney	-28.7	-27.4	-28.0	-28.0	-28.7	-28.0	-28.0	-29.3
Waverley	-12.5	-12.0	-12.3	-12.3	-12.5	-12.3	-12.3	-12.8

Table 38 Load reductions (%) for TSS of selected WSUD scenario options by LGA in 2030: Part 2

	Buffer, GPT and Bioretention (12)	Buffer, GPT and Wetland (17)	Rainwater tank, Buffer and Bioretention (26)	Rainwater tank, Buffer and Wetland (29)	Rainwater tank, Buffer, GPT and Wetland (30)	Rainwater tank, Buffer, GPT, Bioretention & Wetland (31)	Swale and Wetland (8)	Swale and Bioretention (4)	Swale, Bioretention and Wetland (13)
Ashfield	-26.2	-25.3	-25.3	-25.3	-25.3	-25.3	-27.2	-25.6	-25.3
Auburn	-6.1	-5.9	-5.9	-5.9	-5.9	-5.9	-6.3	-5.9	-5.9
Bankstown	-28.4	-27.4	-27.4	-27.4	-27.4	-27.4	-29.4	-27.7	-27.4
Botany Bay	-11.1	-10.7	-10.7	-10.7	-10.7	-10.7	-11.5	-10.8	-10.7
Burwood	-26.2	-25.3	-25.3	-25.3	-25.3	-25.3	-27.1	-25.6	-25.3
Campbelltown	-17.2	-16.6	-16.6	-16.6	-16.6	-16.6	-17.8	-16.8	-16.6
Canterbury	-11.6	-11.2	-11.2	-11.2	-11.2	-11.2	-12.0	-11.3	-11.2
Fairfield	-29.9	-28.9	-28.9	-28.9	-28.9	-28.9	-31.0	-29.2	-28.9
Holroyd	-23.8	-23.0	-23.0	-23.0	-23.0	-23.0	-24.7	-23.2	-23.0
Hurstville	-11.5	-11.1	-11.1	-11.1	-11.1	-11.1	-11.9	-11.3	-11.1
Kogarah	-11.6	-11.2	-11.2	-11.2	-11.2	-11.2	-12.1	-11.4	-11.2
Liverpool	-22.5	-21.7	-21.7	-21.7	-21.7	-21.7	-23.3	-22.0	-21.7
Marrickville	-11.6	-11.2	-11.2	-11.2	-11.2	-11.2	-12.0	-11.3	-11.2
Randwick	-12.6	-12.1	-12.1	-12.1	-12.1	-12.1	-13.0	-12.3	-12.1
Rockdale	-10.2	-9.8	-9.8	-9.8	-9.8	-9.8	-10.6	-9.9	-9.8
Strathfield	-19.8	-19.2	-19.2	-19.2	-19.2	-19.2	-20.6	-19.4	-19.2
Sutherland	-8.8	-8.5	-8.5	-8.5	-8.5	-8.5	-9.1	-8.6	-8.5
Sydney	-29.0	-28.0	-28.0	-28.0	-28.0	-28.0	-30.1	-28.3	-28.0
Waverley	-12.7	-12.3	-12.3	-12.3	-12.3	-12.3	-13.1	-12.4	-12.3

Table 39 Load reductions (%) for TSS of selected WSUD scenario options by LGA in 2030: Part 3

	Swale, GPT and Wetland (11)	Swale, GPT and Bioretention (5)	Rainwater tank, Swale and Wetland (24)	Rainwater tank, Swale, GPT and Wetland (27)	Rainwater tank, Swale and Bioretention (18)	Rainwater tank, Swale, GPT and Bioretention (20)	GPT and Bioretention (3)	GPT and Wetland (6)
Ashfield	-28.1	-26.1	-25.3	-25.3	-25.3	-26.1	-27.1	-27.2
Auburn	-6.5	-6.1	-5.9	-5.9	-5.9	-6.1	-6.3	-6.3
Bankstown	-30.4	-28.3	-27.4	-27.4	-27.4	-28.3	-29.3	-29.5
Botany Bay	-11.9	-11.1	-10.7	-10.7	-10.7	-11.1	-11.4	-11.5
Burwood	-28.1	-26.1	-25.3	-25.3	-25.3	-26.1	-27.0	-27.2
Campbelltown	-18.5	-17.2	-16.6	-16.6	-16.6	-17.2	-17.8	-17.9
Canterbury	-12.4	-11.6	-11.2	-11.2	-11.2	-11.6	-12.0	-12.0
Fairfield	-32.0	-29.8	-28.9	-28.9	-28.9	-29.8	-30.8	-31.0
Holroyd	-25.5	-23.7	-23.0	-23.0	-23.0	-23.7	-24.6	-24.7
Hurstville	-12.4	-11.5	-11.1	-11.1	-11.1	-11.5	-11.9	-12.0
Kogarah	-12.5	-11.6	-11.2	-11.2	-11.2	-11.6	-12.0	-12.1
Liverpool	-24.1	-22.4	-21.7	-21.7	-21.7	-22.4	-23.2	-23.4
Marrickville	-12.4	-11.6	-11.2	-11.2	-11.2	-11.6	-12.0	-12.1
Randwick	-13.5	-12.5	-12.1	-12.1	-12.1	-12.5	-13.0	-13.0
Rockdale	-10.9	-10.2	-9.8	-9.8	-9.8	-10.2	-10.5	-10.6
Strathfield	-21.3	-19.8	-19.2	-19.2	-19.2	-19.8	-20.5	-20.6
Sutherland	-9.4	-8.8	-8.5	-8.5	-8.5	-8.8	-9.1	-9.1
Sydney	-31.1	-28.9	-28.0	-28.0	-28.0	-28.9	-29.9	-30.1
Waverley	-13.6	-12.7	-12.3	-12.3	-12.3	-12.7	-13.1	-13.2

Table 40 Load reductions (%) for TSS of selected WSUD scenario options by LGA in 2030: Part 4

	GPT, Bioretention and Wetland (10)	Bioretention and Wetland (7)	Rainwater tank, GPT and Bioretention (16)	Rainwater tank, GPT and Wetland (22)	Rainwater tank, GPT, Bioretention and Wetland (28)	Rainwater tank, Bioretention and Wetland (25)
Ashfield	-25.3	-25.3	-25.3	-25.3	-25.3	-25.3
Auburn	-5.9	-5.9	-5.9	-5.9	-5.9	-5.9
Bankstown	-27.4	-27.4	-27.4	-27.4	-27.4	-27.4
Botany Bay	-10.7	-10.7	-10.7	-10.7	-10.7	-10.7
Burwood	-25.3	-25.3	-25.3	-25.3	-25.3	-25.3
Campbelltown	-16.6	-16.6	-16.6	-16.6	-16.6	-16.6
Canterbury	-11.2	-11.2	-11.2	-11.2	-11.2	-11.2
Fairfield	-28.9	-28.9	-28.9	-28.9	-28.9	-28.9
Holroyd	-23.0	-23.0	-23.0	-23.0	-23.0	-23.0
Hurstville	-11.1	-11.1	-11.1	-11.1	-11.1	-11.1
Kogarah	-11.2	-11.2	-11.2	-11.2	-11.2	-11.2
Liverpool	-21.7	-21.7	-21.7	-21.7	-21.7	-21.7
Marrickville	-11.2	-11.2	-11.2	-11.2	-11.2	-11.2
Randwick	-12.1	-12.1	-12.1	-12.1	-12.1	-12.1
Rockdale	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8
Strathfield	-19.2	-19.2	-19.2	-19.2	-19.2	-19.2
Sutherland	-8.5	-8.5	-8.5	-8.5	-8.5	-8.5
Sydney	-28.0	-28.0	-28.0	-28.0	-28.0	-28.0
Waverley	-12.3	-12.3	-12.3	-12.3	-12.3	-12.3

Table 41 Annuatised lifecycle costs of selected WSUD scenario options by LGA ($'000/yr) in 2030: Part 1

	Bioretention (2)	Next generation bioretention (1)	Rainwater tank and Bioretention (14)	Rainwater tank and Wetland (21)	Buffer and Bioretention (9)	Buffer and Wetland (15)	Buffer, Bioretention and Wetland (19)	Buffer, GPT and Bioretention
Ashfield	15	14	46	62	38	50	58	43
Auburn	4	4	11	15	9	12	14	11
Bankstown	4,081	3,991	12,788	17,157	10,486	13,901	16,118	11,970
Botany Bay	729	712	2,283	3,063	1,872	2,481	2,877	2,137
Burwood	134	131	419	562	344	456	528	392
Campbelltown	4,922	4,812	15,422	20,690	12,646	16,763	19,437	14,435
Canterbury	939	918	2,943	3,948	2,413	3,199	3,709	2,754
Fairfield	4,865	4,757	15,242	20,450	12,499	16,568	19,212	14,267
Holroyd	677	662	2,120	2,845	1,739	2,305	2,672	1,985
Hurstville	625	611	1,957	2,626	1,605	2,127	2,467	1,832
Kogarah	449	439	1,407	1,888	1,154	1,529	1,773	1,317
Liverpool	4,294	4,198	13,454	18,050	11,032	14,624	16,957	12,593
Marrickville	318	311	996	1,337	817	1,083	1,256	933
Randwick	335	328	1,050	1,409	861	1,141	1,323	983
Rockdale	641	626	2,007	2,693	1,646	2,182	2,530	1,879
Strathfield	338	330	1,058	1,420	868	1,151	1,334	991
Sutherland	1,716	1,678	5,377	7,214	4,409	5,845	6,777	5,033
Sydney	846	827	2,650	3,555	2,173	2,880	3,340	2,480
Waverley	34	33	107	144	88	116	135	100

Table 42 Annuatised lifecycle costs of selected WSUD scenario options by LGA ($'000/yr) in 2030: Part 2

	Buffer, GPT and Bioretention (12)	Buffer, GPT and Wetland (17)	Rainwater tank, Buffer and Bioretention (26)	Rainwater tank, Buffer and Wetland (29)	Rainwater tank, Buffer, GPT and Wetland (30)	Rainwater tank, Buffer, GPT, Bioretention & Wetland (31)	Swale and Wetland (8)	Swale and Bioretention (4)	Swale, Bioretention and Wetland (13)
Ashfield	55	63	68	82	85	93	36	25	45
Auburn	13	15	16	20	21	23	9	6	11
Bankstown	15,159	17,368	18,736	22,758	23,493	25,788	10,006	6,785	12,547
Botany Bay	2,706	3,100	3,345	4,063	4,194	4,604	1,786	1,211	2,240
Burwood	497	569	614	746	770	845	328	222	411
Campbelltown	18,281	20,944	22,593	27,444	28,331	31,099	12,066	8,182	15,131
Canterbury	3,488	3,996	4,311	5,237	5,406	5,934	2,302	1,561	2,887
Fairfield	18,069	20,700	22,331	27,126	28,002	30,737	11,926	8,087	14,955
Holroyd	2,513	2,879	3,106	3,773	3,895	4,276	1,659	1,125	2,080
Hurstville	2,320	2,658	2,867	3,483	3,595	3,946	1,531	1,038	1,920
Kogarah	1,668	1,911	2,061	2,504	2,585	2,837	1,101	746	1,380
Liverpool	15,949	18,272	19,711	23,943	24,716	27,131	10,526	7,138	13,201
Marrickville	1,181	1,353	1,460	1,773	1,830	2,009	780	529	978
Randwick	1,245	1,426	1,538	1,868	1,929	2,117	821	557	1,030
Rockdale	2,379	2,726	2,941	3,572	3,687	4,048	1,570	1,065	1,969
Strathfield	1,255	1,437	1,551	1,884	1,945	2,134	828	562	1,039
Sutherland	6,374	7,302	7,878	9,569	9,878	10,843	4,207	2,853	5,276
Sydney	3,141	3,599	3,882	4,716	4,868	5,344	2,073	1,406	2,600
Waverley	127	145	157	191	197	216	84	57	105

Table 43 Annuatised lifecycle costs of selected WSUD scenario options by LGA ($'000/yr) in 2030: Part 3

	Swale, GPT and Wetland (11)	Swale, GPT and Bioretention (5)	Rainwater tank, Swale and Wetland (24)	Rainwater tank, Swale, GPT and Wetland (27)	Rainwater tank, Swale and Bioretention (18)	Rainwater tank, Swale, GPT and Bioretention (20)	GPT and Bioretention (3)	GPT and Wetland (6)
Ashfield	42	30	65	70	55	60	20	31
Auburn	10	7	16	17	13	15	5	8
Bankstown	11,634	8,238	17,998	19,254	15,176	16,582	5,599	8,610
Botany Bay	2,077	1,471	3,213	3,437	2,709	2,960	999	1,537
Burwood	381	270	590	631	497	544	184	282
Campbelltown	14,030	9,935	21,704	23,218	18,301	19,997	6,752	10,382
Canterbury	2,677	1,896	4,141	4,430	3,492	3,816	1,288	1,981
Fairfield	13,867	9,819	21,452	22,949	18,089	19,764	6,673	10,262
Holroyd	1,929	1,366	2,984	3,192	2,516	2,749	928	1,427
Hurstville	1,780	1,261	2,754	2,946	2,322	2,537	857	1,317
Kogarah	1,280	906	1,980	2,118	1,670	1,824	616	947
Liverpool	12,240	8,667	18,935	20,256	15,966	17,445	5,890	9,058
Marrickville	906	642	1,402	1,500	1,182	1,292	436	671
Randwick	955	676	1,478	1,581	1,246	1,361	460	707
Rockdale	1,826	1,293	2,825	3,022	2,382	2,603	879	1,351
Strathfield	963	682	1,490	1,594	1,256	1,372	463	713
Sutherland	4,892	3,464	7,567	8,096	6,381	6,972	2,354	3,620
Sydney	2,411	1,707	3,729	3,990	3,145	3,436	1,160	1,784
Waverley	97	69	151	161	127	139	47	72

Table 44 Annuatised lifecycle costs of selected WSUD scenario options by LGA ($'000/yr) in 2030: Part 4

	GPT, Bioretention and Wetland (10)	Bioretention and Wetland (7)	Rainwater tank, GPT and Bioretention (16)	Rainwater tank, GPT and Wetland (22)	Rainwater tank, GPT, Bioretention and Wetland (28)	Rainwater tank, Bioretention and Wetland (25)
Ashfield	40	36	50	63	71	67
Auburn	10	9	12	15	17	16
Bankstown	11,148	9,937	13,937	17,314	19,635	18,621
Botany Bay	1,990	1,774	2,488	3,091	3,505	3,324
Burwood	365	326	457	567	644	610
Campbelltown	13,444	11,983	16,807	20,879	23,678	22,455
Canterbury	2,565	2,287	3,207	3,984	4,518	4,285
Fairfield	13,288	11,844	16,611	20,636	23,403	22,194
Holroyd	1,848	1,648	2,311	2,871	3,255	3,087
Hurstville	1,706	1,521	2,133	2,649	3,005	2,849
Kogarah	1,226	1,093	1,533	1,905	2,160	2,049
Liverpool	11,729	10,455	14,662	18,215	20,657	19,590
Marrickville	869	774	1,086	1,349	1,530	1,451
Randwick	915	816	1,144	1,421	1,612	1,529
Rockdale	1,750	1,560	2,187	2,717	3,082	2,923
Strathfield	923	822	1,154	1,433	1,625	1,541
Sutherland	4,687	4,178	5,860	7,280	8,256	7,829
Sydney	2,310	2,059	2,888	3,587	4,068	3,858
Waverley	93	83	117	145	164	156

Table 45 Upfront costs of selected WSUD scenario options by LGA (S'000) in 2030: Part 1

	Bioretention (2)	Next generation bioretention (1)	Rainwater tank & Bioretention (14)	Rainwater tank and Wetland (21)	Buffer and Bioretention (9)	Buffer and Wetland (15)	Buffer, Bioretention & Wetland (19)	Buffer, GPT and Bioretention
Ashfield	162	158	704	1,552	477	1,248	1,253	641
Auburn	39	38	171	377	116	303	304	156
Bankstown	44,712	43,719	194,501	428,981	131,682	344,826	346,349	177,165
Botany Bay	7,982	7,804	34,721	76,579	23,507	61,556	61,828	31,626
Burwood	1,466	1,433	6,375	14,061	4,316	11,302	11,352	5,807
Campbelltown	53,919	52,721	234,552	517,315	158,797	415,831	417,667	213,645
Canterbury	10,289	10,060	44,757	98,712	30,301	79,348	79,698	40,767
Fairfield	53,293	52,108	231,827	511,305	156,952	411,000	412,814	211,163
Holroyd	7,413	7,248	32,248	71,124	21,832	57,171	57,423	29,373
Hurstville	6,842	6,690	29,764	65,646	20,151	52,768	53,001	27,111
Kogarah	4,919	4,810	21,398	47,194	14,487	37,936	38,103	19,491
Liverpool	47,040	45,995	204,627	451,314	138,537	362,778	364,380	186,388
Marrickville	3,483	3,406	15,153	33,422	10,259	26,865	26,984	13,803
Randwick	3,671	3,589	15,968	35,218	10,811	28,309	28,434	14,545
Rockdale	7,018	6,862	30,528	67,331	20,668	54,123	54,362	27,807
Strathfield	3,701	3,619	16,099	35,506	10,899	28,541	28,667	14,664
Sutherland	18,800	18,382	81,780	180,370	55,367	144,986	145,627	74,491
Sydney	9,265	9,059	40,302	88,888	27,285	71,450	71,766	36,710
Waverley	374	366	1,629	3,593	1,103	2,888	2,901	1,484

Table 46 Upfront costs of selected WSUD scenario options by LGA (S'000) in 2030: Part 2

	Buffer, GPT and Bioretention (12)	Buffer, GPT and Wetland (17)	Rainwater tank, Buffer and Bioretention (26)	Rainwater tank, Buffer and Wetland (29)	Rainwater tank, Buffer, GPT and Wetland (30)	Rainwater tank, Buffer, GPT, Bioretention & Wetland (31)	Swale and Wetland (8)	Swale and Bioretention (4)	Swale, Bioretention and Wetland (13)
Ashfield	1,395	1,398	994	1,777	1,884	1,915	1,001	246	1,024
Auburn	339	339	241	432	457	465	243	60	249
Bankstown	385,348	386,211	274,583	491,107	520,547	529,088	276,473	67,896	283,037
Botany Bay	68,790	68,944	49,017	87,670	92,925	94,450	49,354	12,120	50,526
Burwood	12,630	12,659	9,000	16,097	17,062	17,342	9,062	2,225	9,277
Campbelltown	464,696	465,738	331,124	592,233	627,735	638,034	333,403	81,876	341,318
Canterbury	88,672	88,871	63,184	113,008	119,783	121,748	63,619	15,623	65,129
Fairfield	459,297	460,327	327,277	585,353	620,442	630,622	329,529	80,925	337,353
Holroyd	63,889	64,032	45,525	81,424	86,305	87,721	45,838	11,257	46,926
Hurstville	58,969	59,101	42,019	75,153	79,658	80,965	42,308	10,390	43,312
Kogarah	42,394	42,489	30,208	54,029	57,267	58,207	30,416	7,469	31,138
Liverpool	405,409	406,318	288,878	516,674	547,646	556,632	290,866	71,430	297,772
Marrickville	30,022	30,089	21,393	38,262	40,555	41,221	21,540	5,290	22,051
Randwick	31,636	31,707	22,542	40,318	42,735	43,436	22,698	5,574	23,236
Rockdale	60,483	60,618	43,098	77,082	81,703	83,043	43,394	10,657	44,424
Strathfield	31,895	31,966	22,727	40,648	43,085	43,792	22,883	5,620	23,427
Sutherland	162,024	162,387	115,452	206,492	218,870	222,461	116,246	28,548	119,006
Sydney	79,847	80,026	56,896	101,761	107,861	109,631	57,287	14,068	58,647
Waverley	3,227	3,235	2,300	4,113	4,360	4,431	2,315	569	2,370

Table 47 Upfront costs of selected WSUD scenario options by LGA (S'000) in 2030: Part 3

	Swale, GPT and Wetland (11)	Swale, GPT and Bioretention (5)	Rainwater tank, Swale and Wetland (24)	Rainwater tank, Swale, GPT and Wetland (27)	Rainwater tank, Swale and Bioretention (18)	Rainwater tank, Swale, GPT and Bioretention (20)	GPT and Bioretention (3)	GPT and Wetland (6)
Ashfield	1,181	407	1,457	1,602	770	926	330	1,106
Auburn	287	99	354	389	187	225	80	269
Bankstown	326,393	112,390	402,530	442,649	212,693	255,782	91,229	305,656
Botany Bay	58,266	20,063	71,857	79,019	37,969	45,661	16,286	54,564
Burwood	10,698	3,684	13,194	14,509	6,971	8,384	2,990	10,018
Campbelltown	393,602	135,532	485,417	533,796	256,490	308,451	110,014	368,595
Canterbury	75,106	25,862	92,626	101,857	48,943	58,858	20,993	70,334
Fairfield	389,029	133,958	479,777	527,595	253,510	304,868	108,736	364,313
Holroyd	54,115	18,634	66,738	73,390	35,264	42,408	15,125	50,677
Hurstville	49,947	17,199	61,598	67,737	32,548	39,142	13,960	46,774
Kogarah	35,908	12,364	44,284	48,698	23,399	28,140	10,036	33,626
Liverpool	343,385	118,241	423,486	465,693	223,766	269,098	95,978	321,569
Marrickville	25,429	8,756	31,361	34,486	16,571	19,928	7,108	23,813
Randwick	26,796	9,227	33,046	36,340	17,461	20,999	7,490	25,093
Rockdale	51,229	17,640	63,179	69,476	33,383	40,147	14,319	47,975
Strathfield	27,015	9,302	33,317	36,638	17,604	21,171	7,551	25,299
Sutherland	137,236	47,256	169,249	186,117	89,429	107,547	38,358	128,517
Sydney	67,631	23,288	83,407	91,720	44,071	53,000	18,903	63,334
Waverley	2,734	941	3,371	3,707	1,781	2,142	764	2,560

Table 48 Upfront costs of selected WSUD scenario options by LGA (S'000) in 2030: Part 4

	GPT, Bioretention and Wetland	Bioretention and Wetland	Rainwater tank, GPT and Bioretention	Rainwater tank, GPT and Wetland	Rainwater tank, GPT, Bioretention and Wetland	Rainwater tank, Bioretention and Wetland
Ashfield	1,093	956	846	1,598	1,613	1,489
Auburn	265	232	206	388	392	362
Bankstown	301,991	264,062	233,910	441,517	445,754	411,325
Botany Bay	53,910	47,139	41,756	78,817	79,573	73,427
Burwood	9,898	8,655	7,667	14,471	14,610	13,482
Campbelltown	364,175	318,436	282,076	532,431	537,541	496,022
Canterbury	69,491	60,763	53,825	101,597	102,572	94,650
Fairfield	359,944	314,737	278,799	526,245	531,296	490,259
Holroyd	50,069	43,781	38,782	73,202	73,904	68,196
Hurstville	46,213	40,409	35,795	67,564	68,212	62,944
Kogarah	33,223	29,051	25,733	48,573	49,039	45,251
Liverpool	317,713	277,809	246,088	464,502	468,960	432,738
Marrickville	23,528	20,573	18,224	34,398	34,728	32,046
Randwick	24,793	21,679	19,203	36,247	36,595	33,768
Rockdale	47,399	41,446	36,714	69,299	69,964	64,560
Strathfield	24,995	21,856	19,361	36,544	36,895	34,045
Sutherland	126,976	111,028	98,350	185,641	187,423	172,946
Sydney	62,575	54,715	48,468	91,485	92,363	85,229
Waverley	2,529	2,212	1,959	3,698	3,733	3,445

Table 49. Maintenance costs of selected WSUD scenario options by LGA ($’000/yr) in 2030: Part 1

	Bioretention (2)	Next generation bioretention (1)	Rainwater tank and Bioretention (14)	Rainwater tank and Wetland (21)	Buffer and Bioretention (9)	Buffer and Wetland (15)	Buffer, Bioretention & Wetland (19)	Buffer, GPT and Bioretention
Ashfield	31	30	48	35	71	58	80	76
Auburn	7	7	12	8	17	14	19	18
Bankstown	8,479	8,291	13,207	9,586	19,575	16,020	22,148	20,884
Botany Bay	1,514	1,480	2,358	1,711	3,494	2,860	3,954	3,728
Burwood	278	272	433	314	642	525	726	684
Campbelltown	10,225	9,998	15,927	11,560	23,606	19,318	26,709	25,184
Canterbury	1,951	1,908	3,039	2,206	4,504	3,686	5,097	4,805
Fairfield	10,106	9,882	15,742	11,426	23,332	19,094	26,399	24,891
Holroyd	1,406	1,375	2,190	1,589	3,245	2,656	3,672	3,462
Hurstville	1,298	1,269	2,021	1,467	2,996	2,451	3,389	3,196
Kogarah	933	912	1,453	1,055	2,154	1,762	2,437	2,297
Liverpool	8,921	8,722	13,895	10,085	20,594	16,854	23,301	21,971
Marrickville	661	646	1,029	747	1,525	1,248	1,726	1,627
Randwick	696	681	1,084	787	1,607	1,315	1,818	1,714
Rockdale	1,331	1,301	2,073	1,505	3,072	2,514	3,476	3,278
Strathfield	702	686	1,093	793	1,620	1,326	1,833	1,729
Sutherland	3,565	3,486	5,553	4,031	8,231	6,736	9,313	8,781
Sydney	1,757	1,718	2,737	1,986	4,056	3,319	4,589	4,327
Waverley	71	69	111	80	164	134	185	175

Table 50 Maintenance costs of selected WSUD scenario options by LGA ($'000/yr) in 2030: Part 2

	Buffer, GPT and Bioretention (12)	Buffer, GPT and Wetland (17)	Rainwater tank, Buffer and Bioretention (26)	Rainwater tank, Buffer and Wetland (29)	Rainwater tank, Buffer, GPT and Wetland (30)	Rainwater tank, Buffer, GPT, Bioretention & Wetland (31)	Swale and Wetland (8)	Swale and Bioretention (4)	Swale, Bioretention and Wetland (13)
Ashfield	62	84	86	75	77	101	39	53	63
Auburn	15	20	21	18	19	24	10	13	15
Bankstown	17,040	23,166	23,730	20,727	21,351	27,857	10,832	14,526	17,387
Botany Bay	3,042	4,135	4,236	3,700	3,811	4,973	1,934	2,593	3,104
Burwood	559	759	778	679	700	913	355	476	570
Campbelltown	20,549	27,936	28,617	24,995	25,748	33,593	13,063	17,517	20,968
Canterbury	3,921	5,331	5,461	4,769	4,913	6,410	2,493	3,343	4,001
Fairfield	20,310	27,611	28,284	24,704	25,449	33,203	12,911	17,313	20,724
Holroyd	2,825	3,841	3,934	3,436	3,540	4,619	1,796	2,408	2,883
Hurstville	2,608	3,545	3,631	3,172	3,267	4,263	1,658	2,223	2,661
Kogarah	1,875	2,549	2,611	2,280	2,349	3,065	1,192	1,598	1,913
Liverpool	17,927	24,372	24,966	21,806	22,463	29,307	11,396	15,282	18,292
Marrickville	1,328	1,805	1,849	1,615	1,663	2,170	844	1,132	1,355
Randwick	1,399	1,902	1,948	1,702	1,753	2,287	889	1,193	1,427
Rockdale	2,675	3,636	3,725	3,253	3,351	4,372	1,700	2,280	2,729
Strathfield	1,410	1,917	1,964	1,716	1,767	2,306	897	1,202	1,439
Sutherland	7,165	9,740	9,978	8,715	8,977	11,713	4,554	6,108	7,311
Sydney	3,531	4,800	4,917	4,295	4,424	5,772	2,244	3,010	3,603
Waverley	143	194	199	174	179	233	91	122	146

Table 51 Maintenance costs of selected WSUD scenario options by LGA ($'000/yr) in 2030: Part 3

	Swale, GPT and Wetland (11)	Swale, GPT and Bioretention (5)	Rainwater tank, Swale and Wetland (24)	Rainwater tank, Swale, GPT and Wetland (27)	Rainwater tank, Swale and Bioretention (18)	Rainwater tank, Swale, GPT and Bioretention (20)	GPT and Bioretention (3)	GPT and Wetland (6)
Ashfield	44	57	54	58	69	73	36	19
Auburn	11	14	13	14	17	18	9	5
Bankstown	12,268	15,806	14,913	16,031	19,003	20,242	9,817	5,197
Botany Bay	2,190	2,822	2,662	2,862	3,392	3,614	1,753	928
Burwood	402	518	489	525	623	663	322	170
Campbelltown	14,794	19,060	17,984	19,332	22,915	24,410	11,839	6,268
Canterbury	2,823	3,637	3,432	3,689	4,373	4,658	2,259	1,196
Fairfield	14,622	18,839	17,775	19,108	22,649	24,127	11,701	6,195
Holroyd	2,034	2,621	2,473	2,658	3,151	3,356	1,628	862
Hurstville	1,877	2,419	2,282	2,453	2,908	3,098	1,502	795
Kogarah	1,350	1,739	1,641	1,764	2,091	2,227	1,080	572
Liverpool	12,907	16,629	15,690	16,866	19,992	21,296	10,329	5,468
Marrickville	956	1,231	1,162	1,249	1,480	1,577	765	405
Randwick	1,007	1,298	1,224	1,316	1,560	1,662	806	427
Rockdale	1,926	2,481	2,341	2,516	2,983	3,177	1,541	816
Strathfield	1,015	1,308	1,234	1,327	1,573	1,675	813	430
Sutherland	5,158	6,646	6,270	6,740	7,990	8,511	4,128	2,185
Sydney	2,542	3,275	3,090	3,322	3,937	4,194	2,034	1,077
Waverley	103	132	125	134	159	170	82	44

Table 52 Maintenance costs of selected WSUD scenario options by LGA ($'000/yr) in 2030: Part 4

	GPT, Bioretention and Wetland (10)	Bioretention and Wetland (7)	Rainwater tank, GPT and Bioretention (16)	Rainwater tank, GPT and Wetland (22)	Rainwater tank, GPT, Bioretention and Wetland (28)	Rainwater tank, Bioretention and Wetland (25)
Ashfield	45	41	51	37	62	59
Auburn	11	10	12	9	15	14
Bankstown	12,361	11,350	14,179	10,169	17,167	16,270
Botany Bay	2,207	2,026	2,531	1,815	3,065	2,904
Burwood	405	372	465	333	563	533
Campbelltown	14,907	13,687	17,098	12,263	20,702	19,620
Canterbury	2,844	2,612	3,263	2,340	3,950	3,744
Fairfield	14,734	13,528	16,900	12,120	20,461	19,392
Holroyd	2,049	1,882	2,351	1,686	2,846	2,697
Hurstville	1,892	1,737	2,170	1,556	2,627	2,490
Kogarah	1,360	1,249	1,560	1,119	1,889	1,790
Liverpool	13,005	11,941	14,917	10,698	18,061	17,117
Marrickville	963	884	1,105	792	1,337	1,268
Randwick	1,015	932	1,164	835	1,409	1,336
Rockdale	1,940	1,781	2,225	1,596	2,694	2,554
Strathfield	1,023	939	1,174	842	1,421	1,347
Sutherland	5,198	4,772	5,962	4,276	7,218	6,841
Sydney	2,561	2,352	2,938	2,107	3,557	3,371
Waverley	104	95	119	85	144	136

Riparian rehabilitation scenario

This section (Table 53) provides load reductions and costs in 2030 for the riparian rehabilitation scenario described in section 4.2.2

Table 53. Load reductions (%) and costs ($) in 2030 associated with riparian rehabilitation scenario by LGA

LGA	TN	TP	TSS	Annuatised lifecycle cost (/yr)	Upfront cost	Maintenance cost (/yr)
Ashfield	0%	0%	0%	$0	$0	$0
Auburn	-7%	-9%	-8%	$17	$428	$21
Bankstown	-2%	-2%	-2%	$1,060	$27,461	$1,373
Botany Bay	-4%	-5%	-5%	$793	$20,549	$1,027
Burwood	0%	0%	0%	$0	$0	$0
Campbelltown	-2%	-3%	-3%	$9,382	$242,953	$12,148
Canterbury	-1%	-1%	-1%	$407	$10,534	$527
Fairfield	-4%	-5%	-5%	$3,071	$79,531	$3,977
Holroyd	-4%	-6%	-5%	$337	$8,719	$436
Hurstville	0%	0%	0%	$81	$2,087	$104
Kogarah	-2%	-3%	-2%	$120	$3,103	$155
Liverpool	-3%	-5%	-4%	$9,280	$240,331	$12,017
Marrickville	0%	0%	0%	$17	$447	$22
Randwick	-4%	-5%	-5%	$133	$3,438	$172
Rockdale	-1%	-2%	-2%	$426	$11,025	$551
Strathfield	-1%	-2%	-2%	$117	$3,031	$152
Sutherland	-1%	-1%	-1%	$818	$21,194	$1,060
Sydney	0%	0%	0%	$49	$1,282	$64
Waverly	-2%	-3%	-3%	$8	$217	$11
Wollondilly	0%	0%	0%	$196	$5,072	$254
Wollongong	0%	0%	0%	$0	$0	$0
Grand Total	**-2%**	**-3%**	**-2%**	**$26,312**	**$681,400**	**$34,070**

Appendix 3. Description of the Botany Bay CAPER DSS

The CAPER DSS is a decision support system designed to:

- *Integrate* information from catchment water quality models, receiving water quality models, MUSIC modelling, literature and expert opinion;
- Provide information on the *costs and benefits* associated with different management options;
- Allow the *trade-offs* associated with different *land use and land management* options in the Catchment to be assessed;
- Be *accessible to non-technical users* (i.e. people without any modelling skills or background) and stakeholders; and,
- Provide a *memory of project methods and outputs* and make models more accessible to stakeholders, managers and policy makers.

The CAPER DSS delivers on these needs by using a generic modelling platform and an easy-to-use interface shell that can be rapidly tailored to meet the needs of new applications. The system has been designed to include 'soft' data such as text descriptions, photos and maps. It contains a significant amount of contextual information and provides internal documentation of assumptions and models used in each application to make these available to people without significant modelling skills.

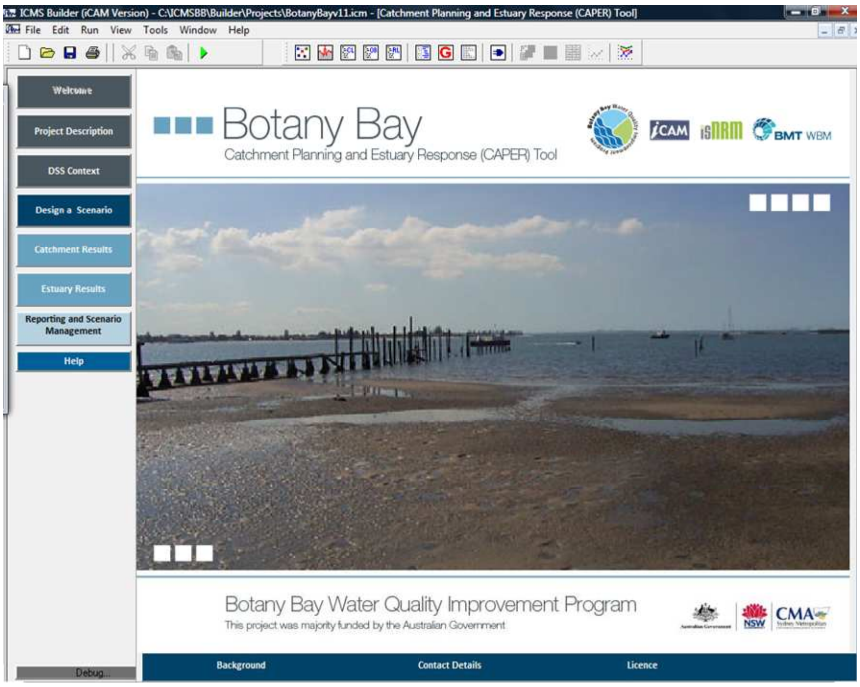


Figure 19. Botany Bay CAPER DSS interface: Welcome page

The Botany Bay version of the CAPER DSS has been developed to allow users to design scenarios and view results on the basis of subcatchment boundaries or local government areas (LGAs). Results can be viewed in table form, as graphs or on maps. Data can also be exported from the DSS to Excel for use outside the system.

A training workshop package of tutorials, presentations and a User Guide for the DSS is also available. Training in the DSS has been provided to a range of potential end-users and stakeholders in the Botany Bay Catchment. Alternatively training materials have also been developed to allow potential users to work through them independently to develop basic skills in using the Botany Bay CAPER DSS.

Components of the model underlying the Botany Bay CAPER DSS

The CAPER DSS relies on metamodels (i.e. simplified versions of full models) which are integrated together to create an integrated model capable of running quickly enough and yet providing a sufficient level of accuracy to meet management and planning needs. For Botany Bay the basic structure of the integrated model is given in Figure 20.

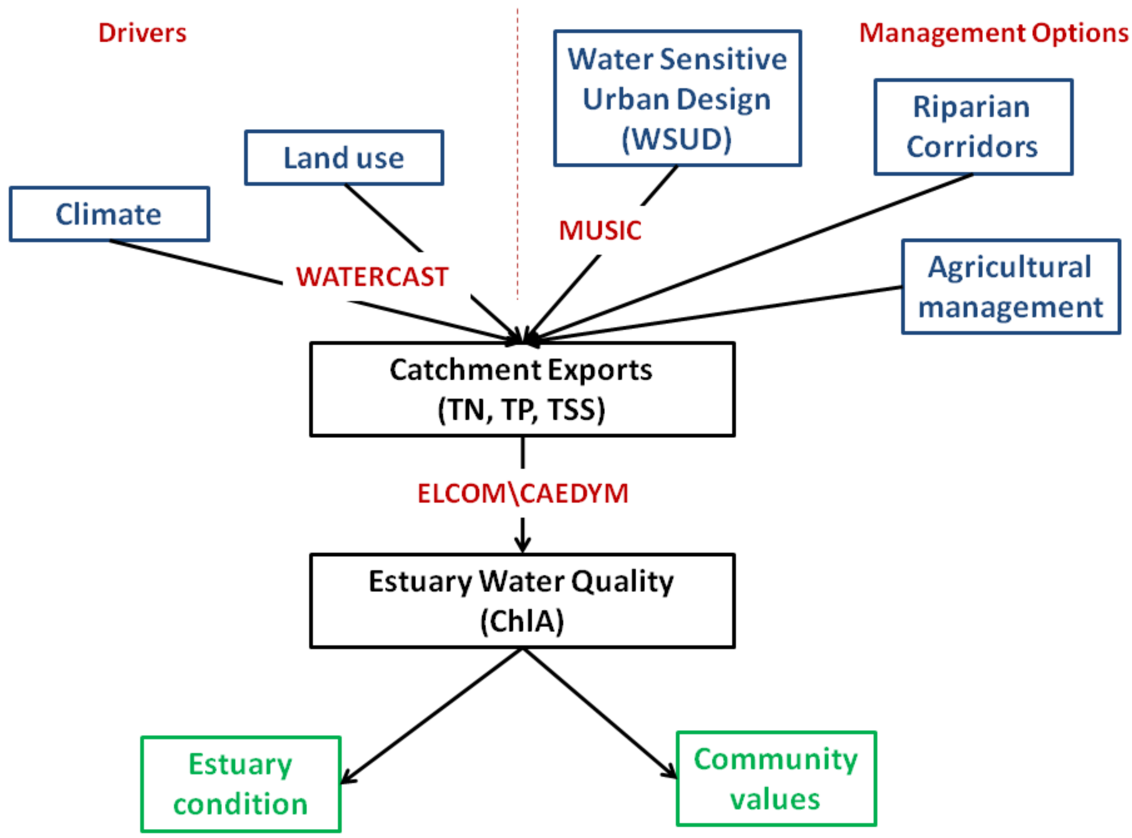


Figure 20. Structure of the model underlying the Botany Bay CAPER DSS

This figure shows that the integrated model contains a 'Catchment Exports' component that includes metamodels of: the Source Catchments model, linking climate and land use to flow, nutrient and sediment exports; the MUSIC model, providing the impacts of water sensitive urban design options on catchment exports; a model of the impact of riparian corridors on catchment exports, taken from a paper which reviewed results of a broad range of studies of these impacts from around the world; and, a simple agricultural management model, which allows for user defined agricultural land management scenarios to be considered. Both the Source Catchments model and MUSIC model were developed by BMT WBM, who also provided basic data inputs for the metamodel used in the DSS.

This metamodel then links to a metamodel of estuary water quality which relies on the ELCOM\CAEDYM model developed by DECCW(see SMCMA 2009a). This model links TSS and TN loads from the Catchment to estuary water quality as measured by Chl-A. The metamodel is based on interpolation of duration curves of Chl-A between modelled levels at specified levels of TN and TSS. The results used to develop the metamodel used in the DSS were provided by BMT WBM using the model developed by DECCW.

This metamodel then links to two small calculators: one for estuary condition, indicating the proportion of the time that the estuary will meet the ecological condition targets under each scenario; and one for community values, indicating the proportion of the time the estuary will meet threshold values allowing for community values to be met.

Accuracy of the component metamodels

The Catchment Exports model is reliant on the Source Catchments and MUSIC models. These models are highly accepted and used by hydrologists within Australia. Calibration and testing of these models was undertaken by BMT WBM. Flow results were found to by strongly correlated with available data. The metamodel of Source Catchments used inside the DSS was also tested. It was found that this model produced results within 1% of the original Source Catchments model. MUSIC model results are used directly within the DSS and so are not expected to be a source of error, although MUSIC model assumptions should be carefully noted when using the DSS. These are all documented within the DSS.

The Estuary Water Quality model is reliant on a receiving water quality model developed by DECCW. Subsequent testing of this model has raised questions about the reliability of the results. In particular the model appears to be relatively insensitive to catchment exports. Further analysis is on-going and it is recommended that results from this component of the DSS be used with extreme caution at this time.

How should the DSS be used?

It is important to understand that DSS does NOT make decisions. It can provide you with information that can support you in the decisions you need to make. It allows knowledge and rules to be applied consistently, over and over again. It can help you interpret information from models and other studies and can play a role in educating people. A good DSS should be easy to use and designed to provide information in the ways you need to make decisions.

The Botany Bay CAPER DSS can be used to assist with planning and evaluation of larger scale developments and management actions. It will provide you with easy to interpret impacts on catchment load and estuary health and can help you understand the trade-offs between different options. It will also give you information on the costs of management actions. It should be further improved over time so that, for example, when better modelling or data becomes available over time this is incorporated. If the DSS is not updated, such as to reflect new land use data layers, then it will become out of date.

The Botany Bay CAPER DSS does not allow examination of very small scale (e.g. single lot) developments. It doesn’t provide detailed spatial or temporal output (e.g. daily). Outputs are in terms of average annual loads and costs. For the estuary, results are given as median or other percentiles (75, 90) of concentrations as well as probabilities of exceedence of specific thresholds. The DSS will never tell you what the ‘best’ option is. It is designed to allow you to explore the trade-offs associated with a set of options. The best option will depend on available finances and community preferences and tolerance for impacts in the rivers, estuaries and Bay. Where detailed MUSIC modelling is undertaken it can be put into the DSS using the ‘User defined WSUD’ option to see the extent to which this helps meet Catchment or estuary targets.

Appendix 4. Reasonable Assurance Statement

The science that underpins this Plan has been undertaken in good faith, is of a high degree of rigour and employs methods that are considered 'best practice'. This science has been captured and applied for developing the Plan using the Botany Bay CAPER DSS. This DSS includes:

- A metamodel of the Source Catchments model developed by BMT WBM Pty Ltd for the Botany Bay Catchment. This metamodel reproduces the original model to within 1% of the total load.
- A metamodel of the ELCOM/CAEDYM receiving water quality model developed by DECCW. This model has some know issues with insensitivity to the input of pollutants. Work is currently underway to improve the responsiveness and calibration of this model. Once this work is complete both the Botany Bay DSS and the Plan will be updated. This will affect Section 3.5 of the Plan only and is likely to mean that the scenarios will be shown to have an increased impact on estuary condition.
- A metamodel of results from the MUSIC model on WSUD treatment trains. This information has been provided by BMT WBM Pty Ltd and has been reviewed by senior researchers with considerable experience in the design and implementation of WSUD treatment trains.
- Literature information on the impact of riparian interventions on pollutant loads in stream as well as cost information on previous riparian works provided by Great Lakes Council. Information on the effectiveness of riparian buffer has been taken from: Zhang, X. Liu, X., Zhang, M., Dahlgren, R.A., Eitzel, M. (2010) "Review of vegetated buffers and a meta-analysis of their mitigation efficiency in reducing non-point source pollution", Journal of Environmental Quality, 39:76-84. This paper provides a review of literature on the effectiveness of vegetated buffers in removing nutrients and sediments from runoff and develops mathematical equations to summarise these relationships.

Given the high quality of the scientific information used to construct this Plan, we can be reasonably certain that the scenarios outlined in this Plan will have a similar magnitude and direction of impact as described in this Plan. We have a high degree of confidence that these impacts will be sufficient to move the Botany Bay Catchment much closer to meeting ecological condition targets in the estuary.

Climate change scenarios are, by their nature, much less certain. They have been provided in an Appendix to this Plan in the spirit of exploration. They are intended to start the conversation on the potential consequences of climate change and do not provide accurate predictions of the future. Many potential consequences of climate change have not been considered in developing these results. These could potentially have impacts as great as any caused by changes in rainfall and evaporation on the Catchment.