11 November 2021

NSW Department of Planning, Industry and Environment
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Re: Draft State Environmental Planning Policy (Water Catchments) 2021 - feedback

To whom it may concern,

Thank you for the opportunity to provide comment on the Draft State Environmental Planning Policy (Water Catchments) (Catchment SEPP).

This is a joint submission by the Cooks River Alliance (CRA), Georges Riverkeeper (GRK), the Parramatta River Catchment Group (PRCG), and the Sydney Coastal Councils Group (SCCG). Together we represent 23 of 30 local Councils in Sydney.

As development authorities, councils will play a critical role in the implementation of the Catchment SEPP to ensure Sydney's catchments and waterways are protected. The Catchment SEPP, once enacted, will consolidate, replace and repeal multiple state environmental planning instruments. Consequently, these changes and subsequent enactment of the Catchment SEPP will have significant implications for the community and our member councils that could be felt for generations.

The Catchment SEPP presents a significant opportunity to improve on the existing legislation. This includes providing greater consistency and clarity to development authorities and developers whilst offering far better protection to our city's natural assets and the benefits that they bring to the region's social and economic fabric. However, we feel that the draft Catchment SEPP in its current form falls well short of this unique opportunity.

Lack of engagement with Councils and Catchment Groups during the development of the Catchment SEPP

We would like to applaud the consultation process for the SEPP (Environment) Explanation of Intended Effect (EIE) during October 2017 – January 2018. This consultation was thorough and included a reasonable time frame for a considered submission to be prepared. All four catchment groups provided a detailed submission at that stage of the process.

Unfortunately, this level of consultation has not carried on throughout the process. Following the closing of submissions in January 2018, as far as we are aware, nothing has occurred until 28 October 2021, where we were given 15 days to submit feedback on the Catchment SEPP. Due to staff turnover and changing email addresses, in the end we had effectively only one week to read the documentation provided, familiarise ourselves with our submissions from four years ago, digest the details of the EIE, and determine if the draft Catchment SEPP was a true representation of the EIE and our feedback. Because this time frame is far too short to provide detailed and considered feedback, it greatly diminishes the authority and authenticity of the consultative process undertaken by at the NSW Department of Planning, Industry and Environment (DPIE).

Further, local councils are now in caretaker mode ahead of local government elections. Consequently, the ability to acquire considered feedback from locally elected representatives is not practically possible, further diminishing the democratic authority of the draft Catchment SEPP consultation process.

Recommendation: Develop a consistent consultation process for consulting with councils and their catchment groups for all environmental and planning instruments produced by DPIE and mandate that this process is followed. This process needs to allow for a reasonable amount of time to develop considered feedback, including opportunities for dialogue with relevant DPIE representatives.

We understand that the development of the Catchment SEPP was purely to consolidate several similar SEPPs into one SEPP. This has highlighted several opportunities that we believe can be taken to improve on the SEPP to further clarify development constraints for councils and developers, and to better protect the Sydney natural areas to the benefit of our community and for generations to come. However, since nothing new has been added to the draft Catchment SEPP, and a considerable amount of time has been lost, we feel it is imperative that a detailed review occur subsequent to its enactment.

Our recommendations for improving the Catchment SEPP are detailed below. Given the fast pace of development within Greater Sydney, we consider the following recommendations to be urgent. This is because, with each passing year, developments that occur without these recommendations will represent opportunities lost to protect Sydney's natural assets and, accordingly, reduce the liveability of our city and our region for generations to come.

The Cooks River Catchment is not included in the Catchment SEPP

We understand that the Catchment SEPP is a consolidation of existing SEPPs and Regional Environmental Plans. However, there are no existing SEPPs or Regional Environmental Plans for the Cooks River Catchment; a well-recognised and problematic gap in existing planning instruments. Consequently, and concerningly, this gap continues to be carried over into the Draft SEPP, leaving the Cooks River catchment at high risk of development not conducive to the needs of the river and, therefore, the community.

Taking into account the implications of this omission, and the intent of the EIE to address such gaps, we consider this situation to be untenable. Currently the Catchment SEPP includes: the Sydney Drinking Water Catchment (from Lithgow south to Braidwood and from Wollondilly west past Goulburn to Taralga, Crookwell, and Oberon), the Sydney Harbour catchment, the Georges River catchment and the Hawkesbury-Nepean catchment. To exclude the Cooks River catchment, which lies between the Sydney Harbour and Georges River catchment, is clearly inconsistent with the intention of the EIE and should be corrected in the Catchment SEPP before it is enacted.

Recommendation: The Cooks River catchment be included as a regulated catchment.

Draft Maps provided do not provide a consistent approach

Providing the Catchment SEPP Maps online offers transparency and efficiencies which the catchment groups and councils appreciate. Their publication via the Planning Portal would have multiple benefits.

The Catchment SEPP only reflects the mapping previously completed for the proposed repealed SEPPs, resulting in inconsistencies in the mapping component of the Catchment SEPP. Consequently, multiple seagrass and critical habitats across the region will not be protected if the draft Catchment SEPP is enacted in its current form. For example,

- The rocky foreshores and seagrasses areas that are mapped in the Draft Catchment SEPP apply only to Sydney Harbour. None of the other catchments are mapped and, therefore, are not afforded any protection under the current draft Catchment SEPP.

- Extensive seagrasses that have been mapped in the Upper, Mid and Lower Georges River are not included in the current draft Catchment SEPP. This is also the case for the Towra Point Aquatic and Nature Reserve, which is a Ramsar Site incorporating endangered seagrasses. Consequently, these seagrass areas will not be protected under the current draft Catchment SEPP.

- With the exception of the critical habitat for Sydney's Little Penguin population, recognised critical habitats and their associated endangered and threatened species are also not captured by the current draft Catchment SEPP.

Recommendation: Additional work be done to create consistency in the mapping to allow for greater protection of rocky foreshores, seagrasses, critical habitat, endangered and threatened species throughout all of the regulated catchments.

Including water quality or stormwater targets, excluding weak language

Water quality or stormwater targets were not discussed or set in the Catchment SEPP. This is a serious and significant omission in the Draft Catchment SEPP. As other jurisdictions demonstrate (e.g., Victorian Planning Provisions), setting targets provides a practical and essential basis for planning and designing appropriate development that minimises catchment impacts and protects our waterways.

In place of targets, language currently used in the Catchment SEPP is ambiguous and doesn't provide the level of clarity or the rigour required to protect Sydney's natural assets. Words like 'as close as possible' and 'must be minimised' and 'must be considered' cannot be adequately interpreted without supporting guidelines or standards that incorporate water quality targets.

For example, Part 2, Division 2, 13 Total Catchment Management of the draft Catchment SEPP states: "In deciding whether to grant development consent to development on land in a regulated catchment, the consent authority must consult with the council of each adjacent or downstream local government area on which the development is likely to have an adverse environmental impact." The details of what this consultation must entail are not articulated and, consequently, 'consultation' could mean as little as a letter informing downstream councils that development and subsequent pollution will occur. Accordingly, for this passage to have any concrete meaning, an authentic engagement process and framework must be developed.

Recommendation: Include water quality and stormwater targets. Make the language more robust and less vague. Develop a consultation framework / process.

Detailed and appropriate Guidelines are needed for the implementation of the Catchment SEPP

We strongly assert that guidelines and / or standards for the implementation of the Catchment SEPP are created in consultation with the catchment groups and councils. Given the lack of detail and process provided in the Catchment SEPP, the absence of such guidelines and standards renders much of the draft SEPP effectively inoperable. We believe guidelines and standards for implementation would be beneficial for the following reasons:

- The wording of many of the clauses in the Catchment SEPP is far too ambiguous, leaving too much open to interpretation. This will likely cause significant confusion for development authorities and developers. In order to optimise protection of the environment and provide clarity for councils and developers, more explanation of how to implement the Catchment SEPP and its requirements is sorely needed.

- It would be prudent and beneficial to allow for guidelines and documentation to be included as they are developed. This will ensure that as science and knowledge improves, so too will the implementation of the Catchment SEPP.

Recommendation: In consultation with catchment groups and councils develop a set of guidelines for the implementation of the Catchment SEPP.

Finally, and importantly, we acknowledge and sincerely appreciate the time taken by Daniel Cutler and Danijela Karac from DPIE, to speak with us about the draft Catchment SEPP and our submission.

Thank you for the opportunity to provide feedback and we would be happy to discuss any of the above points to progress the adoption and implementation of the Catchment SEPP.

Yours sincerely,

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Part E – General Controls – Environmental Controls

Chapter E15: Water Sensitive Urban Design

Contents

1 INTRODUCTION

This chapter of the DCP outlines Council's requirements for the incorporation of Water Sensitive Urban Design for certain development types.

The integration of urban water cycle management with urban planning and design is known as Water Sensitive Urban Design (WSUD). WSUD is a holistic approach to the planning and design of urban development that aims to minimise negative impacts on the natural water cycle and protect the health of aquatic ecosystems. WSUD promotes the integration of stormwater, water supply and wastewater management at the development stage. WSUD requires the consideration of the urban water cycle at the early planning stage to ensure all possible opportunities for application of best practice water cycle management solutions can be realised. The urban water cycle involves the cycling of water through the urban environment.

WSUD promotes innovative integration of urban water management technologies into an urban environment.

This chapter focuses on WSUD stormwater quality management and improvement measures only and should be specifically read in conjunction with the Stormwater Management and Floodplain Management chapters contained in Part E of this DCP.

This chapter should also be read and applied in conjunction with other parts of the DCP, especially Part D of the DCP which provides Council's requirements for residential subdivision, residential development, mixed use development, industrial development / subdivision and development in the business zones.

2 OBJECTIVES

1. The main objectives of water sensitive urban design are:

(a) To sustainably integrate natural systems with urban development.

(b) To integrate stormwater drainage treatments into the landscape.

(c) To ensure water sensitive urban design treatment measures are incorporated in new developments taking into account stormwater management and floodplain management issues.

(d) To improve the potential for urban run-off reuse.

(e) To minimise the volume of stormwater run-off.

(f) To protect the quality of water run-off from urban development.

(g) To reduce run-off and peak flows from urban developments by local detention basins and minimising impervious areas, wherever practicable.

(h) To preserve, restore and enhance riparian corridors as natural systems.

(i) To minimise the drainage infrastructure cost of development.

3 KEY PRINCIPLES OF WATER SENSITIVE URBAN DESIGN (WSUD)

1. The key principles of WSUD are to:

   (a) Protect existing natural features and ecological processes.

   (b) Maintain the natural hydrologic behaviour of catchments.

(c) Protect water quality of surface and ground waters.

(d) Minimise demand on the reticulated water supply system.

(e) Minimise sewage discharges to the natural environment.

(f) Integrate water into the landscape to enhance ecological, visual, social, economic and cultural values.

4 DEVELOPMENT TO WHICH THIS POLICY RELATES

1. The incorporation of appropriate water sensitive urban design measures may be required for the following types of development (subject to Council's confirmation at the formal pre-lodgement meeting):

   (a) Residential land subdivisions involving 50 or more proposed allotments.

   (b) Medium density housing involving 20 or more dwellings.

   (c) Residential apartment buildings involving 20 or more residential apartments.

   (d) Mixed use developments involving 20 or more residential apartments or a gross floor area of 3,000 square metres or more (whichever the lesser).

   (e) Serviced apartment or hotel developments.

   (f) Industrial developments (including major alterations and additions to existing industrial buildings) involving a site area of 2 hectares or more.

   (g) Industrial subdivisions involving 10 or more proposed allotments or a site area of 2 hectares or more (whichever is the lesser).

   (h) Business parks.

   (i) Commercial office developments involving a gross floor area of 10,000 square metres or more.

5 STORMWATER TREATMENT TRAINS

1. A series of treatment measures that collectively address all stormwater pollutants is termed a "treatment train". The selection and order of treatments is a critical factor in developing treatment trains. The coarse fraction of pollutants generally requires removal so that treatments target fine pollutants can operate effectively. The proximity of a treatment to its source and the distribution of treatments throughout a catchment are other factors which are important in developing a treatment train.

2. Stormwater treatments that target the removal of gross pollutants and coarse sediments such as gross pollutant traps (GPTs) and sedimentation basins can operate under high hydraulic loading and can treat high flow rates.

3. As the target pollutant particle size reduces, the nature of the treatment process changes to include enhanced sedimentation, bio film absorption and biological transformation of the pollutants. The treatment processes include grass swales, vegetated buffer strips, surface wetlands and infiltration systems which require longer detention times than for GPTs, in order to

allow various pollutant removal processes to occur. The hydraulic loading on these treatment processes is relatively low in comparison to gross pollutant removal measures.

4. A treatment train consists of a combination of treatment measures that can address the range of pollutant particle sizes in stormwater. Therefore, a treatment train employs a range of processes to achieve pollutant reduction targets such as physical screening, enhanced sedimentation and filtration.

6 SELECTING A WSUD TREATMENT MEASURE

1. The Water Sensitive Urban Design (WSUD) treatment measures can be grouped into three (3) main categories, namely:

   (a) *Primary Treatment* – Physical screening or rapid sedimentation techniques – gross pollutants and coarse sediments.

   (b) *Secondary Treatment* – Finer particle sedimentation and filtration techniques – fine particles and attached pollutants.

   (c) *Tertiary Treatment* – Enhanced sedimentation and filtration, biological uptake, absorption onto sediments.

2. The CSIRO *Urban Stormwater : Best Practice Environmental Management Guidelines* 1999 recommends that a range of treatments may be required to reduce one or more of the following pollutant categories, in order to protect receiving waters:

   (a) *Gross pollutants* – trash, litter and vegetation larger than 5 millimetres;

   (b) *Coarse sediment* – contaminant particles are between 5 millimetres and 0.5 millimetres;

   (c) *Medium sediment* – contaminant particles are between 0.5 millimetres and 0.062 millimetres;

   (d) *Fine sediments* – contaminant particles are smaller than 0.062 millimetres;

   (e) *Attached pollutants* – Those pollutants that are attached to fine sediments, specifically, nutrients, heavy metals, toxicants and hydrocarbons and / or;

   (f) *Dissolved pollutants* – typically, nutrients, heavy metals and salts.

7 TYPES OF WATER SENSITIVE URBAN DESIGN (WSUD) TREATMENT MEASURES

7.1 General

1. The main WSUD treatment measures include:

   (a) Rainwater tanks.

   (b) Gross Pollutant Traps / Litter Traps.

   (c) Grassed and Vegetated Swales.

   (d) Bio-Retention Systems.

(e) Bio-Retention Basins.

(f) Sedimentation Basins.

(g) Constructed Wetlands.

(h) Infiltration Measures.

(i) Aquifer Storage and Recovery.

(j) Porous Pavements.

2. The role and function level of the various WSUD treatment measures is summarised in the following Table 1:

Table 1: Primary Role and Function of WSUD Treatment Measures

WSUD Treatment Measure	Water Quality Function	Water Quantity Function
Rainwater Tanks	Low	High
Gross Pollutant Traps (GPTs)	High	Low
Grassed and Vegetated Swales	High	Low
Bio-retention Systems	High	Medium
Bio-retention Basins	High	Medium
Sedimentation Basins	High	Medium
Constructed Wetlands	High	Low
Infiltration Measures	High	Medium
Aquifer Storage and Recovery	Medium	Low
Porous Pavements	Medium	Medium

7.2 Rainwater Tanks

1. Rainwater tanks reduce the hydraulic loading supplied to on-site treatment measures (therefore improving treatment measures) and act as detention systems for storing rainfall that would otherwise be conveyed to a point of discharge.

2. The water from a rainwater tank may be used for internal toilet flushing and hot water uses and for external uses such as watering gardens, car washing and topping up swimming pools etc.

3. Rainwater tanks are a suitable WSUD element for all scales of residential, mixed use, commercial and industrial development.

4. Rainwater tanks are particularly suited to detached housing, multi dwelling developments and high density residential apartment buildings and mixed use buildings where a greater proportion of the site (roofing area) contributes to rainwater tanks and minimises adverse effects associated with stormwater runoff.

5. Where rainwater tanks are not fitted during the initial development phase, it is recommended that the development be designed to enable the retrofitting of rainwater tanks at a later stage.

6. Rainwater tanks must be:

   (a) Sized to have a rainwater storage volume not less than that required by any BASIX

   Certificate issued for the development, and configured in accordance with the requirements of that Certificate;

   (b) Sized to have a rainwater storage volume not less than that defined in this DCP;

   (c) Designed and located to capture rainwater from at least 50 per cent of the roof area in low and medium-density residential developments, and 100 per cent of the roof area for high-density residential developments;

   (d) Designed and connected to provide water at least for site irrigation (garden watering etc.) and toilet flushing;

   (e) Fitted with a first-flush device, which diverts a maximum of 1mm of roof water. The device is to include a primary litter/leaf mesh screen and a first-flush containment storage with a small orifice to empty the storage between rain events. The first-flush water is to be directed to a vegetated area or other WSUD measure, before discharging to the drainage system;

   (f) Designed and configured to ensure provision of water for all purposes in the event of a power failure or the tank water level falling below a defined level or volume. This may comprise:

      (i) A bypass mechanism to allow mains water to be used for toilet flushing, site irrigation etc. in the event of power failure disabling the pump (subject to water authority approval). The tank bypass line must incorporate an appropriate backflow prevention device; or

      (ii) A float-valve system (or equivalent) to allow the tank to be filled to a pre-determined level when the tank water level fall below a defined volume.

   (g) Designed so the overflow drains to a bio-retention system and may incorporate additional storage volume for (temporary) on-site detention of stormwater.

7.3 Gross Pollutant Traps (GPTs)

1. A gross pollutant trap (GPT) is a sediment trap incorporating a litter or trash rack (with vertical steel bars), at the downstream end of the trap.

2. Gross pollutant traps (GPTs) are designed to screen and trap litter and debris before it enters watercourses. Some GPTs also remove bed load sediments and some suspended sediments through rapid sedimentation. Gross pollutant traps are used in conventional drainage systems either in stormwater drainage pipes, at outfalls and in open channels and may also be used as pre-treatments for WSUD elements including the protection of rehabilitated waterways.

3. Gross pollutant traps generally remove coarse litter and sediment greater than 5 millimetres.

4. Gross pollutant traps enable coarse sediments to settle to the bottom by decreasing the stormwater flow velocity. This is achieved by increasing the width and depth of the channel of the GPT wet basin. The trash rack at the downstream end of the basin is intended to collect floating and submerged debris as per a conventional trash rack.

5. Gross pollutant traps are designed to retain solid litter that has washed into the system without retarding flows or increasing water levels in the drainage system. However, many water sensitive urban design (WSUD) elements do not require a GPT as the entry of litter and debris into the stormwater system can be restricted by filtration media.

6. The type and capacity of the GPT should be based upon the likely pollutant loading expected which may be determined using computer simulation modelling.

7. The selection and design of the GPT is dependent upon the land uses in the catchment, the likely pollutants and the treatment provided upstream. In this regard, GPTs can be designed for different catchment scales from less than one (1) hectare to more than 100 hectares. Different GPTs employ different methods of litter separation and containment and their performance varies greatly.

8. The regular maintenance of the GPT structure is required and involves the removal of litter and debris as well as the removal of collected coarse sediment.

7.4 Vegetated or Grassed Swales

1. Swales are vegetated or grass lined channels used as an alternative to kerb and channel.

2. Vegetated swales are used to convey stormwater in lieu of underground stormwater piped drainage systems and are designed to remove coarse and medium sediment.

3. Swales are beneficial in providing a ‘buffer’ between the receiving water and the impervious areas of a catchment such as roads. Swales work by interacting and slowing stormwater runoff as it passes through a locality. This control of flow means pollutants can settle in the vegetation contained in the swale.

4. Swales form part of an overall stormwater ‘treatment train’ to deliver acceptable stormwater quality for discharge to aquatic ecosystems or for potential reuse applications.

5. Swales should also be designed to disconnect impervious areas from hydraulically efficient piped drainage systems, in order to protect aquatic ecosystems in receiving waterways by managing the frequency of damage to aquatic habitats by storm flows. This is achieved by slower travel times for flows along swale systems compared with efficient pipe drainage systems. This reduces the rapid response from impervious areas, particularly for frequent storm events and resultant impact on natural receiving waterways.

Figure 3: Example of grassed swale (top) and vegetated swale (bottom) (Source: Water Sensitive Urban Design of the Sydney Region)

6. The longitudinal slope of a swale is recommended to be between 2% to 4%, in order to prevent any water ponding or water logging problems on sites. Steeper slopes (greater than 4%) are not recommended given potential embankment scouring and erosion problems along the swale. However, if steeper slopes cannot be avoided, the provision of dense vegetation, check banks along swales and / or drop structures may help to distribute flows evenly across the swales and to assist in slowing runoff velocities. The creation of check banks may be achieved through depressions in the grassed invert level of the channel. A porous base or infiltration trench with perforated drain is required below the check dam area.

7. A filtration trench or sub-soil drain system is required under the invert level of swales with longitudinal slopes of less 2% to prevent water ponding.

8. Swales with longitudinal slopes of 2% or less should be “V” shaped, whereas swales with slopes greater than 2% should incorporate wider parabolic shaped bases.

9. Vegetation is an integral component of swales since it promotes constant distribution and retardation of flows. Vegetation is required to cover the full width of a swale and be designed to withstand the likely design flows and velocities. The vegetation of the swale must also be of a sufficient density in order to guarantee significant contact between flows and vegetation.

10. If run-off enters a swale as distributed flow (ie perpendicular to the main flow direction), the swale batter receiving the inflows acts as a vegetated buffer and can provide an important pre-treatment function for the swale by removing coarse sediment prior to flows concentrating along the invert of the swale.

Figure 6: Examples of grassed swale (Source: Water Sensitive Urban Design of the Sydney Region)

Figure 7: (Top left) Examples of Vegetated Swale (Source: Water Sensitive Urban Design of the Sydney Region)

7.5 Buffer Strips

1. Buffer strips provide discontinuity between impervious surfaces and the drainage system. Buffer strips should be placed lower than the road surface to allow for sediment accumulation. The set down required is a trade-off between potential scouring effect and providing adequate depth to enable the sufficient build-up space for accumulated sediment.

7.6 Bio-Retention Swales

General

1. Bio-retention swales (or bio-filtration trenches) are treatment systems that are located at the downstream end of a swale (ie immediately upstream of the swale overflow pit). Bio-retention swales provide both stormwater treatment and conveyance functions. The swale component provides a stormwater pre-treatment function by removing coarse to medium sediments whilst the bio-retention system removes finer particles and associated pollutants.

2. Bio-retention swales provide efficient treatment of stormwater through fine filtration, extended detention treatment with some biological uptake. Bio-retention swales are very efficient at removing nitrogen and other soluble or fine particulate contaminants and provide a run-off conveyance function along the full length of the swale.

3. Runoff is filtered through a filter media as it percolates downwards under gravity. The filtered runoff is then collected at the base of the filter media via perforated pipes and flows to downstream watercourses or to storages for potential reuse.

4. The reduction of runoff volumes can be primarily attributed to maintaining soil moisture of the filter media and evapotranspiration losses.

5. The longitudinal slope of a bio-retention swale should be between 2% to 4%, in order to prevent any water ponding or water logging problems on sites.

Vegetation in Bio-retention Swales

1. Vegetation that grows in the filter media of bio-retention swales is an integral component of these treatment measures.

2. Bio-retention swales can use a variety of vegetation types including turf (swale component only), sedges and tufted grasses. Vegetation is required to cover the whole width of the swale and bio-retention filter media surface. The vegetation must be capable of withstanding design flows and be of sufficient density to prevent preferred flow paths and scour of deposited sediments.

3. Grassed (turf) bio-retention swales may be used in a residential or industrial subdivision where a continuous bio-retention trench approach is used. However, grassed bio-retention swales need to be mown to protect the conveyance capacity of the swale component and therefore repeated mowing of the grass over a continuous bio-retention trench can result in long term compaction of the filter media and reduce its treatment performance. Therefore, the preferred vegetation type for bio-retention swales is sedges and tufted grasses (with potential occasional tree plantings) that do not require mowing.

4. The denser and taller the vegetation planted in the bio-retention filter media, the better the treatment provided, especially during extended detention. Taller vegetation has better interaction with temporarily stored stormwater during ponding, which results in enhanced sedimentation of suspended sediments and associated pollutants. The vegetation that grows in the bio-retention filter media also acts to continuously break up the surface of the media through plant root growth and wind induced agitation, which prevents surface clogging. Vegetation also provides a substrate for bio-film growth in the upper layer of the filter media which facilitates biological transformation of pollutants (particularly nitrogen).

5. Dense vegetation planted along the swale component can also offer improved sediment retention by reducing flow velocity and providing vegetation enhanced sedimentation for deeper flows. However, densely vegetated swales have higher hydraulic roughness and therefore require a larger area and/ or more frequent use of swale field inlet pits to convey flows compared to grass swales. Densely vegetated bio-retention swales can become features of an urban landscape and once established, require minimal maintenance and are hardy enough to withstand large flows.

6. Bio-retention swales may be located within passive open space areas, car parks or along roadway corridors within road verges or centre medians. Landscape design of bio-retention swales along the road edge can assist in defining the boundary of road corridors as well as providing landscape character and amenity. It is therefore important that the landscape design of bio-retention swales addresses stormwater quality objectives whilst also being sensitive to stormwater flow requirements and as well as these other important landscape functions.

7.7 Bio-Retention Basins

General

1. Bio-retention basins operate with the same treatment processes as bio-retention swales but do not have a conveyance function. High stormwater runoff flows are bypassed away from the bio-retention basin or are discharged into an overflow structure.

2. Bio-retention basins should be designed to provide efficient treatment of stormwater through fine filtration, extended detention treatment and some biological uptake, particularly for nitrogen and other soluble or fine particulate contaminants.

3. Bio-retention basins can be installed in a range of scales and shapes with smaller systems taking the form of planter beds in car park areas or within the verge of the footpath area. Larger bio-retention basins may be constructed at the outfall of a drainage system, to provide suitable end of pipe treatment to runoff from larger sub-catchments.

4. Bio-retention basins must be located, configured and designed to treat runoff from at least 90 per cent of the impervious area of the site (i.e. driveway, paved areas and any roof area not draining to a rainwater tank). Vegetated filter strips should be located between impervious areas and the bio-retention measure wherever possible.

5. Bio-retention basins must have temporary storage (detention) depth 150mm and a filter media depth of not less than 600mm.

Figure 8: Examples of Bio-Retention Basins (Source: Water Sensitive Urban Design of the Sydney Region)

6. Bio-retention basins must be constructed using a loamy sand filter medium of the following characteristics:

   (a) Well graded, with no gaps in the particle size distribution.

   (b) Total silt and clay content of less than 3 per cent w/w.

   (c) Organic matter content of less than 5 per cent w/w.

   (d) Not hydrophobic and not indicate dispersive properties.

7. Bio-retention basins must incorporate an impervious liner where surrounding soils are likely to be sensitive to any exfiltration from the bio-retention measure (e.g. sodic soils, shallow groundwater or close proximity to significant structures).

8. Bio-retention basins must be planted with hardy plants that are able to withstand prolonged periods of dry and wet conditions (preferably local indigenous plants). Plants with extensive and deep root systems will provide the best water quality treatment.

Hydraulic Design of Bio-retention Basins

1. The hydraulic design of a bio-retention basin is critical in ensuring the effective stormwater treatment performance of the basin as well as protecting the hydraulic integrity and function of associated minor and major drainage systems, to minimise storm flow damage.

2. The following aspects are critical in the design of an effective bio-retention basin:

   (a) The finished surface of the bio-retention filter media must be horizontal (i.e. flat) to ensure full engagement of the filter media by stormwater flows and to prevent concentration of stormwater flows within depressions and ruts resulting in potential scour and damage to the filter media.

   (b) The temporary ponding of up to 0.3 metres depth over the surface of the bio-retention filter media (ie created through the use of raised field inlet pits (overflow pits)) can assist in managing flow velocities over the surface of the filter media as well as increase the overall volume of stormwater runoff that can be treated by the bio-retention filter media.

(c) The overflow pit or bypass channel should be located near the inflow zone to prevent high flows passing over the surface of the filter media. If this is not possible, then velocities during the minor (2-10 year ARI) and major (50-100 year ARI) floods should be maintained sufficiently low (preferably below values of 0.5 m/s and not more than 1.5 m/s for major flood) to avoid scouring of the filter media and vegetation.

(d) Where the field inlet(s) in a bio-retention system is required to convey the minor storm flow (i.e. is part of the minor drainage system), the inlet must be designed to avoid blockage, flow conveyance and public safety issues.

7.8 Sedimentation Basins

1. Sedimentation basins are designed to retain coarse sediments from run-off and are generally the first element in a treatment train. Sedimentation basins are primarily used for the trapping of sediments in runoff from construction sites and as pre-treatment measure, in order to protect downstream stormwater treatment measures (eg wetlands) from becoming overloaded with sedimentation.

2. Sedimentation basins operate by reducing flow velocities and encouraging sediments to settle out of the water column. The recommended target particle size is 0.125mm for the design of a sediment basin.

Figure 9: Examples of Bio-Retention Basins (Source: Water Sensitive Urban Design of the Sydney Region)

3. Sedimentation basins are typically constructed as ephemeral basins so that they drain during prolonged dry periods and refill only during rainfall runoff events.

4. Sedimentation basins are also generally constructed to a maximum depth of 1.5 metres to 2 metres, in order to allow sufficient depth for sediment accumulation whilst minimising the potential for fringing aquatic macrophytes to colonise the basin.

5. Enhanced sedimentation processes allow finer particles to settle within the basin.

6. The large quantity of coarse sediment carried in stormwater will require a suitable maintenance regime, to enable regular removal of sediment from the sediment basin. In this regard, the maintenance regime should involve processes which separate the coarser sediment from the finer sediment material since the fine sediment material typically contains the higher concentration of contaminants such as hydrocarbons and / or heavy metals.

7. The batter slopes on approaches and immediately beneath the permanent water level within a sedimentation basin, must be designed to ensure public safety.

8. The public safety requirements will vary from site to site and requires careful consideration. The maximum batter slope for a sedimentation basin should be 1 in 5 (Vertical: Horizontal).

7.9 Constructed Wetlands

7.9.1 General

1, Constructed wetlands are generally shallow water bodies with extensive aquatic vegetation.

2. Constructed wetlands generally consist of:

   (a) An inlet zone (or sediment basin) regulates water flow runoff into the wetland and removes coarse sediments;

   (b) A marcophyte zone which is a shallow heavily vegetated area to remove fine particulates and uptake of soluble pollutants; and

   (c) A high flow bypass channel which is designed to protect the macrophyte zone from high velocity flood flows.

3. Wetland processes are improved by slowly passing runoff through heavily vegetated areas, allowing plants to filter sediments and pollutants from the water. Bio-films which grow on plants absorb nutrients and other contaminants.

4. Wetlands can also provide a flood protection function when used as a detention basin. Additionally, wetlands can also provide a water storage function for later reuse for spray irrigation purposes.

5. Constructed wetlands are designed to mimic the natural efficiency of these areas in treating both the quality and peak discharge flow rate of large stormwater flows.

6. Constructed wetlands are typically best suited to large scale residential or industrial subdivisions and are designed as end of line treatment devices.

7.9.2 Inlet Zone of a Constructed Wetland

1. The inlet zone of a constructed wetland is designed as a sedimentation basin and serves two functions: (1) pre-treatment of inflow to remove coarse to medium sized sediment; and (2) the hydrologic control of inflows into the macrophyte zone and bypass of floods during ‘above design’ operating conditions.

2. The inlet zone in a constructed wetland should contain the following elements:

   (a) A sedimentation basin ‘pool’ to capture coarse to medium sediment (125 μm or larger).

   (b) An inlet zone connection to the macrophyte zone consisting of an overflow pit within the inlet zone connected to one or more pipes through the embankment separating the inlet zone and the macrophyte zone.

   (c) High flow bypass weir (or ‘spillway’ outlet structure to deliver ‘above design’ flood flows to the high flow bypass channel.

   (d) The inlet zone typically must comprise a deep open water body (> 1.5m) that operates essentially as a sedimentation basin designed to capture coarse to medium sized sediment (i.e. 125 μm or larger).

(e) A Gross Pollutant Trap (GPT) may need to be installed such that litter and large debris can be captured at the interface between the incoming waterway or pipe and the open water of the inlet zone.

(f) The crest of the overflow pit must be set at the permanent pool level of the inlet zone (which is typically set 0.3 metres above the permanent water level of the macrophyte zone).

(g) The dimension of the overflow pit (control structure) should be set at the permanent pool level of the inlet zone (which is typically set 0.3 metre above the permanent water level of the macrophyte zone).

(h) The pipe that connects the sedimentation basin to the macrophyte zone needs to have sufficient capacity to convey a 1 year ARI flow, assuming the macrophyte zone is at the permanent pool level and without resulting in any flow over the high flow bypass weir.

(i) An energy dissipater is generally required at the end of the pipes to reduce velocities and distribute flows into the macrophyte zone.

(j) The inlet zone is to have a structural base (e.g. rock or concrete) to define the base when desilting and provide support for maintenance plant/ machinery when entering the basin for maintenance.

(k) The high flow bypass weir ('spillway' outlet) is to be set at the same level as the top of extended detention in the macrophyte zone.

7.9.3 Macrophyte Zone Design Considerations

1. The layout of the macrophyte zone is recommended to be designed to ensure that the hydraulic efficiency of the system is optimised and healthy vegetation is sustained over the long term.

2. The general design considerations for the layout of the macrophyte zone within a constructed wetland include (but are not necessary limited to) the following:

(a) The preferred extended detention depth is 0.5 metres. Deeper extended detention depths up to a maximum of 0.75 metres may be acceptable where the wetland hydrologic effectiveness is greater than 80% and where the botanic design uses plant species tolerant to greater depths of inundation.

(b) The bathymetry of the macrophyte zone should be designed to promote a sequence of ephemeral, shallow marsh, marsh and deep marsh zones in addition to small open water zones. The relative proportion of each zone will be dependent on the target pollutant and the wetland hydrologic effectiveness.

(c) The macrophyte zone is required to retain water permanently and therefore the base must be lined with a suitable clay material to retain water. If in-situ soils are unsuitable for water retention, a clay liner (ie compacted a minimum 300mm thick) must be used to ensure there will be permanent water for vegetation and habitat.

(d) The bathymetry of the macrophyte zone should be designed so that all marsh zones are connected to a deeper open water zone to allow mosquito predators such as frogs to seek refuge in the deeper open water zones during periods of extended dry weather.

(e) The placement of the inlet and outlet structures and the length to width ratio of the macrophyte zone and flow control features are particularly critical, in order to promote a high hydraulic efficiency within the macrophyte zone.

(f) The constructed wetland should be designed to enable draining of the macrophyte zone for water level management, during the plant establishment phase.

(g) The macrophyte zone outlet structure needs to be designed to provide a notional detention time (usually 48 to 72 hours) for a wide range of flow depths. The outlet structure should also include measures to exclude debris to prevent clogging.

7.9.4 Wetlands Constructed within Retention (or Detention) Basins

1. Wetlands may in some cases be constructed at the base of retention basins, thus reducing the land required for stormwater treatment. In these situations, wetland systems may occasionally become inundated to greater depths than the extended detention depth; however, the inundation duration is generally relatively shorter (hours) and is unlikely to affect the wetland vegetation provided there is a safe pathway to drain the wetland following flood events which avoids scour of the wetland vegetation and banks.

2. When designing a wetland within a retention basin, the outlet control structure of the retention basin (typically culverts) should be placed at the end of the wetland bypass channel. This ensures flood flows ‘backwater’, across the wetland thus protecting the macrophyte vegetation from scour by high velocity flows.

Figure 10: Example of a constructed wetland (left) and a constructed wetland within a retention basin (Source: Water Sensitive Urban Design of the Sydney Region)

7.9.5 Vegetation Type

1. Vegetation planted in the macrophyte zone has an important functional role in treating stormwater flows as well as adding aesthetic value. Dense planting of the littoral zone will also inhibit public access to the macrophyte zone, minimising potential damage to wetland plants and reducing the safety risks posed by water bodies.

2. The plant species for the constructed wetland should be selected based on the hydrologic regime, microclimate and soil types of the locality and physiological and structural characteristics, natural distribution of the wetland plants. The planting densities should ensure that 70 - 80 % cover is achieved within two growing seasons (2 years). The distribution of the species within the wetland should relate to their structure, function, relationship and compatibility with other species.

7.9.6 Wetland Design to Reduce Mosquito Incidence

1. The following aspects should be considered in the design of a constructed wetland, in order to minimise the incidence of mosquitoes:

(a) Access for mosquito predators such as frogs, fish and predatory insects, to all parts of the water body (avoid stagnant isolated areas of water).

(b) Provision for a deep sump of permanent water (for long dry periods or for when water levels are artificially lowered) so that mosquito predators such as frogs may seek refuge and maintain a presence in the wetland.

(c) Maintaining natural water level fluctuations that disturb the breeding cycle of some mosquito species.

(d) Wave action from wind over open water will discourage mosquito egg laying and disrupt the ability of larvae to breathe.

(e) Providing a bathymetry such that regular wetting and drying is achieved and water draws down evenly so isolated pools are avoided.

(f) Providing sufficient gross pollutant control at the inlet such that human derived litter does not accumulate and provide breeding habitat.

(g) Ensuring overflow channels don't have depressions that will hold water after a storm event.

2. Each case has to be considered on its own merits. It may be possible that a well established constructed wetland will have no significant mosquito breeding associated with it; however, changes in climatic and vegetation conditions could change that situation rapidly. Maintaining awareness for mosquito problems and regular monitoring for mosquito activity should be considered as a component of the management of these sites.

7.9.7 Access into the Constructed Wetland

1. Access to all areas of a constructed wetland is required for maintenance. In particular, inlet zones and gross pollutant traps require a track suitable for heavy machinery for removal of debris and de-silting as well as an area for dewatering removed sediments. If sediment removal requires earthmoving equipment to enter the basin, then a stable ramp suitable for heavy plant will be required into the base of the inlet zone (maximum slope 1:8).

2. To aid maintenance, it is recommended that the inlet zone be constructed with a hard rock or concrete bottom. This is important if maintenance is performed by driving into the basin. It also serves an important role by allowing excavator operators to detect when they have reached the base of the inlet zone during desilting operations.

3. Macrophyte zones also require access for weeding and replanting work as well as regular inspections.

4. Maintenance access to constructed wetland needs to be considered when determining the layout of the proposed wetland system.

7.9.8 Batter Slopes to Permanent Water within a Constructed Wetland

1. The batter slopes on approaches and immediately under the permanent water level within a constructed wetland must be designed to ensure public safety.

2. The public safety requirements for individual wetlands will vary from site to site and requires careful consideration. However, a gentle slope to the waters edge and extending below the water line must be adopted. The maximum batter slope for constructed wetlands should be 1 in 8 (Vertical: Horizontal).

3. Palisade (open metal type) fencing at a minimum height of 1.5 metres will be required to be erected on top of concrete or stone walls for constructed wetlands where:

   (a) There is a risk of serious injury in the event of a fall (where the batter slope of the wetland is greater than 0.5 metres high or is too steep to comfortably walk up/ down or the lower surface has sharp or jagged edges);

   (b) There is a high pedestrian or vehicular exposure (on footpaths, near bikeways, near playing/ sporting fields, near swings and playgrounds);

   (c) Where the water level (permanent or temporary) is at a depth of greater than 300mm;

   (d) Where the water is expected to contain concentrated pollutants

   (e) Where mowed grassed areas abut the asset.

4. In some cases, a dense vegetation screen around the perimeter of the wetland at least 2 metres wide and 1.2 metres high (minimum) may be suitable. However, this option will only be considered where the fencing of the wetland is physically restricted due to topographical or other constraints. Any such dense vegetation must be designed to minimise potential hiding places, particularly in areas close to any pathway / cycleway.

7.10 Infiltration Measures

1. Infiltration measures are designed to enable pre-treated stormwater runoff to infiltrate into surrounding soils and underlying groundwater. The purpose of infiltration measures is to act as a conveyance measure to facilitate infiltration of surface waters to groundwater and not as a treatment device.

2. Infiltration measures generally consist of a shallow excavated trench designed to detain a certain volume of runoff water and to subsequently allow for the infiltration of the runoff into the soil strata. Infiltration measures also assist in reducing surface runoff volumes by providing a pathway for treated stormwater runoff to recharge into the groundwater table. These measures are best suited to highly permeable soils so that water can infiltrate the soil strata at a sufficient rate and to prevent water ponding.

7.11 Porous Pavements

1. Porous pavements are suitable for use in areas with light traffic loads such as car parking spaces, private driveways and private roads within a small community title subdivision. Porous pavements allow run-off to infiltrate through the pavement’s surface to the underlying soil strata, instead of overland run-off directly into a piped stormwater drainage system.

2. Porous paving provides both stormwater flow and pollution retention measures but these surfaces require regular maintenance to ensure correct operation at optimal treatment capacity.

3. Porous pavements are generally constructed with a deep layer of gravel which is bedded on a sand filter layer. This allows run-off to percolate through the porous pavement into the gravel reservoir and then into the sand filter underneath. The removal of particulates and some dissolved pollutants is achieved by filtration and absorption onto soil particles.

4. Regular pavement surface maintenance is required to ensure the optimal infiltration efficiency of the porous pavement.

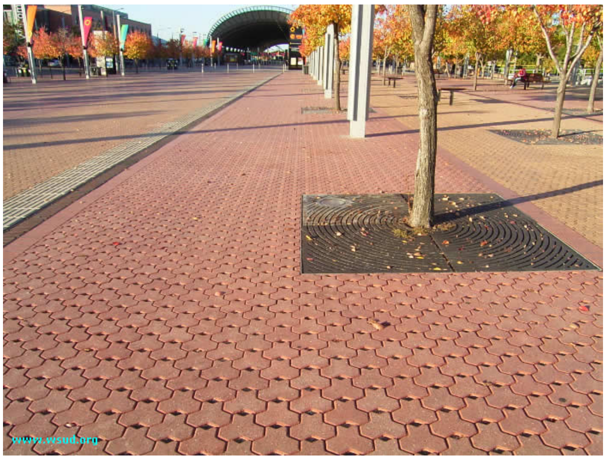

Figure 11: (Top left) Grassed infiltration area (Source: Water Sensitive Urban Design of the Sydney Region)

Figure 12: (Top right) Example of porous pavement (Source: Water Sensitive Urban Design of the Sydney Region)

Figure 13: Infiltration trench and rain garden surrounding car parks (Source: Water Sensitive Urban Design of the Sydney Region)

Figure 14: Infiltration trenches surrounding car parks prior to (left) and after (right) vegetation establishment (Source: Water Sensitive Urban Design of the Sydney Region)

8 WSUD PRINCIPLES FOR SUBDIVISION ROAD AND LOT LAYOUT DESIGN

1. The general WSUD principles for subdivision road design and lot layout include:

   (a) The subdivision layout should promote the retention of existing landforms with cut and fill land re-shaping works being minimised, wherever possible.

   (b) The retention of natural watercourses and drainage lines is recommended, wherever practicable.

   (c) The layout of roads in a subdivision should be designed to fit the existing topography and landform features of the site.

   (d) The road layout pattern should minimise road lengths running perpendicular to the slope of the site, in order to reduce run-off velocities.

   (e) Road design should take into account the cleansing of stormwater through the use of grass swales, filter (buffer) strips, infiltration trenches etc.

   (f) Road carriageways are required to be designed to minimise the amount of impermeable area through reduced road carriageway widths and / or porous pavements, in order to encourage infiltration of stormwater run-off into the soil strata.

   (g) Any trunk drainage design should be based on a system of natural watercourses and designed to mimic natural conditions and in particular natural flows.

   (h) The retention of the natural alignment and profile of watercourses, wherever possible.

   (i) Water and stormwater quality improvement devices (SQIDs) such as detention basins, constructed wetlands, gross pollutant traps (GPTs), litter traps and sedimentation ponds should be designed as off-line systems, in order to maintain the physical integiry and aesthetics of the natural watercourse.

   (k) Any stormwater outlets and discharge points are to be provided with energy dissipation devices, in order to minimise any potential scouring or erosion problems.

   (l) The replanting of indigenous vegetation within the subdivision, including any watercourse is recommended.

2. All proposed WSUD treatment measures are to be considered upfront in the planning process and are to be incorporated into the proposed subdivision plan for the site at the time of lodgement of the Development Application. This is necessary to ensure all relevant WSUD treatment options are considered upfront for water quality and quantity objectives.

9 STORMWATER QUALITY PERFORMANCE TARGETS

9.1 Development Control

1. The following minimum stormwater quality performance targets (prescribed in Table 2 below) are required to be achieved in the required WSUD strategy for the development:

Table 2: WSUD Stormwater Quality Performance Targets

Performance target reduction loads*	**Development Type**	
	Residential Subdivisions greater than 20 lots **Industrial Subdivision** **Business Parks**	**Multi-dwelling housing development** **Residential Flat Buildings** **Mixed Use Developments** **Minor Residential subdivisions (up to 20 lots)** **Commercial Office Development** **Industrial Development**
Gross Pollutants	90%	90%
Total Suspended Solids	85%	80%
Total Phosphorus	60%	55%
Total Nitrogen	45%	40%

* Reduction in loads are relative to the pollution generated from the development without treatment

Note: The stormwater quality performance targets set in Table 1 may be adjusted by Council, at its discretion, as part of the WSUD Strategy development. This is particularly applicable to developments located in sensitive catchments (e.g. Lake Illawarra catchment and the Hacking River upper catchment). Further, Council may require proponents to add other analytes and related performance criteria to WSUD Strategies for specific developments (eg. Development upon land affected by soil strata or groundwater contamination).

10 PRE-LODGEMENT CONSULTATION OF PROPOSED WSUD STRATEGY

1. Pre-lodgement discussions with Council are highly recommended at an early stage in the application process to discuss and agree on the overall design approach before a detailed WSUD Strategy is completed.

2. The aim of the consultation process is to provide direction and guidelines to the applicant and to provide advice on Council's requirements.

3. The level of consultation required will largely depend on the size and the complexity of the development.

4. Where WSUD assets are proposed to be ultimately handed over to Council following the completion of the subdivision or development, a formal pre-lodgement meeting with Council staff is required to consider the draft WSUD strategy. The pre-lodgement meeting will enable Council staff to be fully briefed of the proposed WSUD strategy treatment measures by the applicant's consultant(s) and enable Council staff to provide specific advice on the parameters to be included in the final WSUD strategy, especially as to the performance and maintenance requirements for any WSUD assets proposed to be dedicated / handed over to Council.

5. In cases where a pre-lodgement meeting is not held upfront on a proposed WSUD Strategy or the parameters determined by Council are not met in the WSUD Strategy, Council may either require a major redesign of the WSUD Strategy at the Development Application stage or may decline to accept the dedication of the WSUD asset to Council.

11 PREPARATION OF WSUD STRATEGY

11.1 General

1. The preparation of the WSUD Strategy must be undertaken by a suitably qualified and experienced consultant and must take into account any Council requirements discussed at a formal pre-lodgement meeting with Council.

2. The preparation of the WSUD Strategy will require baseline and construction phase water quality monitoring and / or suitable computer simulation modelling of stormwater quality and peak stormwater flow discharges upfront.

3. The WSUD Strategy should define the specific stormwater treatment and management measures for both the construction and operational phases of the development.

4. The WSUD Strategy shall also provide comprehensive details of proposed WSUD measures to be incorporated into the proposed development.

5. The stormwater quality objectives for each development must provide specific information on both the temporary and permanent measures to be used in order to ensure the quantity of pollutants and the peak discharge flow rates from the site will meet the ‘no net’ increase objective, where applicable. The objectives should also include details on the stormwater control measures proposed for both the construction and operational phases of the development.

6. All WSUD elements should not contribute to any increased flooding risk and must be designed to take into account the requirements of the Stormwater Management and Floodplain Management chapters contained in Part B to this DCP.

7. The WSUD Strategy is to be submitted with the Development Application.

11.2 Key Issues / Chapters to be included in a WSUD Strategy

1. The WSUD Strategy shall include (but is not necessarily limited to) the following information:

   (a) *Background information* - Summarise any background information available, including previous studies, concurrent studies, mapping data.

   (b) *Site context* – identify catchments, drainage lines and receiving environments (both within and downstream of the site). Characterise the ecological values of the site and its receiving environments.

   (c) *Proposed development* - Describe the proposed development at the site, including site boundaries, proposed land uses, densities, population, infrastructure, development staging.

   (d) *WSUD objectives* - Identify the WSUD objectives and targets that apply to the proposed development. Objectives should give consideration not only to water quality and water flow objectives, but should also consider the following;

      (i) Ease of maintenance.

(ii) Performance monitoring (i.e. designing inlets and outlets so that monitoring equipment can be easily fitted and so that reliable data can be collected).

(iii) Large rainfall/storm event fail safes that not only protect nearby private and public assets, but also protect the WSUD infrastructure (e.g. bypasses for constructed wetlands rather than spillways).

(iv) Aesthetics (i.e. integration into urban environment such that it does not detract but improves the visual quality of the development).

(v) Provision of habitat for local native plant and animal species.

(vi) Non potable water re-use opportunities.

(e) *Constraints and opportunities* **-** Identify the key constraints and opportunities for water management on the site, including flooding. This should include the identification of natural watercourses and other sensitive environments within the site that should be preserved and/or remediated by the development.

(f) *WSUD Measures* – identify the WSUD Infrastructure to be installed and constructed to meet the WSUD objectives (conceptual plans are sufficient at the Development Application stage. However, future detailed designs at the Construction Certificate stage must ensure that the objectives and performance parameters for the WSUD asset are met.

(g) *Best planning practice* **–** the capital and life-cycle costs of infrastructure required to meet WSUD targets can be minimised by considering site planning opportunities early in the planning process.

(h) *Water conservation* **-** This section should demonstrate how the potable water conservation targets will be met, and how potable water will be supplemented with roofwater, treated stormwater and/or wastewater.

(i) *Stormwater management* **-** This section is to demonstrate how the WSUD stormwater quality targets will be met. It is to include stormwater quality and flow modeling results and identify the location, size and configuration of stormwater treatment measures proposed for the development. This section must also detail a methodology for validating the performance of the WSUD relative to the objectives identified in this WSUD Strategy.

(j) *Integration with the urban design* - The WSUD Strategy should outline how WSUD elements will integrate with the urban design.

(k) *Costs* - Prepare capital and operation and maintenance cost estimates of proposed water cycle management measures. Both typical annual maintenance costs and corrective maintenance or renewal/adaptation costs should be included.

(l) *Operation and Maintenance Plan* – should outline inspection and maintenance requirements to ensure proposed measures remain effective. The Operation and Maintenance Plan should account for, as a minimum, the following;

(i) Litter accumulation management,

(ii) Sedimentation management,

(iii) Structural condition (this will depend on the type of WSUD infrastructure in question, but should included where applicable pits, pipes, ramps, erosion, bank integrity, etc),

(iv) Evidence of dumping,

(v) Maintaining functional and landscape vegetation to a satisfactory condition (including weed control),

(vi) Settling or erosion of bunds/batters,

(vii) Damage, including vandalism, to structures,

(viii) Inlets and outlets management to ensure flows,

(ix) Maintenance drain operational (check).

11.3 Modeling Tools for determining the size and configuration of WSUD Treatment Measures

1. Suitable modeling tools must be used to determine the size and configuration of WSUD treatment elements required to meet applicable WSUD targets.

2. The Cooperative Research Centre for Catchment Hydrology has developed the Model for Urban Stormwater Improvement Conceptualisation *25 or MUSIC stormwater management evaluation software package. This software package is a planning and decision support system which deals with the performance of stormwater treatment measures into an easily used tool. MUSIC is designed to operate at a range of temporal and spatial scales, so it is suitable for modelling stormwater quality treatment systems for individual lots up to regional scales.

   Importantly, MUSIC allows a first estimate on expected pollutant load from catchments following development in the absence of stormwater treatment initiatives, setting a baseline. From this figure, alternative stormwater treatment strategies can be compared, for compliance to state and local government stormwater quality objectives.

   The MUSIC model is the most widely used model in Australia. As with all such models, however, the accuracy of the model predictions is based on the validity of the inputs to the model. Therefore MUSIC modeling must be undertaken in accordance with the recommendations contained in the MUSIC Modeling Guidelines for NSW (available at www.toolkit.net.au), unless alternative modeling parameters are justified on the basis of local studies.

   Therefore, Council highly recommends that applicants employ the services of appropriately qualified and experienced practitioner(s) for the development of appropriate WSUD Strategy and associated modeling.

12 POST DEVELOPMENT CONSENT PHASE

12.1 Construction Phase – Inspection of WSUD Assets

1. The developer must permit adequate access for the accredited certifier(s) access during the construction of WSUD measures (as required) and prior to filling to check the general locations and sizing of associated piping, protection systems (e.g. overflows, backflow, first flush), storage, and any other hidden elements.

2. Connection to Council's pipelines and underground infrastructure shall be inspected by a Council inspector.

3. Works for Council owned infrastructure or infrastructure that will revert to Council ownership shall be inspected by a Council inspector, prior to pipe backfilling and following surface restoration.

4. Final inspection shall be carried out by the accredited certifier, prior to issuing the relevant Compliance Certificate and shall include checking that:

   (a) Pits, pipes, basins, filtration systems etc are clean and are free draining,

   (b) Where filtration systems are present (e.g. permeable pavement, biofiltration measures), infiltration rates are within 10% of the design parameters and that filtration medium are not clogged and are free from detritus.

   (c) Orifices are secure and correctly sized and located.

   (d) All design details are according to plan.

   (e) Any required warning signs are installed with the correct information.

12.2 Monitoring and Validation of WSUD Measures

1. The purpose of validating WSUD measures is to ensure that the measures implemented are achieving their design objectives as per the WSUD Strategy. As a minimum, validation must involve the following:

   (a) The performance of a WSUD measure must be validated by measuring the load reduction performance of the measure. This will necessarily require the monitoring of inflow water immediately prior to entry into the WSUD measure (i.e. at the inlet) and at the point of final discharge into receiving waters (i.e. at the outlet).

   (b) As a minimum, load reduction needs to be determined for suspended solids, total phosphorus and total dissolved nitrogen.

   (c) In cases where land has been identified as containing soil strata or groundwater contamination, the contamination must also be appropriately monitored and load reductions determined, in order to ensure the design criteria identified for the contaminant is being met, as per the approved WSUD Strategy.

   (d) Water quality monitoring must continue for at least 12 months (ie with at least 80% of the proposed development within the treatment catchment of the WSUD measure being complete).

   (e) All water quality data generated by the monitoring of WSUD measures must be subjected to statistical regression analysis and monitoring reports. This must include all laboratory certificates and chain of custody forms.

   (f) All water quality analysis must be undertaken by a NATA accredited and registered laboratory.

2. Council may add or remove items from this list in consultation with proponents for specific development should local conditions, the nature of the development, or particular WSUD measures require it. This will be done at the DA stage, and will need to be identified in the WSUD Strategy for the development concerned.

3. If monitoring results indicate that the system is not performing according to the performance targets set in the WSUD Strategy for the development, Council reserves the right to not accept ownership of the WSUD measure concerned. In such circumstances, the WSUD measure will remain under the ownership and responsibility of the proponent until such time as performance targets can be adequately met.

4. It is highly recommended that a qualified consultant be engaged by the proponent to undertake the validation of WSUD measures.

5. It is recommended that proponents meet with Council shortly after monitoring has begun (e.g. after the first measurable rain event) to ensure monitoring methods are consistent with Council requirements, and that the correct analytes are being monitored. This will help to ensure the validation process is completed in a timely and cost-effective manner.

12.3 Works as Executed (WAE) Drawings & Compliance Certificates

1. Works as executed drawings are required for all WSUD measures. Such drawings must include storage capacities and finished and invert levels of the constructed system. Where built systems vary significantly from approved design plans, a suitably qualified engineer shall certify that the constructed system satisfies Council's requirements and shall submit all supporting calculations leading to this assertion.

2. All works as executed drawings must be submitted as per Wollongong City Council's most recent issue Design and Technical Services Drafting Standards (Ref 513).

3. A Certification of WSUD Compliance shall be prepared and certified by the original design consultant in conjunction with the works as executed drawings and the final inspection prior to refund of any security deposits. The Compliance Certificate shall include:

   (a) Certification that the built management measures will function in accordance with the approved design.

   (b) Identification of any variation from the approved design and their impact on performance.

   (c) Certifications that all waste water, rainwater and stormwater re-use systems comply with relevant legislation and guidelines.

12.4 Handover of WSUD Assets

1. This section applies to developments where WSUD measures will ultimately be handed over to Council. In this regard, Council will not consider accepting ownership of any WSUD measures unless all of the following conditions are met:

   (a) The WSUD assets / measures are constructed and operate in accordance with the approved design specifications / parameters and any other specific design agreements previously entered into with Council.

   (b) The performance of the WSUD measure(s) has been validated, which must include the provision of a Performance Validation Report supporting the performance of the WSUD measure.

   (c) Where applicable, the build up of sediment has resulted in no more than a 10% reduction of operational volume (e.g. of the pond, settling basin, constructed wetland).

   (d) Asset inspections for defects has been completed and, if any defects are found, rectified to the satisfaction of Council.

   (e) The WSUD infrastructure is to the satisfaction of Council, structurally and geotechnically sound (this will require the submission of documents demonstrating that such infrastructure has been certified by suitably qualified persons).

   (f) Design drawings have been supplied in a format acceptable to Council.

(g) Works as Executed (WAE) drawings have been supplied for all infrastructure in a format and level of accuracy acceptable to Council.

(h) Other relevant digital files have been provided (e.g. design drawings, surveys, bathymetry, models etc).

(i) Landscape designs have been supplied, particularly those detailing the distribution of functional vegetation, i.e. vegetation that plays a role in water quality improvement (clearance certificates from the landscape architect will need to be supplied).

(j) The condition of the infrastructure and associated land is generally to the satisfaction of Council (this includes well maintained open space, boardworks, viewing platforms, etc).

(k) Where applicable, filter media infiltration rates are within 10% of the rates of the design parameters for the filtration system concerned (e.g. bio-retention system, permeable pavement).

(l) Comprehensive operation and maintenance manuals (including indicative costs) have been provided.

(m) Inspection and maintenance forms provided.

(n) Vegetation establishment period successfully complete (2 years unless otherwise approved by Council).

(o) Copies of all required permits (both construction and operational) have been submitted.

13 REFERENCES / ACKNOWLEDGEMENTS

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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)*

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CARING FOR OUR COUNTRY

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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.

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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.

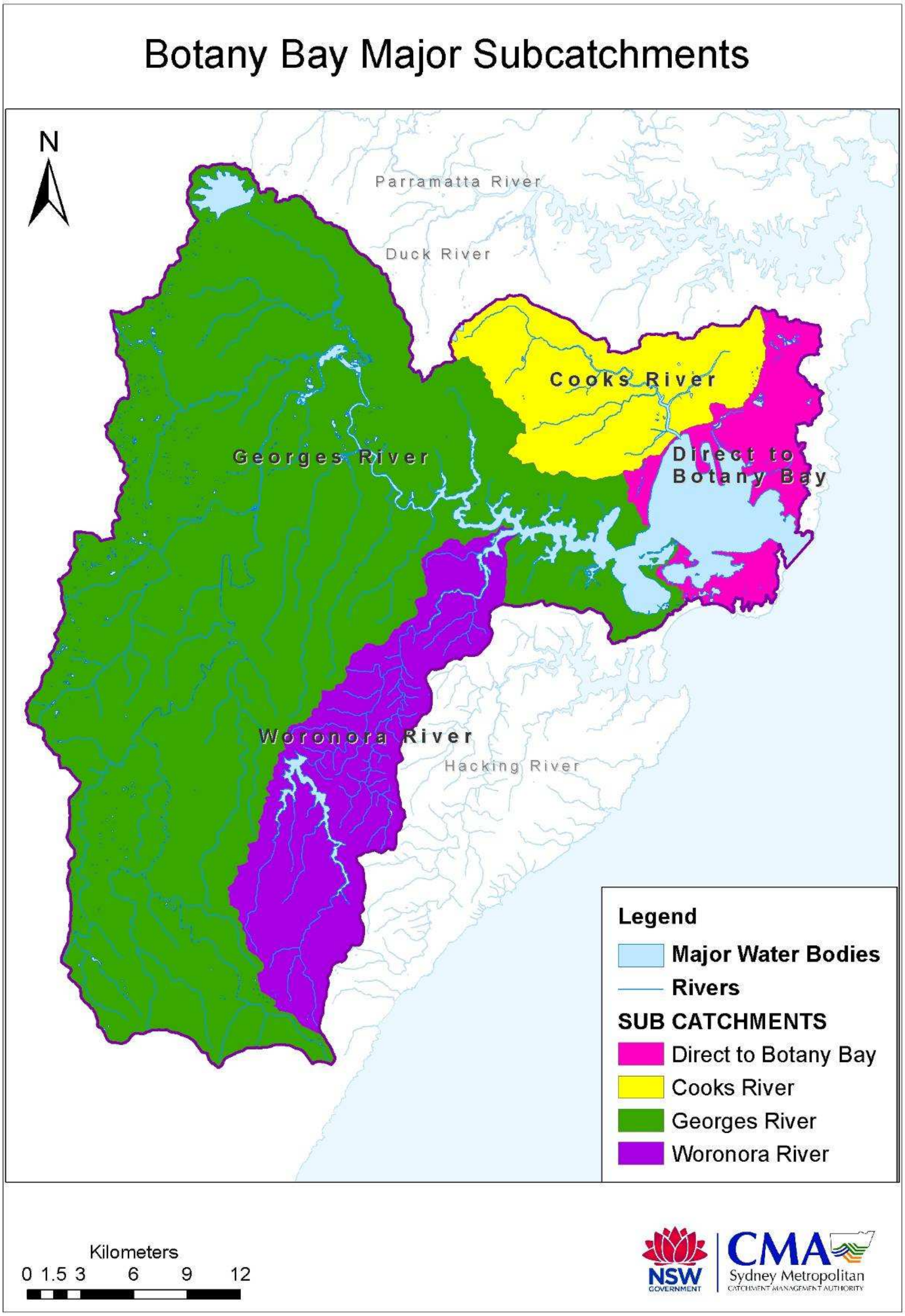


Figure 1. Major subcatchments of Botany Bay

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.

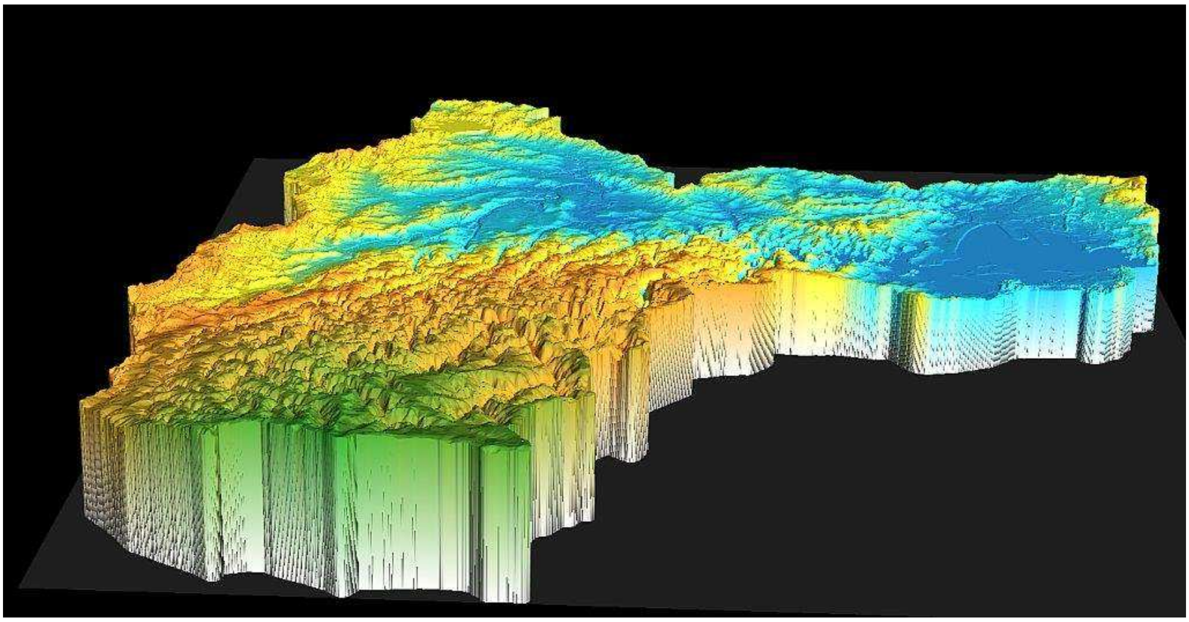


Figure 2. 3D view of DEM for Botany Bay Catchment

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).

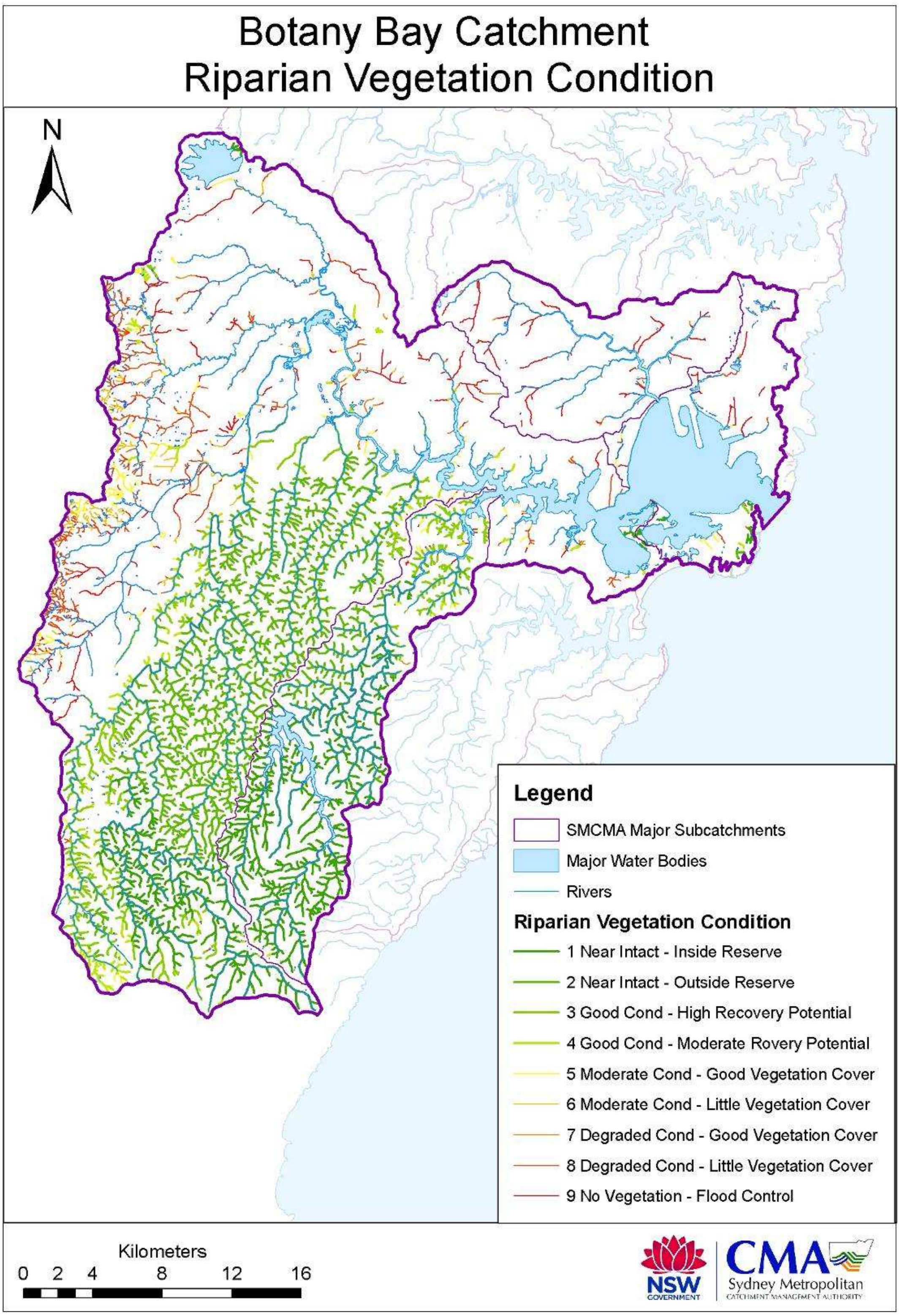


Figure 3. Riparian vegetation cover on stream reaches in the Botany Bay Catchment (from EarthTech 2007)

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).

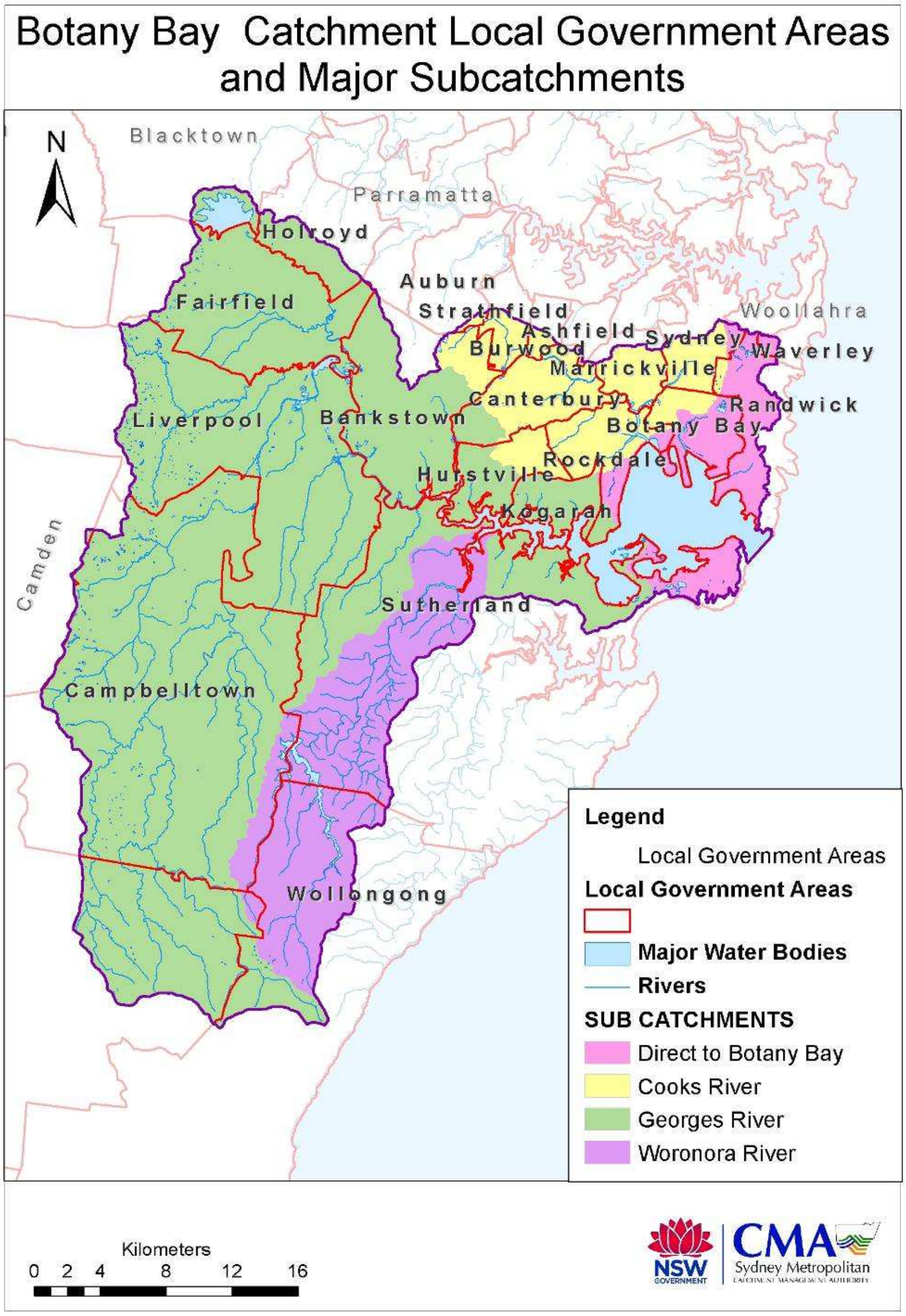


Figure 4. LGAs in the Botany Bay Catchment

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.

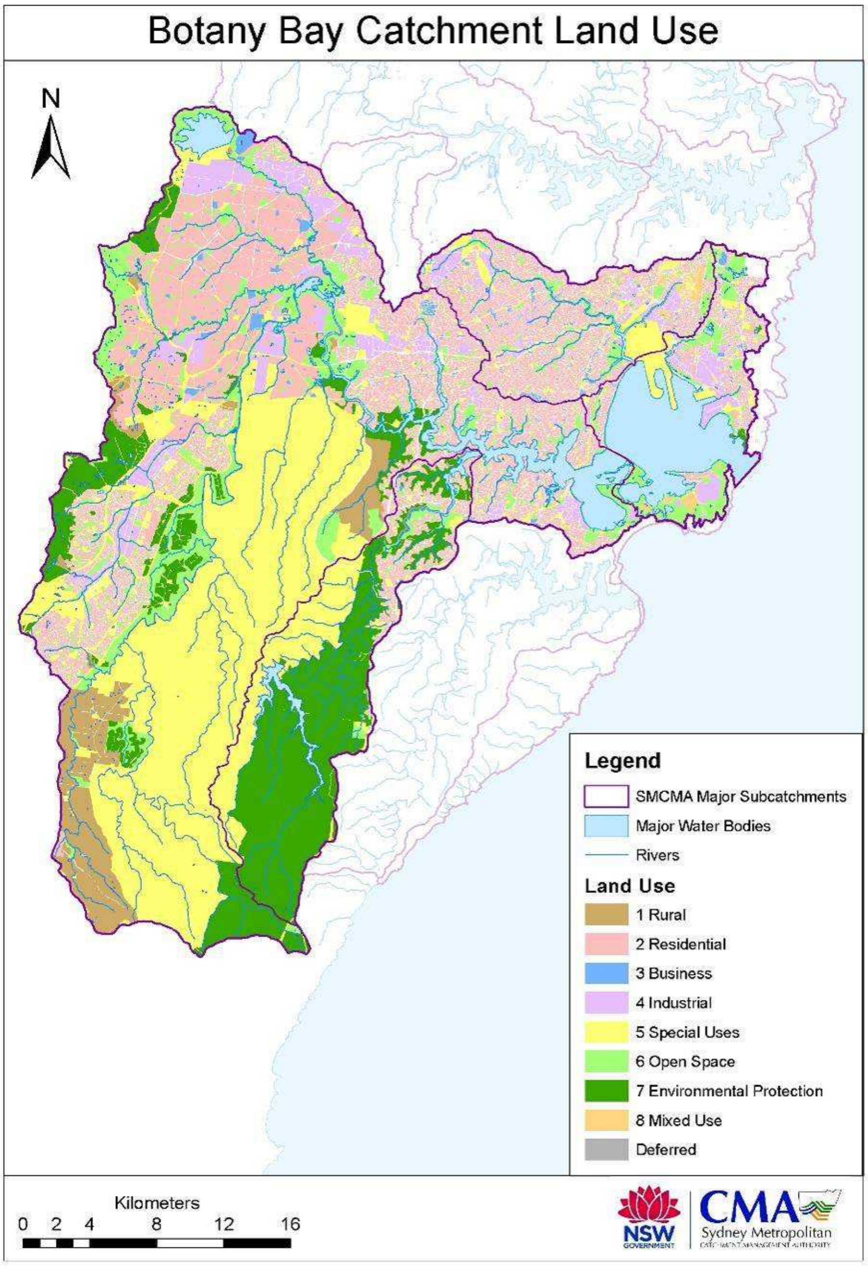


Figure 5. Major land uses in the Botany Bay Catchment

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

Land Use Class	***% Catchment Area***	***Area (km^2)***
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

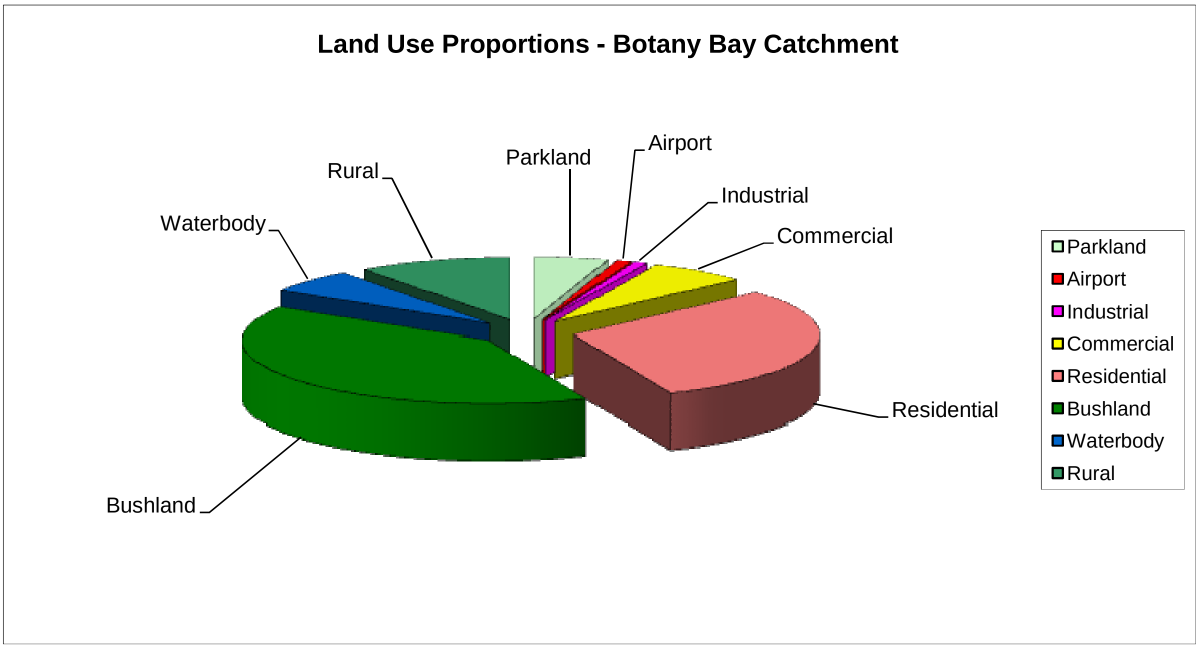


Figure 6. Major land use proportions in the Botany Bay Catchment

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.

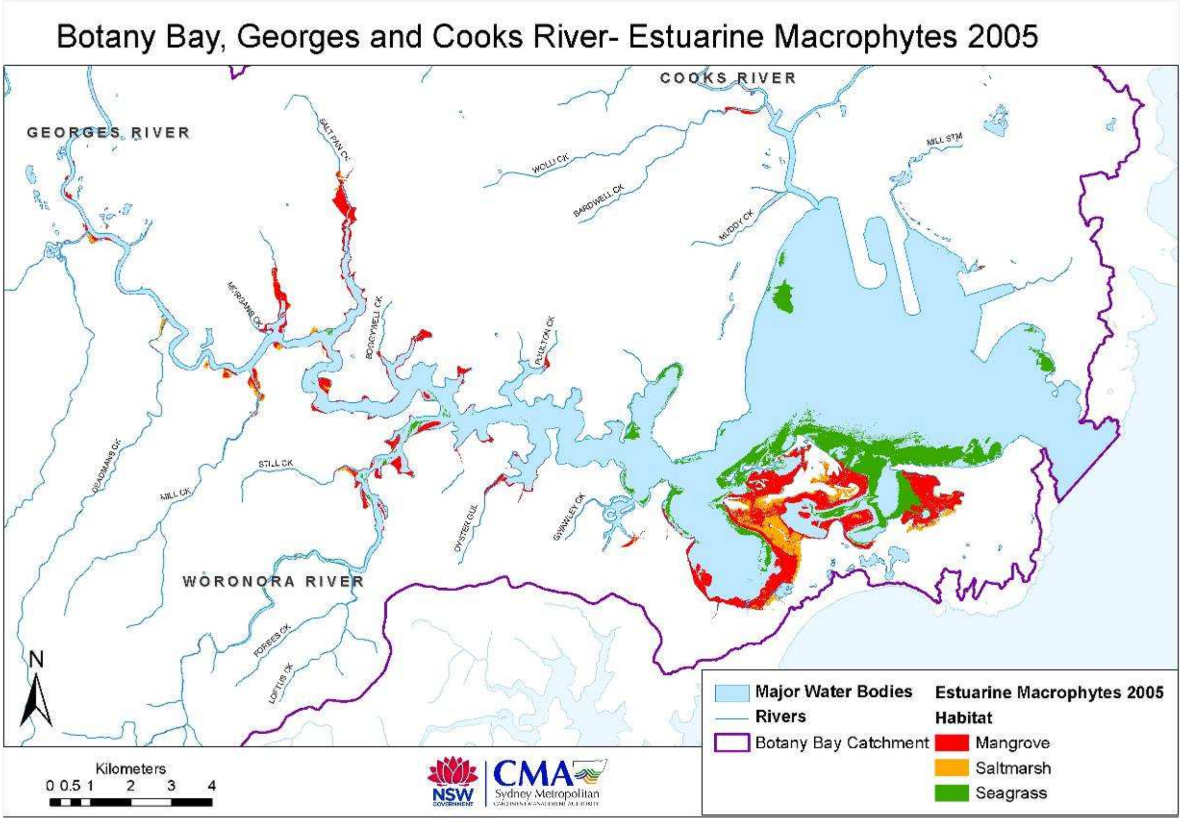


Figure 7 Mapped macrophytes in Botany Bay and its estuaries

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.

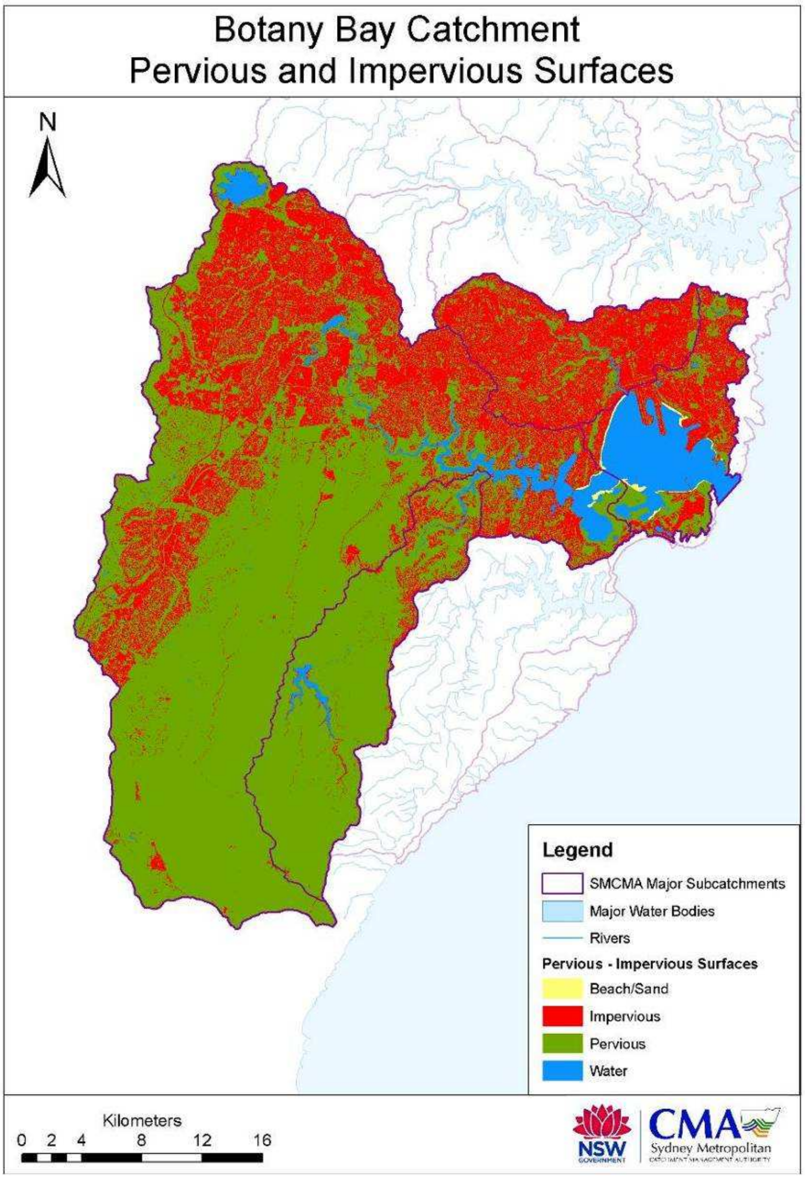


Figure 8. Pervious and impervious areas in the Botany Bay Catchment

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.

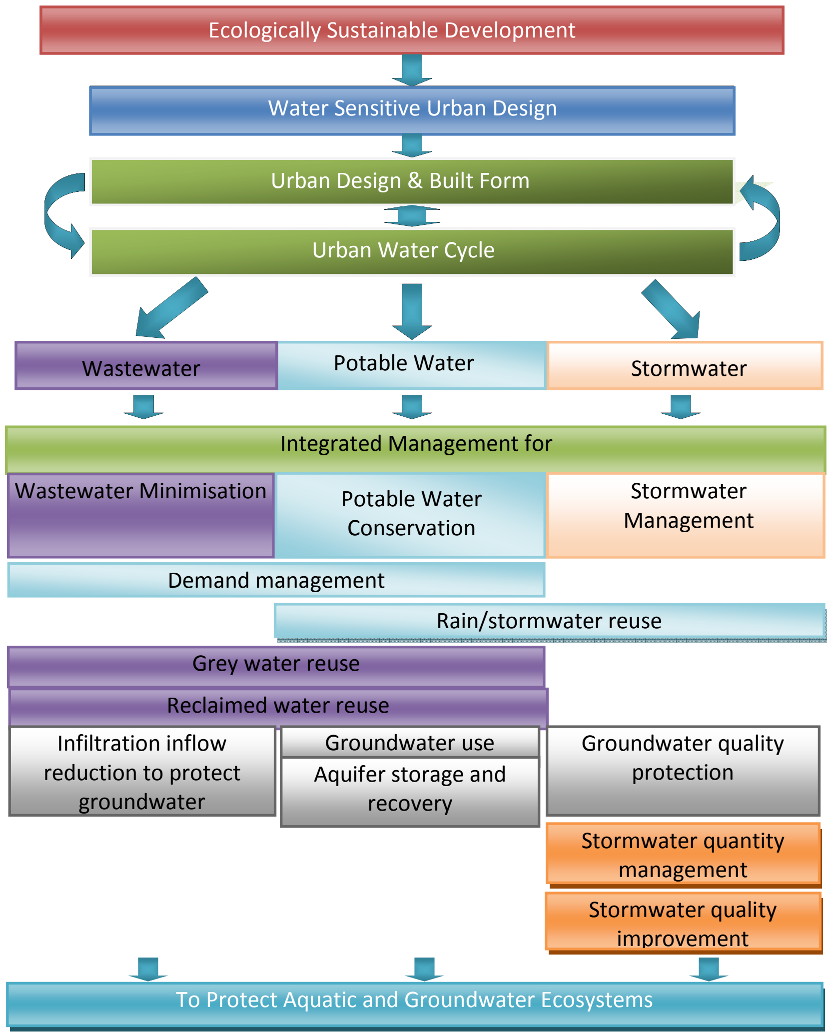


Figure 9. WSUD Framework (after Engineers Australia 2006).

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.

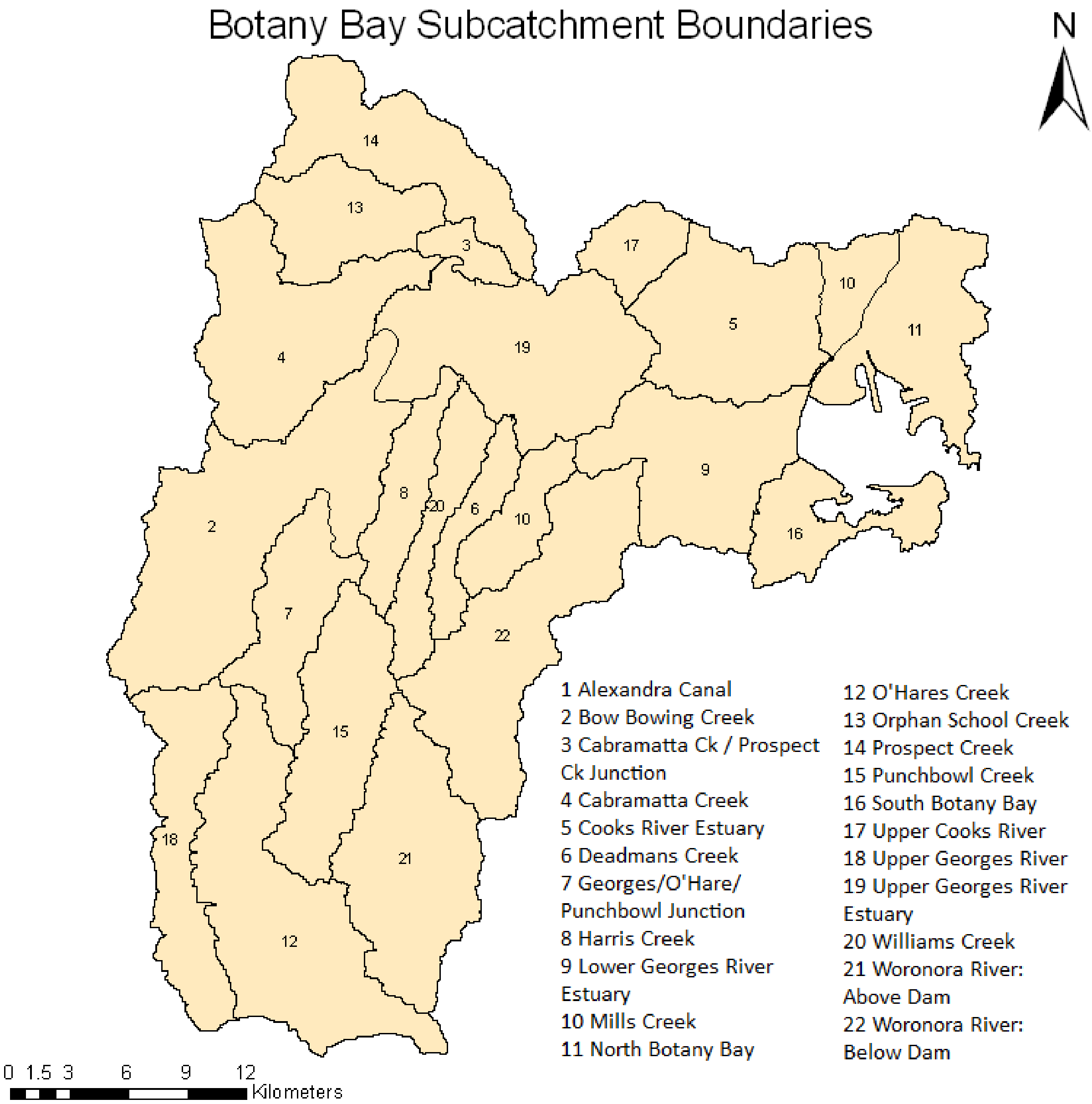


Figure 10. Map of subcatchment areas referred to in Table 5

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.

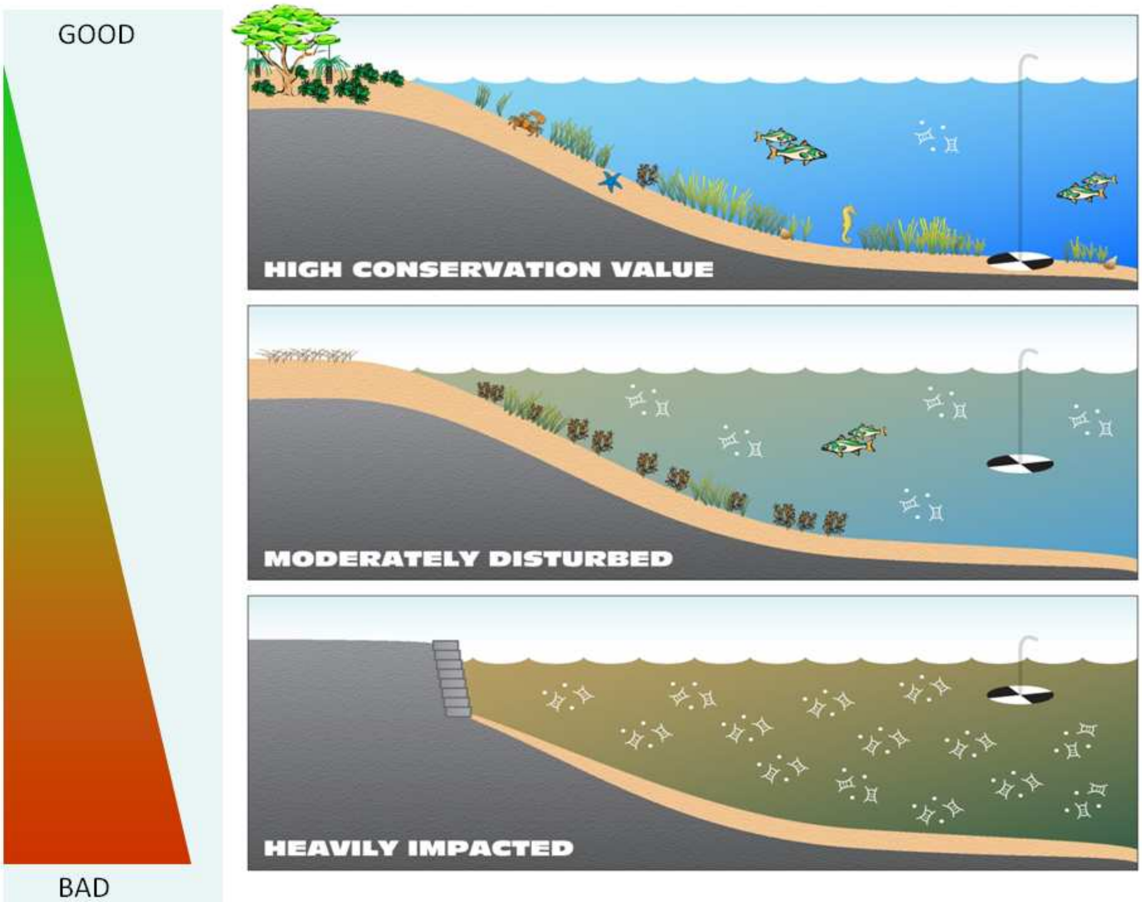


Figure 11. Ecological features of coastal lakes moving from good to poor condition (Source: Peter Scanes, DECCW)

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 80^{th} 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.

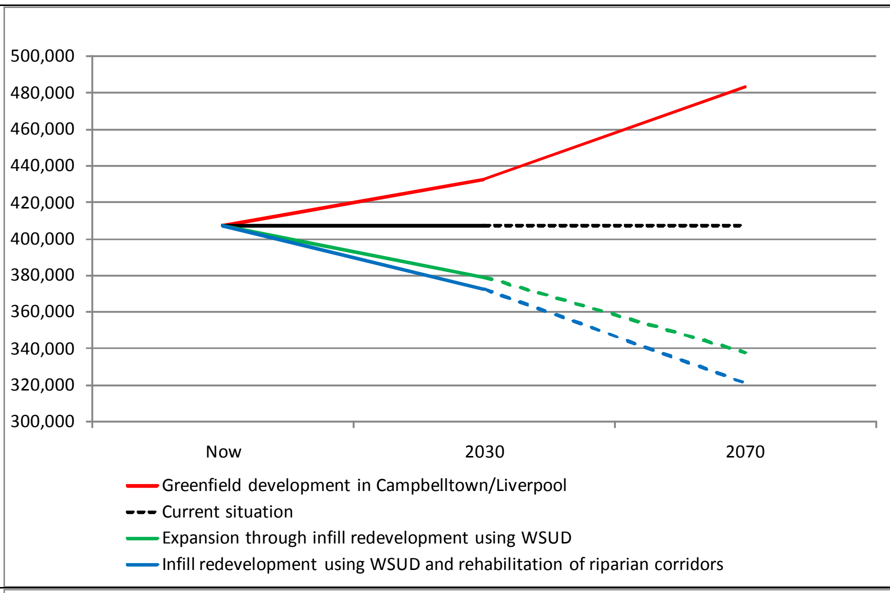
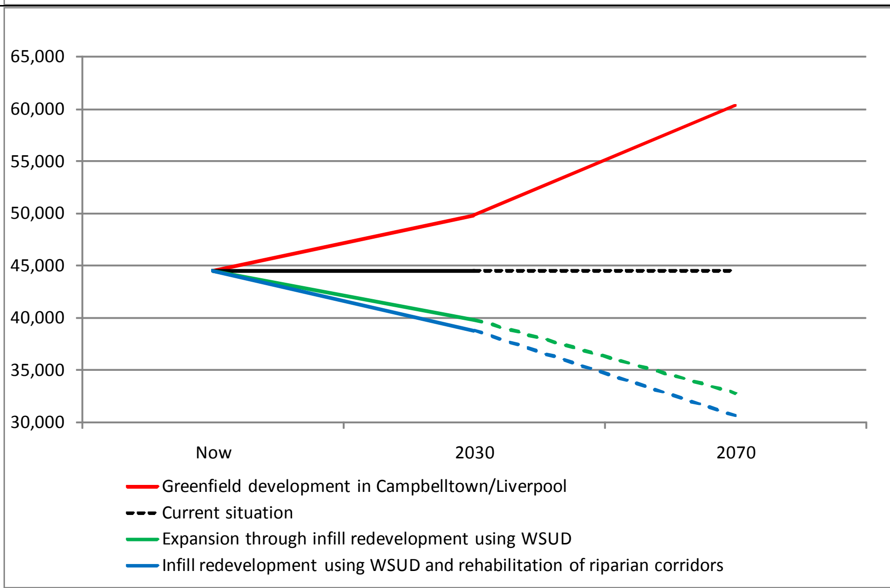
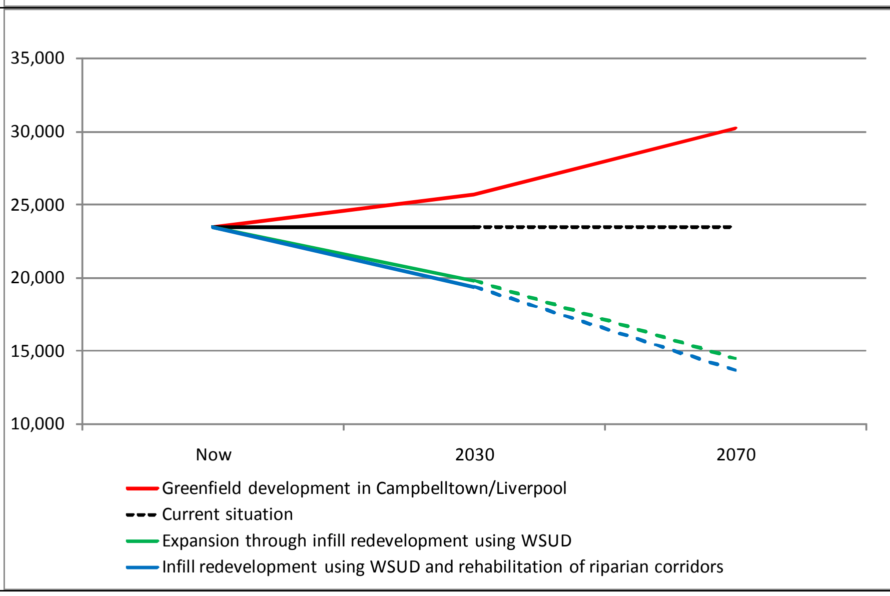
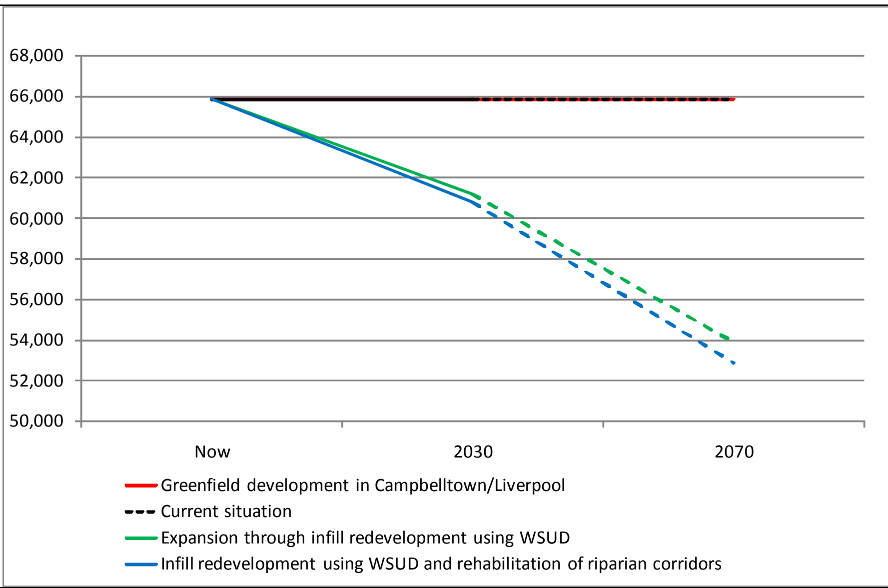
TN **Kg/Y**	
TP **Kg/Y**	
TSS **Tonnes/Y**	

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

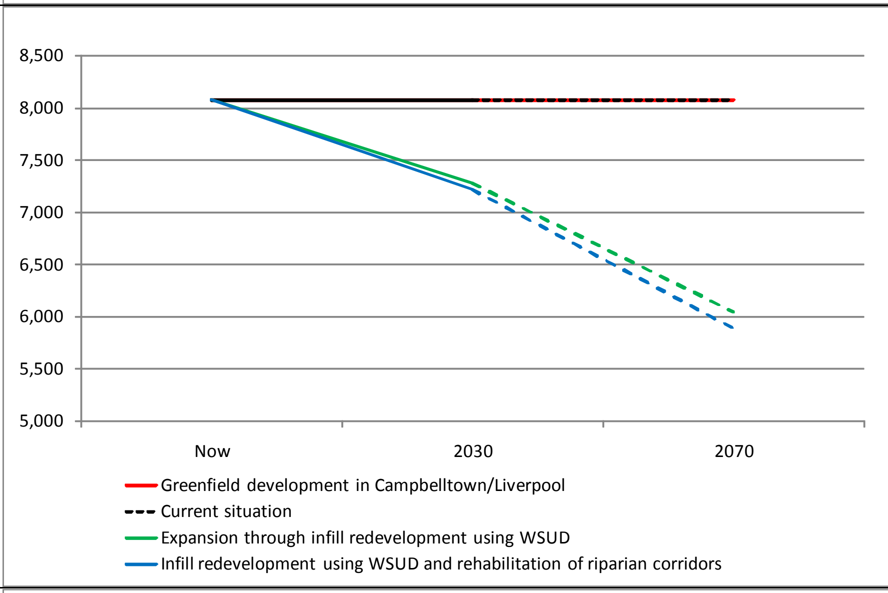
TN

Kg/Y



TP

Kg/Y



TSS

Tonnes/Y

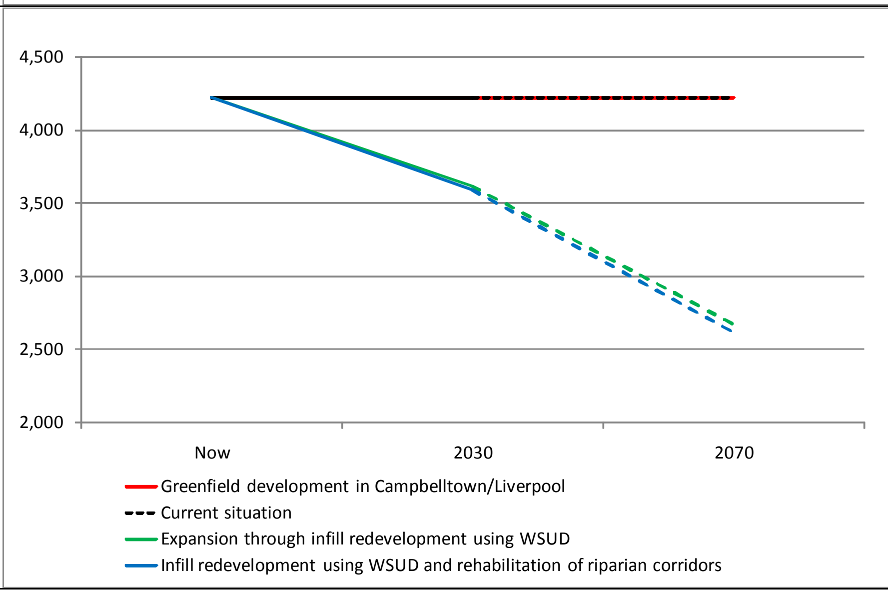
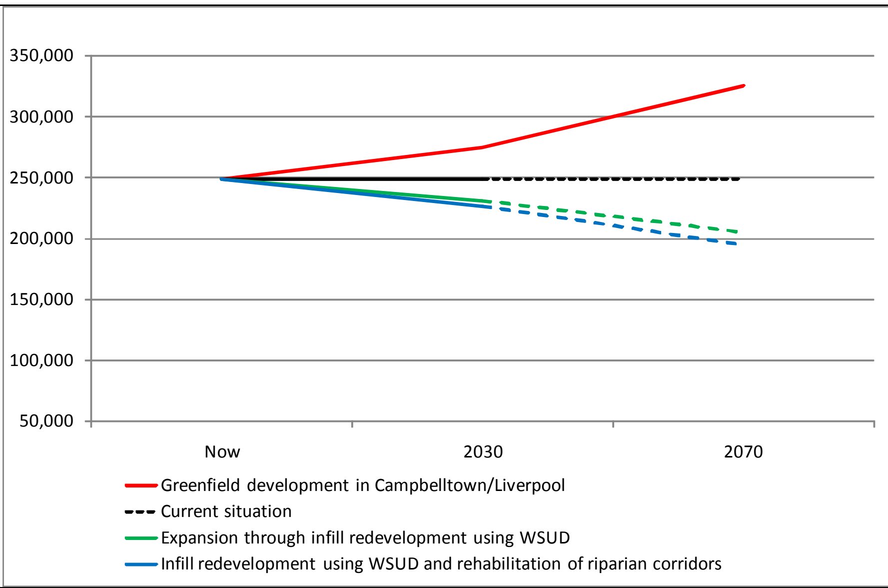


Figure 13. Trajectories of future pollutant loads for scenario options described in Table 9: Cooks River subcatchment

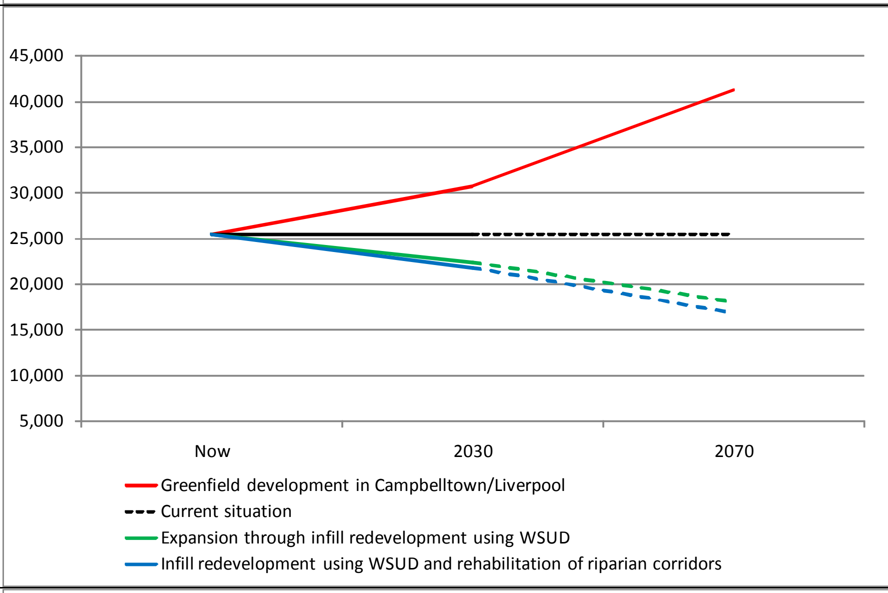
TN

Kg/Y



TP

Kg/Y



TSS

Tonnes/Y

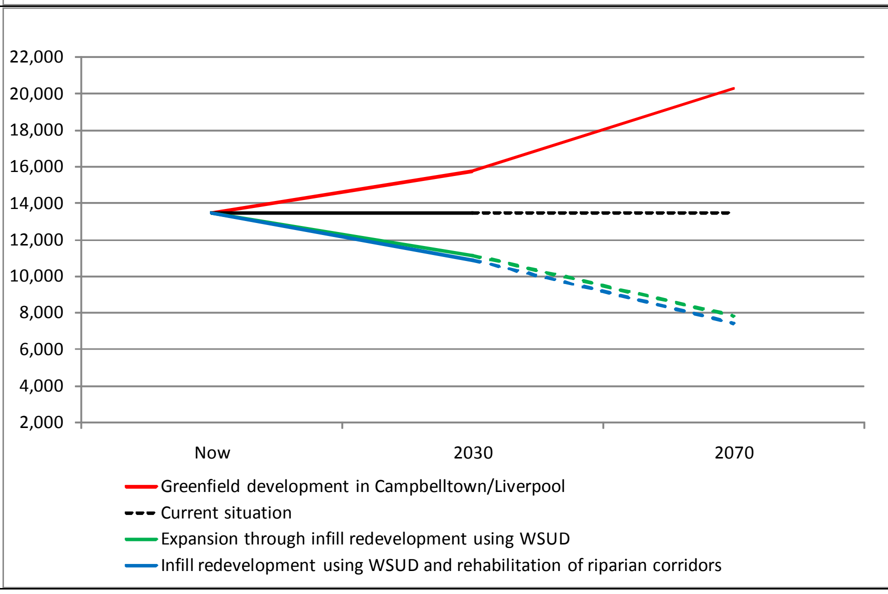
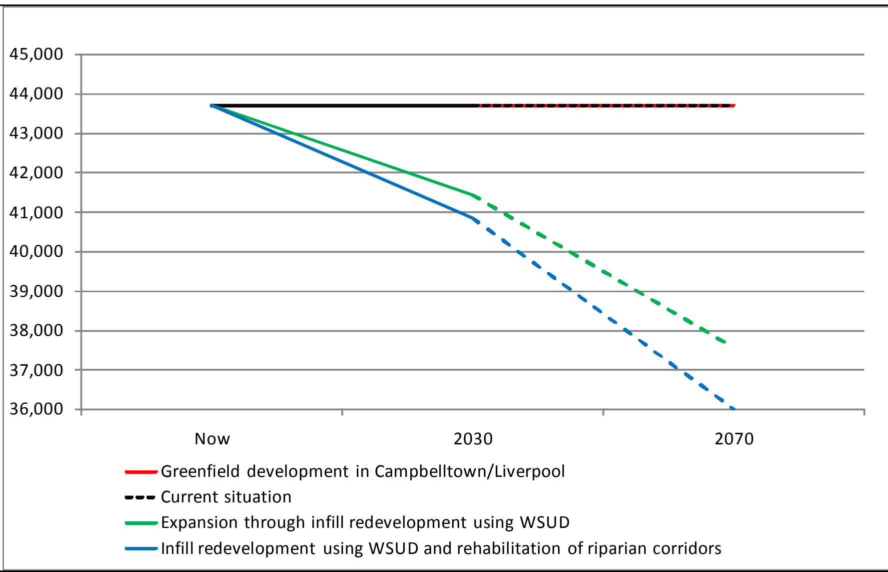


Figure 14. Trajectories of future pollutant loads for scenario options described in Table 9: Upper Georges River subcatchment

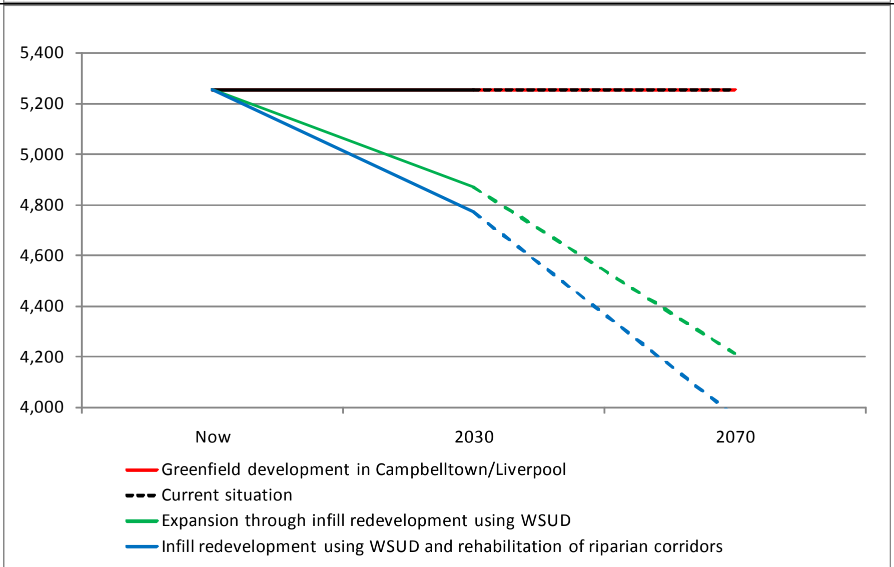
TN

Kg/Y



TP

Kg/Y



TSS

Tonnes/Y

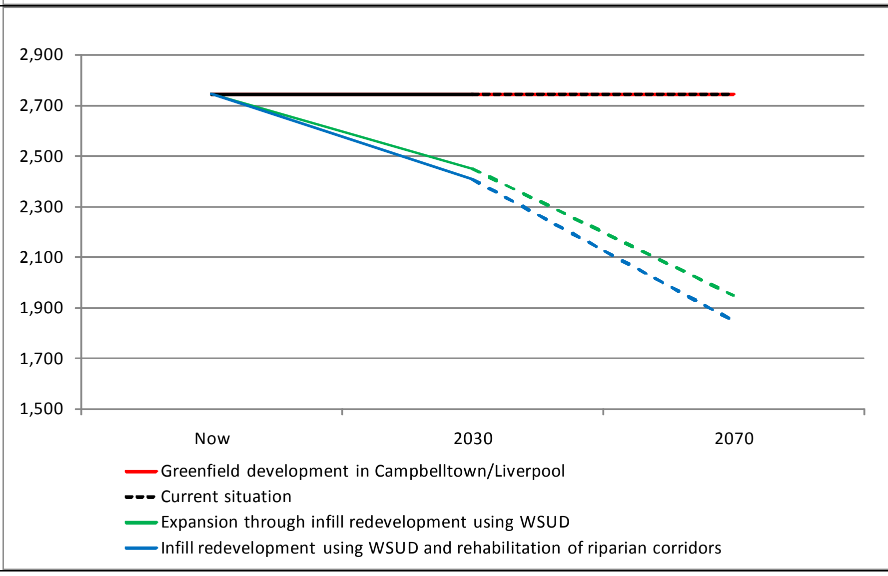
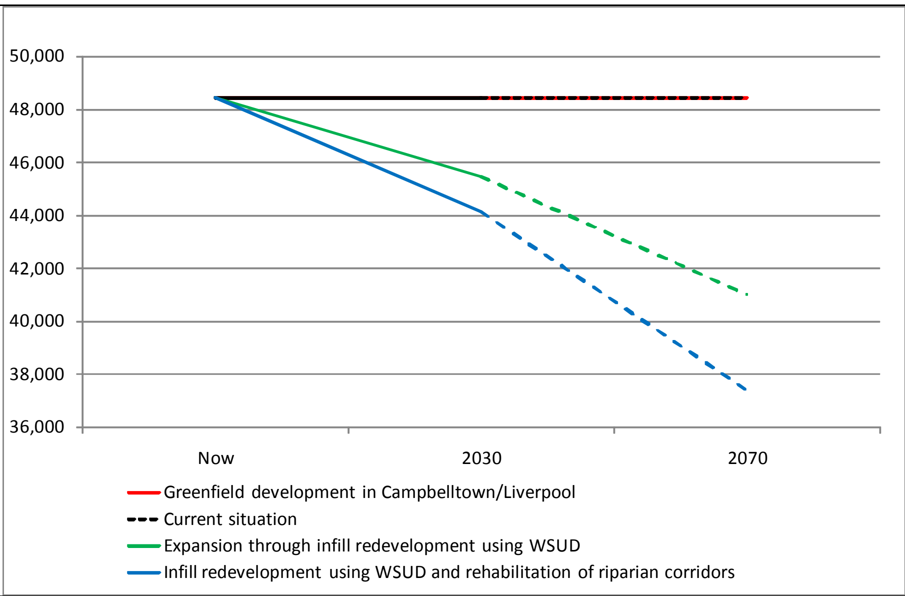


Figure 15. Trajectories of future pollutant loads for scenario options described in Table 9: Lower Georges River subcatchment

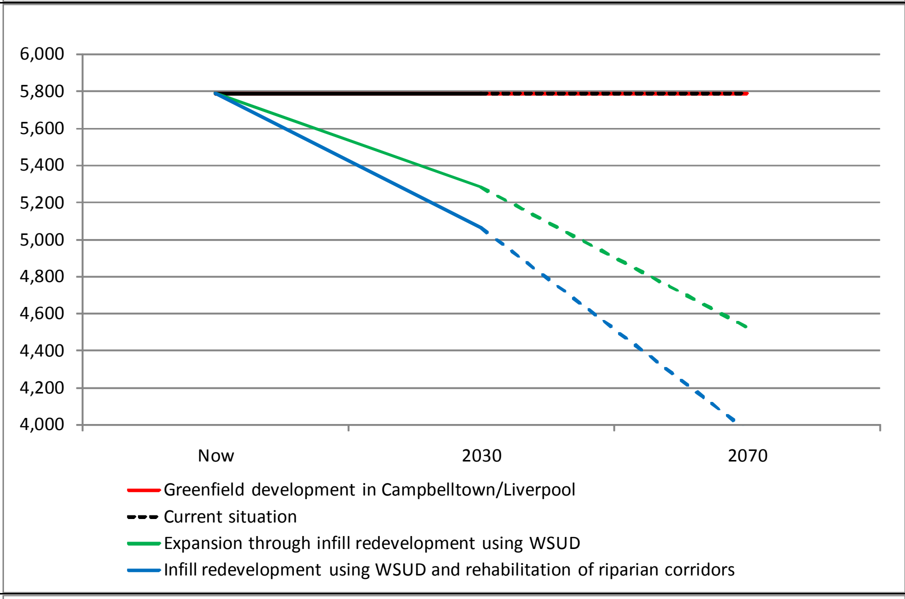
TN

Kg/Y



TP

Kg/Y



TSS

Tonnes/Y

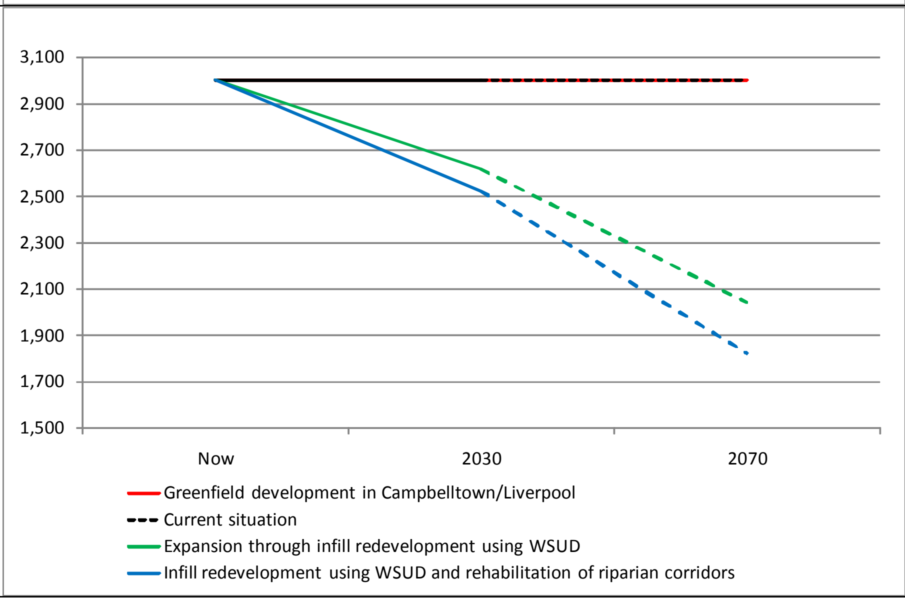


Figure 16. Trajectories of future pollutant loads for scenario options described in Table 9: Botany Bay foreshore subcatchments

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%

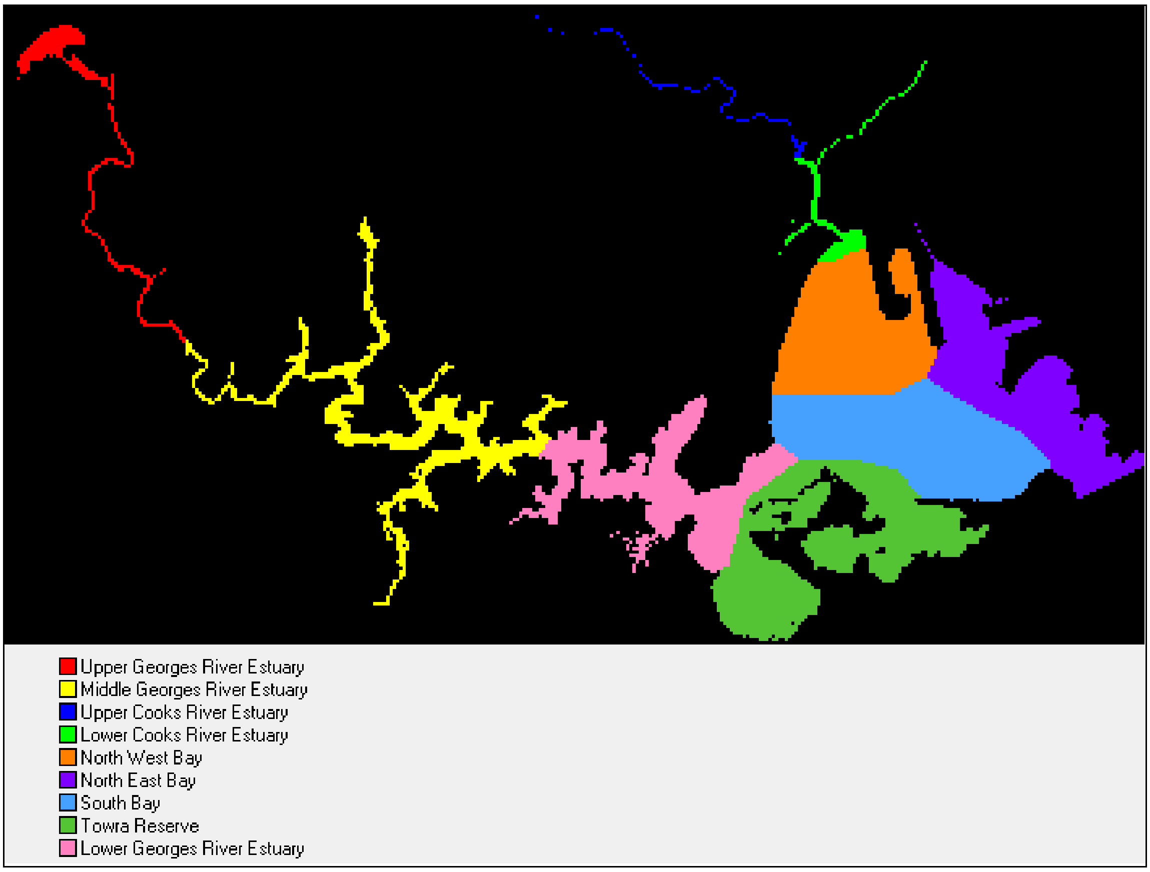


Figure 17. Estuary zones used in the analysis of Plan scenarios

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 GPT Buffer Swale Wetland Rainwater tank and Buffer Rainwater tank and GPT Rainwater tank and Swale Buffer and GPT Rainwater tank, GPT and Buffer Swale and GPT Rainwater tank, Swale and GPT	1- Next generation bioretention 2- Bioretention 3- GPT and Bioretention 4- Swale and Bioretention 5- Swale, GPT and Bioretention 6- GPT and Wetland 7- Bioretention and Wetland 8- Swale and Wetland 9- Buffer and Bioretention 10- GPT, Bioretention and Wetland 11- Swale, GPT and Wetland 12- Buffer, GPT and Bioretention 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	20- Rainwater tank, Swale, GPT and Bioretention 21- Rainwater tank and Wetland 22- Rainwater tank, GPT and Wetland 23- Buffer, GPT, Bioretention and Wetland 24- Rainwater tank, Swale and Wetland 25- Rainwater tank, Bioretention and Wetland 26- Rainwater tank, Buffer and Bioretention 27- Rainwater tank, Swale, GPT and Wetland 28- Rainwater tank, GPT, Bioretention and Wetland 29- Rainwater tank, Buffer and Wetland 30- Rainwater tank, Buffer, GPT and Wetland 31- Rainwater tank, Buffer, GPT, 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 1/20th 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

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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.

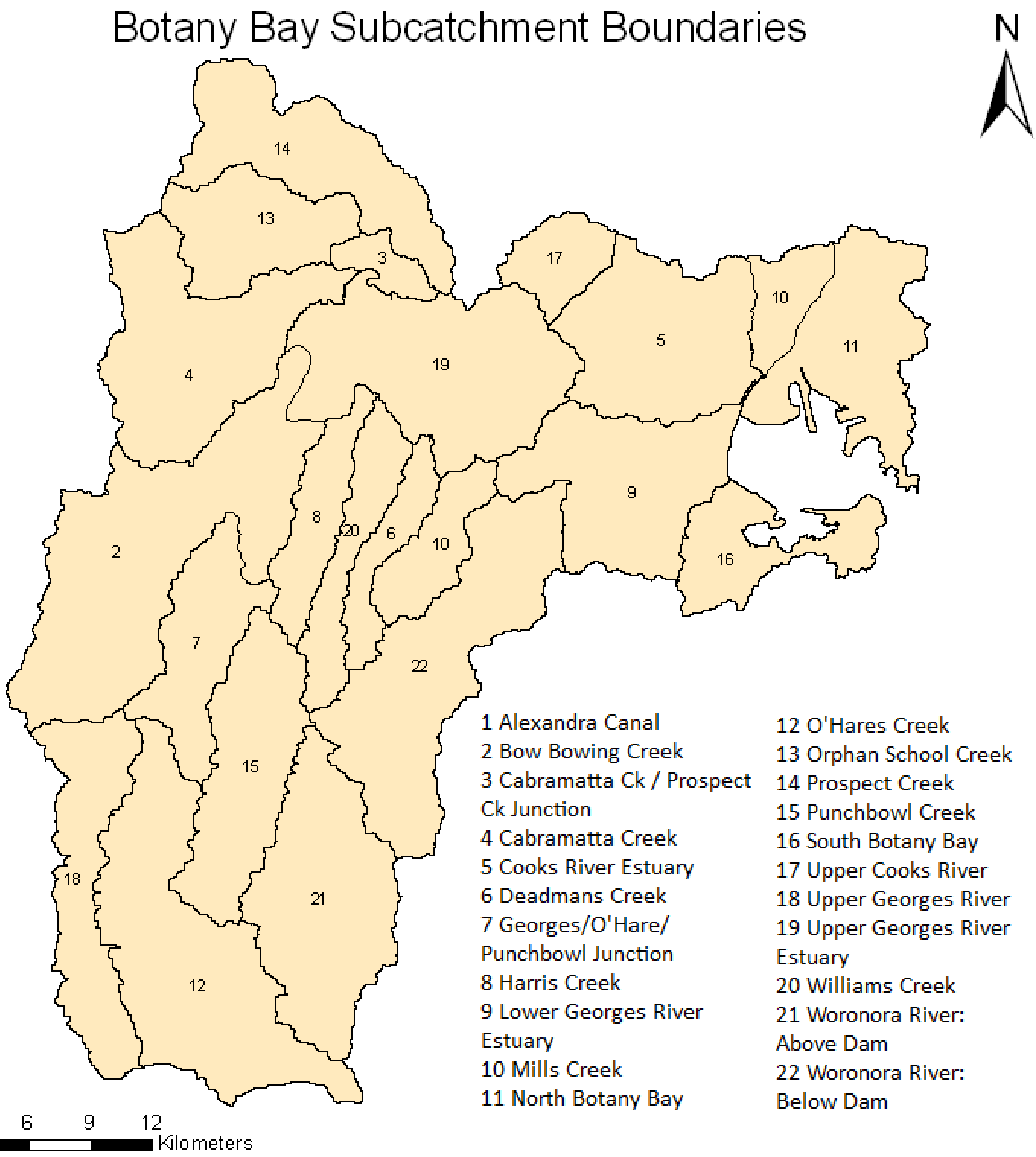

Figure 18. Map of subcatchment boundaries in the Botany Bay Catchment

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.

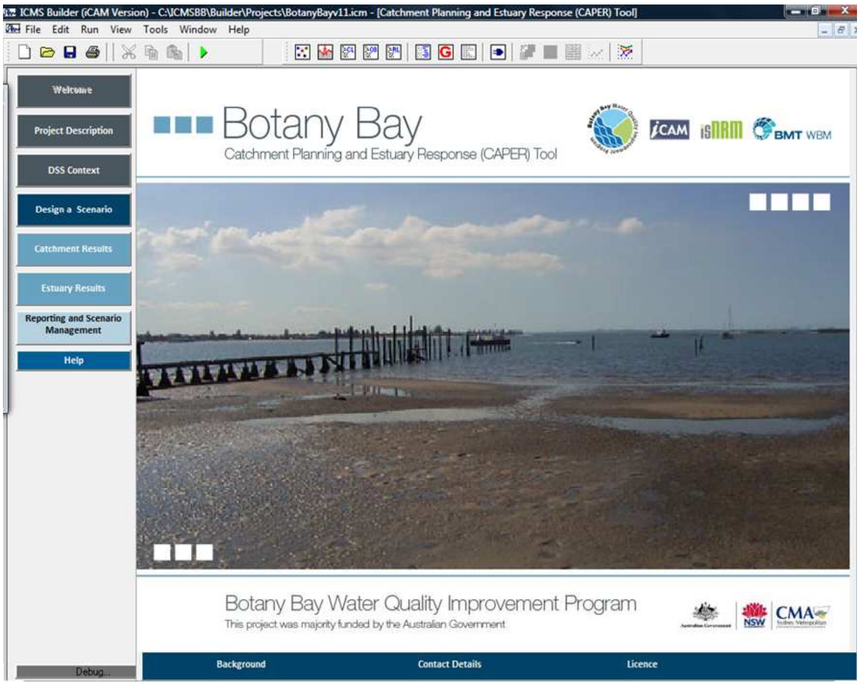

Figure 19. Botany Bay CAPER DSS interface: Welcome page

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.

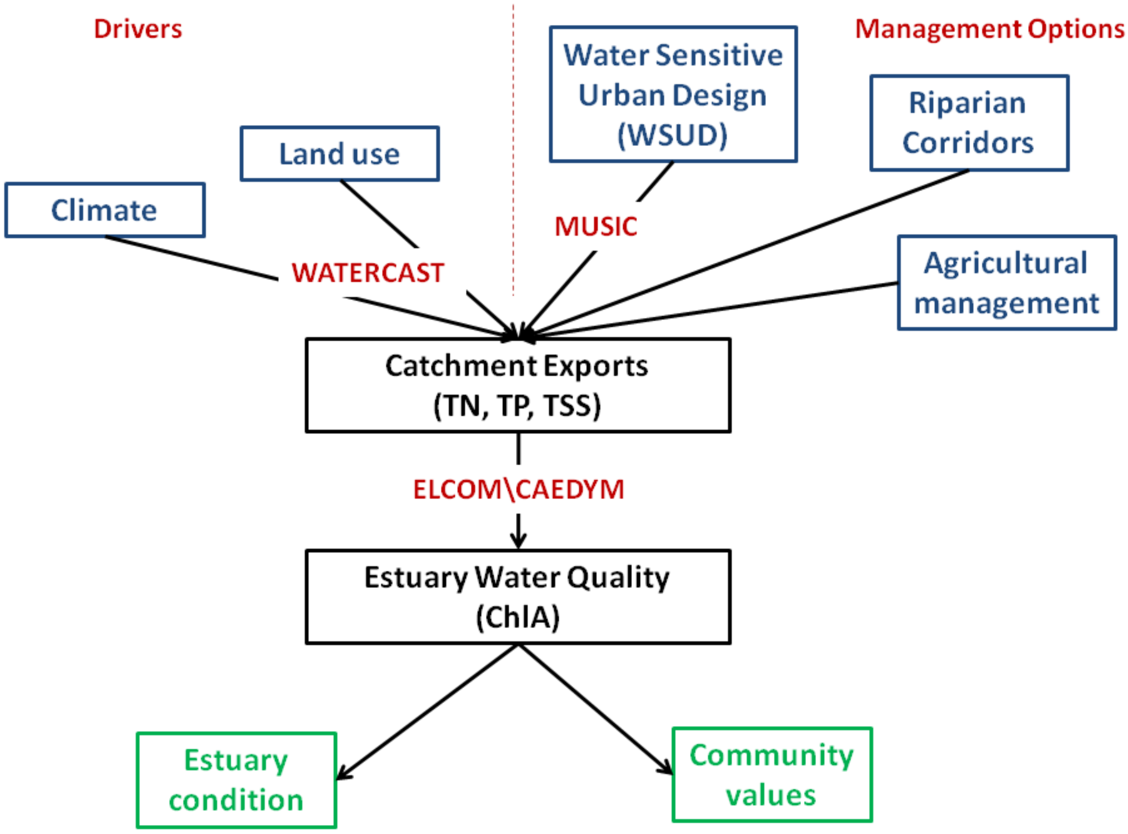

Figure 20. Structure of the model underlying the Botany Bay CAPER DSS

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.

56 RESIDENTIAL SUBDIVISION

19/09/2017
VC132

Purpose

To implement the State Planning Policy Framework and the Local Planning Policy Framework, including the Municipal Strategic Statement and local planning policies.

To create liveable and sustainable neighbourhoods and urban places with character and identity.

To achieve residential subdivision outcomes that appropriately respond to the site and its context for:

- Metropolitan Melbourne growth areas.
- Infill sites within established residential areas.
- Regional cities and towns.

To ensure residential subdivision design appropriately provides for:

- Policy implementation.
- Liveable and sustainable communities.
- Residential lot design.
- Urban landscape.
- Access and mobility management.
- Integrated water management.
- Site management.
- Utilities.

Application

These provisions apply to an application to subdivide land in the Neighbourhood Residential Zone, General Residential Zone, Residential Growth Zone, Mixed Use Zone or Township Zone and any Comprehensive Development Zone or Priority Development Zone that provides for residential development.

These provisions do not apply to an application to subdivide land into lots each containing an existing dwelling or car parking space.

Operation

The provisions of this clause contain:

- **Objectives.** An objective describes the desired outcome to be achieved in the completed subdivision.
- **Standards.** A standard contains the requirements to meet the objective.

A standard should normally be met. However, if the responsible authority is satisfied that an application for an alternative design solution meets the objective, the alternative design solution may be considered.

Requirement

An application to subdivide land:

- Must be accompanied by a site and context description and a design response.
- Must meet all of the objectives included in the clauses specified in the zone.
- Should meet all of the standards included in the clauses specified in the zone.

Certification of standards

A subdivision may be certified by a person authorised by the Minister for Planning as meeting the requirements of a standard in this clause.

A standard that is certified as met is deemed to have met the objective of that standard.

56.01 SUBDIVISION SITE AND CONTEXT DESCRIPTION AND DESIGN RESPONSE

16/01/2018
VC142

56.01-1 Subdivision site and context description

16/01/2018
VC142

The site and context description may use a site plan, photographs or other techniques and must accurately describe:

- In relation to the site:
  - Site shape, size, dimensions and orientation.
  - Levels and contours of the site.
  - Natural features including trees and other significant vegetation, drainage lines, water courses, wetlands, ridgelines and hill tops.
  - The siting and use of existing buildings and structures.
  - Street frontage features such as poles, street trees and kerb crossovers.
  - Access points.
  - Location of drainage and other utilities.
  - Easements.
  - Any identified natural or cultural features of the site.
  - Significant views to and from the site.
  - Noise and odour sources or other external influences.
  - Soil conditions, including any land affected by contamination, erosion, salinity, acid sulphate soils or fill.
  - Any other notable features or characteristics of the site.
  - Adjacent uses.
  - Any other factor affecting the capacity to develop the site including whether the site is affected by inundation.
- An application for subdivision of 3 or more lots must also describe in relation to the surrounding area:
  - The pattern of subdivision.
  - Existing land uses.
  - The location and use of existing buildings on adjacent land.
  - Abutting street and path widths, materials and detailing.
  - The location and type of significant vegetation.
- An application for subdivision of 60 or more lots must also describe in relation to the surrounding area:
  - Location, distance and type of any nearby public open space and recreational facilities.
  - Direction and distances to local shops and community facilities.
  - Directions and walking distances to public transport routes and stops.
  - Direction and walking distances to existing neighbourhood, major and principal activity centres and major employment areas.
  - Existing transport routes, including freeways, arterial roads and streets connecting neighbourhoods.
  - Local street network including potential connections to adjacent subdivisions.
  - Traffic volumes and movements on adjacent roads and streets.
  - Pedestrian, bicycle and shared paths identifying whether their primary role is neighbourhood or regional access.

- Any places of cultural significance.
- Natural features including trees and other significant vegetation, drainage lines, water courses, wetlands, ridgelines and hill tops.
- Proximity of any fire threats.
- Pattern of ownership of adjoining lots.

If in the opinion of the responsible authority a requirement of the site and context description is not relevant to the assessment of an application, the responsible authority may waive or reduce the requirement.

Satisfactory subdivision site and context description

If the responsible authority decides that the site and context description is not satisfactory, it may require more information from the applicant under Section 54 of the Act.

The responsible authority must not require notice of an application to be given or decide an application until it is satisfied that the site and context description meets the requirements of Clause 56.01-1 and is satisfactory.

This does not apply if the responsible authority refuses an application under Section 52(1A) of the Act.

56.01-2 Subdivision design response

09/10/2006
VC42

The design response must explain how the proposed design:

- Derives from and responds to the site and context description.
- Responds to any site and context features for the area identified in a local planning policy or a Neighbourhood Character Overlay.
- Responds to any relevant objective, policy, strategy or plan set out for the area in this scheme.
- Meets the relevant objectives of Clause 56.

The design response must include a dimensioned plan to scale showing the layout of the subdivision in context with the surrounding area. If in the opinion of the responsible authority this requirement is not relevant to the assessment of an application, it may waive or reduce the requirement.

An application for subdivision of 60 or more lots must also include a plan that meets the requirements of Standard C2. The plan must also show the:

- Proposed uses of each part of the site.
- Natural features of the site and identify any features proposed to be altered.
- Proposed integrated water management system.
- Proposed staging of the subdivision.

56.02 POLICY IMPLEMENTATION

09/10/2006
VC42

56.02-1 Strategic implementation objective

09/10/2006
VC42

To ensure that the layout and design of a subdivision is consistent with and implements any objective, policy, strategy or plan for the area set out in this scheme.

Standard C1

An application must be accompanied by a written statement that describes how the subdivision is consistent with and implements any relevant growth area, activity centre, housing, access and mobility, community facilities, open space and recreation, landscape (including any native vegetation precinct plan) and urban design objective, policy, strategy or plan for the area set out in this scheme.

56.03 LIVEABLE AND SUSTAINABLE COMMUNITIES

19/09/2017
VC132

56.03-1 Compact and walkable neighbourhoods objectives

09/10/2006
VC42

To create compact neighbourhoods that are oriented around easy walking distances to activity centres, schools and community facilities, public open space and public transport.

To allow easy movement through and between neighbourhoods for all people.

Standard C2

A subdivision should implement any relevant growth area or any approved land-use and development strategy, plan or policy for the area set out in this scheme.

An application for subdivision must include a plan of the layout of the subdivision that:

- Meets the objectives (if relevant to the class of subdivision specified in the zone) of:
  - Clause 56.03-2 Activity centres
  - Clause 56.03-3 Planning for community facilities
  - Clause 56.04-1 Lot diversity and distribution
  - Clause 56.06-2 Walking and cycling network
  - Clause 56.06-3 Public transport network
  - Clause 56.06-4 Neighbourhood street network
- Shows the 400 metre street walking distance around each existing or proposed bus stop, 600 metres street walking distance around each existing or proposed tram stop and 800 metres street walking distance around each existing or proposed railway station and shows the estimated number of dwellings within those distances.
- Shows the layout of the subdivision in relation to the surrounding area.
- Is designed to be accessible for people with disabilities.

56.03-2 Activity centre objective

09/10/2006
VC42

To provide for mixed-use activity centres, including neighbourhood activity centres, of appropriate area and location.

Standard C3

A subdivision should implement any relevant activity centre strategy, plan or policy for the area set out in this scheme.

Subdivision should be supported by activity centres that are:

- Accessible by neighbourhood and regional walking and cycling networks.
- Served by public transport that is connected to the regional public transport network.
- Located at public transport interchange points for the convenience of passengers and easy connections between public transport services.
- Located on arterial roads or connector streets.
- Of appropriate size to accommodate a mix of uses that meet local community needs.
- Oriented to support active street frontages, support street-based community interaction and pedestrian safety.

56.03-3 Planning for community facilities objective

09/10/2006
VC42

To provide appropriately located sites for community facilities including schools, libraries, preschools and childcare, health services, police and fire stations, recreation and sports facilities.

Standard C4

A subdivision should:

- Implement any relevant regional and local community facility strategy, plan or policy for the area set out in this scheme.
- Locate community facilities on sites that are in or near activity centres and public transport.

School sites should:

- Be integrated with the neighbourhood and located near activity centres.
- Be located on walking and cycling networks.
- Have a bus stop located along the school site boundary.
- Have student drop-off zones, bus parking and on-street parking in addition to other street functions in abutting streets.
- Adjoin the public open space network and community sporting and other recreation facilities.
- Be integrated with community facilities.
- Be located on land that is not affected by physical, environmental or other constraints.

Schools should be accessible by the Principal Public Transport Network in Metropolitan Melbourne and on the regional public transport network outside Metropolitan Melbourne.

Primary schools should be located on connector streets and not on arterial roads.

New State Government school sites must meet the requirements of the Department of Education and Training and abut at least two streets with sufficient widths to provide student drop-off zones, bus parking and on-street parking in addition to other street functions.

56.03-4 Built environment objective

09/10/2006
VC42

To create urban places with identity and character.

Standard C5

The built environment should:

- Implement any relevant urban design strategy, plan or policy for the area set out in this scheme.
- Provide living and working environments that are functional, safe and attractive.
- Provide an integrated layout, built form and urban landscape.
- Contribute to a sense of place and cultural identity.

An application should describe the identity and character to be achieved and the elements that contribute to that identity and character.

56.03-5 Neighbourhood character objective

09/10/2006
VC42

To design subdivisions that respond to neighbourhood character.

Standard C6

Subdivision should:

- Respect the existing neighbourhood character or achieve a preferred neighbourhood character consistent with any relevant neighbourhood character objective, policy or statement set out in this scheme.
- Respond to and integrate with the surrounding urban environment.
- Protect significant vegetation and site features.

56.04 LOT DESIGN

09/10/2006
VC42

56.04-1 Lot diversity and distribution objectives

09/10/2006
VC42

To achieve housing densities that support compact and walkable neighbourhoods and the efficient provision of public transport services.

To provide higher housing densities within walking distance of activity centres.

To achieve increased housing densities in designated growth areas.

To provide a range of lot sizes to suit a variety of dwelling and household types.

Standard C7

A subdivision should implement any relevant housing strategy, plan or policy for the area set out in this scheme.

Lot sizes and mix should achieve the average net residential density specified in any zone or overlay that applies to the land or in any relevant policy for the area set out in this scheme.

A range and mix of lot sizes should be provided including lots suitable for the development of:

- Single dwellings.
- Two dwellings or more.
- Higher density housing.
- Residential buildings and Retirement villages.

Unless the site is constrained by topography or other site conditions, lot distribution should provide for 95 per cent of dwellings to be located no more than 400 metre street walking distance from the nearest existing or proposed bus stop, 600 metres street walking distance from the nearest existing or proposed tram stop and 800 metres street walking distance from the nearest existing or proposed railway station.

Lots of 300 square metres or less in area, lots suitable for the development of two dwellings or more, lots suitable for higher density housing and lots suitable for Residential buildings and Retirement villages should be located in and within 400 metres street walking distance of an activity centre.

56.04-2 Lot area and building envelopes objective

09/10/2006
VC42

To provide lots with areas and dimensions that enable the appropriate siting and construction of a dwelling, solar access, private open space, vehicle access and parking, water management, easements and the retention of significant vegetation and site features.

Standard C8

An application to subdivide land that creates lots of less than 300 square metres should be accompanied by information that shows:

- That the lots are consistent or contain building envelope that is consistent with a development approved under this scheme, or
- That a dwelling may be constructed on each lot in accordance with the requirements of this scheme.

Lots of between 300 square metres and 500 square metres should:

- Contain a building envelope that is consistent with a development of the lot approved under this scheme, or
- If no development of the lot has been approved under this scheme, contain a building envelope and be able to contain a rectangle measuring 10 metres by 15 metres, or 9 metres by 15 metres if a boundary wall is nominated as part of the building envelope.

If lots of between 300 square metres and 500 square metres are proposed to contain dwellings that are built to the boundary, the long axis of the lots should be within 30 degrees east and 20 degrees west of north unless there are significant physical constraints that make this difficult to achieve.

Lots greater than 500 square metres should be able to contain a rectangle measuring 10 metres by 15 metres, and may contain a building envelope.

A building envelope may specify or incorporate any relevant siting and design requirement. Any requirement should meet the relevant standards of Clause 54, unless:

- The objectives of the relevant standards are met, and
- The building envelope is shown as a restriction on a plan of subdivision registered under the *Subdivision Act 1988*, or is specified as a covenant in an agreement under Section 173 of the Act.

Where a lot with a building envelope adjoins a lot that is not on the same plan of subdivision or is not subject to the same agreement relating to the relevant building envelope:

- The building envelope must meet Standards A10 and A11 of Clause 54 in relation to the adjoining lot, and
- The building envelope must not regulate siting matters covered by Standards A12 to A15 (inclusive) of Clause 54 in relation to the adjoining lot. This should be specified in the relevant plan of subdivision or agreement.

Lot dimensions and building envelopes should protect:

- Solar access for future dwellings and support the siting and design of dwellings that achieve the energy rating requirements of the Building Regulations.
- Existing or proposed easements on lots.
- Significant vegetation and site features.

56.04-3 Solar orientation of lots objective

09/10/2006
VC42

To provide good solar orientation of lots and solar access for future dwellings.

Standard C9

Unless the site is constrained by topography or other site conditions, at least 70 percent of lots should have appropriate solar orientation.

Lots have appropriate solar orientation when:

- The long axis of lots are within the range north 20 degrees west to north 30 degrees east, or east 20 degrees north to east 30 degrees south.
- Lots between 300 square metres and 500 square metres are proposed to contain dwellings that are built to the boundary, the long axis of the lots should be within 30 degrees east and 20 degrees west of north.

- Dimensions of lots are adequate to protect solar access to the lot, taking into account likely dwelling size and the relationship of each lot to the street.

56.04-3 Street orientation objective

09/10/2006
VC42

To provide a lot layout that contributes to community social interaction, personal safety and property security.

Standard C10

Subdivision should increase visibility and surveillance by:

- Ensuring lots front all roads and streets and avoid the side or rear of lots being oriented to connector streets and arterial roads.
- Providing lots of 300 square metres or less in area and lots for 2 or more dwellings around activity centres and public open space.
- Ensuring streets and houses look onto public open space and avoiding sides and rears of lots along public open space boundaries.
- Providing roads and streets along public open space boundaries.

56.04-3 Common area objectives

09/10/2006
VC42

To identify common areas and the purpose for which the area is commonly held.

To ensure the provision of common area is appropriate and that necessary management arrangements are in place.

To maintain direct public access throughout the neighbourhood street network.

Standard C11

An application to subdivide land that creates common land must be accompanied by a plan and a report identifying:

- The common area to be owned by the body corporate, including any streets and open space.
- The reasons why the area should be commonly held.
- Lots participating in the body corporate.
- The proposed management arrangements including maintenance standards for streets and open spaces to be commonly held.

56.05 URBAN LANDSCAPE

01/10/2009
VC58

56.05-1 Integrated urban landscape objectives

09/10/2006
VC42

To provide attractive and continuous landscaping in streets and public open spaces that contribute to the character and identity of new neighbourhoods and urban places or to existing or preferred neighbourhood character in existing urban areas.

To incorporate natural and cultural features in the design of streets and public open space where appropriate.

To protect and enhance native habitat and discourage the planting and spread of noxious weeds.

To provide for integrated water management systems and contribute to drinking water conservation.

Standard C12

An application for subdivision that creates streets or public open space should be accompanied by a landscape design.

The landscape design should:

- Implement any relevant streetscape, landscape, urban design or native vegetation precinct plan, strategy or policy for the area set out in this scheme.
- Create attractive landscapes that visually emphasise streets and public open spaces.
- Respond to the site and context description for the site and surrounding area.
- Maintain significant vegetation where possible within an urban context.
- Take account of the physical features of the land including landform, soil and climate.
- Protect and enhance any significant natural and cultural features.
- Protect and link areas of significant local habitat where appropriate.
- Support integrated water management systems with appropriate landscape design techniques for managing urban run-off including wetlands and other water sensitive urban design features in streets and public open space.
- Promote the use of drought tolerant and low maintenance plants and avoid species that are likely to spread into the surrounding environment.
- Ensure landscaping supports surveillance and provides shade in streets, parks and public open space.
- Develop appropriate landscapes for the intended use of public open space including areas for passive and active recreation, the exercising of pets, playgrounds and shaded areas.
- Provide for walking and cycling networks that link with community facilities.
- Provide appropriate pathways, signage, fencing, public lighting and street furniture.
- Create low maintenance, durable landscapes that are capable of a long life.

- The landscape design must include a maintenance plan that sets out maintenance responsibilities, requirements and costs.

56.05-2 Public open space provision objectives

01/10/2009
VC58

To provide a network of quality, well-distributed, multi-functional and cost-effective public open space that includes local parks, active open space, linear parks and trails, and links to regional open space.

To provide a network of public open space that caters for a broad range of users.

To encourage healthy and active communities.

To provide adequate unencumbered land for public open space and integrate any encumbered land with the open space network.

To ensure land provided for public open space can be managed in an environmentally sustainable way and contributes to the development of sustainable neighbourhoods.

Standard C13

The provision of public open space should:

- Implement any relevant objective, policy, strategy or plan (including any growth area precinct structure plan) for open space set out in this scheme.
- Provide a network of well-distributed neighbourhood public open space that includes:
- Local parks within 400 metres safe walking distance of at least 95 percent of all dwellings. Where not designed to include active open space, local parks should be generally 1 hectare in area and suitably dimensioned and designed to provide for their intended use and to allow easy adaptation in response to changing community preferences.
- Additional small local parks or public squares in activity centres and higher density residential areas.
- Active open space of a least 8 hectares in area within 1 kilometre of 95 percent of all dwellings that is:
- Suitably dimensioned and designed to provide for the intended use, buffer areas around sporting fields and passive open space
- Sufficient to incorporate two football/cricket ovals
- Appropriate for the intended use in terms of quality and orientation
- Located on flat land (which can be cost effectively graded)
- Located with access to, or making provision for, a recycled or sustainable water supply
- Adjoin schools and other community facilities where practical
- Designed to achieve sharing of space between sports.
- Linear parks and trails along waterways, vegetation corridors and road reserves within 1 kilometre of 95 percent of all dwellings.

Public open space should:

- Be provided along foreshores, streams and permanent water bodies.
- Be linked to existing or proposed future public open spaces where appropriate.

- Be integrated with floodways and encumbered land that is accessible for public recreation.
- Be suitable for the intended use.
- Be of an area and dimensions to allow easy adaptation to different uses in response to changing community active and passive recreational preferences.
- Maximise passive surveillance.
- Be integrated with urban water management systems, waterways and other water bodies.
- Incorporate natural and cultural features where appropriate.

56.06 ACCESS AND MOBILITY MANAGEMENT

18/06/2010
VC62

56.06-1 Integrated mobility objectives

18/06/2010
VC62

To achieve an urban structure where compact and walkable neighbourhoods are clustered to support larger activity centres on the Principal Public Transport Network in Metropolitan Melbourne and on the regional public transport network outside Metropolitan Melbourne.

To provide for walking (including persons with impaired mobility), cycling, public transport and other motor vehicles in an integrated manner.

To contribute to reduced car dependence, improved energy efficiency, improved transport efficiency, reduced greenhouse gas emissions and reduced air pollution.

Standard C14

An application for a subdivision must include a plan of the layout of the neighbourhood that meets the objectives of:

- Clause 56.06-2 Walking and cycling network.
- Clause 56.06-3 Public transport network.
- Clause 56.06-4 Neighbourhood street network.

56.06-2 Walking and cycling network objectives

09/10/2006
VC42

To contribute to community health and well being by encouraging walking and cycling as part of the daily lives of residents, employees and visitors.

To provide safe and direct movement through and between neighbourhoods by pedestrians and cyclists.

To reduce car use, greenhouse gas emissions and air pollution.

Standard C15

The walking and cycling network should be designed to:

- Implement any relevant regional and local walking and cycling strategy, plan or policy for the area set out in this scheme.
- Link to any existing pedestrian and cycling networks.
- Provide safe walkable distances to activity centres, community facilities, public transport stops and public open spaces.
- Provide an interconnected and continuous network of safe, efficient and convenient footpaths, shared paths, cycle paths and cycle lanes based primarily on the network of arterial roads, neighbourhood streets and regional public open spaces.
- Provide direct cycling routes for regional journeys to major activity centres, community facilities, public transport and other regional activities and for regional recreational cycling.
- Ensure safe street and road crossings including the provision of traffic controls where required.
- Provide an appropriate level of priority for pedestrians and cyclists.

- Have natural surveillance along streets and from abutting dwellings and be designed for personal safety and security particularly at night.
- Be accessible to people with disabilities.

56.06-3 Public transport network objectives

09/10/2006
VC42

To provide an arterial road and neighbourhood street network that supports a direct, efficient and safe public transport system.

To encourage maximum use of public transport.

Standard C16

The public transport network should be designed to:

- Implement any relevant public transport strategy, plan or policy for the area set out in this scheme.
- Connect new public transport routes to existing and proposed routes to the satisfaction of the relevant public transport authority.
- Provide for public transport links between activity centres and other locations that attract people using the Principal Public Transport Network in Metropolitan Melbourne and the regional public transport network outside Metropolitan Melbourne.
- Locate regional bus routes principally on arterial roads and locate local bus services principally on connector streets to provide:
    - Safe and direct movement between activity centres without complicated turning manoeuvres.
    - Direct travel between neighbourhoods and neighbourhood activity centres.
    - A short and safe walk to a public transport stop from most dwellings.

56.06-4 Neighbourhood street network objective

18/06/2010
VC62

To provide for direct, safe and easy movement through and between neighbourhoods for pedestrians, cyclists, public transport and other motor vehicles using the neighbourhood street network.

Standard C17

The neighbourhood street network must:

- Take account of the existing mobility network of arterial roads, neighbourhood streets, cycle paths, shared paths, footpaths and public transport routes.
- Provide clear physical distinctions between arterial roads and neighbourhood street types.
- Comply with the Roads Corporation’s arterial road access management policies.
- Provide an appropriate speed environment and movement priority for the safe and easy movement of pedestrians and cyclists and for accessing public transport.
- Provide safe and efficient access to activity centres for commercial and freight vehicles.

- Provide safe and efficient access to all lots for service and emergency vehicles.
- Provide safe movement for all vehicles.
- Incorporate any necessary traffic control measures and traffic management infrastructure.

The neighbourhood street network should be designed to:

- Implement any relevant transport strategy, plan or policy for the area set out in this scheme.
- Include arterial roads at intervals of approximately 1.6 kilometres that have adequate reservation widths to accommodate long term movement demand.
- Include connector streets approximately halfway between arterial roads and provide adequate reservation widths to accommodate long term movement demand.
- Ensure connector streets align between neighbourhoods for direct and efficient movement of pedestrians, cyclists, public transport and other motor vehicles.
- Provide an interconnected and continuous network of streets within and between neighbourhoods for use by pedestrians, cyclists, public transport and other vehicles.
- Provide an appropriate level of local traffic dispersal.
- Indicate the appropriate street type.
- Provide a speed environment that is appropriate to the street type.
- Provide a street environment that appropriately manages movement demand (volume, type and mix of pedestrians, cyclists, public transport and other motor vehicles).
- Encourage appropriate and safe pedestrian, cyclist and driver behaviour.
- Provide safe sharing of access lanes and access places by pedestrians, cyclists and vehicles.
- Minimise the provision of culs-de-sac.
- Provide for service and emergency vehicles to safely turn at the end of a dead-end street.
- Facilitate solar orientation of lots.
- Facilitate the provision of the walking and cycling network, integrated water management systems, utilities and planting of trees.
- Contribute to the area's character and identity.
- Take account of any identified significant features.

56.06-5 Walking and cycling network detail objectives

09/10/2006
VC42

To design and construct footpaths, shared path and cycle path networks that are safe, comfortable, well constructed and accessible for people with disabilities.

To design footpaths to accommodate wheelchairs, prams, scooters and other footpath bound vehicles.

Standard C18

Footpaths, shared paths, cycle paths and cycle lanes should be designed to:

- Be part of a comprehensive design of the road or street reservation.
- Be continuous and connect.
- Provide for public transport stops, street crossings for pedestrians and cyclists and kerb crossovers for access to lots.
- Accommodate projected user volumes and mix.
- Meet the requirements of Table C1.
- Provide pavement edge, kerb, channel and crossover details that support safe travel for pedestrians, footpath bound vehicles and cyclists, perform required drainage functions and are structurally sound.
- Provide appropriate signage.
- Be constructed to allow access to lots without damage to the footpath or shared path surfaces.
- Be constructed with a durable, non-skid surface.
- Be of a quality and durability to ensure:
  - Safe passage for pedestrians, cyclists, footpath bound vehicles and vehicles.
  - Discharge of urban run-off.
  - Preservation of all-weather access.
  - Maintenance of a reasonable, comfortable riding quality.
  - A minimum 20 year life span.
- Be accessible to people with disabilities and include tactile ground surface indicators, audible signals and kerb ramps required for the movement of people with disabilities.

56.06-6 Public transport network detail objectives

09/10/2006
VC42

To provide for the safe, efficient operation of public transport and the comfort and convenience of public transport users.

To provide public transport stops that are accessible to people with disabilities.

Standard C19

Bus priority measures must be provided along arterial roads forming part of the existing or proposed Principal Public Transport Network in Metropolitan Melbourne and the regional public transport network outside Metropolitan Melbourne to the requirements of the relevant roads authority.

Road alignment and geometry along bus routes should provide for the efficient, unimpeded movement of buses and the safety and comfort of passengers.

The design of public transport stops should not impede the movement of pedestrians.

Bus and tram stops should have:

- Surveillance from streets and adjacent lots.
- Safe street crossing conditions for pedestrians and cyclists.

Safe pedestrian crossings on arterial roads and at schools including the provision of traffic controls as required by the roads authority.

- Continuous hard pavement from the footpath to the kerb.
- Sufficient lighting and paved, sheltered waiting areas for forecast user volume at neighbourhood centres, schools and other locations with expected high patronage.
- Appropriate signage.

Public transport stops and associated waiting areas should be accessible to people with disabilities and include tactile ground surface indicators, audible signals and kerb ramps required for the movement of people with physical disabilities.

56.06-7 Neighbourhood street network detail objective

15/09/2008
VC49

To design and construct street carriageways and verges so that the street geometry and traffic speeds provide an accessible and safe neighbourhood street system for all users.

Standard C20

The design of streets and roads should:

- Meet the requirements of Table C1. Where the widths of access lanes, access places, and access streets do not comply with the requirements of Table C1, the requirements of the relevant fire authority and roads authority must be met.
- Provide street blocks that are generally between 120 metres and 240 metres in length and generally between 60 metres to 120 metres in width to facilitate pedestrian movement and control traffic speed.
- Have verges of sufficient width to accommodate footpaths, shared paths, cycle paths, integrated water management, street tree planting, lighting and utility needs.
- Have street geometry appropriate to the street type and function, the physical land characteristics and achieve a safe environment for all users.
- Provide a low-speed environment while allowing all road users to proceed without unreasonable inconvenience or delay.
- Provide a safe environment for all street users applying speed control measures where appropriate.
- Ensure intersection layouts clearly indicate the travel path and priority of movement for pedestrians, cyclists and vehicles.
- Provide a minimum 5 metre by 5 metre corner splay at junctions with arterial roads and a minimum 3 metre by 3 metre corner splay at other junctions unless site conditions justify a variation to achieve safe sight lines across corners.
- Ensure streets are of sufficient strength to:
  - Enable the carriage of vehicles.
  - Avoid damage by construction vehicles and equipment.
- Ensure street pavements are of sufficient quality and durability for the:
  - Safe passage of pedestrians, cyclists and vehicles.
  - Discharge of urban run-off.
  - Preservation of all-weather access and maintenance of a reasonable, comfortable riding quality.

- Ensure carriageways of planned arterial roads are designed to the requirements of the relevant road authority.
- Ensure carriageways of neighbourhood streets are designed for a minimum 20 year life span.
- Provide pavement edges, kerbs, channel and crossover details designed to:
  - Perform the required integrated water management functions.
  - Delineate the edge of the carriageway for all street users.
  - Provide efficient and comfortable access to abutting lots at appropriate locations.
  - Contribute to streetscape design.
- Provide for the safe and efficient collection of waste and recycling materials from lots.
- Be accessible to people with disabilities.
- Meet the requirements of Table C1. Where the widths of access lanes, access places, and access streets do not comply with the requirements of Table C1, the requirements of the relevant fire authority and roads authority must be met. Where the widths of connector streets do not comply with the requirements of Table C1, the requirements of the relevant public transport authority must be met.

A street detail plan should be prepared that shows, as appropriate:

- The street hierarchy and typical cross-sections for all street types.
- Location of carriageway pavement, parking, bus stops, kerbs, crossovers, footpaths, tactile surface indicators, cycle paths and speed control and traffic management devices.
- Water sensitive urban design features.
- Location and species of proposed street trees and other vegetation.
- Location of existing vegetation to be retained and proposed treatment to ensure its health.
- Any relevant details for the design and location of street furniture, lighting, seats, bus stops, telephone boxes and mailboxes.

56.06-8 Lot access objective

18/06/2010
VC62

To provide for safe vehicle access between roads and lots.

Standard C21

Vehicle access to lots abutting arterial roads should be provided from service roads, side or rear access lanes, access places or access streets where appropriate and in accordance with the access management requirements of the relevant roads authority.

Vehicle access to lots of 300 square metres or less in area and lots with a frontage of 7.5 metres or less should be provided via rear or side access lanes, places or streets.

The design and construction of a crossover should meet the requirements of the relevant road authority.

Table C1 Design of roads and neighbourhood streets

Access Lane

A side or rear lane principally providing access to parking on lots with another street frontage.

Traffic volume[1]	300vpd
Target speed[2]	10kph
Carriageway width[3] & parking provision within street reservation	5.5m[6] wide with no parking spaces to be provided. Appropriately signed.
Verge width[4]	No verge required.
Kerbing[5]	
Footpath provision	None Carriageway designed as a shared zone and appropriately signed.
Cycle path provision	None

Access Place

A minor street providing local residential access with shared traffic, pedestrian and recreation use, but with pedestrian priority.

Traffic volume[1]	300vpd to1000vpd
Target speed[2]	15kph
Carriageway width[3] & parking provision within street reservation	5.5m wide with 1 hard standing verge parking space per 2 lots. or 5.5m wide with parking on carriageway - one side. Appropriately signed.
Verge width[4]	7.5m minimum total width. For services provide a minimum of 3.5m on one side and a minimum of 2.5m on the other.
Kerbing[5]	Semi-mountable rollover or flush and swale or other water sensitive urban design treatment area.
Footpath provision	Not required if serving 5 dwellings or less and the carriageway is designed as a shared zone and appropriately signed. or 1.5m wide footpath offset a minimum distance of 1m from the kerb.
Cycle path provision	None

Access Street - Level 1

A street providing local residential access where traffic is subservient, speed and volume are low and pedestrian and bicycle movements are facilitated.

Traffic volume[1]	1000vpd to 2000vpd
Target speed[2]	30kph
Carriageway width[3] & parking provision within street reservation	5.5m wide with1 hard standing verge parking space per 2 lots.
Verge width[4]	4m minimum each side
Kerbing[5]	Semi-mountable rollover or flush and swale or other water

	sensitive urban design treatment area.
Footpath provision	1.5m wide footpaths on both sides. Footpaths should be widened to 2.0m in vicinity of a school, shop or other activity centre. Be offset a minimum distance of 1m from the kerb.
Cycle path provision	Carriageway designed as a shared zone and appropriately signed.

Access Street - Level 2

A street providing local residential access where traffic is subservient, speed and volume are low and pedestrian and bicycle movements are facilitated.

Traffic volume[1]	2000vpd to 3000vpd
Target speed[2]	40kph
Carriageway width[3] **& parking provision within street reservation**	7m-7.5m wide with parking on both sides of carriageway
Verge width[4]	4.5m minimum each side
Kerbing[5]	Semi-mountable rollover or flush and swale or other water sensitive urban design treatment area.
Footpath provision	1.5m wide footpaths on both sides. Footpaths should be widened to 2.0m in vicinity of a school, shop or other activity centre. Be offset a minimum distance of 1m from the kerb.
Cycle path provision	Carriageway designed as a shared zone and appropriately signed.

Connector Street - Level 1

A street that carries higher volumes of traffic. It connects access places and access streets through and between neighbourhoods.

Traffic volume[1]	3000 vpd
Target speed[2]	50 kph[7] reduced to 40 kph at schools and 20 kph at pedestrian and cycle crossing points.
Carriageway width[3]**, cycle lane provision, parking provision and bus stops within street reservation**	▪ 3.5m minimum lane width in each direction of travel. ▪ 4.0m minimum lane width at approaches to and departures from roundabouts and T-intersections. ▪ For on-street cycling, increase the minimum clear carriageway in each direction by: · 0.7m where the trafficable carriageway is shared by cyclists but no dedicated bicycle lane is marked on the carriageway; or · 1.5m where a trafficable carriageway is shared by cyclists but no dedicated bicycle lane is marked on the carriageway and there is a single lane in each direction separated by a raised trafficable median of at least 2.0m in width with mountable kerbs; or · 1.7m where a dedicated 1.7m wide bicycle lane is marked on the carriageway. ▪ An additional dedicated parking lane or indented parking within the verge must be provided where street parking is required. A parking lane width of 2.3m is required where

	parallel parking is provided. ▪ Bus stops at the kerbside, not indented within the verge.
Verge width[4]	4.5m minimum each side.
Kerbing[5]	Semi-mountable rollover or flush and swale or other water sensitive urban design treatment area.
Footpath provision	▪ 1.5m wide footpaths on both sides. ▪ Footpath widened to a minimum 2.0m in the vicinity of a school, shop, public transport stop or other activity centre. ▪ Footpaths offset a minimum distance of 1m from the kerb.

Connector Street - Level 2

A street that carries higher volumes of traffic. It connects access places and access streets through and between neighbourhoods.

Traffic volume[1]	3,000 vpd to 7,000 vpd
Target speed[2]	60 kph[8] or 50km/h reduced to 40kph at schools.

Carriageway width[3]**, cycle lane provision, parking provision and bus stops within street reservation**	▪ 3.5m minimum lane width in each direction of travel.
	▪ 4.0m minimum lane width at approaches to and departures from roundabouts and T-intersections.
	▪ 7.0m minimum carriageway width in each direction of travel where there are two lanes in each direction separated by a non-trafficable central medium.
	▪ 8.0m minimum carriageway width at approaches to and departures from roundabouts and T-intersections where there are two lanes in each direction separated by an non-trafficable central medium.
	▪ For on-street cycling, increase the minimum clear carriageway in each direction by:
	  · 0.7m where the trafficable carriageway is shared by cyclists but no dedicated bicycle lane is marked on the carriageway; or
	  · 1.7m where a dedicated 1.7m wide dedicated bicycle lane is marked on the carriageway
	  · 0.3m where there are two trafficable lanes in each direction separated by a non-trafficable central median and the carriageways are shared by cyclists but no dedicated bicycle lane is marked on the carriageway; or
	  · 0.5m where there are two trafficable lanes in each direction separated by a non-trafficable central median and a 1.7m wide dedicated bicycle lane is marked on the carriageway.
	▪ An additional dedicated parking lane or indented parking within the verge must be provided where street parking is required. A parking lane width of 2.3m is required where parallel parking is provided.
	▪ Bus stops located at the kerbside, not indented within the verge.

Verge width[4]	▪ 6m minimum each side (plus central median).
Kerbing[5]	▪ Semi-mountable rollover or flush and swale or other water sensitive urban design treatment area.
Footpath and cycle path provision	▪ 1.5m wide footpath on each side and 1.7m bicycle lanes on the carriageway; or ▪ 2.5m wide shared foot and cycle path on both sides and no

	dedicate bicycle lanes marked on the carriageway. ▪ Footpaths widened to a minimum of 2.0m in the vicinity of a school, shop, public transport stop or other activity centre. ▪ Footpaths or shared foot and cycle paths offset a minimum distance of 1m from the kerb.

Arterial Road

Traffic volume[1]	Greater than 7000vpd
Target speed[2]	Arterial road design as required by the relevant roads authority.
Carriageway width[3] & parking provision within street reservation	Arterial road design as required by the relevant roads authority.
Verge width[4]	Arterial road design as required by the relevant roads authority.
Kerbing[5]	Arterial road design as required by the relevant roads authority.
Footpath & cycle path provision	3m wide shared path on each side or as otherwise required by the relevant roads authority.

Key to Table C1

1. Indicative maximum traffic volume for 24-hour period. These volumes depend upon location. Generation rates may vary between existing and newly developing areas.
2. Target speed is the desired speed at which motorists should travel. This is not necessarily the design speed and is not greater than the marked legal speed limit.
3. Width is measured from kerb invert to kerb invert. Widening may be required at bends to allow for wider vehicle paths using appropriate Australian Standards for on street and off-street parking but should not negate the function of bends serving as slow points.
4. Verge width includes footpaths. Additional width may be required to accommodate a bicycle path.
5. Where drainage is not required a flush pavement edge treatment can be used. Layback kerbs are preferred for safety reasons. Upright kerbs may be considered for drainage purposes or in locations where on-street parking should be clearly defined and parking within the verge is not desired.
6. Turning requirements to access and egress parking on abutting lots may require additional carriageway width. The recommended carriageway width of 5.5m will provide adequate access to a standard 3.5m wide single garage built to the property line.
7. 50kph is the default urban speed limit in Victoria.
8. Target speed must not exceed the legal speed limit.

56.07 INTEGRATED WATER MANAGEMENT

29/10/2015
VC101

56.07-1 Drinking water supply objectives

09/10/2006
VC42

To reduce the use of drinking water.

To provide an adequate, cost-effective supply of drinking water.

Standard C22

The supply of drinking water must be:

- Designed and constructed in accordance with the requirements and to the satisfaction of the relevant water authority.
- Provided to the boundary of all lots in the subdivision to the satisfaction of the relevant water authority.

56.07-2 Reused and recycled water objective

29/10/2015
VC101

To provide for the substitution of drinking water for non-drinking purposes with reused and recycled water.

Standard C23

Reused and recycled water supply systems must be:

- Designed, constructed and managed in accordance with the requirements and to the satisfaction of the relevant water authority, Environment Protection Authority and Department of Health and Human Services.
- Provided to the boundary of all lots in the subdivision where required by the relevant water authority.

56.07-3 Waste water management objective

09/10/2006
VC42

To provide a waste water system that is adequate for the maintenance of public health and the management of effluent in an environmentally friendly manner.

Standard C24

Waste water systems must be:

- Designed, constructed and managed in accordance with the requirements and to the satisfaction of the relevant water authority and the Environment Protection Authority.
- Consistent with any relevant approved domestic waste water management plan.

Reticulated waste water systems must be provided to the boundary of all lots in the subdivision where required by the relevant water authority.

56.07-4 Urban run-off management objectives

09/10/2006
VC42

To minimise damage to properties and inconvenience to residents from urban run-off.

To ensure that the street operates adequately during major storm events and provides for public safety.

To minimise increases in stormwater run-off and protect the environmental values and physical characteristics of receiving waters from degradation by urban run-off.

Standard C25

The urban stormwater management system must be:

- Designed and managed in accordance with the requirements and to the satisfaction of the relevant drainage authority.
- Designed and managed in accordance with the requirements and to the satisfaction of the water authority where reuse of urban run-off is proposed.
- Designed to meet the current best practice performance objectives for stormwater quality as contained in the Urban Stormwater – Best Practice Environmental Management Guidelines (Victorian Stormwater Committee 1999) as amended.
- Designed to ensure that flows downstream of the subdivision site are restricted to pre-development levels unless increased flows are approved by the relevant drainage authority and there are no detrimental downstream impacts.

The stormwater management system should be integrated with the overall development plan including the street and public open space networks and landscape design.

For all storm events up to and including the 20% Average Exceedence Probability (AEP) standard:

- Stormwater flows should be contained within the drainage system to the requirements of the relevant authority.
- Ponding on roads should not occur for longer than 1 hour after the cessation of rainfall.

For storm events greater than 20% AEP and up to and including 1% AEP standard:

- Provision must be made for the safe and effective passage of stormwater flows.
- All new lots should be free from inundation or to a lesser standard of flood protection where agreed by the relevant floodplain management authority.
- Ensure that streets, footpaths and cycle paths that are subject to flooding meet the safety criteria $d_a V_{ave} < 0.35\ m^2/s$ (where, d_a = average depth in metres and V_{ave} = average velocity in metres per second).

The design of the local drainage network should:

- Ensure run-off is retarded to a standard required by the responsible drainage authority.
- Ensure every lot is provided with drainage to a standard acceptable to the relevant drainage authority. Wherever possible, run-off should be directed to the front of the lot and discharged into the street drainage system or legal point of discharge.
- Ensure that inlet and outlet structures take into account the effects of obstructions and debris build up. Any surcharge drainage pit should discharge into an overland flow in a safe and predetermined manner.

- Include water sensitive urban design features to manage run-off in streets and public open space. Where such features are provided, an application must describe maintenance responsibilities, requirements and costs.

Any flood mitigation works must be designed and constructed in accordance with the requirements of the relevant floodplain management authority.

56.08 SITE MANAGEMENT

09/10/2006
VC42

56.08-1 Site management objectives

09/10/2006
VC42

To protect drainage infrastructure and receiving waters from sedimentation and contamination.

To protect the site and surrounding area from environmental degradation or nuisance prior to and during construction of subdivision works.

To encourage the re-use of materials from the site and recycled materials in the construction of subdivisions where practicable.

Standard C26

A subdivision application must describe how the site will be managed prior to and during the construction period and may set out requirements for managing:

- Erosion and sediment.
- Dust.
- Run-off.
- Litter, concrete and other construction wastes.
- Chemical contamination.
- Vegetation and natural features planned for retention.

Recycled material should be used for the construction of streets, shared paths and other infrastructure where practicable.

56.09 UTILITIES

22/08/2014
VC118

56.09-1 Shared trenching objectives

22/08/2014
VC118

To maximise the opportunities for shared trenching.

To minimise constraints on landscaping within street reserves.

Standard C27

Reticulated services for water, gas, electricity and telecommunications should be provided in shared trenching to minimise construction costs and land allocation for underground services.

56.09-2 Electricity, telecommunications and gas objectives

09/10/2006
VC42

To provide public utilities to each lot in a timely, efficient and cost effective manner.

To reduce greenhouse gas emissions by supporting generation and use of electricity from renewable sources.

Standard C28

The electricity supply system must be designed in accordance with the requirements of the relevant electricity supply agency and be provided to the boundary of all lots in the subdivision to the satisfaction of the relevant electricity authority.

Arrangements that support the generation or use of renewable energy at a lot or neighbourhood level are encouraged.

The telecommunication system must be designed in accordance with the requirements of the relevant telecommunications servicing agency and should be consistent with any approved strategy, policy or plan for the provision of advanced telecommunications infrastructure, including fibre optic technology. The telecommunications system must be provided to the boundary of all lots in the subdivision to the satisfaction of the relevant telecommunications servicing authority.

Where available, the reticulated gas supply system must be designed in accordance with the requirements of the relevant gas supply agency and be provided to the boundary of all lots in the subdivision to the satisfaction of the relevant gas supply agency.

56.09-3 Fire hydrants objective

15/09/2008
VC49

To provide fire hydrants and fire plugs in positions that enable fire fighters to access water safely, effectively and efficiently.

Standard C29

Fire hydrants should be provided:

- A maximum distance of 120 metres from the rear of the each lot.
- No more than 200 metres apart.

Hydrants and fire plugs must be compatible with the relevant fire service equipment. Where the provision of fire hydrants and fire plugs does not comply with the requirements of standard C29, fire hydrants must be provided to the satisfaction of the relevant fire authority.

56.09-4 Public lighting objective

09/10/2006
VC42

To provide public lighting to ensure the safety of pedestrians, cyclists and vehicles.

To provide pedestrians with a sense of personal safety at night.

To contribute to reducing greenhouse gas emissions and to saving energy.

Standard C30

Public lighting should be provided to streets, footpaths, public telephones, public transport stops and to major pedestrian and cycle paths including public open spaces that are likely to be well used at night to assist in providing safe passage for pedestrians, cyclists and vehicles.

Public lighting should be designed in accordance with the relevant Australian Standards.

Public lighting should be consistent with any strategy, policy or plan for the use of renewable energy and energy efficient fittings.