



CATCHMENTS REMEDIATION RATE PROGRAM

2011–2012 Annual Report
Water Catchments Team

HORNSBY SHIRE COUNCIL

Catchments Remediation Rate Program

2011 - 2012 Annual Report



Plate 1 – Eastcote Road, North Epping – Bioretention System

Acknowledgements

The 2011 - 2012 Catchments Remediation Rate Annual Report was produced by David Beharrell and Elizabeth Bulley under the direction of Diane Campbell - Manager, Natural Resources Branch, Hornsby Shire Council. Comments, assistance with programs and report contributions were provided by staff from Council's Natural Resources Branch.

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Executive Summary

This report aims to provide both quantitative and qualitative commentary on a number of programs run as part of the Catchments Remediation Program and funded by Catchment Remediation Rate. These programs include the capital works program, asset maintenance and monitoring, asset renewal, landfill and leachate remediation, street sweeping and catchment education.

The primary focus of the report is to provide quantitative data and analysis of the relative performance of different water quality treatment measures, including gross pollutant devices (GPD's), sediment basins, wetlands and bioretention systems that have been constructed to improve stormwater quality in Hornsby Shire. The results of the report will be used by stormwater and catchment managers to provide a better insight into determining the type of structures that are suitable for specific sites. Furthermore, the data provides valuable information about the costs (both capital and maintenance), benefits and device optimisation which can aid in the formulation of strategies to improve catchment and landuse practices by both structural and non-structural means.

Gross pollutant devices, sediment basins, wetlands and bioretention systems all come under the general description of Stormwater Quality Improvement Devices (SQUIDS). The principal objective of installing SQUIDS is to improve water quality by removing pollutants and in some instances retaining stormwater flows. In the 2011 - 2012 financial year, \$1,030,000 was spent on capital works with 9 catchments remediation projects being initiated and completed. These works involved the construction of:

- Six end-of-pipe bioretention systems: Cherrybrook, Hornsby, Hornsby Heights, Mount Colah and North Epping (2)
- Three creek stabilisation projects: Cherrybrook, Epping and Hornsby Heights
- One car park raingarden and bioswale: Galston
- Two large trash racks: Cherrybrook

While these structural interventions treat and remove pollutants directly, the Catchments Remediation Program also promotes and funds non-structural initiatives in the pursuit of improving water quality in the Shire's creeks, waterways and receiving waters. These include:

monitoring, maintenance, street sweeping, riparian bush regeneration, environmental education, business auditing, compliance programs, pollution clean-ups and estuary management initiatives.

The collection of performance data over the 2011 - 2012 financial year has allowed Council to quantify the volume of gross pollutant (sediment, litter and organic matter) removal from Council's 422 water quality improvement assets. The data show that 1,074 cubic metres of sediment, litter and organic matter was captured and prevented from entering the Shire's waterways during this period. In addition, modeling indicates that over 2024kg of phosphorous and 6378kg of nitrogen was removed by CRR funded initiatives which is of particular significance because of their known detrimental impact on aquatic ecosystems, such as creeks and estuaries.

The total cost to Council to maintain its water quality improvement devices and adjacent landscaped areas was approximately \$437,000 in the 2011 - 2012 financial year. This included \$198,000 for the cleaning of SQUIDS and disposal of waste to landfill and \$146,000 for landscaping maintenance and bush regeneration at the sites. Other associated costs included the monitoring and maintenance of leachate treatment facilities, tree work and staff wages.

The report also provides information on the design principles behind innovative stormwater treatment measures known as bioretention systems. Projects of particular interest in the 2011 - 2012 period was the large two tiered bioretention systems constructed below Braidwood Avenue, North Epping and the two large graduated trash racks installed at the headwaters of Berowra Creek, Cherrybrook.

Overall, the findings of this report give stormwater managers a better insight into the cost-effectiveness and performance of water quality improvement structures and the management of life-cycle costs for individual stormwater treatment measures. The performance of these devices allows Council to both refine and modify the design of future water quality control measures, and judge their appropriateness for proposed remediation sites based on catchment size and land use impact.

1.0 Introduction & Background

Hornsby is located 25 kilometres north-west of the Sydney CBD and is the Council base for a Shire covering approximately 50,990 hectares and serving the needs of an estimated 164,000 residents (Australian Bureau of Statistics, 2011). The Shire extends from Epping in the south to Brooklyn and Wisemans Ferry in the north fronting a large expanse of the Lower Hawkesbury River. A majority of the northern and central Shire consists of National Park and Nature Reserve. This unique natural character combined with the many creeks and estuaries has led to Council being termed the 'Bushland Shire'.

In an attempt to conserve the ecological value of the Shire's many natural waterways and to improve the quality of urban stormwater Hornsby Shire Council has taken an integrated approach to stormwater quality management by developing a range of capital and non-capital (preventative) measures. This initiative includes all major catchments under the Stormwater Management Plan framework, together with more closely modelled sub-catchment plans. Council's progressive strategy has recognised the need to tackle these challenges using a broad approach to understanding and managing the total water cycle. This has led to the development of a Sustainable Total Water Cycle Management Strategy (2005).

This report focuses on the performance of different stormwater treatment measures, including gross pollutant traps, constructed wetlands, sediment basins, stream remediation, and bioretention systems that have been constructed under Council's Catchments Remediation Rate (CRR) Capital Works Program. The report also outlines Council's work on leachate treatment and stormwater harvesting schemes.

1.1 Report Objective

To provide quantitative data and an analysis of the relative performance of different stormwater and leachate quality improvement devices that have been implemented under the Catchments Remediation Rate Program. Specific reference will be made to those devices constructed and / or installed in the 2011 - 2012 financial year.

1.2 Background of the Catchments Remediation Program

1.2.1 Catchments Remediation Program

In response to general water quality degradation, including red algal blooms and fish kills in the Berowra Creek estuary in September 1993, Hornsby Council placed a moratorium on all development assessments within the catchments of the West Hornsby STP. To resolve this, the Minister for Planning established a Technical Working Party (TWP), comprising representatives of Council, the Water Board (Sydney Water) and the Department of Urban Affairs and Planning (DUAP) which are now known as The NSW Department of Planning. Representatives from the Environment Protection Authority (EPA) and the Hawkesbury-Nepean Catchment Management Trust joined the TWP in early 1994. The TWP confirmed that the two Sewage Treatment Plants (STP's) contributed to the poor water quality of the creek. Moreover, it highlighted the significant role of polluted urban stormwater, particularly runoff from developing and newly developed residential areas.

On 27 April 1994, the participating organisations of the TWP signed a Statement of Joint Intent (SoJI - also known as the Community Contract for Berowra Creek) agreeing to work together to achieve the ecologically sustainable development (ESD) of the Berowra Creek catchment and the recovery of the environmental health of the creek. The Community Contract, included agreements to upgrade the STP's and it bound the parties to the preparation and implementation of a Water Quality Management Strategy. It also required Council to prepare and implement a strategy to reduce stormwater nutrient ingress to Berowra Creek and to utilise water sensitive design in its consideration of future developments.

However, the level of pollutants and the urgent need for action was not confined to Berowra Creek. Water quality in the other major catchments within the Shire had also deteriorated as a result of urbanisation. Remedial works to reduce pollution and improve water quality were required throughout the entire Shire including relevant areas draining the Cowan Creek, Lane Cove River and the Hawkesbury River catchments.

In 1995, the Water Catchments Team initiated the first phase of the ongoing strategic planning for catchment management within the Shire. The result was the production of a Catchments Remediation Program Five-Year Plan which detailed the proposed expenditure

1.0 Introduction & Background

of the Catchments Remediation Rate towards meeting the objectives of the Statement of Joint Intent and in turn improving water quality in the Shire's waterways. The Plan included financial forecasts of rate income over a five year period together with capital investment and non-capital expenditure including asset management.

It was hoped that Hornsby Shire Council's Catchments Remediation Program would give stormwater managers a better insight into the cost-efficiency and performance of individual devices, but more importantly, monitoring of devices would reflect the individual characteristics of sub-catchments and the associated point sources of pollution, which can be targeted through pollutant minimisation strategies. It was also seen that community and industry awareness projects are important to complement the Catchments Remediation Program, whilst Local Government can also review work practices and strategies in relation to sediment and erosion controls on building sites (and their enforcement), street sweeping, street tree planting, rubbish collections and kerbside recycling collections.

Additional objectives of the Catchments Remediation Program, which still apply today, aim to address:

- Innovative Products and Services – generate and use ideas to add value to the community as stakeholders, provide productivity improvements, continue leadership and management capabilities in local government
- Health and Safety – provide a safe and healthy aquatic environment for the community, council staff and contractors
- Performance – to better understand community needs and expectations and deliver reliable devices which maximise the cost / benefit of installed capital projects
- Reporting – detail expenditure through regular reporting to the community; and
- Service – protect and service assets and continually improve operations.

1.2.2 Catchments Remediation Rate (CRR) and Panel

Council's catchments remediation work up to 1997 was only partly funded by the CRR, with the majority of funding being at the expense of other traditional Council services e.g. Parks. However, the cost of Council's 'Statement of Joint Intent (SoJI) for Berowra

Creek' obligations and remediation works in the other catchments was highlighted to be much more than was covered by the rate. The proposal to increase the CRR from 2% to a 5% levy on ordinary rates in 1997 was presented with the idea to accelerate remediation capital works and return resources to traditional services that had suffered funding cuts. The increased funding was intended for planning, design, construction, maintenance and management of remediation devices. The proposal to increase the CRR to 5% was adopted by Council on the 13th April 1997 and still applies today.

Approximately 50% of the CRR is directed to non-capital costs including project management and a series of studies, associated with meeting the SoJI objectives. These studies are designed to identify more precisely the cause and effect mechanisms of pollution generation in the Shire, develop effective longer term remedies for the problems, and establish appropriate technological and monitoring techniques to determine and report progress. The remaining 50% of CRR funding is allocated to on-ground capital remediation works and subsequent routine maintenance of all constructed devices. Current remedial environmental protection works include the design and construction of wetlands, SQUIDs, leachate control from old landfill sites, sediment basins and creek stabilisation / rehabilitation.

The Catchments Remediation Rate Expenditure Review Panel (the Panel) was established in July 1997 following community consultation on increasing the CRR from 2% to 5%. The Panel meets twice annually to review expenditure following the second and fourth quarters of each financial year and currently comprises six community members, relevant council staff and two nominated Councillors. The purpose of the Panel is to ensure accountability and transparency of expenditure of CRR funds. The terms of reference for the Panel were to:

- note the criteria which enables costs to be eligible for CRR funding;
- assess the validity of funding decisions made by Council staff against the criteria;
- note information relevant to CRR funding, available from Council's accounts;
- determine, in consultation with Council and staff, if the CRR funds have been appropriately assigned; and
- report to Council on the Panel's determination.

1.0 Introduction & Background

1.2.3 Synergies between the CRR program and Council's Strategic Direction, Management Plans and Programs

Council's Community Plan 2010- 2020

The Hornsby Shire Community Plan has been prepared by Hornsby Shire Council in partnership with local residents, our business community, other levels of government, educational institutions, non-government community and cultural organisations and neighbouring councils.

The Hornsby Shire Community Plan sets the strategic direction for where the people of Hornsby Shire want to be in 2020. It's a long term plan to deliver the best possible services to the people of the Hornsby Shire.

The Hornsby Shire Community Plan covers the period from 2010 until 2020, and will be reviewed each four years following the local government elections. It builds on and integrates previous work undertaken by various teams in Council, particularly the Social Plan 2010-2014, the Cultural Plan 2008–2010, the Local Environmental Plan and the Housing Strategy.

The Community Plan is aligned to the Hornsby Shire 2020 Framework for a Sustainable Future which states that a sustainable future requires a successful combination of:

- Protection and enhancement of our natural environment
- A resilient local economy and sustainable resource use
- Enhanced social and community wellbeing
- Effective community infrastructure and services
- Leadership that is accountable and effective

These strategic themes are supported by key goals that will guide the Shire for the next 10 years. The Catchments Remediation Program has a key role to play in delivering Goal 1.2: Maintain healthy waterways and catchments, which emphasises protecting the landscapes and health of our waterways and catchments, including the Hawkesbury River, Berowra Creek and associated tributaries and applying a total water cycle management approach to maintain water quality in our creeks, wetlands and rivers. The strategy pursuant to this goal and related actions are identified below.

Table 1.1 - Link to Council's Community Plan

| Goal | Strategy | Actions for Council |
|---|--|--|
| 1.2 Maintain healthy waterways and catchments | Strategy 1.2.1: Protect and improve the catchments in the Shire by providing support and direction to the water catchments program | Construct water quality remediation devices as per the Catchments Remediation Rate (CRR) 10 year capital works program Undertake the Estuary Management Program |
| | Strategy 1.2.2: Identify and implement innovative water conservation and sustainable water cycle management practices | Implement the Total Water Cycle Management Strategy Implement water conservation and reuse projects |
| | Strategy 1.2.3: Work with the community to care for, protect, enjoy and enhance the health of waterways in the Shire | Provide education to the community on the importance of waterways and estuaries |
| | Strategy 1.2.4: Provide a water quality monitoring service using methods that are reliable, professional and contemporary | Monitor and report environmental conditions, including water quality, at creeks and estuaries |

1.0 Introduction & Background

Water Management Plan 2004

This Water Management Plan (WMP) was developed to better prioritise and integrate the range of water management initiatives currently being delivered within Hornsby Shire and those which are planned to be delivered over the medium to long term. The WMP sets goals and targets for water consumption and quality within the Shire and develops a framework within which all stakeholders can participate and easily understand their place within the management of the water cycle in this region.

The actions set out in this WMP have been developed to give a prioritised structure to the management of the Shire's water resources. The Catchments Remediation Program is one of the core established programs relating to water management in the Shire and many of its core objectives are identified within the WMP Management Action Plan as shown in Table 1.2

Table 1.2 - Water Management Plan - Management Action Plan

| Hornsby Shire Council and ICLEI Water Campaign | |
|--|--|
| Local Action Plan | |
| Water Quality | |
| STRATEGY | ACTIONS |
| 3. Conduct a stormwater quality improvement program | Conduct the Catchments Remediation Rate water quality improvement capital works program as per the rolling 5 year plan. |
| 9. Implement a non piping, conservation and protection of the Shire's natural streams and watercourses. | Develop a protection and remediation of urban streams element for incorporation into all Hornsby DCPs. Watercourses shall be retained or restored to their natural condition and shall be integrated into the urban design of the development that will encourage and support habitat and aid visual amenities and water quality improvements. |
| 24. Improve management of leachate and runoff from disused waste disposal sites. | Develop inventory and audit waste disposal sites with regard to leachate and runoff problems. |
| 27. Ensure application of Best Management Practices to control stormwater pollution. | Maximise the retention of natural watercourse and buffer zones in new developments. |
| 32. Increase and enhance vegetation cover on degraded bank sites to improve stability of bank and maintain biodiversity. | Audit creek and stream banks and identify degraded and vulnerable sites. Regenerate and replant degraded sites with native species. |

1.0 Introduction & Background

Total Sustainable Water Cycle Management Strategy 2006

Council has shown leadership in successful water quality management since the break out of algal blooms in Berowra Creek in the early 1990s with the implementation of the Berowra Creek Water Quality Management Strategy. However, the Water Catchments Team recognised the need to expand traditional thinking of water quantity and quality, to include an understanding of the total water cycle which culminated in the adoption of the Sustainable Water Cycle Management Strategy 2005.

Council's recognition of the need to tackle these challenges using a strategic approach places it at the forefront of sustainable water cycle management and provides the inspiration for this project. The continuation of the Catchments Remediation Program is critical to the successful implementation of this strategic approach to total water cycle management.

Stormwater Drainage Asset Management Plan 2005-2025

The Stormwater Drainage Asset Management Plan (SDAMP) 2006 formalises the process for the financial and physical requirements for a 20 year long-term performance of Council's stormwater and water quality infrastructure assets. The Plan demonstrates responsible stewardship as well as defines and articulates how the stormwater and water quality infrastructure assets are and will be managed to achieve Council's objectives. The Plan also identifies the future service delivery funding requirements for the adopted levels of service, future demand for infrastructure, current asset performance, asset failure, risk, required works and funding constraints.

1.2.4 Statutory Considerations

It should be noted that the Hornsby Shire Local Environment Plan (LEP), 1994, permits Council to undertake the construction or maintenance of stormwater drainage and water quality treatment devices, bush regeneration and landscaping without obtaining development consent. The proposals for construction are assessed under Part V of the Environmental Planning and Assessment Act, 1979, which requires Council to prepare a Review of Environmental Factors (REF). This identifies and evaluates the impacts of an activity to determine whether the impacts are likely to significantly affect the environment. The REF must also consider impacts of the activity on critical habitat or threatened species, populations or ecological communities or their habitat, under section 5A of the EP&A Act.

The Threatened Species Conservation Act (TSC Act) 1995 specifies a set of seven factors which must be considered by decision makers in assessing the effect of a proposed activity on threatened species, populations or ecological communities, or their habitats. These factors are collectively referred to as the seven part test of significance.

The outcome of any threatened species assessment should be that activities are undertaken in an environmentally sensitive manner, and that appropriate measures are undertaken to minimise adverse effects on threatened species, populations or ecological communities, or their habitats.

1.0 Introduction & Background

1.2.5 Asset Auditing and Lifecycle Management

Lifecycle Management

Lifecycle management enables Council to plan interventions, whether its maintenance or renewal, at the optimum stage of an asset's deterioration to enable cost effective extensions of its useful life. There are a number of activities considered in lifecycle management:

- **Operations:** those activities that have no effect on asset condition but are necessary to keep the asset appropriately utilised.
- **Maintenance:** the day to day work required to keep assets operating at agreed service levels. This falls into two broad categories: planned (proactive) maintenance which are maintenance activities planned to prevent asset deterioration; and unplanned (reactive) maintenance which are maintenance activities to correct asset malfunctions and failures on an as required basis (e.g. emergency repairs). Maintenance work is required to maintain the asset's ability to provide the agreed service level but does not extend the life of the asset. Operations and Maintenance expenditure are considered an "Expense" for Council's financial accounting purposes. A key element of asset management planning is determining the most cost-effective mix of planned maintenance in order to reduce unplanned maintenance to a minimum.
- **Renewal work:** the substantial replacement of the asset, or a significant asset component, to its original size and capacity. This work generally aims to return the asset to a condition or state similar to the original asset.
- **Replacements (or reconstruction):** are those projects that are created for the extension or upgrading of assets required to cater for growth or to maintain or improve on the levels of service.

The Stormwater Drainage Asset Management Plan (SDAMP) 2006 was prepared to provide a financial forecast for water quality assets in the Shire over a 20 year period. Cumulative operating expenditure identified in the Plan includes the cumulative operation / maintenance expenditure and asset renewals and

upgrades associated with assets reaching their optimum life or age. To ensure responsible financial management the assumptions made in the modelling were very conservative. Hence, both renewal and projected maintenance cost were set at a high level to allow for unforeseen circumstances or unpredictable rises in costs.

The key feature of these financial projections is that it is envisaged that operational and renewal costs will take an increasingly larger proportion of CRR funds in future years as the number of assets increases. The life cycle analysis modelling of the catchments remediation program, as with Council's Asset Management Plans, will be reviewed at regular intervals to allow for the input of monitoring and knowledge gained over time.

Asset Auditing

Over the previous 12 months Council's CRR Assets Officer has concentrated on assets auditing. By the end of the 2011- 2012 period all but a few of the 400 + assets had been audited. The audits were undertaken using a risk assessment approach which included assessing:

- Public Safety, resulting in:
 - An action register
 - Signage requirements
- Performance – both functionality and structural integrity
- Contractor and Staff OH&S requirements

This proactive auditing regime will be ongoing as it provides a much more realistic assessment of asset condition and hence the requirement for renewal and repair than lifecycle modelling. The information gained from this auditing process along with careful tracking of the costs associated with maintenance, renewal and repair have shown that at present there is little need for a CRR sinking fund for asset renewal/repair.

2.0 Catchments Remediation Rate Capital Works Program

2.1 Delivery of Capital Work

The selection and implementation of structural stormwater quality improvement devices involves numerous steps. These include: site identification and prioritisation; determination of treatment objectives; development of treatment train; concept design; comparison of potential treatments (modelling); detailed design; review of environmental factors; notification and authority to commence construction.

2.1.1 Project Management and Construction

Due to the varying degrees of expertise in different fields the Divisions of Environment and Human Services and Infrastructure and Recreation have forged a partnership approach to deliver CRR capital works projects. The Infrastructure and Recreation Division's Design and Construction Branch now incorporate the design, construction and project management responsibilities associated with CRR capital works routinely into their annual civil works improvement program.

There are a number of benefits to both Divisions and to the Council as a whole as a result of this partnership. Some of these are:

- Projects are developed ensuring compatibility with local engineering and environmental standards, and making sure that all issues are addressed;
- Experience and knowledge from involvement in these projects is utilised in all Council works so that Council sets the standard for developers / builders to follow;
- Opportunities for the Infrastructure and Recreation Division staff to be involved in environmentally "cutting edge" technologies;
- Involvement of staff in the Infrastructure and Recreation Division in an area of environmental management, with a flow-on effect resulting in better understanding of sustainability issues;
- Opportunities for Environment and Human Services Division staff to become more aware of engineering issues in the development of projects;

- Expansion of the core business of the Infrastructure and Recreation Division; and
- Flexibility during the construction phase not necessarily afforded in contractual arrangements.

The combination of the push towards competitive tendering and the need to seek specialised engineering and contractor services results in the contracting out or tendering of some of the design and construction activities. At present a small proportion of the works is contracted out (usually low-risk remediation projects such as stream remediation works and small scale gross pollutant devices) together with specialised design and consulting services.

To date the Environment and Human Services Division has been satisfied with the quality of work achieved and the cost-benefit involved. To reaffirm this, Council recently benchmarked the cost of constructing bioretention systems against other Sydney Councils. As Figure 2.1 illustrates the in-house arrangement represents good value for money.

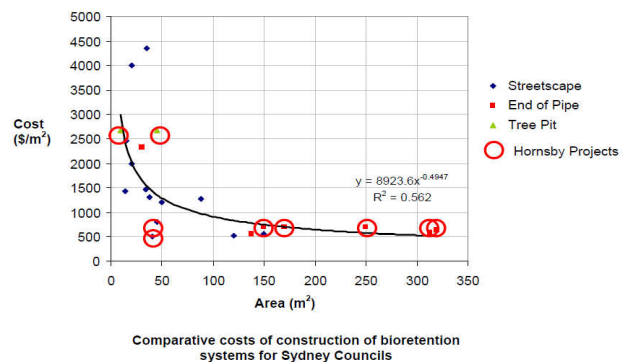


Figure 2.1 - Comparative construction of bioretention systems (Knights et al, 2010)

2.0 Catchments Remediation Rate Capital Works Program

2.1.2 Occupational Health and Safety (OH&S) and Risk Management

All contractors are required by Council to have an OH&S Policy in accordance with the NSW OHS Act 2000 and OHS Regulation 2001 which aim to secure and promote the health, safety and welfare of people at work. Employers and supervisors of staff and contractors have a duty of care under the Act to protect employees and demonstrate due diligence in their OHS Management Systems. Council and contractor policies must address:

- certificates of currency for public liability, third party motor vehicle insurance and workers compensation;
- safe work practices and procedures (hazard identification and risk analysis per site / device);
- induction and safety training (Green or White card);
- corrective action and documentation;
- incident / accident recording and investigation; and
- personal protective equipment (PPE).

By ensuring these requirements are met by both Council staff and contractors the risks identified during the cleaning and maintenance process can be analysed, evaluated and risk treatment plans implemented in accordance with AS / NZS 4360 Risk Management.

2.2 Types of Stormwater Quality Improvement Assets

1.2.1 Objective of Stormwater Treatment

Historically, the principal objective of stormwater treatment measures was to improve the quality of stormwater by removing pollutants, including litter, sediment, nutrients, metals and associated bacterial contamination. Stormwater treatment can be grouped into three categories: primary, secondary and tertiary (Refer to Table 2.1 and Section 2.2.2).

Recent research suggests that to further protect stream ecosystems stormwater management systems should be designed to retain water from small-to-moderate rain events. By doing this the disturbance or damage caused by frequent events can be reduced (Walsh et al 2004).

With this in mind Council’s Catchments Remediation Program has been implementing and providing funding to projects which retain and use stormwater, e.g., bioretention systems (through plant evapotranspiration) and stormwater harvesting schemes (through sports field irrigation).

Table 2.1 - Pollutant ranges for stormwater treatment measures (Engineers Australia, 2006).

| Particle Size Grading | Treatment Measures | Treatment Process |
|--|---|-------------------------|
| Gross Solids > 5000 µm | Gross Pollutant Traps | Screening |
| Coarse- to Medium-Sized Particulates 5000 µm – 125 µm | Sedimentation Basins (Wet & Dry) | Sedimentation |
| Fine Particulates 125 µm – 10 µm | Grass Swales & Filter Strips Surface Flow Wetlands | Enhanced Sedimentation |
| Very Fine/ Colloidal Particulates 10 µm – 0.45 µm | Infiltration Systems Sub-Surface Flow Wetlands | Adhesion and Filtration |
| Dissolved Particles < 0.45 µm | | Biological Uptake |

2.0 Catchments Remediation Rate Capital Works Program

Typical Stormwater Pollutants and Contaminants

- **Gross pollutants** are typically those materials greater than 0.05mm, both degradable and non-degradable, which detrimentally impact physically, visually and bio-chemically on aquatic ecosystems.
- The deposition of **suspended solids** can block pipes, change flow conditions, decrease light penetration and disrupt the habitat of aquatic invertebrates and fish (e.g. by infilling pool habitat). Equally important is that they are associated with other contaminants such as heavy metals, hydrocarbons and phosphorus (Engineers Australia, 2006).
- Increased **nutrients** (phosphorous and nitrogen) levels may cause excessive and unbalanced growth of plants and algae leading to oxygen depletion. Sources of nutrients include atmospheric deposition, tree leaves, domestic and agricultural fertilisers, industrial waste, sewer overflows, animal droppings, detergents and lubricants (Engineers Australia, 2006).
- A wide variety of **heavy metals** are present in stormwater and toxic effects can occur once concentrations exceed certain levels.

2.2.2 Bioretention Systems

Bioretention systems or basins can be simply thought of as “vegetated sand filters.” Stormwater run-off is delivered, either directly or via a low flow diversion, to the bioretention basin where it is spread over the vegetated area and slowly percolates through a filter media. Pollutant removal is achieved through the interface of the vegetation and filter media as a result of enhanced sedimentation in the vegetation zone, mechanical filtration, sorption and other chemical processes in the filter media and plant and biofilm uptake of pollutants (Hatt, et al 2006). An underdrain collects the treated water and delivers it to existing stormwater infrastructure or waterways.

Bioretention systems can be constructed at different locations within the catchment; they can be at-source within the streetscape (e.g. within traffic calming devices or tree pits) or at the “end-of-pipe” where stormwater infrastructure (pipes) run into bushland or waterways.

End-of-Pipe Bioretention Systems

These systems encapsulate the “treatment train” approach by providing primary, secondary and tertiary treatment through the one bioretention system. To provide optimal treatment both the vegetation type

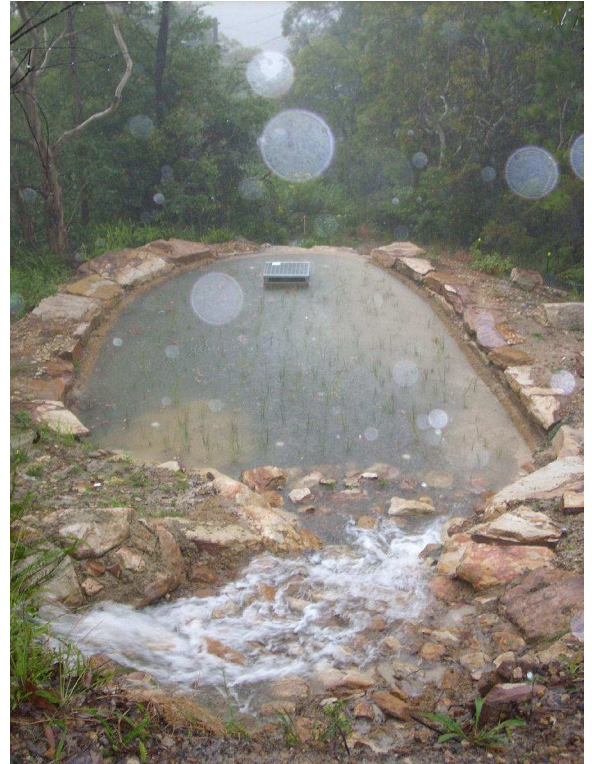
and filter media have been specified to comply with recent research findings. While the concept is simple, extensive research has refined the specifications to optimise performance of these systems.

Primary Treatment: Stormwater flows into sediment forebays which captures larger sediments. It then flows into a distribution swale where the stormwater is evenly spread across the basin surface to allow litter, leaves and finer sediment to be trapped on the surface of the filter media. Through the CRR maintenance program these larger litter items and accumulated sediment are removed on an as needs basis.

Secondary Treatment: After the stormwater has entered the bioretention basin it percolates down into the filter media where finer sediment and pollutants are retained by attaching to soil particles or becoming trapped within pore spaces.

Tertiary Treatment: Tertiary treatment also occurs as biofilms on the highly fibrous root system of the plants take up nutrients and metals. In addition, this system has been installed with the option to create a permanent saturated zone which assists in the depletion of available nitrogen through the process of denitrification.

2.0 Catchments Remediation Rate Capital Works Program



Plates 2-7: Bioretention Basins Constructed in 2011-2012

(clockwise from top left)

Lawson Road, Cherrybrook, Peter Close, Hornsby Heights, Eastcoate Road, North Epping, Parish Place, Mount Colah, Braidwood Avenue, North Epping, Stewart Avenue, Hornsby (during construction)

2.0 Catchments Remediation Rate Capital Works Program

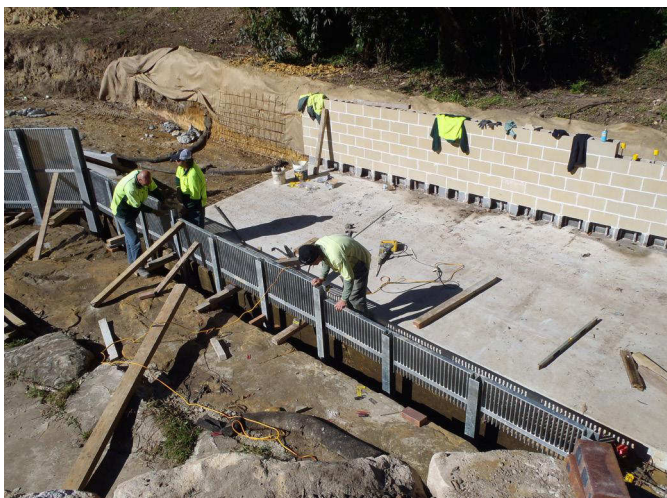
2.2.3 Gross Pollutant Devices and Sediment Basins

Gross Pollutant Devices (GPD's) and sediment basins can operate in isolation to protect immediate downstream receiving waters or as part of a more comprehensive treatment system. When acting in isolation they are used primarily to protect downstream waters from litter or to address specific issues such as excessive leaf drop. When maintained at a prescribed level they can be useful in retaining a significant proportion of all pollutant types.

In an integrated treatment system (or treatment train), they are the most upstream measure and are important in protecting the integrity of downstream treatments (such as wetlands and bioretention systems) by removing the coarse fraction of contaminants (e.g. litter, coarse sediment etc) (Engineers Australia, 2006, p8-2).

For the purposes of this report, GPD's take many forms including trash racks, litter baskets, channel nets, pit inserts and underground sumps. Some GPD's are fabricated to fit specific locations, whereas others are bought off the shelf (proprietary devices). At present over 422 stormwater treatment measures have been installed and / or constructed throughout the Shire.

Hornsby Shire Council maintains 68 sediment basins throughout the Shire. As with GPD's, proper maintenance is essential to ensure optimal performance, therefore, Council scheduled the cleaning of a number of established basins in the 2011 - 2012 period. It is important that sediment basins are cleaned at least biennially (or at 30% capacity) so as to prevent colonisation of weeds and the release of potentially bio-available contaminants caused by disturbance events (e.g. scour and re-suspension).



Plates 8-11 – Flametree Crescent, Cherrybrook – Trash Racks

2.0 Catchments Remediation Rate Capital Works Program

2.2.4 Constructed Wetlands

Natural wetlands are transitional environments between terrestrial and aquatic habitats. They are characteristically shallow environments that are cyclically, intermittently or permanently inundated by fresh, brackish or saline water. Wetlands provide habitat for biota such as emergent macrophytes, macroinvertebrates, fish, amphibians, reptiles and birds which are dependant on the inundation of the wetland.

In managing urban stormwater pollution of natural waterways, constructed wetlands are often built to mimic nature and to achieve improvements in stormwater quality through natural physical and chemical processes. Furthermore, they provide additional benefits through the provision of habitat for aquatic and terrestrial fauna, maximising biodiversity and enhancing aesthetics.

In January 2012, as part of Council's ongoing CRR maintenance program a constructed wetland at The Outlook, Hornsby Heights was partially cleaned out. This wetland has been designed with side channels to capture litter, organics and sediment before they enter the wetland system. These channels were cleaned out to allow future capacity for pollutant drop-out.

2.2.5 Stream Remediation

Many creeks become physically degraded when the natural hydrology of the catchment is altered. This most often results in creek bank scour and erosion which is accelerated through processes such as the clearing of riparian vegetation and increased stormwater runoff from impervious surfaces. This degradation can have a detrimental impact on water quality often resulting in an increase in sediment transport and associated sediment bound contaminants.

Aquatic flora and fauna are impacted through a loss of habitat, increased competition with weeds, poor light penetration into the water column due to increased turbidity levels and smothering of benthic organisms with increased sedimentation.

In the remediation of a degraded section of stream the following techniques are used:

- **Creek bank stabilisation** - Typically using locally sourced sandstone boulders that prevent the creek bank from eroding any further and provide habitat for fauna and flora on the rock surface and in cracks between rocks. A variety of softer creek bank armouring strategies are also incorporated, including the pinning or staking of jute mesh/ matting, woven blankets, fallen logs and chain-wire mesh. These approaches are often combined with the planting of native plant cells or tubestock.
- **Use of meanders** - To aid in the reduction of flow velocities during storms.
- **Riffle zones and natural rock fall structures** - Are used to provide in-stream habitat, stabilise the creek bed, aerate the water and allow maximum UV light treatment from sunlight to destroy faecal bacteria.
- **Pool zones** - Are incorporated to create habitat for fauna and macrophytes and to dissipate flow velocities which allows sediments to drop out for later removal.
- **Revegetation of riparian zone** - This zone is planted with indigenous native tubestock to improve habitat, enhance faunal corridors and vegetation links, provide a food source for both terrestrial and aquatic organisms and to stabilise the banks.
- **Stabilising stormwater outlets** - Rock armouring around stormwater outlets reduces erosion and scour caused by high flows.

In addition, the majority of stormwater treatment measures discussed in this report also incorporate some stream remediation to stabilise banks around the devices and improve habitat immediately up and downstream. Although the environmental benefit of stream remediation works is difficult to quantify, the works provide a significant benefit in terms of a reduction in erosion and associated sediment loads moving to the lower reaches of creeklines and receiving waters, improved native riparian and aquatic habitat and enhanced visual aesthetics.

2.0 Catchments Remediation Rate Capital Works Program



**Plates 11-12 – Essex Street, Epping,
Lawson Road, Cherrybrook - Drainage line rock armouring**

2.3 Projects delivered in 2011/2012

In the 2011 - 2012 financial year, \$1,030,000 was spent on capital works with 9 catchments remediation projects being initiated and completed. These works involved the construction of:

- Six end-of-pipe bioretention systems: Hornsby Heights, Hornsby, Cherrybrook, Mount Colah and North Epping (2)
- Three creek stabilisation projects: Epping, Cherrybrook, Hornsby Heights
- One car park raingarden and bioswale: Galston
- Two large trash racks: Cherrybrook

In addition:

- 11042 native plants were planted at new and existing sites to replace weeds and help facilitate the process of water quality treatment
- Four projects from previous years had minor residual expenditure
- Six projects on the 2012/2013 works schedule had survey and design work done

Some sites combined a number of measures to provide optimal treatment of stormwater, referred to as a treatment train, whereas others focused on a specific type of treatment. Catchment characteristics, site conditions and constraints are the core factors in determining what type of measure is constructed. However, where possible, Council aims to provide primary, secondary and tertiary treatment to optimise benefits to the downstream environment.

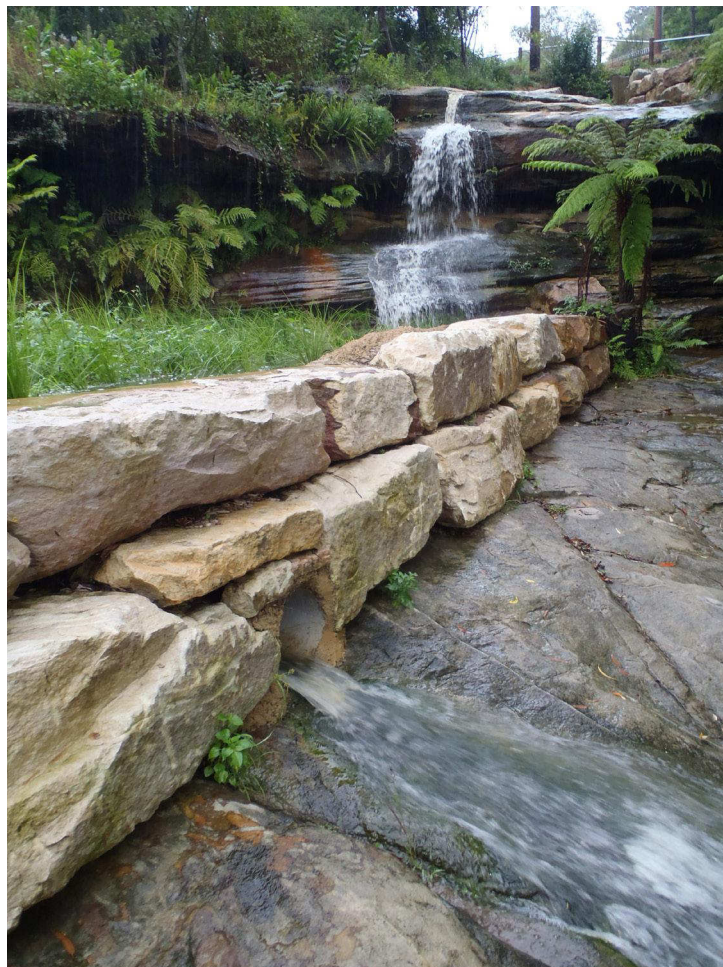
Following this is Table 2.2 which list the locations and treatment measures for projects completed in 2011 - 2012. A full list of all devices managed by Hornsby Shire Council is detailed in Appendix A with projects from the 2011 – 2012 period defined in bold.

2.0 Catchments Remediation Rate Capital Works Program

Table 2.2 - Capital Works Projects 2011 – 2012

(1-main treatment 2- supplementary treatment, TP-tree pit, EP- End-of-pipe bioretention, SC-streetscape, CP-carpark)

| Project Location | Treatment Measure | | |
|-------------------------------|-------------------|-------------------------|-----------------------------|
| | Bioretention | Gross Pollutant Devices | Creek / Channel Remediation |
| Flametree Cr, CHERRYBROOK X 2 | | 1 | |
| Lawson Road, Cherrybrook | 1 (EP) | | 2 |
| Fagan Park, GALSTON X 2 | 1(CP) | | |
| Stewart Avenue, HORNSBY | 1(EP) | | |
| Peter Close, HORNSBY HEIGHTS | 1(EP) | | 2 |
| Parrish Place, MOUNT COLAH | 1(EP) | | |
| Eastcote Road, NORTH EPPING | 1(EP) | | |
| Braidwood Road, NORTH EPPING | 1(EP) | | |
| Essex Street, EPPING | | | 1 |



3.0 Catchments Remediation Rate Asset Maintenance

3.1 CRR Asset Maintenance

3.1.1 Cleaning and Maintenance of CRR Assets

Included within the CRR capital works budget is provision for monitoring and maintenance of all structures on a regular, recorded basis. Due to the current strain on Council's resources, the increasing number of structures being built and the resulting demand for timely and efficient maintenance, Council has continued to utilise contractors (on a 3 year contract) to undertake maintenance works under Council supervision.

Maintenance typically involves regular cleaning of SQIDs and periodic maintenance of sediment traps and wetlands in terms of sediment removal, bank repair, weed control / spraying and some landscaping / bush regeneration work. Fundamental design principles allow ease of draining / flow bypass and access for maintenance of all water quality control devices which results in efficient and cost-effective maintenance techniques in the long term. The cleaning / maintenance and bush regeneration / landscaping contracts were re-let for another three-year period in the 2009 - 2010 financial year.

The existing contracts stipulate the contractor's responsibilities. These are outlined as follows:

- To maintain existing water quality remediation structures to ensure optimal functioning and a weed-free surrounding landscape of many devices;
- To ensure quality control / assurance throughout the maintenance process incorporating:
- minimal pollution of the site during cleaning and transport of materials; and
- efficient, accurately documented records of contents removed and / or actions taken.
- Contractors are required to provide both a status and cleanout report sheet for each structure after maintenance. Council requires this to evaluate SQID performance, device accountability and landscaping / bush regeneration costs per unit area;

- Contractors are required to dispose of waste material to a nominated landfill or a privately operated screening operation that offers a competitive rate per tonne. The only exception being the liquid / solid mix waste removed by vacuum from wet sump devices. This waste shall be disposed of to an approved location at Council's expense; and
- That the contractor has a proven record of Occupational Health and Safety (OH&S) commitment, training and record keeping.

The frequency of maintenance varies between treatment measures and a majority of SQIDs need regular inspections and maintenance after each significant rainfall event. In 2011 - 2012 Hornsby Shire recorded approximately 41 large events (>10mm of rainfall in the previous 24hrs) and 7 very large events (>50mm in the previous 24hrs) which has resulted in much higher yields than in previous years (refer to Appendix B for statistical data).

Larger wet vault SQIDs are inspected and maintained on a quarterly basis, whilst constructed wetlands and leachate treatment systems are maintained on a more regular schedule. Sediment basins are inspected regularly and maintained as required biennially. These basins need periodic maintenance in terms of sediment removal, bank repair or minor structural repairs. The scope of these works is based on additional quotations for specific works and upon joint inspection by Council's Superintendent and the Contractor (Refer to Table 3.1)

3.0 Catchments Remediation Rate Asset Maintenance

Table 3.1 - Maintenance Operations for Stormwater Treatment Measures

| Stormwater Treatment Measure | Inspection Frequency | Maintenance Frequency | Waste Destination | Reporting |
|--|--|--|---|--------------------------------|
| GPD (end-of-pipe) | Storm event (>10mm in 48hrs) | Selective based on inspection (within 5 working days) | Council nominated site. | Within 2 weeks from completion |
| GPD (wet vault) | No inspection. Quarterly empty as scheduled | Quarterly empty as scheduled | Council nominated site. Liquid fraction decanted to passive open space or to an approved facility | Within 2 weeks from completion |
| GPD (pit insert) | Quarterly or after a Storm Event (>10mm in 48hrs) | Selective based on inspection (within 5 working days) | Council nominated site | Within 2 weeks from completion |
| Constructed wetlands, Leachate treatment, Bioretention | Monthly | Scheduled monthly or as required | Weed material composted onsite or disposed of to an approved facility. Sediment disposed of to a Council nominated site | Monthly |
| Sediment basins, Creek remediation | Biannually or after a storm event (depending on magnitude) | Selective based on inspection (within 10 working days) | Weed material composted onsite or disposed of to an approved facility. Sediment disposed of to a Council nominated site | Within 2 weeks from completion |

3.1.2 Landscape Maintenance & Bush Regeneration

Due to the increasing number of devices being built and the resulting demand for timely and efficient maintenance, Council has continued to engage bush regeneration contractors on a 3 year basis. The contracts are annually renewed based on a performance evaluation of the previous year's work and compliance with the conditions of the contract. The key objectives of the contract are:

- i) to maintain planted native vegetation around water quality structures and nominated wetlands, using methods that have minimal environmental impact on aquatic organisms and water quality;
- ii) treatment and eradication of any riparian and aquatic weeds giving priority to the treatment of categorised noxious weeds, applying herbicide according to manufacturers specifications and in a responsible and recorded manner (in terms of both environmental and personal safety); and
- iii) to provide a maintenance report for each site after treatment, including a more detailed maintenance report for the wetland sites which is required to assess the extent of plant growth and site recovery from weed infestation.

3.0 Catchments Remediation Rate

Asset Maintenance

3.1.3 Maintenance Costs

The total cost to Council to maintain its water quality improvement devices and adjacent landscaped areas was approximately \$437,000 in the 2011 - 2012 financial year. This included \$198,000 for the cleaning of SQUIDS and disposal of waste to landfill and \$146,000 for landscaping maintenance and bush regeneration at the sites. Other associated costs included the monitoring and maintenance of leachate treatment facilities, tree work and staff wages.

Gross Pollutant Devices

Table 3.2 presents the efficiencies in terms of cubic metre of waste collected against the cost of maintenance in the July 2011 – June 2012 financial year for each type of device. The total clean cost for each device and average clean cost per device are also presented. The table shows that reasonable efficiencies can be achieved with minimal fiscal input for devices such as Pit Inserts, Ski-Jumps and Trash Racks. Higher costs are associated with Net-Tech devices though due to the fact that these devices can often release with minimal waste capture.

Table 3.2 - SQID comparative costs from July 2001 - June 2011

| Device | Total Clean Cost / Total m3 | Total Clean Cost for 2011-2012 | Average Clean Cost per Device |
|--|-----------------------------|--------------------------------|-------------------------------|
| Net-Tech (Proprietary Net), (n=23) | \$131.27/m3 | \$5,500 | \$239.00 |
| Proprietary Underground Vaults ¹ (n=25) | \$128.94/m3 | \$21,000 | \$840.00 |
| Litter Basket (n=11) | \$126.32/m3 | \$2,600 | \$236.00 |
| Channel Nets (Proprietary Net), (n=51) | \$124.62/m3 | \$14,000 | \$274.00 |
| Trash Rack (n=22) ² | \$94.97/m3 | \$26,000 | \$1,181.00 |
| Ski-Jump (Proprietary Device), (n=4) | \$61.64/m3 | \$2,200 | \$550.00 |
| Pit inserts (n=171) | \$32.28/m3 | \$4,700 | \$27.00 |

¹Note: Proprietary Underground Vaults include Rocla, CDS and Humeceptor Vaults.

²Note: m3 collected included large sediment deposits upstream.

3.0 Catchments Remediation Rate Asset Maintenance

Wetlands

Wetland maintenance involves the weeding/spraying of riparian areas and removal of weeds and nuisance plants within the shallow wetland ponds. In 2011 - 2012, contractors were responsible for maintaining 16 wetland sites carrying out 1,613 maintenance hours at a cost of \$62,000 (this includes four wetlands not built using funding from the CRR budget) and covered works on approximately 46,000 m² of land and wetland under this contract. Of this 80% was dedicated to Council's four largest wetlands (Wallumeda, Laurence Street, Hastings Road and Clarinda Street). Time is also allocated to the removal of stormwater litter / rubbish strewn throughout the pond and edge areas. Replacement planting with macrophytes is also carried out, including occasional wetland establishment at new sites. A wetland maintenance sheet is required to be completed when conducting works within wetlands, as Council requires this information for wetland condition monitoring.

Target aquatic weed species include Typha (Bullrush), Barnyard Grass, Milfoil, Watercress, Cyperus eragrostis and other undesirable or noxious water plants (e.g. Ludwigia (peruviana), Alligator Weed and Salvinia). If a W1 Noxious Weed category plant is found onsite, the Contractor is to immediately notify Council as required under the Noxious Weeds Act 1993.

Landscape Maintenance and Bush Regeneration

In 2011 - 2012, contractors were responsible for landscape maintenance around seventy one sites at a cost of \$84,000 (approximately 2186 hours) which covered bush regeneration activities on approximately 69,000m² of land managed under this contract. This involved weeding and spot spraying of the immediate area surrounding each water quality control asset including landscaped areas that have been mulched and planted with local native species. Some replacement planting and staking of existing tubestock is also required. Newly constructed devices will also require planting of terrestrial tubestock and in some cases, aquatic (macrophyte) plantings, with all plant stock being supplied by Council's nursery. Maintenance reports and invoices are submitted to Council on a fortnightly basis. Targeted terrestrial weed species include - Privet, Camphor Laurel, Lantana, Blackberry, Turkey Rhubarb, Castor Oil plant, Balloon Vine, Madeira Vine, Honeysuckle, Morning Glory, Asparagus Fern, Mist Flower, Crofton Weed, Ochna, Ginger, Wandering Jew and other herbaceous weeds and grasses such as Kikuyu and Paspalum.



4.0 Catchments Remediation Rate Asset Performance

4.1 Rainfall Measurement

Daily rainfall data is obtained from the Bureau of Meteorology at eight sites across the Shire. This data is used to examine the relationship between total yields of gross pollutants and rainfall. In 2011 - 2012 the Hornsby Council area recorded more rainfall than the 2010 - 2011 annual totals (Refer to Appendix B for statistical data).

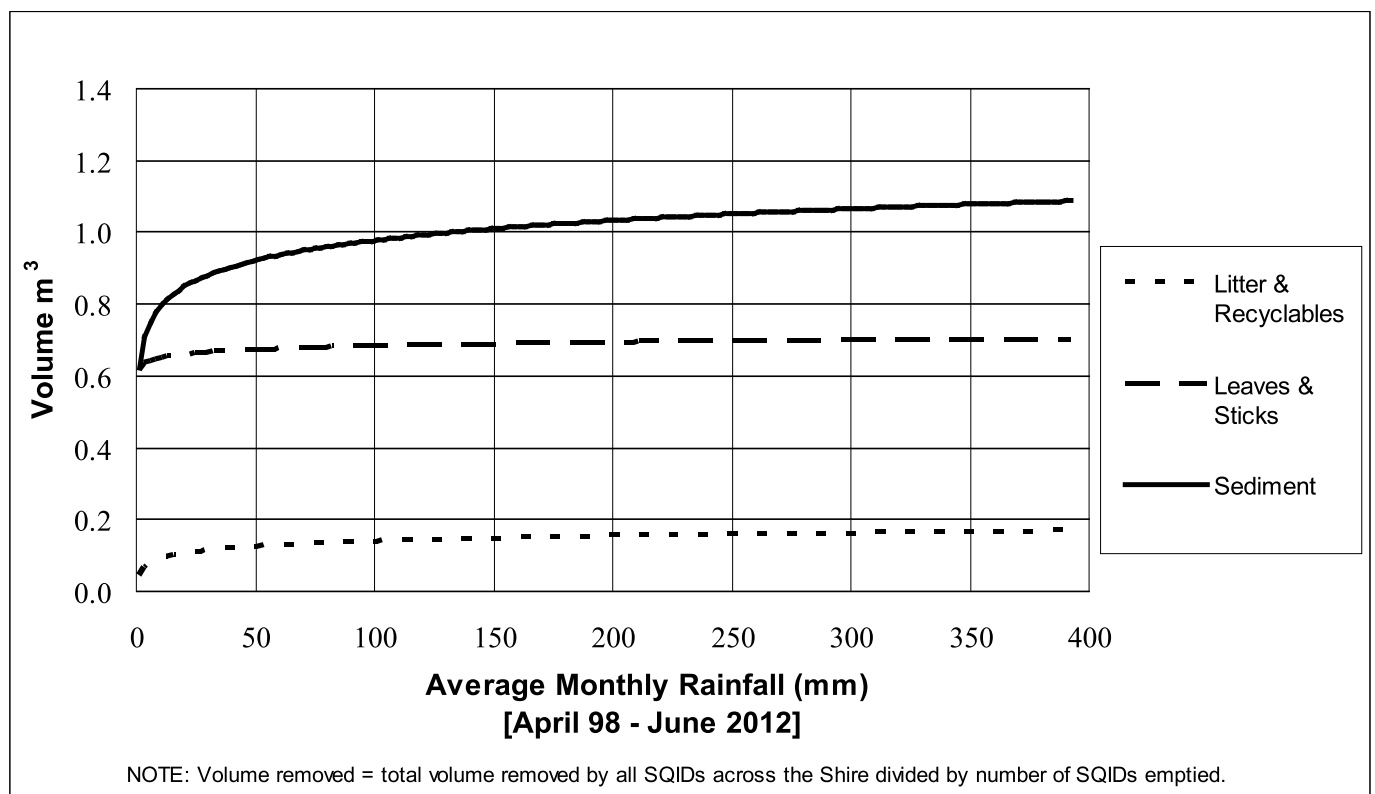
4.2 Pollutant Removal Trends

The collection of performance data over the 2011 - 2012 financial year has allowed Council to examine the indicative maintenance costs and gross pollutant removal trends for the 422 water quality improvement devices in the LGA. The results indicate that in 2011 - 2012, SQIDs have served to remove approximately 1074 cubic metres of sediment, litter and organic matter from the Shire's waterways. These volumes were much higher than the previous year and can be best explained by two anomalies:

- The elevated levels of rainfall experienced during the 2011 - 2012 period compared to the previous year. Additionally, the maintenance of gross pollutant devices is often event based which has resulted a higher number of empties than experienced in previous years, and
- The high yield of sediment and organic matter resulting from the cleaning out of a number of large sediment basins in the 2011-2012 period.

The following series of figures examine the performance of SQIDs in 2011 - 2012 and against previous years.

Figure 4.1 - The relationship between average monthly volume of gross pollutants and average monthly rainfall



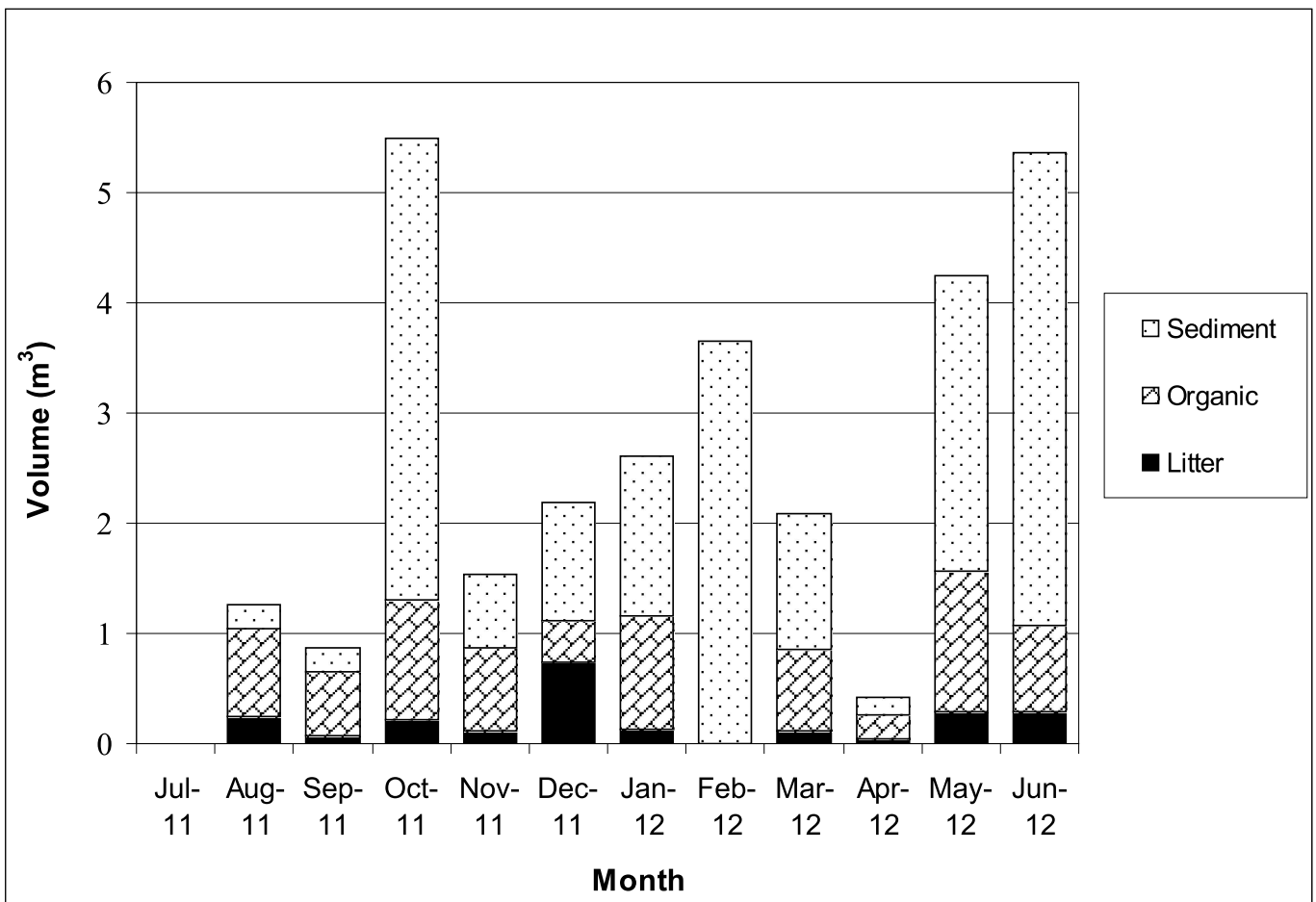
4.0 Catchments Remediation Rate Asset Performance

When pollutant volume is analysed against average annual rainfall all three categories of gross pollutants are mobilised and captured after only 10 mm of rainfall as evidenced in Figure 4.1 by the steep rise in the curve. This phenomenon is referred to as the "first flush" effect, after which the volume captured continues to rise at a much slower rate in relation to rainfall volumes.

It can be seen that the load of litter recovered from all devices over the period is fairly consistent for all size rainfall events (indicated by the relatively flat dotted line).

This is most likely due to the fact that litter is readily mobile and floatable in the formal drainage system (curb, gutter and pipes) and most of it will be flushed and collected in downstream SQIDs, even in small rain events. However, the fact that the curve for sediment is steadily climbing, proportional to rainfall, illustrates that after the initial flush the transport of sediment is directly proportional to stormwater volumes and associated energy.

Figure 4.2 - Volumes of pollutants removed from SQIDs (2011 - 2012)

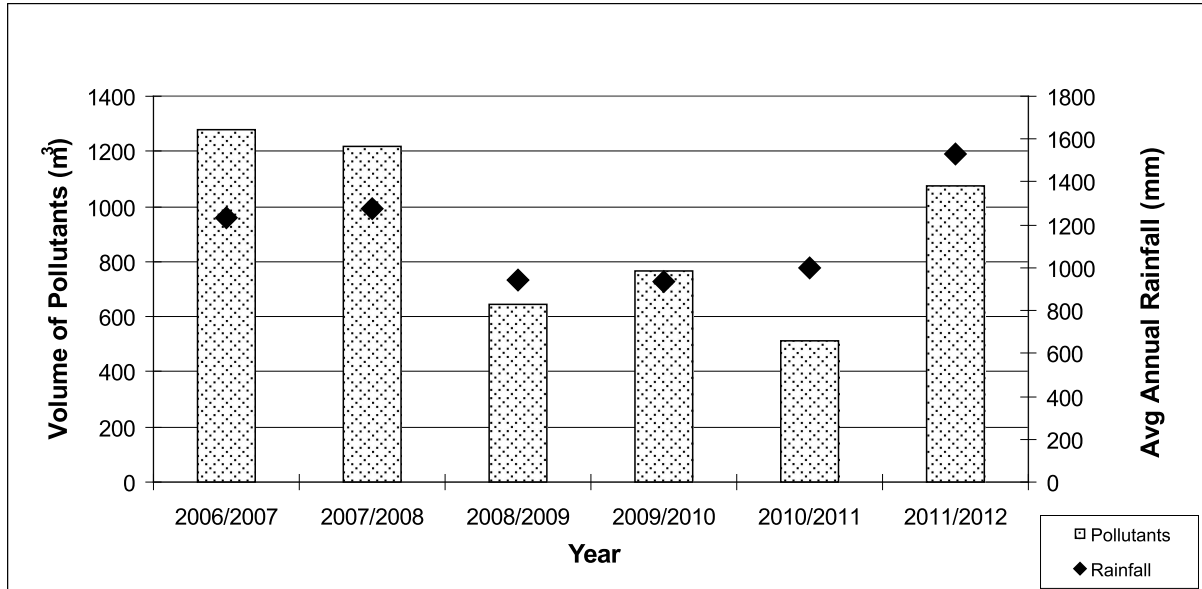


The actual volume of pollutants removed from month to month shown in Figure 4.2 varied greatly in the 2011 - 2012 period. A clear correlation between monthly removal rates and rainfall cannot be made due to: 1)

variable lag times between rainfall events and cleaning events, and 2) the disproportionately high volumes removed from sediment basins and wetlands which are in addition to regular cleaning events.

4.0 Catchments Remediation Rate Asset Performance

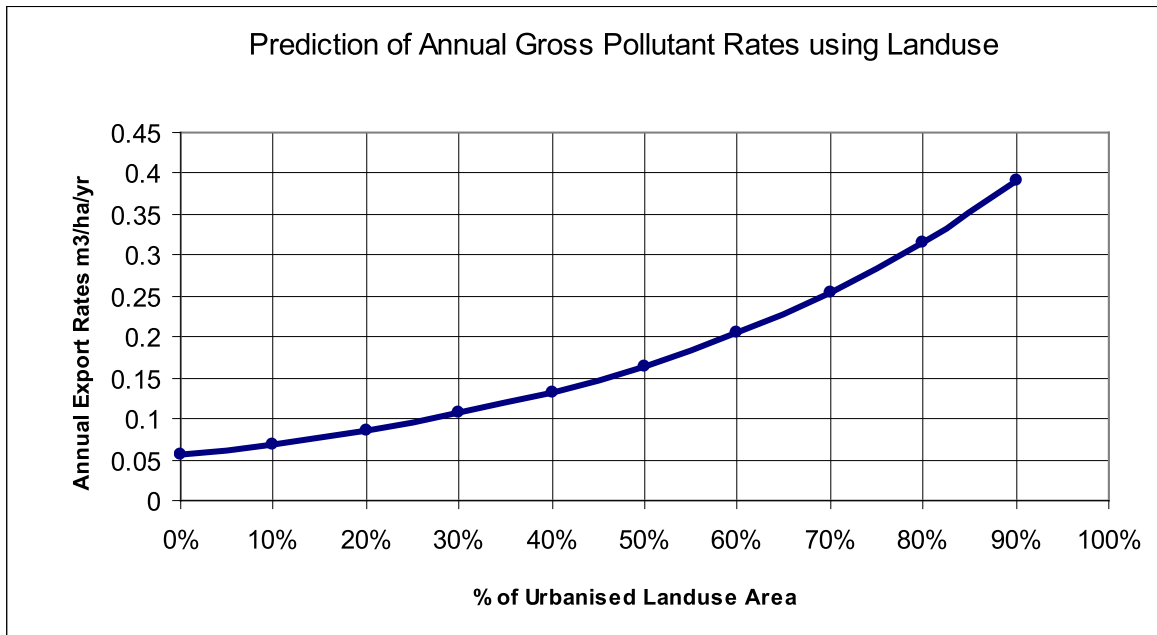
Figure 4.3 - Pollutant volume (m³) removed from SQIDs against average annual rainfall July 2006 – June 2012



However, a strong correlation is found between rainfall and pollutant yield from Council's SQIDs when viewed annually, as shown in Figure 4.3. With increased rainfall there is increased stormwater run-off into Council's drainage system that results in pollutants being

mobilised, transported and trapped by SQIDs. This trend is however skewed in the 2011 - 2012 period due to high levels of rainfall resulting in elevated capture of gross pollutants, sediment and organics.

Figure 4.4 - Prediction of annual gross pollutant rates using landuse area



4.0 Catchments Remediation Rate Asset Performance

Hornsby Shire Council is now at a stage where the data gathered from the various SQIDs can be used to predict the annual gross pollutant (export) rates on the basis of landuse. Figure 4.4 shows how the annual export rate of pollutants exponentially increases with the amount of catchment that is urbanised (excludes bushland / open space). This information can be used when planning for future devices, in terms of expected export rates and known device capabilities. Stormwater managers can then compare actual pollutant export rates with the predicted values in order to gauge the efficiencies of devices through time.

The high frequency of Hornsby Council's inspection and cleaning of the devices combined with the unique trap designs for ease of maintenance, ensures that the pollutant trapping efficiency is optimum for each storm event and that materials do not decompose or stagnate causing additional problems with the release of pollutants into downstream receiving waters.

4.3 Asset Renewal and Repair

In 2011 - 2012, Council initiated repair and renewal works at a number of SQIDs. Two sites required major repair as a consequence of spillway failure at a cost of \$20,000. Other minor repair works were undertaken (e.g. fencing repairs etc) on numerous other sites.

4.4 Wetland Performance

4.4.1 Pollutant Removal Trends and Costs

The size of catchments draining to these constructed wetlands ranges from 15-400 hectares. The average pond surface area to catchment area ratio calculates at 0.23% which is below the minimum design size recommended by DLWC (1998) of 2% of the catchment area. It should be noted that this recommendation does not account for the variability associated with different catchment land uses, pollutant loads, peak flows, topography and soils. It is best used to determine preliminary wetland feasibility. Because the nature of Hornsby Shire is so topographically constrained (ridge top development that does not afford large areas for wetland construction) and contains significant remnant bushland, the wetland feasibility threshold is much lower than average.

Water quality monitoring of five separate systems managed by council over the past 10 years has shown that levels of total nitrogen, phosphorus, suspended solids and faecal coliforms are significantly reduced under base flow and small storm flow events. Monitoring results are based on both grab and load-based samples

(and multi-probe analytes) obtained by Council over multiple rainfall events and inter-events.

4.5 Assessment of Nutrient Removal by the CRR program

The principal objective of the CRR program is to improve water quality by removing pollutants. From the beginning of the program there has always been a particular focus on the removal and/or capture of nutrients because of their known impact on aquatic ecosystems, such as creeks and estuaries.

Quantitative data recorded to date on the performance of SQIDs has primarily looked at the mass and/or volume of gross pollutants removed through maintenance. While this provides a good data source the Water Catchments Team has been looking at ways that give a better indication of the amount of nutrients removed from our waterways by the CRR program.

To do so, Council has used the modelling software MUSIC (Model for Urban Stormwater Improvement Conceptualisation) and modelled all urban sub-catchments within the LGA. However, Council has found the continuous updating of these models cumbersome and that they don't truly represent all nutrient capture from GPT's and do not include the benefits of other non-structural initiatives such as street sweeping.

Consequently, Council commissioned the formulation of a tool to provide a simplified and rapid assessment of the mass of nutrients captured by the CRR Program, which explicitly included estimates of the pollutant loads captured by GPT's and street sweeping. The findings have been encouraging with the tool indicating that over 2024kg of phosphorus and 6378kg of nitrogen was captured and removed from our waterways in the 2011/2012 period. Furthermore, it shows that in areas where concerted catchment remediation initiatives, e.g. on-ground works and frequent street sweeping have been rolled-out the overall pollution reduction that has been achieved is relatively good (Refer to Table 4.2).

This will prove to be an effective tool for Council in reporting on water quality improvements over time as well as aiding in future decisions on the most appropriate devices for specific areas and situations. This will enable Council to make cost savings by choosing the best management options and will provide greater clarity as to the areas contributing the most nutrient input to the waterways.

4.0 Catchments Remediation Rate Asset Performance

Table 4.1 - Constructed Wetland annual costs and monitoring records to end of June 2012

| Wetland | Capital Cost \$ (Year Built) | Pond Surface Area (m2) | Pond Surface Area to Catchment Area (%) | Cost per m2 of pond (\$/m2)* | Average Annual Maint. Cost2 (\$/yr) | Monitoring Data (year/s) |
|--|------------------------------|------------------------|---|------------------------------|-------------------------------------|-------------------------------|
| Asquith | | | | | | |
| Baldwin Avenue | 38,000 | 123 | 0.46 | 323 | 1,789 | Nil |
| Beecroft | | | | | | |
| Lamorna Ave (2005) | 134,000 ⁴ | 400 | 0.44 | 348 | 5,263 | Nil |
| Midson Rd (2003) | 252,000 | 1,220 | 0.03 | 208 | 2,3183 | Nil |
| Plympton Rd (2000) | 305,000 | 350 | 0.06 | 877 | 1,9103 | Nov 99-Jun 2002 |
| Brooklyn | | | | | | |
| Brooklyn Rd (1997) | 46,000 | 205 | 0.26 | 230 | NA ³ | Nil |
| Castle Hill | | | | | | |
| Hastings Park (2002) | 445,000 | 1,500 | 0.60 | 301 | 5,845 | Jul 2001-Aug 2003 grab & load |
| Cherrybrook | | | | | | |
| Cherrybrook Lakes (1988) | 70,000 | 4,615 | 0.58 | 16 | 1,564 | 2007-current |
| Dural | | | | | | |
| Millstream Gr(1995) | 60,000 | 1,014 | 1.06 | 61 | 2,188 | Nil |
| Galston | | | | | | |
| Salloway Rd (2000) | 36,000 | 190 | 0.01 | 193 | 693 | Nil |
| Hornsby | | | | | | |
| Clovelly Rd (1999) | 117,000 | 210 | 0.02 | 562 | 1,113 | Nil |
| Clarinda St (2001) | 241,000 | 1,550 | 0.82 | 159 | 5,5853 | Jul 2002-current |
| Pennant Hills | | | | | | |
| Laurence St (1996) | 135,000 | 225 | 0.06 | 620 | 4,500 | Jun 1995-Jun 2002 |
| Thornleigh | | | | | | |
| Dartford Rd (2006) | 80,000 | 250 | 2.27 | 326 | 1,400 | Nil |
| West Pennant Hills | | | | | | |
| Boundary Rd (1996) | 288,000 | 1,875 | 0.14 | 158 | 9,1353 | Aug 1998-Jun 2002 |
| John Savage Cres (2004) | 203,000 | 1,050 | 0.09 | 194 | 1,2193 | Nil |
| Mean | 163,333 | 985 | 0.46 | 305 | 3,180 | NA |
| <p>1 Includes monthly grab sampling (wet / dry) and probe (total of 13 parameters). Analysis by NATA lab 2 Includes weeding/spraying, sediment / rubbish/debris removal, planting / mulching and replacement and reporting (excludes volunteer Bushcare labour) 3 Volunteer Bushcare present onsite 4 Capital costs incorporates up to 100m of stream remediation *Cost/m2 of pond is calculated using capital cost and average annual cost / year</p> | | | | | | |

4.0 Catchments Remediation Rate Asset Performance

Table 4.2 - Capture of Nutrient Exports (CANUTE) in Hornsby LGA from July 2011 to June 2012

| Sub-catchments | Total Phosphorus | | | | Total Nitrogen | | | |
|--------------------------------|------------------|---------------------|------------|------|----------------|---------------------|------------|------|
| | Source | To Receiving Waters | Reductions | | Source | To Receiving Waters | Reductions | |
| | (kg) | (kg) | (kg) | (%) | (kg) | (kg) | (kg) | (%) |
| Berowra Creek | 13,375 | 12,146 | 1,229 | 18% | 133,306 | 129,284 | 4022 | 7.4% |
| Hornsby Creek / Cowan Creek | 1,511 | 1,239 | 272.7 | 24% | 16,664 | 15,450 | 1214 | 13% |
| Hawkesbury River (local total) | 5,510 | 5,506 | 3.8 | 3.8% | 49,058 | 49,056 | 1.3 | 0.2% |
| Lane Cove River | 3,322 | 2,803 | 519 | 16% | 24,817 | 23,676 | 1142 | 5% |



5.0 Landfill and Leachate Remediation

The Catchments Remediation Program has also been responsible for funding the treatment of polluted leachate from two of the Shire's largest former municipal tip sites at Arcadia Park, Arcadia and Foxglove Oval, Mt Colah. Instead of using the traditional technologies available for the treatment of leachate, Council has looked to more sustainable and innovative methods that can achieve pollution reductions and serve as a model for leachate treatment at a local government, state and national level.

This work is significant by way of the methodology which mimics natural processes of nitrification and denitrification. Council staff have worked together in a trans-disciplinary manner, together with specialised scientific consultants to design, construct and monitor both treatment systems. Council is committed to the long-term maintenance, monitoring and management of the two facilities in order to justify and apply the technological benefits to other landfills within the Shire. Monitoring to date has revealed a dramatic reduction in ammonia which has maximised the opportunities for reuse on adjoining open space and landscapes.

Monitoring results illustrating the high level of treatment achieved by the system can be viewed in the "Water Quality Monitoring Program 2011 – 2012 Annual Report".

6.0 Catchments Remediation Rate Environmental Education

Environmental education is delivered by council's Catchment Education Officer to rate payers, residents, local business & industry, community groups, council staff, teachers and students within the Shire.

The definition of "environmental education" generally refers to organised efforts to teach about how natural environments function and, particularly, how human beings can manage their behaviour and ecosystems in order to live sustainably.

In the context of the Catchments Remediation Program, council's environmental education activities generally focus on promoting community awareness of:

- CRR-funded capital works program
- Stormwater quality improvement devices
- Hornsby's water quality monitoring program
- Hornsby's catchments, creeks and estuarine areas
- Total water cycle management
- Stormwater pollution
- Stormwater harvesting
- Water conservation
- Catchment care personal actions

Activities undertaken by the Catchment Education Officer include:

- CRR Promotion at Community Events
- Hosting stalls and displays at various community events, such as
- Bushland Shire Festival
- Berowra Woodchop Festival
- Brooklyn Spring Fair
- Hornsby's Christmas Spectacular
- Hornsby TAFE Environmental Expo
- Council's Native Plant Giveaways
- Media campaigns

- Promotional Material
 - developing print material and website content
 - preparing case studies of CRR devices
 - interpretive signage
- Catchment tours
- Guided tours promoting the CRR program and capital works installed
- Workshops
- Rainwater tank and grey water awareness workshops
- Schools program
- Hornsby Environment Network for Schools (HENS)
- School presentations
- Resource materials for school assignments
- Streamwatch water quality monitoring support
- Lane Cove River Catchment Day
- Grant Funded Projects
- Water for Life Council Partnership Kit (stormwater awareness)
- Catchment Connections (stormwater and catchment awareness)
- Tankscape – Rainwater Tanks in Schools Program
- Hornsby Creek Catchment Urban Sustainability Program

6.0 Catchments Remediation Rate Environmental Education

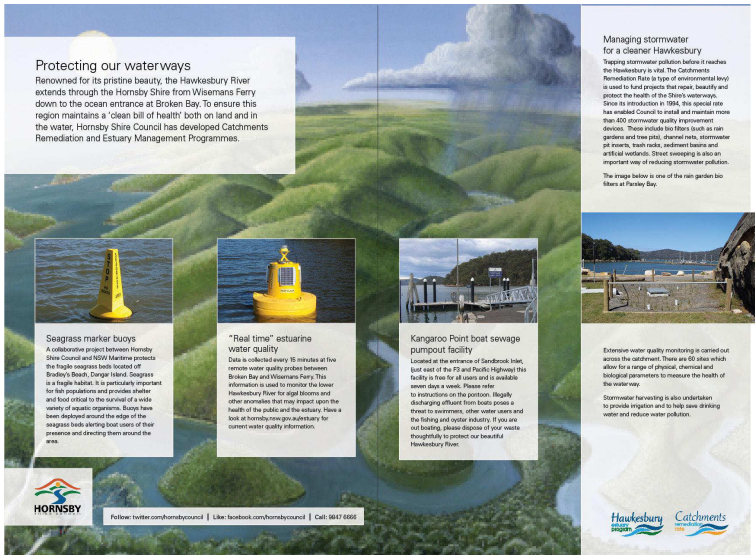
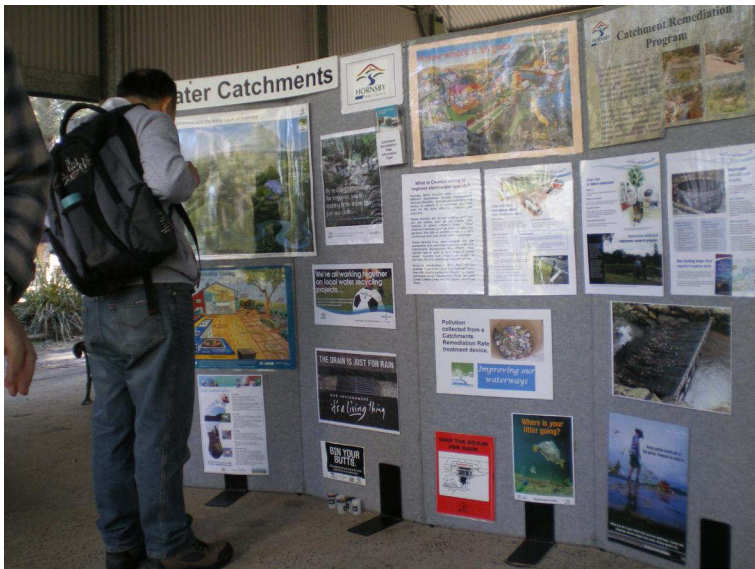


Plate 13-15 Educational Initiatives (top to bottom)

Catchment Tour of CRR device

Display at a community event

Media Promotion: Hornsby Shire Visitors Guide, July 2012

Environmental education is a learning process that increases people's knowledge and awareness about the environment and associated challenges, develops the necessary skills and expertise to address the challenges, and fosters attitudes, motivations, and commitments to make informed decisions and take responsible action (UNESCO, Tbilisi Declaration, 1978).

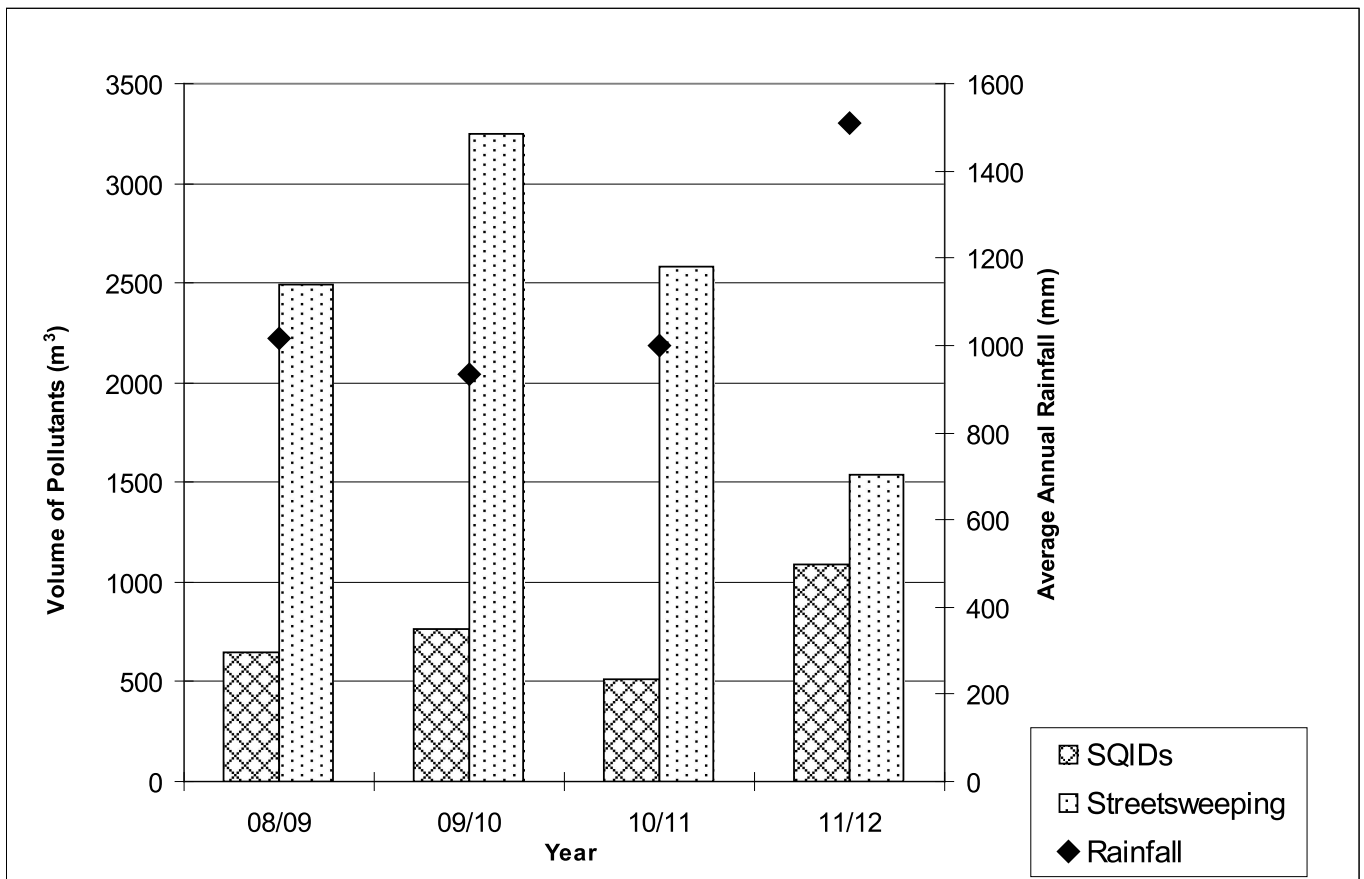
7.0 Street Sweeping

Since 1997, the Catchments Remediation Rate (CRR) has funded a proportion of Council’s Street Sweeping Program at a total cost of \$233,000 per year. Street sweeping is an effective method by which gross pollutants (sediment, leaves and litter) can be collected at source by targeting problem leaf drop areas and high pollutant load land use areas, e.g. commercial and industrial.

In 2011 - 2012, 1,536 cubic metres of material was collected from scheduled cleaning of roadside curb and guttering. A large majority of the material in previous years has been leaf and bark (organic matter) resulting from high leaf drop during dry weather whereas there has been a distinct drop in this matter being available for collection due to favourable conditions for street trees in the 2011-2012 period.

Figure 7.1 compares volumes extracted by SQIDs against street sweeping. Interestingly, when comparing street sweeping for previous years against the 2011 – 2012 years, the higher rainfall experienced looks to have resulted in lower street sweeping collection. This can be attributed to greater movement of litter from gutters into gross pollutant devices before street sweepers can collect this waste. Additionally, higher rainfall has resulted in less bark and leaf drop from street trees and therefore less for street sweepers to collect.

Figure 7.1 - Pollution yield (m3) extracted by SQIDs and street sweeping against average annual rainfall July 2008 – June 2012



8.0 Conclusions

This report has aimed to provide quantitative data and analysis of the relative performance of different water quality treatment measures, including GPD's, sediment basins, wetlands and bioretention systems that have been constructed to improve stormwater quality in Hornsby Shire. The results of the report can be used by stormwater and catchment managers to provide a better insight into determining the type of structure and suitability for specific sites. Furthermore, the data provides valuable information about the costs (both capital and maintenance), benefits and device optimisation which can aid in the formulation of strategies to improve catchment / landuse practices by both structural and non-structural means.

Overall, the findings of this report should give stormwater managers a better insight into the cost-effectiveness and performance of water quality improvement structures and the management of life-cycle costs for individual stormwater quality assets. The performance of these devices has allowed Council to both refine and modify future designs, and judge their appropriateness to proposed remediation sites based on catchment size and land use impacts.

9.0 References

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Appendix A: SQID Site Locations across Hornsby LGA

Stormwater Quality Improvement Devices Non - Proprietary (33)

Trash Racks (22)

| | | |
|--|--|---|
| Beecroft Norwood Avenue | Cherrybrook Woodgrove Road Odney Close Flametree Crescent (2) | Mt Kuring-gai Hamley Road |
| Berowra Berkeley Close The Gully Road | Epping Beecroft Road | Normanhurst Denman Parade |
| Berowra Heights Warrina Street | Glenorie Tekapo Road | Pennant Hills Bellamy Street |
| Castle Hill Belltree Place Cheltenham Castle Howard Road | Hornsby Northcote Road Water Street Clarinda Street Malsbury Road Old Berowra Road | Thornleigh The Comenarra Parkway Larool Crescent West Pennant Hills New Farm Road Wilga Street |

Litter Baskets (11)

| | | |
|---|--|--|
| Asquith Mittabah Road | Berowra Heights Berowra Waters Road | Hornsby Clovelly Road Burdett & Sherbrook Roads |
| Beecroft Sutherland Road Berowra Bambil Road x 3 | Cherrybrook Shepherds & Macquarie Drives | Thornleigh The Comenarra Parkway Janet Avenue |

Appendix A: SQID Site Locations across Hornsby LGA

Stormwater Quality Improvement Devices (SQIDs) - Proprietary (272)

Net Techs / Pratten Nets / Channel Nets (71)

| | | |
|--|---|---|
| Asquith Baldwin Avenue Stratford Place | Cowan Alberta Avenue | Mount Colah Jessica Place Murralong Road x 2 Parklands Road |
| Berowra Boundary Street x 3 Ti Tree Crescent | Dural James Henty Drive New Line Road x 3 | Mount Kuringai Gundah Road x 2 Pacific Highway x 5 |
| Berowra Heights Currawong Road x 2 Joalah Crescent | Epping Brucedale Road x 2 Ridge Street Stanley Street | Normanhurst Hinemoa Avenue |
| Castle Hill Childrey Place Cheltenham Castle Howard Road x 2 Kirkham Road x 2 Cherrybrook Gavin Street Glenoak Way Kenburn Avenue New Line Road x 5 Pecan Close | Hornsby Burdett Street x 8 Clarinda Road Pacific Highway Rosemead Road x 2 Sherbrook Road Binya Close Hornsby Heights Galston Road x 5 Raphael Drive | Pennant Hills Britannia Street x 2 Morrison Place x 2 Thornleigh Blantyre Place x 2 Westleigh Duneba Drive x 3 Russell Crescent |

Appendix A: SQID Site Locations across Hornsby LGA

Underground Vaults (25)

| | | |
|--|--|---|
| Asquith Dudley Street Gardenia Street | Castle Hill Foley Place | Hornsby Hunter Street |
| Beecroft Jacinta Avenue | Cheltenham Castle Howard Road | Hornsby Heights Pike Road |
| Berowra The Gully Road | Cherrybrook Greenway Park Millbrook Place Monterey Place Rosemary Place | North Epping Boundary Road |
| Berowra Heights Woodcourt Road | Dural Lockyer Close | Thornleigh Dartford Road x 2 Sefton Road (Council Depot) |
| Berowra Waters Dusthole Bay | Eastwood Blaxland Road (Somerville Park) | Waitara Unwin Road |
| Brooklyn Dangar Road George Street | Epping Somerset Street | West Pennant Hills Cardinal Avenue |

Ski-Jump Litter Traps (4)

| | |
|---|--|
| Carlingford Anthony Street | Pennant Hills George Street |
| Hornsby Heights Off Heights Place | Wisemans Ferry Old Northern Road |

Appendix A: SQID Site Locations across Hornsby LGA

Pit Inserts (172)

| | | |
|--|--|--|
| Beecroft / Carlingford / Epping Various Locations (35) | Eastwood Blaxland Road (Somerville Park) (2) | Pennant Hills Commercial area (4) |
| Asquith Mills Park Tennis Carpark Wattle Street (3) | Glenorie Cairnes Road | Thornleigh Industrial / Commercial Zone (11) |
| Berowra Berowra Waters Road & Pacific Hwy (4) | Hornsby Hornsby Industrial area (20) Dural Street (3) CBD Various Locations (70) | Waitara Thomas and Orara Streets (6) |
| Berowra Waters Dusthole Bay | Mount Colah Pacific Highway Sue Place (2) | Westleigh Eucalyptus Drive |
| Brooklyn Brooklyn Road (5) | Normanhurst Denman Road (2) | |

Bioretention Systems, Streetscape Raingardens and Tree Pit Bioretention (27)

Bioretention Systems/Basins (13)

| | | |
|--|--|--|
| Berowra Boundary Street | Cherrybrook Lawson Place | Mount Kuringai Gundah Road |
| Berowra Heights Currawong Road | Glenorie Tecoma Drive | North Epping Belinda Crescent Malton Road Braidwood ave Eastcoate Ave |
| Cheltenham Castle Howard Road Lyne Road | Hornsby Heights Margaret Avenue Oorin Road Peter Close | Pennant Hills Albion Street Blackbutt Avenue |
| Hornsby Stewart Ave | Mount Colah Parish Place | |

Appendix A: SQID Site Locations across Hornsby LGA

Streetscape Raingardens (19)

| | | |
|---|-------------------------------|---|
| Berowra Heights Turner Road (6) | Epping Ray Road (4) | Waitara Alexandria Parade (4) |
| Brooklyn George Street (4) | Cowan View Street | Galston Fagan Park (2) |

Tree Pit Bioretention (17)

| | | |
|-------------------------------------|---|--|
| Epping Oxford Street (13) | Hornsby Coronation Avenue (4) | |
|-------------------------------------|---|--|

Sediment Basins (68)

| | | |
|---------------------|---------------------|--------------------|
| Asquith (1) | Dural (2) | Mount Kuringai (2) |
| Beecroft (2) | Epping (7) | Normanhurst (2) |
| Berowra (6) | Epping North (1) | Pennant Hills (3) |
| Berowra Heights (1) | Glenorie (1) | Thornleigh (4) |
| Cheltenham (5) | Hornsby (3) | West Hornsby (1) |
| Cherrybrook (14) | Hornsby Heights (2) | Westleigh (5) |
| Cowan (1) | Mount Colah (5) | |

Appendix A: SQID Site Locations across Hornsby LGA

Constructed Wetlands (13)

| | | |
|--|---|--|
| <p>Beecroft Lamorna Avenue Midson Road Plympton Road</p> <p>Brooklyn Brooklyn Road</p> <p>Castle Hill Hastings Park</p> | <p>Epping Ridge Street</p> <p>Galston Sallaway Road</p> <p>Hornsby Clarinda Street Clovelly Road</p> | <p>Pennant Hills Laurence Street</p> <p>Thornleigh Dartford Road</p> <p>West Pennant Hills John Savage Crescent Boundary Road</p> |
|--|---|--|

Developer Constructed Wetlands (10)

| | | |
|---|--|--|
| <p>Berowra Summer Hill Way</p> <p>Castle Hill Foley Place</p> <p>Cherrybrook Shepherds Drive (The Lakes)**</p> <p>** Council managed</p> | <p>Dural Millstream Grove</p> <p>Hornsby Heights Sydney Road** The Outlook**</p> <p>Mount Colah Kalang Road**</p> | <p>Thornleigh Huntingdale Way Wild Ash Avenue</p> <p>Westleigh The Sanctuary</p> |
|---|--|--|

Appendix A: SQID Site Locations across Hornsby LGA

Stream Remediation Projects (46)

| Berowra Creek Catchment | Hawkesbury River Catchment |
|--|--|
| <p>Berowra</p> <ul style="list-style-type: none"> - Boundary Street - Gwandalan Crescent <p>Berowra Heights</p> <ul style="list-style-type: none"> - Wymah Road <p>Castle Hill</p> <ul style="list-style-type: none"> - Hastings Park <p>Cherrybrook</p> <ul style="list-style-type: none"> - Woodgrove Road <p>Glenorie</p> <ul style="list-style-type: none"> - Tecoma Drive <p>Hornsby</p> <ul style="list-style-type: none"> - Clarinda Street - Reddy Park - Stewart Avenue <p>Hornsby Heights</p> <ul style="list-style-type: none"> - Heights Place <p>Mount Colah</p> <ul style="list-style-type: none"> - Murralong Road - Parrish Place - Parklands Road <p>Pennant Hills</p> <ul style="list-style-type: none"> - Albion Street - Laurence Street <p>West Pennant Hills</p> <ul style="list-style-type: none"> - John Savage Crescent - Wearne Avenue - Wilga Street <p>Westleigh</p> <ul style="list-style-type: none"> - Duneba Drive - Eloura Road <p>Cherrybrook</p> <ul style="list-style-type: none"> - Lakes of Cherrybrook | <p>Brooklyn</p> <ul style="list-style-type: none"> - Brooklyn Road |
| <p>Cowan Catchment</p> | <p>Lane Cove River Catchment</p> |
| <p>Hornsby</p> <ul style="list-style-type: none"> - Sherbrook Road | <p>Beecroft</p> <ul style="list-style-type: none"> - Fearnley Park - Lamorna Avenue - Midson Road - Norwood Avenue - Plympton Road - Ray Park <p>Carlingford</p> <ul style="list-style-type: none"> - Anthony Street <p>Cheltenham</p> <ul style="list-style-type: none"> - Castle Howard Road - Kirkham Street - Lyne Road <p>Cherrybrook</p> <ul style="list-style-type: none"> - Flametree Crescent <p>Epping</p> <ul style="list-style-type: none"> - Brucedale Avenue - Kent Street - Ridge Street (east) - Ridge Street (west) - Pembroke Road - Stanley Street - Essex Street <p>Normanhurst</p> <ul style="list-style-type: none"> - Hinemoa Avenue - Nicholas Crescent <p>North Epping</p> <ul style="list-style-type: none"> - Belinda Crescent <p>Pennant Hills</p> <ul style="list-style-type: none"> - Orchard Street <p>Thornleigh</p> <ul style="list-style-type: none"> - The Comenarra Parkway - Thornleigh Street |

Appendix B: Rainfall Data for Hornsby LGA

Location and Sources of Rainfall Data (BOM 2012)

| Monthly / Annual Rainfall For Hornsby Shire (mm) | | | | | | | | | |
|--|---------------------------|---------------------------|-----------------------|------------------|----------------------|-------------------|------------------------|-------------------------|-----------------|
| Location and BOM Station No.s | W. Pennant Hills 67089 | Parramatta North 66124 | Hornsby Pool 67065 | Maroota 67014 | Cherrybrook 67062 | Glenorie 67010 | Pennant Hills 66047 | Wisemans Ferry 61119 | Monthly Average |
| Jul | 160 | 132 | 185 | 106 | 174 | 119 | 193 | 94 | 145 |
| Aug | 54 | 55 | 59 | 110 | 61 | 74 | 59 | 132 | 75 |
| Sep | 100 | 103 | 116 | 82 | 112 | 84 | 125 | 78 | 100 |
| Oct | 61 | 34 | 41 | 63 | 62 | 59 | 49 | 81 | 56 |
| Nov | 151 | 140 | 126 | 142 | 167 | 155 | 177 | 98 | 144 |
| Dec | 169 | 136 | 153 | 96 | 153 | 112 | 179 | 73 | 134 |
| Jan | 198 | 170 | 263 | 104 | 237 | 222 | 236 | 97 | 191 |
| Feb | 181 | 161 | 173 | 217 | 169 | 168 | 189 | 187 | 181 |
| Mar | 199 | 18 | 185 | 190 | 249 | 237 | 220 | 185 | 185 |
| Apr | 193 | 176 | 149 | 114 | 178 | 183 | 192 | 101 | 161 |
| May | 17 | 19 | 6 | 24 | 24 | 21 | 22 | 21 | 19 |
| Jun | 173 | 169 | 145 | 84 | 152 | 107 | 177 | 85 | 137 |
| TOTAL | 1654 | 1313 | 1600 | 1334 | 1738 | 1541 | 1817 | 1232 | NA |

Note: Shaded monthly totals have not been quality assured.

Appendix B: Rainfall Data for Hornsby LGA

Average rainfall and average number of days exceeding 10mm and 50mm of rain for 8 sites across the Shire 2011 - 2012. (Note: Figures in brackets are for 2010 - 2011)

| Month | Average Monthly Rainfall 2011 - 2012 (mm) | Average No. of Days >10mm rain | Average No. of Days >50mm rain |
|--------------|--|-----------------------------------|-----------------------------------|
| Jul | 145 (54) | 4 (1) | 1 (0) |
| Aug | 75 (23) | 1 (1) | 0 (0) |
| Sep | 100 (53) | 3 (2) | 1 (0) |
| Oct | 56 (87) | 2 (3) | 0 (0) |
| Nov | 144 (139) | 5 (5) | 0 (0) |
| Dec | 134 (95) | 4 (4) | 1 (0) |
| Jan | 191 (57) | 5 (1) | 1 (0) |
| Feb | 181 (29) | 6 (1) | 0 (0) |
| Mar | 185 (131) | 7 (3) | 1 (1) |
| Apr | 161 (141) | 3 (5) | 2 (0) |
| May | 19 (88) | 1 (2) | 0 (1) |
| Jun | 137 (107) | 3 (4) | 1 (0) |
| Total | NA | 41 (32) | 7 (2) |

Appendix B: Rainfall Data for Hornsby LGA

All Sites - Average Annual Rainfall vs 2011 - 2012 Annual Rainfall*

| Sites | Maximums, Minimums and Average Annual Rainfall | 2011 - 2012 Annual Total |
|-----------------------------------|--|--------------------------|
| West Pennant Hills – 67089 | Since 1950 (Excluding 13 years of data) Maximum: 2044mm (1950) Minimum: 602mm (1979) Average: 1124mm | 1654mm |
| Parramatta North - 66124 | Since 1966 (Excluding 2 years of data) Maximum: 1713mm (1990) Minimum: 513mm (1979) Average: 975mm | 1313mm |
| Hornsby Pool – 67065 | Since 2009 Maximum: 1600mm (2012) Minimum: 1195mm (2010) Average: 1276mm | 1600mm |
| Maroota – 67014 | Since 1926 (Excluding 30 years of data) Maximum: 1773mm (1950) Minimum: 354mm (1953) Average: 918mm | 1334mm |
| Cherrybrook - 67062 | Since 2008 (Excluding 2 years of data) Maximum: 1776mm (1988) Minimum: 562mm (1979) Average: 1631mm | 1738mm |
| Glenorie – 67010 | Since 1961 (Excluding 2 years of data) Maximum: 1681mm (1950) Minimum: 385mm (1944) Average: 987mm | 1541mm |
| Pennant Hills – 66047 | Since 1901 (Excluding 61 years of data) Maximum: 2035mm (1950) Minimum: 573mm (1941) Average: 1069mm | 1817mm |
| Wisemans Ferry – 61119 | Since 1906 (Excluding 51 years of data) Maximum: 1498mm (1988) Minimum: 437mm (1906) Average: 861mm | 1232mm |

***Note** - Some data has been excluded as not quality assured by the BOM.

- Data totals up to 2011 from Jan-Dec, 2012 from Jul 2011-Jun 2012.

