Challenges of Implementing $270m of Regional Water Quality Infrastructure

Mark Liebman
Drainage Engineer, Blacktown Council, Blacktown, Australia

Director, Sustainability Workshop, Blackheath, Australia
E-mail: mark@sustainabilityworkshop.com

Ross Jennings
Drainage Engineer, Blacktown City Council, Blacktown Australia
E-mail: ross.jennings@blacktown.nsw.gov.au

Georg Eberl
Senior Engineer, Forward Planning, Blacktown City Council, Blacktown Australia
E-mail: georg.eberl@blacktown.nsw.gov.au

Robert Peterson
Senior Engineer, Blacktown City Council, Blacktown Australia
E-mail: robert.petersonl@blacktown.nsw.gov.au

Abstract

Blacktown is delivering approximately $270m of regional water quality treatment infrastructure as part of the greenfield development of the North West Growth Centre and brown field development of four town centres. This presents Council with significant challenges at every stage of delivery and operation. The risks associated with delivery, at this scale, of a relatively immature form of infrastructure are considerable. This paper discusses the challenges and the risk management measures being put in place to ensure that Council's infrastructure objectives are achieved.

1. INTRODUCTION

Blacktown is delivering approximately $270m of regional water quality treatment infrastructure as part of the greenfield development of the North West Growth Centre and brownfield redevelopment of its four major town centres. The four town centres include Blacktown and Seven Hills in the east of the Local Government Area (LGA) and Rooty Hill and Mount Druitt in the west.

This presents Council with significant challenges at every stage of asset creation, adoption and operation. Bioretention systems were first designed in the 1990s in Maryland, USA, however widespread adoption of the technology, at the scale described above, has not occurred in NSW, Australia. While numerous smaller systems have been constructed in NSW, it is reasonable to consider the technology is still in its infancy in Australia.

The risks associated with delivery, at this scale, of a relatively immature form of infrastructure are considerable. $270m worth of GPTs and bioretention translates into over 40 hectares of filter media surface area and approximately 800 million tonnes of gravel and sand.

In addition to the public investment in water quality treatment, a cornerstone of the water quality framework being implemented includes substantial on-site water quality treatment within the private realm. All R3, R4, industrial and business development is required to achieve best practice treatment on site prior to discharging to the public stormwater systems. In many instances, on-site treatment is and will continue to be in the form of bioretention.

This paper discusses the challenges and the risk management measures being put in place to ensure that Council's "Building the Best" mantra is put into practice.

Key challenges in delivery of regional water quality infrastructure are driven by the traditional time, cost and quality tradeoff. Development pressure, from industry and the State Government to get land subdivided and lots created and serviced is high. Again, pressure from the State Government and IPART to reduce the cost of development constrains and caps developer contributions which are used to fund the works. In terms of quality, Council strongly desires livability outcomes as well as protection of its waterways. Open space aesthetic considerations also pose challenges to both engineers and landscape architects. The proposed treatment systems need to have both form and function. In the greenfield areas, a typical bioretention system uses reeds, grasses and ephemeral vegetation to treat the surface of the bioretention.

In infill areas, where bioretention systems will be retrofitted into existing sports fields, Council has proposed the use of grassy bioretention systems. No grassy systems are constructed in Blacktown as of the date of the paper.

Capacity to take on ownership of the forthcoming wave of water quality assets, i.e. to carry out maintenance to a suitable standard to keep them functioning, and the placement of the water quality infrastructure within passive public open space is equally challenging. The challenges here include:

1) simply carrying out maintenance of vegetated assets which treat stormwater; and

2) provision of access for maintenance vehicles in such a way that enhances livability instead of detracting from the open space. From a maintenance perspective, the ideal would be for paved maintenance around the periphery of the bioretention system. This challenges Council's Open Space Planners and Architect's aesthetic ideals.

The adopted stormwater treatment trains include a gross pollutant trap (GPT) or traps as pre-treatment followed by multi cell bioretention basins. The GPTs play a significant life cycle cost role by limiting the amount of sediment that would be deposited on the surface of bioretention basins.

Multi cell bioretention basins are used because Council limits the maximum cell size to 1,000m^2 for the reasons outlined below:

1) Maintenance, using an excavator with a 9m reach from the side of the bioretention cell is essential to ensure that media is not compacted both during construction and then during major renewal events where filter media is either partially or fully replaced. For practical reasons this results in a maximum cell width of 15m where access from both sides is feasible. Where access from one side only is feasible then a maximum cell width of 7.5m is required.

   The minimum width of a cell is also governed by the need to get a 9m long maintenance vehicle around the outside of the cell.

2) The length of cell is limited by subsoil drainage losses and the need to the drainage hydraulic grade line below the base of the filter media so that it can drain at its design saturated hydraulic conductivity rate. A maximum nominal length of 60m is practical and then gives a maximum cell area of 1,000m^2.

3) Typically, a filter media surface area greater than 1,000m^2 is required, which given the constraints identified in 1) and 2) above, mean that more than one cell is required.

Constructed wetlands are rarely proposed, and this is generally due to spatial constraints, i.e. wetlands typically have a much larger footprint than bioretention systems. Rainwater tanks also play a key role in the treatment train that serves greenfield development.

In the North West Growth Centre (NWGC), most bioretention basins are co-located within regional stormwater detention basins, adjacent to creek lines with existing riparian vegetation and frequently with significant aboriginal heritage value. Heritage impact permits need to be obtained. Most basins are constructed on saline, dispersive soils which poses its own construction and establishment challenges.

The paper will also discuss:

- The time challenges including those relating to S7.11 (formerly S94), funding, time taken to gain all the requisite approvals, particularly the Aboriginal Heritage.
- Requirements for temporary on-site bioretention and detention.
- Design assumptions need to be validated and refined as cost and performance information is established. Council intends to do this by a comprehensive research project.
- Quality challenges via multiple objective design together with a skilled construction industry but which still lacks an understanding of how bioretention basins function.

2. BALANCING TIME, COST AND QUALITY

2.1. Time Challenges

There are a number of time challenges involved with the development of regional scale bioretention systems. These are described below.

2.1.1. Timing of contributions

There is a disconnect between development cash flows and the need to provide infrastructure ahead of development. S7.11 (formerly S94) allows Councils to prepare contributions plans and to collect contributions from developers to fund essential infrastructure. IPART has recently challenged the definition of “essential” infrastructure, questioning if the provision of anything more than gross pollutant traps is “essential”. It was agreed with IPART that the provision of bioretention basins which provide enhanced filtration of stormwater to remove more than 85% of suspended solids is essential.

Council ideally needs to provide infrastructure, namely regional detention basins and water quality infrastructure ahead of development so it can be serviced from the date of practical completion. However, Council only collects S7.11 contributions at the release of the Subdivision Certificate.

Up until this point in time Council and the community have benefited from the Local Infrastructure Growth Scheme (LIGS). This saw the State government pay the gap between the Section 94 cap and the cost of essential infrastructure. The LIGS saw Council obtain funds form the State once a DA was approved and allowed early land acquisition to occur. The LIGS is now exhausted and this early funding source has ceased. As a result, Council will be forced to rely on contributions obtained late in the day and only once the subdivision certificate or in the case of buildings, construction certificate has been released. Typically, a catchment will need to experience substantial development before Council can physically collect enough funds to carry out regional works. Once the funds are collected works can proceed. While there is provision for works to be carried out in kind or in lieu of a contribution, there is frequently a delay between construction of regional infrastructure and catchment development.

This can also work in Council’s favour in terms of water quality infrastructure. The delay provides an opportunity for catchments to be fully developed and consequently for exposed soils to be sealed at which point the rates of sediment discharges from a new development would decline.

Constructing a regional bioretention basin too early could see that basin smothered with sediment and clogged. This would then necessitate replacement of the filter media without a commensurate development contribution to pay for it. This has occurred in the Western Sydney Employment Area where a large bioretention basin had its filter media replaced not long after commissioning. Council's risk response is to delay construction of bioretention basins until 90% of the catchment is developed. Where appropriate this becomes a condition of consent.

2.1.2. Temporary works (R2 Greenfield Residential)

Because of the need to:

- collect contributions to fund construction of regional detention and water quality works, and
- protect regional water quality infrastructure from the impacts of very high construction phase sediment loads,

It is necessary to delay construction of basins typically for a period of several years. However during this interim period there remains a need to protect downstream development from elevated flood risk impacts associated with upstream development as well as to protect downstream receiving waters from water quality impacts. Council has developed a policy which requires developers to temporarily install on site detention and on-site water quality basins on their lots.

Within regional water quality basins there is also a temporary phase where some cells are function as sediment basins and other cells as temporary, sacrificial bioretention systems during the period that the catchment is subject to intensive development. This allows temporary on-site bioretention basins to be removed. The temporary bioretention basins need to be decommissioned prior to commissioning the final stages of the bioretention basin. This provides additional treatment, beyond what a typical sediment basing would achieve, during the construction phase of the development.

Note that this policy applies only to greenfield residential development in the NWGC. Other forms of development in the NWGC, such as R3 residential or business or industrial development are required to construct permanent on-site water quality treatment measures.

Typically, this requires that 2 or 3 house lots in a subdivision are sacrificed to construct temporary measures. These are then decommissioned once the regional infrastructure comes on-line. This approach has some challenges including the difficulty of achieving reduced peak flow outcomes from sites which often don't have enough grade to avoid drowned outlets. An impact of this policy is that it causes delays to developers in the sale of those lots burdened with temporary infrastructure.

However, under common law, Council has an obligation to protect existing landowners from an increase in flood risk, especially from more frequent storm events, which are likely to occur during the interim period, where trunk drainage has not yet been constructed and minor events can cause nuisance or more serious flooding.

Typically, temporary on-site water quality basins are constructed and operated as sediment basins during the construction phase and remain in place until the catchment becomes more than 90% developed. Often basins are not converted from combined sediment and OSD basins into combined bioretention and OSD basins as regional infrastructure has been provided.

Council also exercises a risk-based approach to the requirement for temporary OSD and temporary water quality basins. For example, where a proposed subdivision would not result in an increase in flood risk downstream no OSD is required, or where a subdivision is at the bottom of a catchment OSD may not be required.

2.1.3. Integrated design outcomes

Both internal and external approval is required for infrastructure of this scale.

Council's Asset Maintenance and Construction sections are required to approve works. Council's Asset Design team or its contractors, prepares a Review of Environmental Factors for approval by Planners under Part 5 of the EP&A Act. Council's Recreation Planning and City Architect are also required to approve works as they occur in open spaces.

To gain approval from Recreation Planning and the City Architect, a Design Review Panel (DRP) approach has been implemented. This works by having the preferred concept design presented to the panel at key design stages and affords a formal opportunity for Landscape Architects, Recreation Planners and other parties within the Council that have an interest in the look and use of the public reserves to make comments and ensure that their planning objectives are achieved.

The reserve areas are at times wholly taken up by stormwater infrastructure, but still provide an opportunity to co-locate shared paths, picnic areas, fitness stations or many other passive and or active open space uses. Other reserves have large areas of playing field and the stormwater quality component is a smaller part of the reserve, but still needs to be designed to integrate with other uses of the reserve.

Coming out of the design review process have been other developments. Such as, our Landscape Architects having to put together a style guide. This saves time when there are many designers working on different projects and aims to ensure a consistent approach.

Both the Construction and Maintenance Sections are also given concept plans to review and make comment on to ensure that the constructability and maintainability of the water quality infrastructure systems is not compromised. This also allows for comments that could improve the design.

External approvals cover such things as utilities and approvals from the Office for Environment and Heritage (OEH) for Heritage and protected Existing Native Vegetation (ENV).

The NWGC is covered by a biodiversity certification (biobanking) which allows clearing of native vegetation but also protects areas of high value vegetation. In many cases protected vegetation needs to be cleared for works associated with water quality infrastructure, such as outlets to creek lines where the existing riparian vegetation is of good quality. To speed this approval process Blacktown has identified areas of quality vegetation within the LGA that can be protected to bank as offset areas. This acts as a credit bank which streamlines the approvals for individual projects.

The process for obtaining Aboriginal Heritage Impact Permits (AHIP) is quite lengthy, and in the Blacktown LGA, close to watercourses they are needed on at least 2 out of 3 projects. We found that if a project was voted to be designed in a certain financial year that the entire year could be taken up gaining an AHIP. Meaning a design could not be finalised inside the year. To deal with this critical path item it became necessary to gain funding for Heritage investigation in the financial year before funding for design is voted.

Gaining requisite approvals from utilities can also be a time consuming exercise.

3. DESIGN CHALLENGES

Blacktown City Council (Council) has refined its design criteria for bioretention to manage and address local and general risks that Council has become aware of. Ease of maintenance and reduced life cycle costs are also a key design driver as is the need to increase confidence that treatment will be achieved.

Notable design criteria include:

- A submerged zone is required in all bioretention systems of all sizes. With a 450mm saturated depth or storage of $0.12m^3/m^2$ required so that established plants can survive a 95th percentile dry period in the Blacktown LGA. This is approximately 23 days with no rainfall. It also acts as water storage that is available to passively irrigate plantings that are not yet established. Where possible the submerged zone is designed to be able to drain down via gravity to an adjacent watercourse. To allow for major maintenance or reconstruction should it be required without the need for pumping.

The submerged zone is a critical risk response to local conditions where western Sydney can be extremely hot with extended dry periods. In some instances, early designs have resulted in 100% plant mortality as the filter media, designed to be free draining, has a relatively low field capacity with low organic content.

- Due to the frequently heavy clay based, sodic and dispersive soils in the area, infiltration is not only undesirable it is not feasible. The inclusion of a submerged zone also precludes infiltration from the zone.

- Due to the regional nature of the bioretention systems and their large catchments there is often base flow draining to them, at least for a number of days or weeks after significant rainfall. This has caused the blinding of some existing bioretention systems. A potential solution to this is permeable concrete pipes which are described in more detail below.

- The use of permeable concrete pipes and an up-welling inlet system has been included to allow low flows to be kept off the surface of the bioretention and allow up-welling inlets to be spaced evenly around bioretention cells. The upwelling system is intended to evenly distribute flow around the basins. This is considered critical as early designs with a single inlet have resulted in some very wet areas adjacent to inlets and very dry areas, with poor plant survival furthest away from inlets. This causes unintended variations in plant succession with wetland vegetation and blinded filter media occurring at the inlets of some basins. Upwell pits hydraulically distribute flows around the basin with the added benefit of energy dissipation by forcing flows up through the pits.

- The use of permeable concrete pipes allows for additional substantial sediment deposition within the pipes themselves and not on the surface of the bioretention. Removal of sediment from the surface of the bioretention system would be a complex and costly exercise requiring removal of vegetation. Blinding of the surface of the media is considered a principle cause of failure of bioretention systems resulting in them treating less volume than required. Because GPTs typically remove around 50% of TSS, therefore 50% of TSS remains in the bioretention influent. Removal of a portion of this remaining 50% of TSS will extend the life of filter media and reduce life cycle costs. It is also relatively easy to remove sediment from the permeable concrete pipes via eductor truck, more so than removal of sediment from the surface of a bioretention system. The proportion of sediment that could be trapped in the permeable pipes needs to be validated through research. This is discussed further below.

- Following from early, wetland design, bioretention systems are split into cells when their size exceeds 1000m^2, this allows for the maintenance of one cell while others cells in the same system are still operational.

- Flow splitter pits allow for the flows to be distributed evenly to each cell.

- 3m wide access tracks with 1m either side, a total of 5m, to allow maintenance staff to enter and exit vehicles are required and radius to allow 8.8m vehicles to circulate. This allows for not just minor maintenance but also for major maintenance to be carried out without the need to form temporary access during major maintenance. It also allows for the maintenance access tracks to carry out a dual use as shared paths.

- To facilitate improved aesthetic outcomes, Council is now considering linear bioretention systems with access tracks on one side which would double up as shared paths. This approach supersedes earlier designs which had full paved access around the whole of the cell.

Council is currently in the process of establishing a maximum permissible hydraulic loading rate for bioretention systems to ensure that they are not hydraulically overloaded. Hydraulic overloading is a known cause of failure of stormwater quality improvement devices.

The current specification requires the 1 in 3 month storm event to be passed through the systems. However preliminary analysis suggests that this may have detrimental impacts on aspects of the design such as size of outlet pits and scouring of the systems without any commensurate improvement in quality. This could impact on life cycle costs leading to shorter periods between renewal events.

A better approach to specifying design flows is considered to be hydraulic loading rate. Hydraulic loading rate (HLR) is not a widely used concept in bioretention design and there is limited published research data available.

The HLR concept was however widely used in the early days of constructed wetland and sand filter design. It was used to ensure that wetlands were not overloaded and smothered with sediment. Essentially the context for bioretention systems is the same – avoid smothering to keep porosity maintained and avoid scour to avoid the bioretention basin becoming a source of pollution instead of pollutant trap.

It is hoped that by developing a target HLR that Council will see the right balance between GPT sizing and bioretention basin as well as basins that deliver the right balance of treated volume, quality and asset life. In practical terms setting a target HLR will see the maximum size of inlet flows limited combined with a reduction in flow volume that is passed through the bioretention basin without comprising water quality outcomes.

4. RESEARCH TO VALIDATE ASSUMPTIONS AND MINIMISE LIFE CYCLE COSTS

Council is currently preparing a business case to evaluate and inform a proposed, field based bioretention validation and optimization project. If the business case proves the case for investment in the research, Council will partner with a number of organisations including universities, State Agencies and other Councils to carry out the research.

Blacktown City Council and other Growth Centre Councils are predicted to make significant investments on bioretention stormwater treatment systems in the next 30 years to service the development in the Growth Centres. Blacktown alone is predicted to install close to 40 hectares of bioretention systems costing over $270 million in capital investment (mainly from section 7.11 contributions) and then an additional $2 million per year for maintenance. With this level of investment Council Executives need certainty that these systems will provide the predicted water quality benefits.

It is also critical that the design, construction and maintenance of these systems are optimised to provide the best return on investment. It is widely known that maintenance within Council's is typically underfunded and so with financial pressure to keep maintenance costs as low as possible, the research seeks to validate the wholistic life cycle approach adopted by Council.

The core objectives of this project are to:

- Validate the current design specifications from "Blacktown City Council's WSUD Standard Drawings" are achieving the required water quality targets.
- Investigate opportunities to optimise the design specification to ensure they meet these water quality requirements while also reducing capital and operational costs for the life of system.
- Calibrate and validate Council's water quality modelling framework by monitoring pollutant load rates (termed "event mean concentration (EMC) values") for a range of relevant land-uses.

If funding is obtained, the project will see Council and its partners spend between $500k and $1million validating and optimising its design and specification. While the research carried out by the Cooperative Research Centre for Water Sensitive Cities underpins much of the design basis for the bioretention systems being designed by Council, that research has not been field tested in western Sydney.

Moreover, Council's unique solutions to overcoming known problems, such as upwell pits and use of permeable pipes for evenly loading systems needs to be validated. While it is theoretically possible to model every aspect of performance ultimately Council needs to know that it is working and that the design is going to deliver its water quality objectives.

Council is seeking to defer final bioretention basin construction as long as practical to facilitate the learning that may occur from this research project to be applied to as many basins as possible.

This research project is a direct response to uncertainty and risk associated with the capital investment.

5. CONCLUSIONS

Blacktown Council plans to spend over $270 million on bioretention systems to help mitigate against the impact of future urban development in both its greenfield areas as well as its infill areas. While there is a tremendous pool of knowledge of bioretention systems within Council, Council none the less adopts a risk averse approach to design and specification. Given the value of the proposed investment this is a reasonable approach. However there may be opportunities for Council to review its specification through a field based research project which seeks to firstly validate the specification and secondly to optimise the design.

Delivering $270 million of bioretention poses significant challenges to Council. Including the needs to:

1) Keep costs to a minimum

2) Keep operating costs to an absolute minimum

3) Co-location of bioretention systems with open spaces which exposes the tension between function (engineering) and form (planning and urban design).

4) Provide safe access for maintenance which doesn't compromise the aesthetic of open spaces.

5) Design and get the systems built in a timely manner in line with development.

It is concluded that these challenges can best be met through an open-minded, adaptive management approach. This requires a corporate culture which permits both mistakes to be made and learning to occur. It is suggested that Blacktown Council has this culture and the prospects of overcoming the significant challenges noted in this paper are strong.

6. ACKNOWLEDGMENTS

This work was conducted in collaboration with numerous staff members within Council's Asset Design and Waterways sections. While they may not have contributed directly to this paper they have contributed ideas and knowledge to the development of WSUD practice or WSUD Standard Drawings and other tools which define Council's bioretention design and construction requirements.

7. REFERENCES

Payne, E.G, Hatt, B.E, Deletic, A, Dobbie, M.F, McCarthy D.T and Chandrasena G.I., 2015. *Adoption Guidelines for Stormwater Biofiltration Systems*, Melbourne, Australia: Cooperative Research Centre for Water Sensitive Cities.

Blacktown City Council, 2017, WSUD Standard Drawings available at https://www.blacktown.nsw.gov.au/files/assets/public/buidling-and-planning/engineering-designlibrary/water-sensitive-urban-design/wsud_standard_drawings.pdf