THE ROLE OF RAINTANKS IN FLOODPLAIN AND STREAM MANAGEMENT

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Abstract

The increase in impervious area associated with urban development has detrimental impacts on riparian areas. Floodplain management benefits from stable and healthy riparian areas to reduce the risks associated with channel widening and bank instability and thereby maintain the ecological, social and economic values of these areas. In the past, floodplain management has focussed on the larger, low frequency flood events, however, the events critical to the health of riparian areas are the more frequent, low flow events and base flows. By breaking the direct link between impervious areas and the receiving riparian zones using water sensitive urban design techniques such as rainwater tanks, it is possible to mitigate the changes in runoff regime associated with development, particularly for the more frequent flows.

Key Words: Stream hydrology, Urbanisation, Impervious areas, Rain tanks, Riparian areas.

Introduction

This paper presents information on the changing approach to stormwater management that is occurring and how the lessons learned in this area can relate to floodplain management. In the past the general approach has been to reduce roughness and drain stormwater from catchments as quickly as possible. Now, a more sustainable approach involving reduced impervious areas and drainage systems that incorporate retention and infiltration of flows is being encouraged. This is commonly referred to as water sensitive urban design, or water sensitive design.

The general focus of floodplain management has been on the lower frequency events, from the 1 in 5 to 1 in 100 Average Recurrence Interval (ARI) events and higher. These events are crucial to the management of flooding and protection of the community and assets. However, these events - particularly the 1 in 20 ARI and more frequent are of minimal relevance to the protection of ecological values of riparian areas within catchments and floodplains. However we do acknowledge the value of flooding in connecting normally dry parts of a flood plain. The quality of riparian lands is influenced greatly by base flows and the more frequent events (less than the 1 in 5 year ARI).

This paper will discuss how urbanisation of the catchment can influence the quality of riparian areas within the floodplain and how the protection of these areas can:

1. assist directly in the reducing the risks associated with watercourse flooding; and
2. protect and maintain social, environmental and economic values of the floodplains and associated riparian areas.

It will then outline various modelling results from a number of case studies on catchments where impervious areas have increased and a water sensitive design approach has been applied.

Summary of impacts of urbanisation on catchment hydrology

Increasing a catchment's impervious area creates significant changes to the catchment hydrology and water quality, which in turn leads to degradation of riparian areas. This is particularly relevant for the coastal areas of NSW, especially the southern region, where the landscape is likely to change significantly from forested and rural land uses to urban land uses as population growth in coastal areas increases.

The purpose of this summary is to briefly outline the impacts that a change in landscape (increase in impervious area) can have on a catchment. Much of this information has been summarised from a technical paper produced by the Cooperative Research Centre for Catchment Hydrology (CRCCH) (Ladson, 2004).

The increase in impervious areas within a catchment increases flood frequency, particularly at the more frequent recurrence intervals For example it has been shown (Figure 1) that there is an increase in peak flows of up to 10 times for the 3 month to 1 year ARI events (Wong et al, 2000).

As hard surfaces prevent infiltration, so groundwater collection and transfer is reduced (Simmons and Reynolds, 1982), resulting in the constant base flows that maintain ecologies within watercourses being reduced or removed.

Of particular interest to this paper is the increase in runoff frequency for the very small events. Runoff from impervious surfaces can be caused from rainfall events as low as 1-2mm. Therefore, the number of runoff events into creeks increases compared to runoff occurrences in natural catchments (Ladson, 2004). Modelling of catchments in the Sydney and Southern Highlands areas where land use is changed from rural to urban can increase the number of runoff events by a factor of 20 (STORM_CONSULTING, unpub. 2004).

Large urban areas create heat islands which produce their own microclimates. The loss of pervious land reduces the area's ability to transpire heat, in some cases increasing local temperatures by 0.5-1ºC (Perkins, 2004). This can influence the urban runoff regime, increasing storm intensity leading to more frequent runoff.

Due to changes in the hydrologic regime, Streams undergo considerable modification during and after an increase in catchment imperviousness. Responses include:

- Channel incision
- Bank erosion
- Sedimentation
- Stream enlargement; and
- Changes in channel shape

Channel cross sectional area may increase up to a factor of 10 in highly urbanised areas (Morisawa and Laflure, 1982). Urban streams within Sydney, particularly those on shale based geology, show signs of significant geomorphic instability, many showing signs of incision and bank erosion.

U.S. studies on the relationships between imperviousness and stream health have shown that with approximately 10% catchment imperviousness, streams retain good water quality and stability, at 10 – 25% imperviousness, noticeable erosion and widening and at 25% imperviousness, severe physical and ecological damage (Perkins, 2004).

However, the direct link between overall imperviousness itself and stream health is not strong, particularly for lower impervious percentages. Research undertaken on catchments in the Melbourne area have shown that a strong relationship exists between the direct connection of impervious surfaces to streams (pipes and concrete channels) and stream health (Walsh, 2004). Therefore one focus of stormwater management should be on the disconnection of impervious areas from their receiving waters.

The EPA in conjunction with the CRCCH are undertaking research on urban catchments within Sydney to determine where the relationship is applicable there (Shane Barter, pers. comm., 2005).

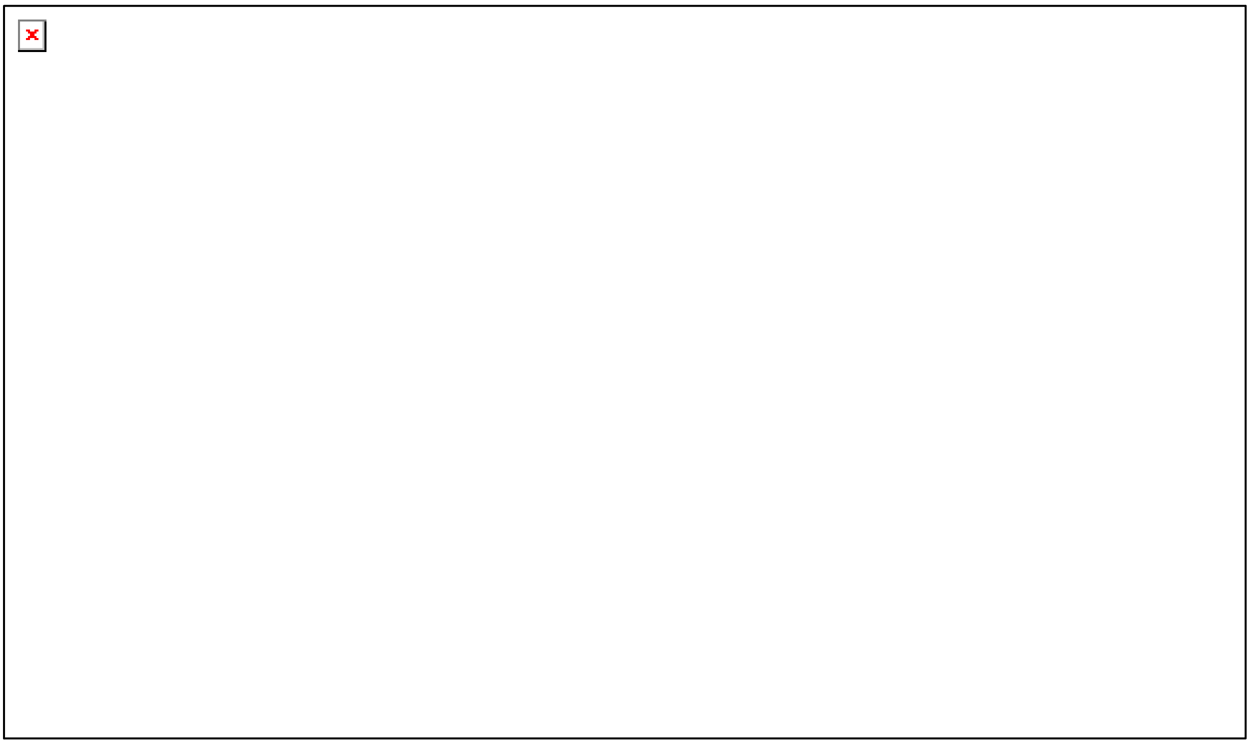

Figure 1. Effect of catchment imperviousness on flood frequency curves (Wong *et al* ,2000).

The benefits of water sensitive design to floodplain management

The primary aim of floodplain management is to protect developed areas from the impacts of flooding. For existing development, this has meant the installation of various mitigation measures such as channel modifications and on line detention basins usually in or close to riparian areas. Awareness of the importance of protecting and retaining riparian lands for their recreational, aesthetic and ecological value has increased (Lawrence and Breen, 2003 and Ladson, 2004). To protect these values changes in approach to floodplain management are required, particularly in relation to new development, (Adamson et al, 2003).

Fundamental to the change in approach is an understanding of the importance of the smaller events and their influence on the riparian areas within a floodplain. Table 1 summarises the importance of both small and large events to the range of values placed associated with riparian areas. The large events are of critical importance to the protection of some social and economic values. However, it can be seen that the smaller events are of similar significance and relate to a wider range of riparian values, including biodiversity and water quality and community and asset protection.

It is possible that the immediately obvious link between dramatic flood impacts and the associated high flows can divert attention away from the less directly linked, but equally important, base flows and more frequent flows. Not incorporating these flows into floodplain management can lead to degraded riparian values and potentially increased flood risk.

There are likely to be significant economic benefits to considering the smaller more frequent flow events and associated water quality. Maintaining the flow regime for the full range of events is likely to lead to more stable stream systems, preventing stream degradation processes such as incision and widening, reducing the loss of land, and maintaining buffers between developed land and channels. Protection and maintenance of riparian values also reduces expenditure on channel stabilisation and stream rehabilitation for degraded streams.

The new *Managing Urban Stormwater* documents to be released by the NSW Department of Environment and Conservation later in 2005 will include flow duration (smaller more frequent events) as a factor in preparing stormwater management measures for new developments (Shane Barter, pers. comm. 2005).

Table 1 Comparison of the importance of high and low frequency flood events to riparian values

Riparian Value		Base flows and small events (< 1.5yr ARI)	Large Events > 1.5yr ARI
Ecological	Biodiversity	Critical to maintaining natural wetting and drying regimes suited to riparian species. Critical to retention of existing bank vegetation.	Infrequency means minimal impact on habitat
	Water Quality	Critical as majority of pollutant loads are carried from developed catchments associated with smaller events	Infrequency means minimal impact on water quality
	Geomorphology	Critical to shaping and alignment of streams and maintaining stream stability	Important, though infrequent modification to channel cross section and alignment

Water sensitive design case studies

STORM_CONSULTING have undertaken a number of projects to quantitatively assess the impacts of water sensitive design features such as rainwater tanks, swales and bioretention on the hydrological regime in order to protect riparian values.

Case Study 1. Proposed industrial estate, Wyong.

Before the rollout of the CRCCH's modelling software MUSIC, STORM undertook a hydrological and water quality assessment of a proposed industrial area between the Pacific Highway and Wyong. The proposed industrial development, known as Precincts 11 and 13, drain to Buttonderry Creek and Porters Creek Wetland which contain high ecological value that Council is committed to maintaining.

Council's major objective was to mitigate the impacts of the proposed development to promote the ecological sustainability of Porters Creek Wetland, especially the sustainability of its stormwater filtration capacity. Development without appropriate drainage controls can severely degrade aquatic ecosystems and wetlands. Maintaining natural wetting and drying cycles is essential for wetland health.

Therefore Council's objectives for the development can be inferred as maintaining the same hydrological and water quality regime post-development as existed pre-development.

A variety of at source, conveyance and end of pipe controls were considered. The optimum design included:

SOURCE CONTROLS:

- A site level stormwater management plan with the objectives of 50% nutrient retention and 75% suspended solids retention.
- Rainwater storage of 100m^3/Ha of industrial lot together with a prescribed irrigation regime
- On site swales
- Collection and treatment of the first 10mm of rainfall on hardstand areas.

CONVEYANCE CONTROLS

- Swales
- Rehabilitation and armouring of existing drainage lines

END OF PIPE CONTROLS

- Constructed wetlands ranging in size from 0.5 to 1.9 Ha
- Buffer strips ranging in size from 1 to 2 Ha

A number of combinations of rainwater tanks, infiltration systems and constructed wetlands were modelled for hydrologic and water quality performance. It was found that rainwater storage of 100m^3/Ha of development was optimal in terms of reducing runoff from the proposed development. This was coupled with the need to ensure that water was regularly drawn out of the rain tanks and used for toilet flushing, other non potable uses and also to irrigate a proportion of the landscaped areas on each lot in accordance with a prescribed irrigation schedule. This was done to increase the amount of water drawn from the tanks making more volume of storage in the tank available for retention of the next storm event.

Results from detailed modelling of rainwater tanks on the hydrological regime (Figure 2) showed significant reductions in various flow percentiles when using a rain tank. For example a 100m^3 tank will reduce the 95% runoff rate from 87m^3/Ha/day down to 65m^3/Ha/day - a 25% reduction. This increases to a 35% reduction for the 90% flow event and by 9% in terms of the total average annual volume of runoff. This provided a secondary benefit by reducing water demand by up to 55% as a result of reuse of the harvested roof water.

Interestingly, runoff from the smaller events (base flows) is reduced to below rural or natural conditions, which could produce a negative impact. Storage and infiltration of a portion of runoff could offset this. Prescribing irrigation would also help to balance the volume of water going into the ground to maintain any base flows present. Clearly however this measure alone was not enough to fully mimic the base flow regime that would have existed in a rural state.

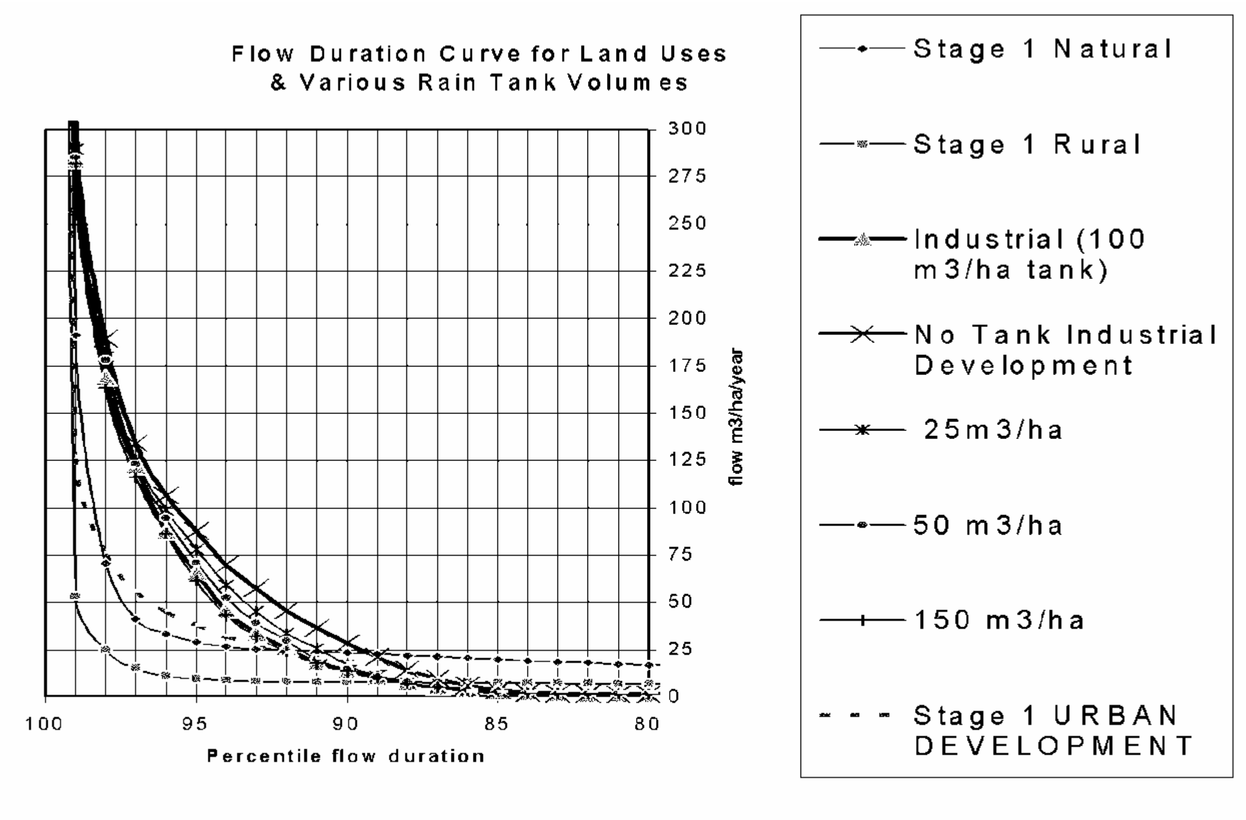

Figure 2. Flow duration curve for land use and various rain tank volumes

In summary, the following benefits were likely to accrue by adopting the proposed water sensitive design:

- A reduction in developer contributions for off site water management infrastructure
- Smaller artificial wetlands and maintenance costs for Council
- Up to 55% reduction in water demand over a traditional development
- 35% reduction in peak flows over a traditional development (benchmarked at 95 percentile flow)
- Predicted increase in total flows by 5% after development
- Improved water quality outcomes compared to traditional development with 45% retention of nutrients.

Case study 2. Harrington Park 2 and Mater Dei Rezoning, Camden

STORM_CONSULTING and URS carried out a water cycle assessment of a 1,200 Ha urban release area in Camden. Council had a strong desire to preserve ecological values of the catchment and demanded a sustainable development approach to the site which included:

- Effective integration of 'lifestyle housing' with a bushland setting, recognising both ecological and bushfire hazard constraints;
- Leading edge implementation of water sensitive design principles;
- Development of management and implementation frameworks which deliver sustainable outcomes over the long term, including through consideration of private ownership and responsibility for those outcomes;
- Protection and successful ongoing management of both the natural and physical heritage aspects of the sites, including the scenic qualities.

As part of the study STORM undertook an assessment of the hydrologic impact of rain tanks to determine the yield and optimum size for supply, and to determine the benefits of tanks in relation to runoff events.

The analysis showed the following:

- Pre-development runoff days per annum = 22
- Post development runoff days per annum (without tanks) = 71
- Post development runoff days per annum (with tanks) = 20

This demonstrates the ability of rain tanks to effectively buffer receiving waters from the increased runoff associated with impervious roof areas.

Runoff volumes for the pre development site were compared with a post development condition with and without controls. The post development scenario with controls included a treatment train of source controls, (rainwater tanks), conveyance controls (swales) and end of pipe controls (such as sandfilters). Importantly we recognised that roof areas were not the only impervious areas that needed to be managed. So we also included storage and irrigation of road runoff. Public open space areas were to be irrigated with treated stormwater. The adopted irrigation regime was one currently used by Council.

The results (Table 2) showed that getting flow volumes and frequencies back to predevelopment levels in this case was not possible however significant in-roads can be made. In this case an integrated water cycle approach was adopted with recycled effluent limiting the amount of stormwater we could dispose of.

Area	Pre-Development Runoff (ML/10Ha/yr)	Post-Development Runoff	
		No Controls (ML/10Ha/yr)	With Controls (ML/10Ha/yr)
Harrington Park 2 (dense urban)	17.6	41.2	22.8
Mater Dei (low density urban)	17.6	38.2	25.1

Table 2. Stormwater runoff volumes for pre and post development scenarios for an indicative 10Ha catchment.

Case study 3. Twin Waters Estate, Nowra and Mary's Mount Urban Release Area, Goulburn

These are two residential developments. For each development an assessment of the impacts on rainwater tanks was undertaken by comparing the number of pre- and post-development runoff days. These studies focused on the frequency of runoff and not the total volume.

These developments were similar in density and style, with lot sizes between 500-800m^2 and roof sizes of between 200-300m^2. Each house was modelled with a 10KL rainwater tank connected to the roof and water supplied to all outdoor uses, toilets, laundry and hot water.

Table 3 summarises the results for the two developments. The benefits in reducing runoff frequency are clear, at both sites runoff frequency is reduced whereby it approximates the pre-development situation. However, this should not be confused with runoff volume, where the benefits are not as great.

The results from Nowra show that the inclusion of hot water in the tank supply significantly improves tank yield and the number of runoff events.

	Runoff events (days/year)					
Location	**Pre-devel-opment**	**Post-devel-opment - no tank**	**Post devel-opment - with tank (including hot water supply)**	**Post devel-opment- with tank (excluding hot water supply)**	**Water supply demand met (including hot water)**	**Water supply demand met (excluding hot water)**
Twin Waters Estate, Nowra	18	89	21	27	51%	44%
Mary's Mount Urban Release Area, Goulburn	6	77	8	N/A	47%	N/A

Table 3. Modelled impact of rainwater tanks on runoff frequency for two residential developments in NSW

Conclusion

The results of the case studies demonstrate that by managing runoff through such means as retention, significant benefits for the higher frequency events can be achieved.

Maintaining the natural hydrologic regime, particularly for the frequent events and base flows is critical for the protection of riparian values, which in turn has significant benefits for floodplain management.

Rain tanks can play a significant role in reducing post-development runoff frequency and volume, but they cannot save our streams on their own. By using a water design sensitive approach that includes rainwater tanks, it is possible to significantly mitigate the water quality and water quantity impacts associated with increases in impervious area. Rainwater tanks can also supply a considerable portion of potable water demand thereby reducing demands on supply infrastructure.

Understanding the importance of the full range of runoff events and base flows which are critical to riparian protection will assist in producing successful floodplain management.

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Author Biography

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Lachlan Bain is an Environmental Engineer with 6 years experience working in the fields of stormwater and integrated urban water cycle management. He has worked on a large number of riparian based projects, including Restoring the Waters and Upper Clear Paddock Creek as well as a variety of rehabilitation projects throughout NSW. He currently works on urban development planning and design for a range of projects in South East NSW.

Lachlan is currently based in Moruya where he runs a small regional office of STORM_CONSULTING. He is currently nearing completion of a Masters in Environmental Management.

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