

Urban Creeks—Streams or Drains?—Implications for Management

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ABSTRACT: *The perception that urban streams are stormwater drains has long influenced, and indeed limited, management policies for these streams. The hydraulic geometry technique was used on Winding Creek, NSW, indicating that while channel parameters for the whole stream are in equilibrium with a discharge surrogate, smaller reaches are apparently more heterogeneous. These results imply that smaller rather than larger channel reaches may provide a better scale for channel management. This process could involve clearing the stream of anthropogenic debris and revegetation of small reaches, while retaining natural fluvial features, as opposed, or in addition to, large scale management of stormwater. Much of this work is time consuming, but community-based groups, such as urban Landcare or Rivercare, could be involved.*

1. INTRODUCTION

Increases in flood frequencies, peaks and velocities, and altered sediment yields are common consequences of urbanisation (Pickup, 1986) because of the replacement of vegetation with impervious surfaces which reduce infiltration rates and increase runoff (Douglas, 1983). In addition, artificial drainage systems, such as gutters and stormwater drains that are superimposed on the natural drainage system, hasten the flow of water entering the channel system (Park, 1981). Channelisation, which can involve the artificial enlarging, straightening or sealing of a channel for the purpose of flood mitigation markedly increases flood velocities (Brookes, 1987). Sedimentation yields often increase during construction phases, reducing channel capacities, causing increased flooding and channel erosion (Douglas, 1985) but may fall below natural levels following urbanisation. The effect that urbanisation will have on a channel is dependant upon precipitation, soil properties, slope, distance from channel, amount, intensity and age of the urbanisation and riparian vegetation (Hammer, 1972; Ebisemiju, 1989).

In many areas of Australia, and within the Newcastle and Lake Macquarie areas in particular, urban streams have been grossly neglected by management and local residents, with little interaction between groups. Management of urban streams has generally been the responsibility of local government who have historically interpreted this role as being primarily related to flood control (Rolls, 1995). The urban streams in our environment today have little in common with their

natural state. Many have undergone a succession of transformations to aid flood control by a variety of methods and over a substantial period of time. Early work on urban streams was carried out in a time when humans attempted to control and dominate their environment. However, it is suggested here that not only does present management have to deal with the reality of past management decisions, but is presently restricted by a continuation of this former philosophical stance.

Hydraulic geometry has been suggested by fluvial geomorphologists as a model for estimating flood discharge and to assist in river management (Wharton, 1995). This model is capable of being both general and site specific in nature. It is the aim of this paper to illustrate the complex nature of urban streams, by the examination of Winding Creek, NSW, using hydraulic geometry, and to point out some implications for present and future management.

2. STUDY AREA

Winding Creek is located near Lake Macquarie, NSW (32° 55'S, 157° 40'E) and drains the eastern portion of Cockle Creek catchment, which subsequently flows into the northern side of Lake Macquarie (Fig 1.) The total catchment area of Winding Creek is 19.6 km². Much of the original vegetation of dry sclerophyll forest has been cleared, with residual woodland of 34%. The remainder of the catchment is 16% open area, with approximately 50% urbanised. There are two main business districts included within the catchment: Charlestown at the headwaters, and Cardiff, located in the lowland area. Approximately 30%, or 2.3 km of the trunk stream was channelised between 1930 and the mid 1970s.

3. HYDRAULIC GEOMETRY

Hydraulic geometry has been traditionally used by geomorphologists to describe channel morphology. Channel parameters such as width, depth, channel capacity, velocity, slope and meander wavelength, are explained by their relationship to discharge, or surrogate. These relationships may be quantified by a series of power functions. The exponents of these power functions, which express the ratio of the rates of change for each parameter, vary uniquely for each stream. Hydraulic geometry techniques have been found valuable in the identification of the character and magnitude of human-induced channel change (Ebisemiju, 1991). This is achieved by comparing power functions for natural and urbanised catchments, or downstream reaches along individual streams. The relationships from natural areas

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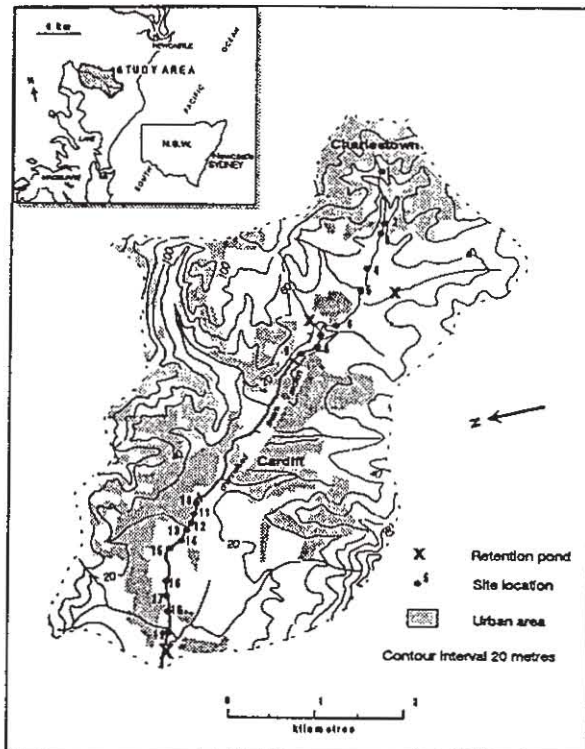


Figure 1: Winding Creek Catchment, N.S.W.

are used as a base from which to quantify changes in the size of channel parameters in areas altered by humans. This technique assumes, however, that the rate of change in any part of a system is a constant fraction of the relative change of the whole system (Ebisemiju, 1991), and may ignore alterations to sedimentation rates associated with urbanisation. Additionally, Wharton (1995) maintains that hydraulic geometry can assist in river management, by estimating flood discharge on ungauged streams where engineering works are being considered, to identify particular reaches that may need increased management, and to monitor stream variation over time.

Oversimplification has often been a major criticism of hydraulic geometry. Phillips (1990, 1991), for example, argues that hydraulic geometry is inherently unstable, and that channel parameters are capable of multiple modes of adjustment, that may take place in both expected and unexpected directions. It is also recognised that there are complex interrelationships operating at a variety of scales at any given point, that will influence the channel morphology (Penning-Rowsell and Townshend, 1978). The complexity of channel responses is further augmented where intricate anthropogenic landuse changes have taken place. Wharton (1995) however, suggests that it is the deviations from expected values, or residuals, that indicate the sensitivity of particular river reaches to changes.

Given that Winding Creek catchment is substantially and unevenly urbanised, and that 30% of its trunk stream is channelised, it was hypothesised that downstream

hydraulic geometry relationships would fail to describe the channel morphology. Channel parameters (width, depth and channel capacity) were derived from 19 pairs of cross sections (Fig 1.), surveyed at adjacent pools and riffles (to overcome the problem of inherent morphological and hydraulic differences (Gippel, 1982)). The stream sites are divided into upstream and downstream sites which are separated by the section of channelisation in the middle section of the stream. The upstream sites are likely to have been impacted upon by urbanisation and the downstream sites by both urbanisation and channelisation. A maximum of three sets of channel parameters were defined at each site. These relate to bankfull levels for a low water bench level, a second bench level defined at the height of flood debris and/or a higher morphologic bench, and thirdly at the valley floor. The valley floor is believed to be a terrace, due to stream incision associated with climatic changes (Erskine and Bell, 1982) and urbanisation (Nanson and Young, 1981; Roberts, 1989). Catchment area was used as a surrogate for discharge.

The results of regression analysis significant at the 0.05 level or better are given in Table 1. Pools and riffles are treated separately, firstly for one set covering the length of the stream and secondly as two data sets relating to sites upstream and downstream of the channelisation.

There were a greater number of significant results for the data set covering all sites rather than for the split sets, but the r^2 values are generally lower than for the other sets. As r^2 values decrease from unity, the degree of equilibrium decreases because of destabilising effects of catchment or climatic changes (Ebisemiju, 1989). Bench level 2 appears to have the strongest relationship indicating that it may be associated with the main channel forming discharge.

For the upstream data set, channel width at bench level 3 appears to be in equilibrium with the surrogate discharge with r^2 of 0.99 for both pools and riffles. However, field observations and comparisons with rural data indicate that bench level 3 is a terrace and therefore a reflection of past landuse and climatic regimes. The number of significant results for pools increases downstream, however the strength of these relationships decreases and there are no significant results for riffles, a situation which may well be expected due to the additional destabilising effects of the channelisation, evident by a marked change in the hydraulic geometry relationships downstream of the channelisation, as indicated by the exponent values.

It is clear from these results that the initial hypothesis must be rejected as hydraulic geometry results appear to more adequately describe channel parameters for the whole stream rather than individual reaches. It is obvious that oversimplification has occurred in this particular example, as hydraulic geometry cannot

TABLE 1
Regression Analysis
(NB—log values are used)

Data Set	Independent Variables	Dependent Variables	R ²	Coefficient (a)	Exponents (b)	Significance Levels
<i>All Sites</i>						
Pools	Catchment Area	W1	0.59	0.49	0.30	0.003
		D1	0.40	-0.45	0.32	0.0041
		C1	0.56	-0.03	0.67	0.0002
		C2	0.67	0.90	0.40	0.002
		D3	0.42	0.07	0.21	0.0164
		C3	0.37	1.34	0.25	0.0279
Riffles	Catchment Area	W1	0.41	0.42	0.35	0.0001
		D1	0.59	-0.62	0.36	0.0001
		C1	0.61	-0.12	0.66	0.0001
		W2	0.36	1.11	0.11	0.05
		D2	0.81	-0.20	0.31	0.0002
		C2	0.96	0.90	0.46	0.0001
		D3	0.58	0.07	0.21	0.0017
		C3	0.49	1.40	0.22	0.005
<i>Upstream and Downstream Sites</i>						
Upstream Pools	Catchment Area	W3	0.99	0.97	1.02	0.0158
Upstream Riffles	Catchment Area	D1	0.60	-0.61	0.30	0.01
		C1	0.67	-0.12	0.61	0.0074
		C2	0.91	0.90	0.50	0.003
		W3	0.99	0.97	1.03	0.003
Downstream Pools	Catchment Area	W1	0.41	5.25	-3.73	0.0472
		D1	0.62	5.99	-5.11	0.0069
		C1	0.56	11.35	-8.93	0.0130
		W2	0.91	11.15	-8.45	0.0457
		C3	0.40	4.84	-2.73	0.05
Downstream Riffles	Catchment Area	No Regression Results are Significant				

W = width; D = depth; C = capacity; 1 = bench level 1; 2 = bench level 2; 3 = bench level 3

distinguish between an equilibrium state of a fully adjusted channel and a channel undergoing continual adjustments (Richards and Greenhalgh, 1984).

There are several explanations for this unexpected result. Firstly, as the highest percentage of urbanisation occurs in the Charlestown area located at the headwaters, it is likely that the major effect of urbanisation in the form of channel enlargement is effected in the upstream sites (Ebisemiju, 1989). The downstream sites may be enlarged primarily in response to channelisation, thus giving an overall impression of equilibrium. Indeed, comparisons with rural catchments within the region (Ormerod, 1988) implied that channel enlargement, predominantly of channel width, had occurred in upstream sites due to urbanisation. Immediately downstream of the channelisation, the stream displayed until recently, a typical 'bulbous caving re-entrance' (Brookes, 1987), as a result of channel incision and bank erosion. The size and depth of the stream at this point

was anomalous, and it was therefore excluded from the sample, thus eliminating the section of the stream that had perhaps undergone the most adjustment. Channel enlargement tended to decrease with distance from the channelised section, as velocities are reduced (Brookes, 1987), and fining of sediment in a downstream direction (Nanson and Young, 1981).

Secondly, as suggested by Phillips (1990, 1991), multiple modes of adjustment are common as channel parameters may be sharing channel responses, thus smoothing out or even negating expected channel responses. These phenomena may manifest as heterogeneous forms that occur along a stream. Some reaches of Winding Creek appeared to be oversized for the upstream catchment area, while others were choked with sediment and debris, thus indicating inadequate channel capacity. Alternating sections of erosion and aggradation, and even combinations of both at the same site, were common along Winding Creek, supporting

the concept of multiple modes of adjustment. Downstream pool and riffle parameters responded differently to changed flow conditions (Table 1), which may be partially explained by an unequal distribution of stream power, with more power being expended over riffles than pools (Leopold, 1969). Planform adjustments may have been significant, especially in stream reaches downstream of the channelisation. Here, sinuosity is reduced due to vigorous bank erosion, thus reducing or increasing the apparent changes in other channel parameters. The concept that the direction of change can be opposite to what might be expected is supported by Ormerod (1988) who found for example, that there were generally weak correlations between channel slope and channel parameters, and in some instances the relationships were direct rather than inverse as anticipated.

Thirdly, adjustments are time dependant so that channel changes due to urbanisation are dependant on the age of the urbanisation, which varies throughout the catchment. During construction phases sediment load may increase dramatically (Wolman and Schick, 1967), and despite increased discharge, channel parameters may decrease because of increased sediment loads (Neller, 1985). There is often a time lag in channel response to increased sediment if temporary storage occurs prior to entering the stream, thus taking several years for sediment to pass through the system (Douglas, 1985). At some upstream sites stripping of benches is evident, implying that sediment is being moved through these reaches. However, large channel bars were present especially in the downstream section of Winding Creek, indicating reduced competency to transport material. Some of these channel bars have become attached to the channel wall, forming compound cross-sections through the construction of channel benches or incipient floodplains. Some degree of stability is maintained by a cover of herbaceous and shrub species.

The presence or absence of channel and bank vegetation can have a profound effect on the channel morphology of Winding Creek. Bank vegetation is able to stabilize banks and help prevent bank erosion and thus channel enlargement. In some areas however, the cover of vegetation within the creek is such that it must inhibit or divert flows.

Debris, both natural and anthropogenic, has had some effect on channel morphology especially in the upstream sites. Flood debris at these sites is directly responsible for channel widening by diverting water around the obstruction. Changes to channel slope are also common where debris jams occur.

There are several other possible factors, such as presence of bridges, weirs and gravel extraction, which may have an influence on the channel morphology of Winding Creek, but these are more likely to further destabilise

hydraulic relationships rather than contribute to a stable channel.

4. MANAGEMENT STRATEGIES

As stated above, both past, and to a lesser degree, present management of urban streams is based on the premise that their primary function is to contain storm water. Large scale flood control and training works, such as channelisation and retention ponds, (Fig. 1) have been the major management strategy to achieve this goal for Winding Creek. This type of management tends to deal with the stream as a whole, rather than individual reaches, whereas it has been demonstrated above, that streams in general and urban streams in particular, exhibit complex responses to inputs manifested as environmental heterogeneity (Ebisujima, 1991). As it is one of the goals of geomorphologists, to develop general models of river form and behaviour, and since geomorphologists are increasingly employed in environmental management areas, there are implications for the use of models such as hydraulic geometry.

While hydraulic geometry relationships may fail to describe a stream's variability, it can quantify general trends of change in channel parameters, and residuals can be used to look in more detail at channel response in particular reaches. From a management point of view, smaller reaches may be more applicable than larger ones.

Since this hydraulic geometry study was undertaken, several retention ponds have been put in place along Winding Creek. Two of these are situated in the upstream section, and the third downstream of the last site (Fig. 1). Each have a dual purpose of retaining floodwaters and trapping sediment. These retention ponds, while addressing flooding further downstream, reducing sediment loads and fit in with a new-found desire to recreate wetlands within our environment, are expensive in contrast to some alternatives, and may be ill-placed for the greatest benefit as far as storing excess floodwater and sediment is concerned.

For example, native trees were cut down to make space for the most upstream retention pond, located within a predominantly forested subcatchment and therefore would contain relatively small amounts of sediment and produce significantly less runoff than other sub-catchments. While available space was given as the main reason for the placement of this retention pond, open land is available further downstream, where a series of smaller ponds could have been built on presently unused land. This land was formerly part of a natural wetland that has been infilled to create useable land, but has been left vacant due to flooding. This would have returned some of the retention storage provided by original natural wetlands (Arnold *et al*, 1988).

The retention pond at its present site appears to be an example of this particular reach of the stream being

overmanaged, where by comparison the channel reach immediately upstream from this retention pond has been grossly neglected and undermanaged. This section of the creek is choked with sediment, weeds and urban refuse, and is 'illegally' dammed in several places to provide water for gardening purposes. The official standing on this overt neglect was that the sediment, weeds and refuse are able to slow down floodwaters because of additional roughness. However, increased sediments may actually reduce roughness by filling in pools and obliterating riffles (Hall and Ellis, 1985). Also, additional debris within the creek, such as old appliances, car bodies and shopping trollies (all a feature of Winding Creek) may increase bank erosion as water washes around these objects. Surely a well maintained creek that is clear of refuse and excess sediment would provide greater capacity for storm water (Knight, 1989), and with more suitable vegetation, and the retention of meanders, pools and riffles, could also reduce velocities.

By contrast, at sites below the channelisation, sediment in the form of incipient floodplains, channel islands and bars has been removed from the channel, along with anthropogenic debris and weeds, in order to provide greater capacities for flood waters. The bed and banks along this channel reach have been reformed by infilling deeply incised pools, battering banks (which had previously been badly eroded by undercutting and slumping), and revegetating them with kikuyu. Despite chicken wire underlying the grass on parts of the banks, renewed erosion is taking place, with subsequent sedimentation within the channel. Perhaps a more sensible revegetation program and the retention of some of the natural features such as pools and riffles, may have produced longer term results for this expensive work and reduced renewed erosion and sedimentation.

5. DRAIN VERSES STREAM

Whether a creek is treated as a natural feature with potential to retain some linkages with a former landscape, or treated merely as a drain which is managed in order to reduce flooding, depends on the perception of both the public and those responsible for its management. The above examples demonstrate that Winding Creek has been treated as a drain by management, and as an agent for the removal of refuse by the general public.

Surely there is an alternative to inevitable transformation of urban streams into totally controlled, single purpose, 'sterile' feature within our cities? Streams generally are one of nature's great connectors between one area and another. This is one of the main axioms behind Total Catchment Management (TCM) which is looked upon as having great potential in NSW as a management strategy, and in thwarting future land degradation.

Is it possible for our urban drains devoid of any riparian vegetation, save for choking weeds, overburdened with sediment from construction sites, and channel erosion,

dumping places to the general public, to become an environmental asset? Imagine a place where water can be heard to flow through green places in our urban environment, where remnant native fauna can still prevail, where channel erosion is kept in check by appropriately vegetated banks and well placed bed controls. The use of vegetation has the added benefit of filtering and utilising anthropogenic pollutants thus reducing their effects further downstream. Urban streams are obvious places to encourage natural vegetation corridors which could link up with other remnant vegetated areas within the catchment.

6. MANAGEMENT SUGGESTIONS

It is my opinion that very little can be done to improve urban streams, as far as amenity and aesthetics is concerned, unless there is a change in attitude of government departments, management agencies and the general public.

How then are urban streams to be rehabilitated in a manageable way? Natural streams are also in a constant state of flux, but they are able to repair unvegetated surfaces and rework sediment. In urban streams this is not always the case. The presence of weeds while being particularly efficient at colonising streams often break off during floods, causing debris jams downstream. In addition, there is no seed stock for specialised native plants such as reeds, that colonise the base of banks and trap sediment.

It is clear that revegetation of urban creeks with native vegetation is a first step to their possible improvement. This may also involve the battering of banks and clearing of some, but not all of the woody debris within the creek. Woody debris is important in creating variety within a channel which may encourage the return of some fauna species. Riparian vegetation is also important to aquatic biota, as it creates variety in stream temperatures due to shading effects and has a crucial role in preventing channel erosion.

Sedimentation within creeks is a symptom of erosion elsewhere within the stream or catchment. Strategies which involve the removal of the sediment from the stream do little in solving the source of the problem (Thoms and Erskine, 1995). Again, revegetation at the source of the erosion is one answer. In recent years councils have been more responsible in trapping sediment from construction sites with meshing. However, there does not appear to be any maintenance of these traps as many become buried or broken over time, allowing sediment to enter nearby creeks.

Over the last few decades there has been greater awareness by the public of environmental problems, but one of the least appreciated problems is that of sedimentation. There has been little public education of the importance of structures, such as sediment traps or

even on the consequences of sedimentation within streams. Public education could also decrease the tendency for streams to be used as refuse dumps for garden wastes or worse. The general public need also to become aware of the connection of streams to their catchment areas. Urban Landcare and Rivercare groups are either non-existent or grossly underutilised. There appears to be a growing number of people within communities that would be willing to provide labour for environmental rehabilitation, Dunecare groups being a good example. However, these groups take time to develop, and appear at present, to lack direction, policies, guidance and information.

7. CONCLUSION

Urbanisation within Winding Creek catchment NSW has had both direct and indirect effects on the stream. Stream management has been mainly implemented to relieve flooding, especially in the commercial centre of Cardiff. Both community and local government attitudes have meant that the stream has been reduced to a single purpose conduit of stream water, and other amenities and aesthetics of the stream have been ignored. Urban streams could play a role in providing natural vegetation corridors, and could be managed in a way to reduce flooding and sedimentation and still provide habitats for native fauna, providing that there is flexibility in the types of models used. However, the attention of management and the general public needs to turn to smaller reaches in addition to whole stream management practices.

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