Dungog Shire Council

Town Creek Catchment

Plan of Management

May 2007

Hunter Water Australia Pty. Limited
ABN 19 080 869 905

EXECUTIVE SUMMARY

This project was undertaken by Hunter Water Australia (HWA) to provide guidelines for future stormwater work in the Town Creek catchment in Clarence Town, NSW. Urban runoff and the current layout and condition of drainage in the catchment is impacting on the amenity of the town and the water quality and ecology of Town Creek and the Williams River.

A catchment audit was conducted that identified problems areas in the catchment. Following a review of Water Sensitive Urban Design concepts, recommendations have been made for remedial action and for future development in the Town Creek catchment.

Recommendations have been tabled for each problem site in the catchment. The most likely and significant short term potential impact on Town Creek from development was found to be from the commercial development of land adjacent to Grey Street that Town Creek flows through. It is a recommendation of this report that a separate development Control Plan or masterplan is prepared prior to the approval of future development in this area. The Town Creek watercourse was found to have significant erosion problems on the corner of Prince and Rifles Streets and this site was also identified for priority remedial action. Numerous others sites require attention throughout the catchment.

This Plan of Management (PoM) for Town Creek catchment in Clarence Town is to be used by Dungog Shire Council, developers, the community and local environment groups as a guide to ensure that future projects and development in the area are designed in accordance with the principles of WSUD and meet the long term objectives of an integrated plan.

The outcome of application of this PoM would be a healthier Town Creek watercourse that is less prone to flooding impacts, provides adequate stormwater drainage services and is aesthetically pleasing. Water quality in the Town Creek as well as the Williams River receiving waters is likely to be improved as a result of WSUD initiatives.

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1 BACKGROUND

1.1 TOWN CREEK

The catchment and watercourse of Town Creek is located within the village of Clarence Town 55km North of Newcastle, 32km North of Maitland and 27km north of Raymond Terrace. Clarence Town has been superimposed and modified by grid pattern development over many years. This has created a creek that in places is still a natural watercourse flowing through private properties and in other places has become part of the street drainage for the area. Development and modification of the landscape has created hydrological issues.

The approximate location of Town Creek in Clarence Town is shown in Figure 1-1. The first order streams which feed into the creek are generally located up slope within private property or have become part of the stormwater system. In the middle reaches, Town Creek flows through a number of properties in the commercial centre of Clarence Town where future population growth and the resulting development in the area will increase pressure to modify the stormwater channel/streambed. In the lower reaches the creek enters a former estuarine area that is deep and well vegetated with native reeds and exotic and native riparian tree species.

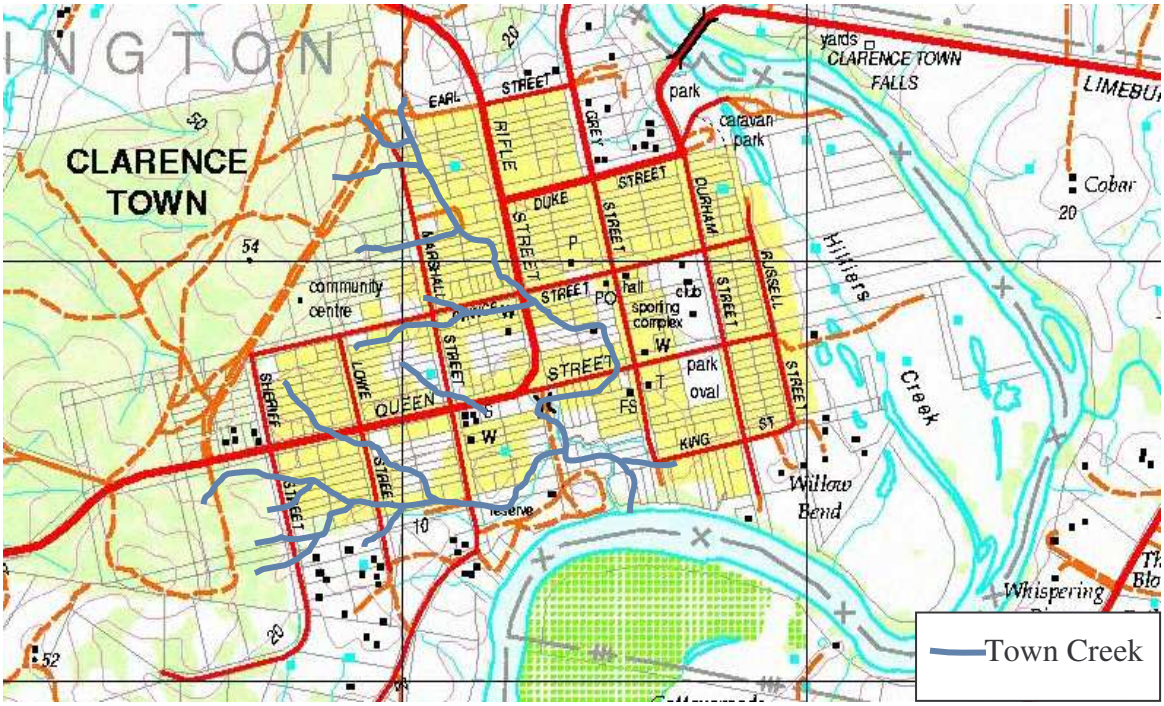

Figure 1-1 Approximate location of Town Creek watercourse in Clarence Town

Local community groups and council have previously carried out several projects in the area to rehabilitate sections of the catchment including fencing off a small wetland area, tree planting and the construction of a wetland stormwater polishing area for a sub catchment of Town Creek.

Urban runoff and the current layout and condition of drainage in the catchment are impacting on the amenity of the town and the water quality and ecology of Town Creek and the Williams River. A Catchment Audit has identified significant erosion and degradation of the natural watercourse throughout the catchment.

1.2 OBJECTIVES

The aim of the project is to provide guidelines for future stormwater work in the catchment area. The plan in addition to providing an overall concept will identify problem areas, recommend potential design solutions and make recommendations for both remedial action and for any future development adjacent to Town Creek. This plan will then be used by Council, developers, the community and local environment groups as a guide to ensure that future projects and development in this area are designed in accordance with the principles of Water Sensitive Urban Design (WSUD) and meet the long term objectives of an integrated plan.

The outcome of such work and development would be a healthier Town Creek watercourse that is less prone to flooding impacts, provides adequate stormwater drainage services and is aesthetically pleasing. Water quality in the Town Creek as well as the Williams River receiving waters is likely to be improved as a result of WSUD initiatives.

1.3 COMMUNITY

A process of community engagement is integral to the sustainability of any outcomes. It is necessary to ensure the loop is closed between policy and planning, and community engagement is crucial for successful design and implementation. By consulting the community, a plan can be:

- Relevant to the community
- Aligned with community values
- Practical to the community
- Supported by the community and
- Enhance the strategic value and sustainability of outcomes.

Inclusion of community should be maintained by means of meaningful and effective community participation at all levels of decision making that affect the public. Therefore, use of community engagement methods that are active, ongoing, and interactive will be essential in this project.

The community will be actively engaged on the findings of this report to further establish and understand catchment issues and to contribute to and take ownership of management plans and activities.

2 EXISTING TOWN CREEK CATCHMENT

2.1 CATCHMENT AUDIT

A recent Catchment Audit has been conducted and is provided in Appendix A with findings from previous catchment audits and the Dungog Stormwater Management Plan 2000. Erosion sites identified in the catchment are shown in Table 2-1. During the audit sites were identified that had potential for either rehabilitation of Town Creek, drainage system maintenance or remediation, or sites that have potential for installation of stormwater related measures. These sites are summarised in Table 2-2.

Table 2-1: **Erosion Sites** in Town Creek Catchment

Site	Location	Eroded
E1	Rifle St below Earl St east side	Drainage system
E2	North east corner of Duke St and Rifle St	Town Creek
E3	Town Creek draining under upper Rifle St	Town Creek
E4	Drainage along Rifle St between Prince St and Duke St on east side	Town Creek
E5	Corner Prince St and Marshall St	Drainage system
E6	Marshall St below Prince St	Drainage system
E7	Drainage along Prince St on south western corner with Rifle St	Drainage system
E8	Town Creek south of Prince St	Town Creek
E9	Town Creek off Grey St between Prince St and Queen St	Town Creek
E10	Drainage system along Durham St beside sporting fields	Drainage system
E11	North side of Queen St west of Lowe St corner	Drainage system
E12	North western corner of Queen St and Marshall Street	Drainage system
E13	Town Creek along Queen St between Rifle St and Grey St	Town Creek
E14	Town Creek through horse paddock besides lower Rifle St	Town Creek
E15	Drainage system along lower Lowe St	Drainage system
E16	Drainage on corner Rifle St and King St	Drainage system

Table 2-2: Sites Identified Requiring Rehabilitation of Town Creek, Drainage System Maintenance or Potential for Stormwater Related WSUD Measures.

Site	Location	Opportunity
Site 1	Duke St	Potential for WSUD measure such as detention/retention basin or baffle box etc in road reserve.
Site 2	West side of upper Rifle St where Town Creek drains underneath road.	Potential to remediate erosion and/or install WSUD flow attenuation measure on west side.
Site 3	East side of upper Rifle St: - Drainage system before discharging to Town Creek - Town Creek alongside Rifle St	- Remediate drainage system erosion and install flow attenuation device(s) and/or water treatment device. - Rehabilitate Town Creek and remediate erosion.
Site 4	North eastern corner of Prince St and Rifle St	Remediate erosion on corner and in Town Creek. Potential for Flow attenuation and/or water treatment device(s).
Site 5	Town Creek along South side of Prince St	Potential to rehabilitate riparian vegetation and or utilise road side space after discharge from or in small wetland for flow detention/retention. Remediate erosion and rehabilitate Town creek behind shops
Site 6	Town Creek through recently zoned Commercial properties off Grey St	This area will be subject to a separate Development Control Plan to consider future development and landform in the area. The DCP should consider the installation of retention/detention devices on drain discharging from Grey St into Town creek and stormwater management requirements on developments including OSD.
Site 7	Town Creek beside Queen St between Rifle St and Grey St	Rehabilitate Town Creek. Infiltration basin on private property to retard flow into wetlands.
Site 8	Town Creek under lower Rifle St and in private property off lower Rifle St	Rehabilitate Town Creek and potential for water treatment and/or flow attenuation device(s) at drain discharging from under Rifle St.
Sites 9	King St road reserve/ public lands	Rehabilitate Town creek (weeds etc) and incorporate WSUD into public/recreational space. Embrace Town Creek as feature.

3 STORMWATER MANAGEMENT

3.1 UNDERLYING PROCESS

Traditionally stormwater has been considered a nuisance to be disposed of as quickly and efficiently as possible. Conventional drainage practices have focused on replacing natural systems and transporting runoff from sources to downstream receiving waters as quickly as possible. The following common effects on stream hydrology in conventionally drained urban areas, as identified by the Cooperative Research Centre (CRC) for Catchment Hydrology and CRC for Freshwater Ecology (Walsh et al. 2004), can be seen in Clarence Town's Town Creek catchment:

1. Creek baseflow has become lower

2. Small-moderate increases in flow become more frequent resulting from direct surface runoff in small rain events.

3. Peak flows resulting from larger rain events become larger, but the high flows do not last as long.

Current stormwater management knowledge (Walsh et al 2004) proposes that the greatest benefit to the ecological condition of streams can be achieved by controlling runoff (i.e. preventing overland flow from the catchment) resulting from more frequent small-to-moderate storms in the catchment and additionally that the most important effect of urban stormwater on channel form and erosion is the increased frequency of these smaller floods. The key therefore to reducing urban hydrological impacts is to limit the direct coupling that occurs between impermeable surfaces and the stream system during frequent (but low magnitude) rainfall events (LHCCREMS, 2003). The dispersed management and control of runoff from impervious surfaces throughout the catchment (to reduce the frequency and intensity of frequent smaller floods) is proposed as the most effective approach to controlling incision of stream channels and protecting stream health.

This source control of stormwater appears to be the most efficient means of minimising impacts on the ecological health and hydrology of Town Creek as identified in the catchment audit. However source control of stormwater in a developed catchment such as Clarence Towns' Town Creek catchment is governed by the willingness of existing landholders to act on source control and is largely beyond regulative responsibilities. Therefore an important aspect of any stormwater management is working with the community to ensure this need for source control is met whilst also establishing policies and development control mechanisms to ensure future development incorporates source control. Large scale physical measures by public catchment managers are generally limited to the stormwater transit/conveyance system. A plan of management for Town Creek therefore requires the whole community to be involved in stormwater management and to strategically tackle source control as well as the conveyance of stormwater through Town Creek. The following section provides some background to the principles of Water Sensitive Urban Design as a potential tool for use in managing the source and conveyance of urban stormwater and Town Creek.

3.2 WATER SENSITIVE URBAN DESIGN

The CRC for Catchment Hydrology (Lloyd et al 2002) describes Water Sensitive Urban Design (WSUD) as a philosophical approach to urban planning and design that aims to minimise the hydrological impacts of urban development on the surrounding environment. Stormwater management is a subset of WSUD directed at providing flood control, flow management, water quality improvements and opportunities to harvest stormwater to supplement mains water for non-potable uses (that is, toilet flushing, garden irrigation etc.).

The key principles of WSUD as presented in the Urban Stormwater: Best Practice Environmental Management Guidelines (Victorian Stormwater Committee, 1999) are:

1. Protect natural systems (creeks, rivers and wetlands) within urban catchments.

2. Protect water quality by improving the quality of stormwater runoff draining from urban developments.

3. Integrate stormwater treatment into the landscape by using stormwater treatment systems in the landscape that incorporate multiple uses providing a variety of benefits such as water quality treatment, wildlife habitat, public open space, recreational and visual amenity for the community.

4. Reduce runoff peak flows from developments by on-site temporary storage measures (with potential for reuse) and minimise impervious areas.

5. Add long-term value while minimising development costs.

6. Reduce potable water demand by using stormwater as a resource through capture and reuse for non-potable purposes.

3.3 WSUD MEASURES

WSUD is about integrating various measures or practices into the management of urban water systems. Measures can involve physical structures or be non structural such as behavioral changes, regulative control and planning. A number of different measures are usually implemented as a 'treatment train' approach.

3.3.1 Structural WSUD Measures

Measures can be focused on controlling or managing stormwater at either the source, during transit and conveyance, at the discharge point commonly referred to as 'end of pipe' or through managing stormwater within natural systems.

Typical WSUD measures and where they can be physically implemented for different management or control levels are displayed in Table 3-1.

Table 3-1: Control Levels in the Urban Hydrological System

Level	Description/Location	Typical WSUD Measures
Source Control	At the individual building allotment (including impervious land in public areas)	Rainwater tanks, infiltration trenches, vegetation filter strips, planting beds, permeable pavements, construction site management, sediment traps
Conveyance Control	Conveyance of stormwater to streets and channels	Vegetated filter strips and swales, on-line bioretention systems, natural channels, streetscapes.
Discharge Control	At the point where water leaves the lot, estate or catchment	Bioretention and infiltration basins, sand filters, constructed wetlands, detention ponds
Natural Systems	Throughout the urban catchment	Use or rehabilitation of natural water courses, creeks, floodplains, wetlands and vegetation

Source URS 2004

Descriptions of WSUD measures are provided in Appendix B.

WSUD measures can be used to manage various impacts of stormwater in a catchment. Table 3-2 shows how different structural WSUD measures can be used for controlling the flow of stormwater in the stormwater system/catchment. Measures such as retarding basins and ponds can be used for flood management whilst most measures are suitable for reducing the flow of stormwater through the system. Several measures are available to reduce the amount of stormwater flowing through the system.

Table 3-2: Flow Control Functions Associated with Structural WSUD Measures

	Primary Flow Control Function		
	Flood Management	Flow Attenuation	Reduction in Volume
Retarding basin	Y	Y	
Pond	Y	Y	
Wetland		Y	
Rehabilitated waterway (pool and riffle system)		Y	
Vegetated Swale		Y	
Buffer Strip		Y	
Infiltration and collection system (bio-filtration system)		Y	Y
Infiltration System		Y	Y
Water reuse scheme		Y	Y

Source Lloyd et al 2002

3.3.2 Non Structural WSUD Measures

The CRC Catchment Hydrology adopts the US EPA's (Taylor & Wong 2002) description of non-structural stormwater management practices as institutional and pollution-prevention practices designed to prevent or minimise pollutants from entering stormwater runoff and/or reduce the volume of stormwater requiring management. Taylor and Wong (2002) further state that they do not involve fixed, permanent facilities and they usually work by changing behaviour through government regulation (e.g. planning and environmental laws), persuasion and/or economic instruments.

Taylor and Wong (2002) group various non-structural stormwater management practices into the following 5 core groups:

1. Town planning controls: e.g. the use of town planning instruments to promote WSUD principles in new developments, such as decreasing the area of impervious surfaces.

2. Strategic planning and institutional controls: e.g. the use of strategic, city-wide urban stormwater quality management plans and secure funding mechanisms to support the implementation of these plans.

3. Pollution prevention procedures: e.g. practices undertaken by stormwater management authorities involving maintenance (e.g. maintenance of the stormwater drainage network) and elements of environmental management systems (e.g. procedures on material storage and staff training on stormwater management).

4. Education and participation programs: e.g. targeted media campaigns, training programs and stormwater drain stenciling programs.

5. Regulatory controls: e.g. enforcement of local laws to improve erosion and sediment control on building sites, the use of regulatory instruments such as environmental licenses to help manage premises likely to contaminate stormwater, and programs to minimise illicit discharges to stormwater.

3.4 WSUD TECHNICAL RESOURCES

The following websites both contain and link to current WSUD technical information and are recommended as a starting point for implementing WSUD initiatives:

http://www.wsud.org/tech.htm

http://www.urbanwater.info/engineering/wsud.cfm

http://wsud.melbournewater.com.au

http://www.stormwater.asn.au/

4 TOWN CREEK MANAGEMENT OPTIONS

The increased frequency of small to moderate flows in Town Creek as a result of urbanisation and conventional stormwater drainage practices have been identified as having the greatest role in the erosion and ecosystem health impacts existing in Town Creek. Specific sites requiring attention have been identified in the catchment audit as per Section 2.5. Recommendations including specific design solutions are provided in the following sections for both remedial action and future development to restore and maintain the ecological health and hydrological function of Town Creek.

4.1 REMEDIAL ACTIONS

4.1.1 Drainage Erosion

Specific erosion sites associated with the drainage system in the catchment that require attention have been identified in the catchment audit. The location and photographs of these sites are shown in Exhibit 1. Recommendations for measures to remediate erosion are shown below in Table 4-1. Where erosion occurs within the Town Creek watercourse, remedial measures are addressed in the following section 4.1.2.

Table 4-1: Site Specific Erosion Issues in the Town Creek Catchment

Site	Location	Component	Recommendations
E1	Rifle St below Earl St east side	Drainage system	Construct swale
E2 **4.1.2**	North east corner of Duke St and Rifle St	Drainage system	Construct swale
E3	Town Creek draining under upper Rifle St	Town Creek	See Site 2 in S4.1.2
E4	Drainage along Rifle St between Prince St and Duke St on east side	Town Creek	See Site 4 in S4.1.2
E5	Corner Prince St and Marshall St	Drainage system	Rehabilitate swale
E6	Marshall St below Prince St	Drainage system	Rehabilitate swales
E7	Drainage along Prince St on south western corner with Rifle St	Drainage system	Construct swales/gutter
E8	Town Creek south of Prince St	Town Creek	See Site 5 in S4.1.2
E9 **4.1.3**	Town Creek off Grey St between Prince St and Queen St	Town Creek	See Site 6 in S4.1.2
E10 **4.1.4**	Drainage system along Durham St beside sporting fields	Drainage system	Rehabilitate swales and restrict parking. Permeable paving or guttering.
E11	North side of Queen St west of Lowe St corner	Drainage system	Rehabilitate swales
E12 **4.1.5**	North western corner of Queen St and Marshall Street	Drainage system	Rehabilitate swales
E13	Town Creek along Queen St between	Town Creek	See Site 7 in S4.1.2

Site	Location	Component	Recommendations
4.1.6	Rifle St and Grey St		
E14	Town Creek through horse paddock besides lower Rifle St	Town Creek	See Site 8 in S4.1.2
E15	Drainage system along lower Lowe St	Drainage system	Rehabilitate swales
E16	Drainage on corner Rifle St and King St	Drainage system	Construct swales

4.1.7 Town Creek Hydrological and Ecosystem Health

Sites requiring rehabilitation in Town Creek to restore hydrological and ecosystem health have been identified in the catchment audit. The location and photographs of these sites to highlight their existing condition are shown in Exhibit 1. Recommendations for measures to restore Town Creek are shown in Table 4-2. Details of typical measures are provided in Appendix B and images of typical measures recommended for sites are also provided in Exhibit 1 to help visualise what adoption of recommended measures may look like.

Table 4-2: Site Specific Restoration Issues in the Town Creek Catchment

Site	Location	Recommendation	Potential Issues
Site 1.	Duke St	• Construction of a buffer storage/retarding basin (some infiltration and retention of particles) to detain runoff and reduce the frequency and velocity of erosive flows downstream.	• Use of road reserve
Site 2.	West side of upper Rifle St where Town Creek drains underneath road.	• Construction of a retarding basin / grass swale to detain runoff and reduce velocity before discharging into drain under Rifle St. • Use of grass swale will allow pedestrian use along side of road in dry times. Opportunity for vegetation/landscaping and or footbridge to improve visual amenity.	• Pedestrian movements along road.
Site 3.	East side of upper Rifle St • Drainage system before discharging to Town Creek • Town Creek alongside Rifle St	• Check dams in drainage system to reduce energy/flow and vegetation of swales or infill with permeable gravel/rocks. • Flow dissipater and/or baffle box for exit from under road drain. • Rehabilitation including revegetation and bank stabilization. • In stream flow dissipaters and/or check dams before corner.	• Difficulty in establishing vegetation in bedrock

Site	Location	Recommendation	Potential Issues
		• Concrete/boulders or vegetated mounded riffles	
Site 4.	North eastern corner of Prince St and Rifle St	• Reinforcement/armouring of bank at the acute corner. • Revegetation/ landscaping for urban water feature.	• Visual amenity • Traffic vision Possible fencing required if pooled water results.
Site 5.	Town Creek along South side of Prince St	• Maintenance of constructed wetland after under road drainage. • Rehabilitation of Town Creek including • Bed control and bank armoring • flow redirection/stabilisation including flow attenuation measures • ongoing weeding and vegetation management/rehabilitation	• Private commercial property. See also Future Development S4.2.
Site 6.	Town Creek through recently zoned Commercial properties off Grey St	• Prepare Development Control Plan to consider development and landscape issues. DCP should include WSUD conditions for future development. Particularly stormwater capture and discharge control measures.	Private commercial property. See also Future Development S4.2.
Site 7.	Town Creek beside Queen St between Rifle St and Grey St	• Rehabilitate swales, construct check dams, channel rehabilitation and in stream flow dissipaters. • Private partnership to improve swales/creek on private property	• Infiltration/detention basins on private property
Site 8.	Town Creek under lower Rifle St and in private property off lower Rifle St	• Check dam before pipe and baffle box at under road drain outlet. • Private partnership with funding/assistance to fence off and rehabilitate creek.	
Sites 9.	King St road reserve/ public lands	• Swales and swale mounds/ check dams. • Detention basins / parks • Constructed vegetative strips and channel variation.	

4.2 FUTURE DEVELOPMENT AND PRIVATE PROPERTY

4.2.1 Planning Instruments

Council policies and planning instruments, in particular Development Control Plans, can provide Council with a practical set of criteria with which to assess development proposals and ensure future development incorporates sustainable stormwater management to protect Town Creek.

Development Control Plan

Council's Development Control Plan No. 32 – Water Efficient Building, was implemented in February 2004 to reduce water demand through the utilisation of efficient devices and rainwater harvesting. It was anticipated that the stormwater system would benefit through the effects of rainwater harvesting in reducing peak flows in trunk drainage systems. This was to be achieved through requiring water efficient appliances, use of rainwater tanks, the limiting of lot hardstand areas and On Site Detention (OSD) for development consent. The approach of limiting hardstand areas does prevent some stormwater runoff, but as discussed in Section 3, source control of all stormwater from both pervious and impervious sources is essential in reducing stormwater impacts.

BASIX

BASIX the NSW Government's Building Sustainability Index currently applying to all new residential developments in NSW has to an extent superseded elements of council's Water Efficient Buildings DCP in reducing water consumption. Whilst BASIX provides uniform requirements across the state for water consumption in residential houses, it does not currently impact on non residential development nor does it comprehensively tackle holistic urban water management. However stormwater is planned for incorporation into BASIX in the future, but the extent of requirements is unknown.

It is therefore necessary to develop policy that builds on Council's Water Efficient DCP across all development, both residential and non residential development at all scales, to include stormwater collection and stormwater discharge and overflow disposal control measures to ensure total sustainable water management in the catchment.

Water Smart Planning Provisions

The Water Smart Planning Provisions for the Lower Hunter Central Coast Region (LHCCREMS 2003) promotes water smart development that is carefully designed, constructed and maintained so as to minimise the impacts on the natural water cycle and counteracts many of the negative impacts of urban development on the natural water cycle as experienced by Town Creek. The Water Smart Planning Provisions provide criteria for with which to assess development proposals in a format that can be readily incorporated in planning instruments.

It is recommended that Council consider the Water Smart Planning Provisions and develop planning policy and/or design specifications that addresses water management in the Town Creek Catchment.

4.2.2 Clarence Town Commercial District

Perhaps the most significant short term potential impact on Town Creek from development is likely to occur in the immediate future from the commercial development of land adjacent to Grey Street that Town Creek flows through, identified as sites 5 & 6 in the Catchment Audit. It is therefore vital to ensure that this development responsibly incorporates the objectives of this plan and that future development minimises downstream impacts.

Any future development in the Grey Street commercial area between Queen and Prince Streets will need to address a number of issues. The site has considerable constraints in relation to flooding, topography and the location of Town Creek. The type of development and the location of parking facilities must be considered in conjunction with the landscape issues previously mentioned.

It is a recommendation of this report that a separate development Control Plan or masterplan is prepared prior to the approval of future development in this area.

Crucial to the viability of a Town Creek waterway and sustainable water management in this area is effective source and discharge control. Future development in this area should aim to minimise runoff and manage the capture and discharge of stormwater through adoption of the following practices:

- Stormwater capture
    - Rainwater tanks
    - Permeable paving
    - On site detention
- Discharge Control
    - Vegetated filter strips
    - Planting Beds

- Infiltration/absorption trenches and basins
- Bioretention systems
- Sand Filters

Any overflow, above the capacity of discharge controls, should be disposed of directly into the Town Creek waterway in a manner that avoids erosional impacts to the water way or adjacent land.

5 CONCLUSION

An audit of the Town Creek catchment has identified sites requiring remediation and/or having potential to be utilised for implementation of WSUD measures. Recommendations have been made for potential WSUD measures for each identified site to manage the impact of current and future development in the catchment on the health of Town Creek. Further site specific details are required however to design site specific solutions. Community consultation is also necessary to assess the viability of options and to garner support for potential WSUD measure's implementation and acceptance.

6 REFERENCES

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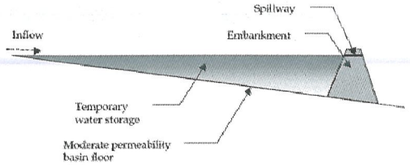
Exhibit 1 Town Creek Catchment Plan of Management with Potential WSUD Measures

DETENTION BASIN EXAMPLES
MORE INFORMATION ON DETENTION BASINS IS AVAILABLE IN THE TOWN CREEK PLAN OF MANAGEMENT – 'APPENDIX B'




E3 & S2


S1


E4 UPPER


E4 & S4

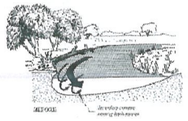

E7

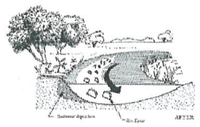
E12


E8

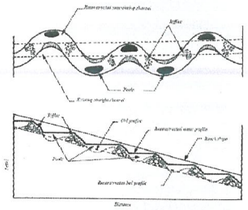

E15 & S7

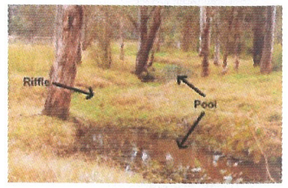
E14 & S8

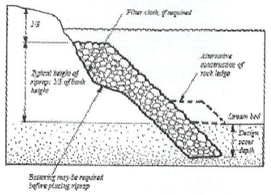




STREAM EXAMPLES
MORE INFORMATION ON STREAMS IS AVAILABLE IN THE TOWN CREEK PLAN OF MANAGEMENT – 'APPENDIX B'

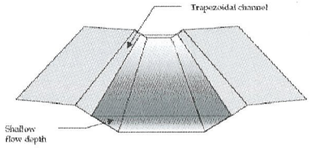






WSUD EXAMPLE
MORE INFORMATION ON WSUD IS AVAILABLE IN THE TOWN CREEK PLAN OF MANAGEMENT – 'APPENDIX B'

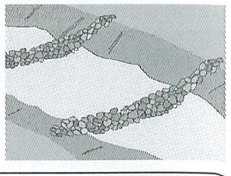
SWALES EXAMPLES
MORE INFORMATION ON SWALES IS AVAILABLE IN THE TOWN CREEK PLAN OF MANAGEMENT – 'APPENDIX B'



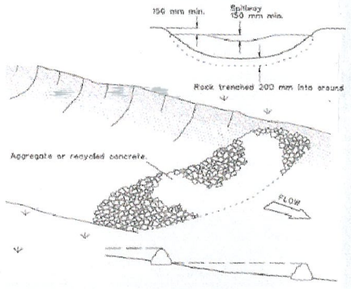

S9


E16


E14 & S8



CHECK DAM EXAMPLES
MORE INFORMATION ON CHECK DAMS IS AVAILABLE IN THE TOWN CREEK PLAN OF MANAGEMENT – 'APPENDIX B'



KEY–

- UNSEALED ROAD
- SEALED ROAD
- SEALED ROAD WITH KERB & GUTTER
- STREAM
- BUSINESS 3(A) ZONE (DUNGOG LEP 2006)
- ENVIRONMENT 7(A) ZONE (DUNGOG LEP 2006)
- EXISTING WETLANDS
- POTENTIAL SITE FOR WSUD MEASURE – SEE TABLE 1 ABOVE
- EROSION SITES – SEE TABLE 2 ABOVE

Table 1. WSUD Measure Recommendations

Further WSUD measure information is available in Appendix B of the Town Creek Plan of Management.

Site	Location	Recommendation
S1.	Duke St	• Construction of a buffer storage/retarding basin (some infiltration and retention of particles) to detain runoff and reduce the frequency and velocity of erosive flows downstream.
S2.	West side of upper Rifle St where Town Creek drains underneath road.	• Construction of a retarding basin / grass swale to detain runoff and reduce velocity before discharging into drain under Rifle St. • Use of grass swale will allow pedestrian use along side of road in dry times. Opportunity for vegetation/landscaping and or footbridge to improve visual amenity.
S3.	East side of upper Rifle St (a) Drainage system before discharging to Town Creek (b) Town Creek alongside Rifle St	• Check dams in drainage system to reduce energy//flow and vegetation of swales or infill with permeable gravel/rocks • Flow dissipater and/or baffle box for exit from under road drain. • Rehabilitation including revegetation and bank stabilisation • In stream flow dissipaters and/or check dams before corner - Concrete/boulders or vegetated mounded riffles
S4.	North eastern corner of Prince St and Rifle St	• Reinforcement/armouring of bank at the acute corner. • Revegetation/ landscaping for urban water feature.
S5.	Town Creek along South side of Prince St	• Maintenance of constructed wetland after under road dminage. • Rehabilitation of Town Creek including - Bed control and bank armoring - flow redirection/stabilisation including flow attenuation measures - ongoing weeding and vegetation management/rehabilitation
S6.	Town Creek through recently zoned Commercial properties off Grey St	• Impose WSUD conditions on developments. Particularly stormwater capture and discharge control measures. • Rehabilitate creek with - Bed control and bank armouring structures. - Reconstruct riffles and ponds and natural swales - Revegetate riparian zone
S7.	Town Creek beside Queen St between Rifle St and Grey St	• Rehabilitate swales, construct check dams, channel rehabilitation and in stream flow dissipaters. • Private partnership to improve swales/creek on private property
S8.	Town Creek under lower Rifle St and in private property off lower Rifle St	• Check dam before pipe and baffle box at under road drain outlet. • Private partnership with funding/assistance to fence off and rehabilitate creek.
S9.	King St road reserve/ public lands	• Swales and swale mounds/ check dams. • Detention basins / parks • Constructed vegetative strips and channel variation.

Table 2. Erosion Remediation Recommendations

Further Swale & WSUD measure information is available in Appendix B of the Town Creek Plan of Management.

Site	Location	Recommendation
E1.	Rifle St below Earl St east side	Construct swale
E2.	North east corner of Duke St and Rifle St	Construct swale
E3.	Town Creek draining under upper Rifle St	See Site 2 in Table 1.
E4.	Drainage along Rifle St between Prince St and Duke St on east side	See Site 4 in Table 1.
E5.	Corner Prince St and Marshall St	Rehabilitate swale
E6.	Marshall St below Prince St	Rehabilitate swales
E7.	Drainage along Prince St on south western corner with Rifle St	Construct swales/gutter
E8.	Town Creek south of Prince St	See Site 5 in Table 1.
E9.	Town Creek off Grey St between Prince St and Queen St	See Site 6 in Table 1.
E10.	Drainage system along Durham St beside sporting fields	Rehabilitate swales and restrict parking. Permeable paving or guttering.
E11.	North side of Queen St west of Lowe St corner	Rehabilitate swales
E12.	North western corner of Queen St and Marshall Street	Rehabilitate swales
E13.	Town Creek along Queen St between Rifle St and Grey St	See Site 7 in Table 1.
E14.	Town Creek through horse paddock besides lower Rifle St	See Site 8 in Table 1.
E15.	Drainage system along lower Lowe St	Rehabilitate swales
E16	Drainage on corner Rifle St and King St	Construct swales

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Quality Endorsed Company

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APP: J.L.Smith	September 2006		

HUNTER WATER CORPORATION

DRAFT EXHIBIT 1
TOWN CREEK PLAN OF MANAGEMENT

A0	ARRGT: –	SCALE: 1:5000	00000–00	ISSUE A
	CADNAME: –			

Appendix A Catchment Audits

Dungog Shire Council

Clarence Town
Town Creek

Catchment Audit

July 2006

Hunter Water Australia Pty. Limited
ABN 19 080 869 905

CATCHMENT AUDIT

Town Creek catchment audits have been conducted to provide information for the Town Creek Plan of Management.

PREVIOUS AUDITS

Previous Catchment Audits were conducted for development of the Dungog Stormwater Management Plan 2000.

Issues identified in the Dungog SMP 2000 Catchment Audit for the Clarence Town Catchment include:

- Litter in waterways and in Prince Street
- Weeds along most of the drainage lines
- Existing silt trap on Grey Street, complaints from community wanting it cleaned
- Viruses, bacteria and nutrients from septic seepage
- Localised flooding – Bottom of Durham Street, King Street, behind butchers, and corner of Prince Street and Dungog Road
- General lack of awareness and insufficient planning
- Litter from commercial areas
- Siltation problems in Prince Street
- Localised flooding in West Lowe Street and Rifle Street

Stormwater issues identified by the community of Clarence Town during the Stormwater Management Plan:

- Cumulative negative impacts of development
- Preventing pollution from effluent and stormwater runoff and other activities
- Maintaining water quality and the flow of rivers by limiting the pumping of river water
- Minimising impacts from developments on the ecology associated with watercourses and wetlands

AUDIT 2006

A current audit has been conducted which duplicated the previous Catchment Audit Protocol. Audit results have also been shown on a detailed streetscape map of Town Creek catchment to identify erosion sites, impacts on Town Creek and possible sites for stormwater related Water Sensitive Urban Design structural measures.

Duplicate Audit – 2006

Catchment Audit Protocol
Obtain map of SW catchment Council to nominate all outfalls, SW channels on map Council to nominate hotspots on map Obtain catchment map showing all creeks and rivers (associated with SW system) Obtain Landuse map (zoning) – residential, density of development, industrial, future residential, rural, nature reserves, national parks, soil landscape, etc. Map major sewer overflow locations, slopes, erosion, reserve areas EPA licensed premises/discharge points Read relevant background information on waterways, eg. TCM reports, SOE reports, Council reports, DLWC water quality reports, Streamwatch reports, Landcare reports/articles etc.

Things to do in field:

Check SW outfalls	
Is litter visible? Yes ~~No~~ describe	Yes – Prince St, Grey St
Is there evidence of erosion?	Yes. Cnr Prince and Rifle, Grey Street and private property in Rifle Street
Are weeds a problem?	Yes – along most of the drainage lines
Is riparian vegetation effected by the outfalls?	No
Take photos and map on location map	
Check existing pollution devises (GPT's etc)	Silt trap on Grey St installed by Landcare
Is the trap maintained on a regular basis?	No
How often are traps cleaned?	N/A
What quantity of rubbish is removed annually?	N/A
Is the trap a potential mosquito breeding area?	Yes
How does the trap cope with 1 in 5 year storms?	Not well unless maintained
Have there been any complaints regarding traps from the community?	Yes – wanting it cleaned
Are there plans to upgrade/replace/remove trap?	No – verify.
Is council happy with the traps?	Verify.
Are there any animal scats near SW channels?	Yes

Sewage Overflows

Check location of major points	Not sewered – septic leachate from ground a problem – directed from transpiration areas via pipes by residents to SW drains
Is the overflow visible?	Yes. Froth and discolouring of pooled water was visible following rain.
Is there evidence of recent overflows?	
Have there been complaints about major overflows?	
How often do overflows occur from major overflow outlets?	
Do overflows enter sensitive waterways?	Yes – into Town Creek and eventually the

	Williams River part of the drinking water catchment
Has the overflow affected residents?	Yes - aesthetically and cause of concerns
Is the EPA concerned about any overflow points?	Yes
Have there been any environmental studies on the overflow's impact?	No - ?

Riparian Vegetation and Bushland

Are there any significant areas of riparian vegetation in the SW catchment?	Only close to the discharge point into the Williams River
Is riparian vegetation affected by stormwater?	Yes as stormwater constitutes significant component of Town Creek flow
Map riparian vegetation (approx. location) and weed infestation?	King Street/south western branch and from Rifle Street to WR
Does Council or any other group intend to restore any riparian vegetation?	Possible funding for wetlands. Recommended to rehabilitate natural watercourses and use native veg as as filter strips and buffer strips
Are there any areas of natural bushland within the urban catchment?	Around king and rifle Street
Have any areas of bushland been protected in a nature reserve/park etc.?	No. Some zoned Environment 7(a) Zone
Map bushland (approx. location only)	Visible on Satellite imagery and verified.
Does council (or other groups) intend to restore bushland?	Zoned 7(a) for protection.

Industrial Areas

Are there any industrial areas in the urban catchment/what types of industries?	No
Are there any proposals to expand existing areas?	NA
Has Council or other agencies carried out surveys of industrial areas?	NA
Are there any water quality problems associated with the industrial areas?	NA
Is there any evidence of industrial pollution in the SW system eg. discolouration/staining, dead flora and fauna downstream etc.?	NA
Have there been any industrial waste incidents, how was it cleaned up, was contaminated waste removed?	No
Where are trucks and other vehicles washed?	Not known
What threats may be in the industrial area, e.g. acid, oils, metals, petrol, solvents	NA

Commercial Centre

Is there evidence of pollution from commercial centres eg. litter, oil, etc.	Yes – litter
Are there any GPT's or silt traps in the SW system?	Yes
Are there any GPT's fitted to any commercial premises?	No
Are there any detention basins in the commercial area?	No

Is there a need for GPT's, silt traps, additional rubbish bins or detention basins?	Yes
Have there been complaints regarding litter from the commercial area?	No
Are there any suitable locations for bins, traps, basins?	Possibly
What are the threats from the commercial area? eg. litter, oil, flooding etc.	Litter, Flooding

Hotspots

Are there any obvious erosion and siltation problems?	Yes • siltation on Prince St • Numerous erosion sites throughout catchment
What condition is the SW system in?	A few culverts and mainly natural and above ground channels to the Williams River
Are there any litter hotspots in the SW system?	Yes – Prince St
Are there any weed hot spots in the SW system?	Yes – throughout Town Creek, particularly adjacent to King St road reserve.
Are there any odour problem hot spots in the SW system?	No
Are there any algae problems in the SW system?	No – Blue Green Algae issues in the Williams river
Are there any mosquito breeding areas in the SW system?	No
Are there any areas prone to animal waste problems e.g. horses, cattle, dogs etc?.	Yes – some agriculture, mainly horse paddocks
Is there any localised flooding?	Yes – Reports of localised flooding in West Lowe St, Rifle St, Kings Street, Durham Street, Queen Sttreet

Streetscape Audit

Location		Streetscape Condition												Sites Potentially suitable for WSUD Measures									Sites	
Street	Section	Kerb (N,S,E,W)	Flooding evident	Erosion evident	Sediment present	Litter evident	Sewerage evident	GPT	Odour	Algae	Animal wastes	Natural veg present	Riparian veg present	Swales	Filter Strips	sand Filters	Bioretention Systems	Pavements	Infiltration trenches	Infiltration basins	developments	Comments	Erosion sites	WSUD measure sites on Town Creek
Duke St	*Lowe and Marshall*																					*Not exist*		
Duke St	Marshall and Rifle	X												y	y		y			y	y	Dead end (does not link to Rifle St) potential in rd reserve for WSUD measure		S1
Duke St	Rifle and Grey	x		y										y							y	Kerbed on Southern side for western half. Erosion on north corner with Rifle Swales on eastern south side good.	E2	
Duke St	Grey and Durham	x												y							y	No kerbs on Grey and Duke cnr. Eastern south side kerbed. Swales alright. Roadworks at eastern end		
Duke St	*East of Durham*																					*not exist*		
Prince St	*West of Sheffield*																					*Not exist*		
Prince St	Sheffield and Lowe	x												y							y	No kerbs		
Prince St	Lowe and Marshall	x		y										y								Alright swales		
Prince St	Marshall and Rifle	y		y										y								North side kerbed. West end drains to town creek. South side good swales on west end. Bad erosion on sth side east end		

Street	Section	Kerb (N,S,E,W)	Flooding evident	Erosion evident	Sediment present	Litter evident	Sewerage evident	GPT	Odour	Algae	Animal wastes	Natural veg present	Riparian veg present	Swales	Filter Strips	sand Filters	Bioretention Systems	Pavements	Infiltration trenches	Infiltration basins	developments	Comments	Erosion sites	WSUD measure sites on Town Creek
Prince St	Rifle and grey	x		y		y				y		y	y	y	y		y				y	No kerbs except on carpark outside shops. Poor swales/drains on north side. Some vegetation on south side. Town creek eroded and poor running behind shops. Crosses Prince St North to south into wetland on south side then into private property. Possible scope for WSUD measure in nature strip between Prince St and Town Creek between wetland and shops. Possible potential also to rehab Town Creek on North side Prince St from crossing to corner Clarence Town road.	E8	S4 W1 S5
Prince St	Grey and Durham	y												x								All kerbed. Poor drainage across Prince St along Grey St		
Prince St	East of Durham	y												y								Kerbed on North side only		
Queen St	West of Sheffield	x																						
Queen St	Sheffield and Lowe	x		y										y	y		y		y	y	y	Some erosion on north side east end. Room in nature strip for better swales or WSUD measures	E11	
Queen St	Lowe and Marshall	x		y										y						?		not kerbed		
Queen St	Marshall and Rifle	y												x							y	Collects stormwater and drains to wetland on cnr Rifle Rd.		

Street	Section	Kerb (N,S,E,W)	Flooding evident	Erosion evident	Sediment present	Litter evident	Sewerage evident	GPT	Odour	Algae	Animal wastes	Natural veg present	Riparian veg present	Swales	Filter Strips	sand Filters	Bioretention Systems	Pavements	Infiltration trenches	Infiltration basins	developments	Comments	Erosion sites	WSUD measure sites on Town Creek
Queen St	Rifle and grey	x		y						y			y	y							y	Town Creek on North side eroded and needing rehabilitation. Cnr Grey and Queen not kerbed or drained properly. South side swales alright but doesn't drain under road.	E13	S7
Queen St	Grey and Durham	y												y							y	Western end towards Grey St kerbed. No kerbs on cnrs Queen and Durham but good swales		
Queen St	East of Durham	y												x							y	All kerbed and OK		
King St	West of Marshall	x										y	y	y			y		y	y	y	Half block dirt road for property access. Rd reserve is basically Town Creek with lots of weeds. Potential for rehab.		S9
King S	Road reserve between Rifle and Lowe	x										y					y			y	y	Rehabilitation of native veg, including weed removal and protection of natural watercourse. Opportunity to establish water quality treatment incorporated with open space		S9
King St	Road reserve between Rifle and Grey	x									y	y	y									Clarence Town Wetland to north of King Street road reserve on eastern side of Town Creek.		
King St	Grey and Durham	x												y			y		y	y	y	Well grassed swales but deep and steep on cnr .		
Sherrif St	South of Queen St	x										y		y					y	y	y	No kerbs. Some swales but grass average. Scope for improvements.		
Sherrif St	North of Queen St	x										y		y					y	y	y	Wraps round to Prince and Lowe. No swales. Erosion on Prince and North Lowe. Veg on West side		

Street	Section	Kerb (N,S,E,W)	Flooding evident	Erosion evident	Sediment present	Litter evident	Sewerage evident	GPT	Odour	Algae	Animal wastes	Natural veg present	Riparian veg present	Swales	Filter Strips	sand Filters	Bioretention Systems	Pavements	Infiltration trenches	Infiltration basins	developments	Comments	Erosion sites	WSUD measure sites on Town Creek
Lowe St west	South of Queen St	x		y								y	y	y			y		y	y	y	New culverts on east side. Alright swales on north end but erosion problems at bottom end. Needing grass etc scope for works	E15	
Lowe St west	North of Queen St	y												y							y	Kerbed on east side between Queen and Prince. Alright swales on west		
Marshall St	South of Queen St	y										y	y	y			y		y	y	y	Kerbed halfway to King Street (King street a dirt road on western side only)		
Marshall St	Queen and Prince St	x		y										y			y				y	Swales with some erosion. Poor drainage. Poor swales on northern half	E6 & E12	
Marshall St	Prince St and Duke St	x		y										y							y	No kerbs, good swales. Erosion on South west corner.	E5	
Marshall St	North of Duke St	x												y							y	Good swales scope for rehab on private property.		
Rifle St	South of Queen St	x		y							y	y	y	y								Erosion on eastern corner with King St. Erosion of Town creek in horse paddock - significant around bend and impact obvious at property boundary. Scope for better wetland on south western corner.	E14 & E16	S8
Rifle St	Queen St and Prince St	y																			y	Steep but all kerbed		

Street	Section	Kerb (N,S,E,W)	Flooding evident	Erosion evident	Sediment present	Litter evident	Sewerage evident	GPT	Odour	Algae	Animal wastes	Natural veg present	Riparian veg present	Swales	Filter Strips	sand Filters	Bioretention Systems	Pavements	Infiltration trenches	Infiltration basins	developments	Comments	Erosion sites	WSUD measure sites on Town Creek
Rifle St	Prince St and Duke St	x		y						y			y	y			y		y	y	y	Swales and drains eroded on west side. Town creek crosses under Rifle and runs alongside Rifle on west side down and around north eastern Prince St Corner. Town Creek is eroded here. Potential for rehab on private property to the west of Rifle and on road verge to the east rifle. Bad erosion on nth eastern corner with prince.	E3 & E4	S2 S3 S4
Rifle St	North of Duke St	x		y										y							y	No kerbs. Steep slopes off road to drains/swales. Top half eroded on verge on east side. Then drains to Duke St.	E1	
Grey St	South of Queen St	y			y			y		y	y	y	y	y							y	Swaled on corner of Grey and King. Kerbed from Queen down Grey on both sides to silt trap into wetland.		W3
Grey St	Queen St and Prince St	y		y						y		y	y								y	Kerbed and drains into Town Creek to west of Grey St.	E9	S6
Grey St	Prince St and Duke St	y												y							y	Kerbed both sides till crest.		
Grey St	North of Duke St	x												y							y	No kerbs. East drains to small creek to Williams River.		
Durham St	South of King St	x										y	y	y							y	A road to a reserve with good grass swales.		
Durham St	King St and Queen St	y												y							y	Kerbed on east side except for southern 2 properties. Swales on west (corners not kerbed)		

Street	Section	Kerb (N,S,E,W)	Flooding evident	Erosion evident	Sediment present	Litter evident	Sewerage evident	GPT	Odour	Algae	Animal wastes	Natural veg present	Riparian veg present	Swales	Filter Strips	sand Filters	Bioretention Systems	Pavements	Infiltration trenches	Infiltration basins	developments	Comments	Erosion sites	WSUD measure sites on Town Creek
Durham St	Queen St and Prince St	y		y										y	y			y		y	y	East side kerbed. West side swales. Corners kerbed. Swales impacted by traffic/parking around sports fields.	E10	
Durham St	Prince St and Duke St	x												y							y			
Durham St	North of Duke St																					Roadworks		
Russell St	King St and Queen St	y												y							y	West side kerbed halfway towards Queen St. Swales well grassed		
Russell St	Queen St and Prince St	y												y							y	West side kerbed. Well grassed		
Russell St	Prince St and Duke St	y																			y	80% of cul de sac kerbed		
Earl St	Grey st to Riflke St	x		y										y							y	No kerbs. Gravelly surface on crest of hill		
Earl St	Rifle west	x		y										y							y	Gravelly dirt track with dirt drains.		
Queen and Rifle	Intersection	y										y	y								y	Wetlands on NE and SW corner. Potential to increase SW corner wetland	W2	

The catchment audit findings have been incorporated into the following figures that display the current kerbing, issues and sites within the Town Creek catchment.

Figure 1. Clarence Town streetscape and kerbing in the Town Creek catchment.

Figure 2. Erosion in the Clarence Town streetscape in the Town Creek catchment.

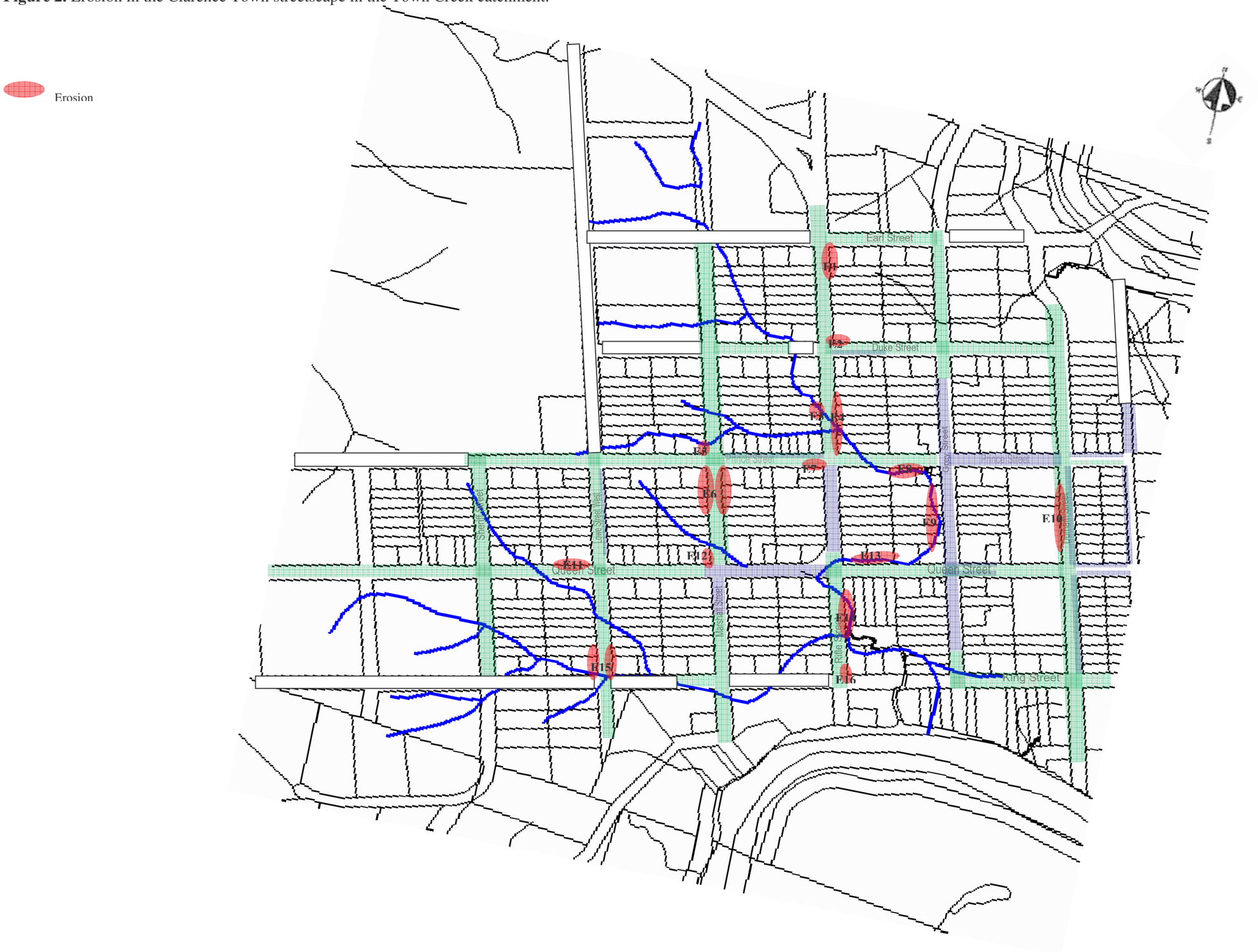


Figure 3. Potential Sites for Stormwater related WSUD Measures in the Town Creek catchment

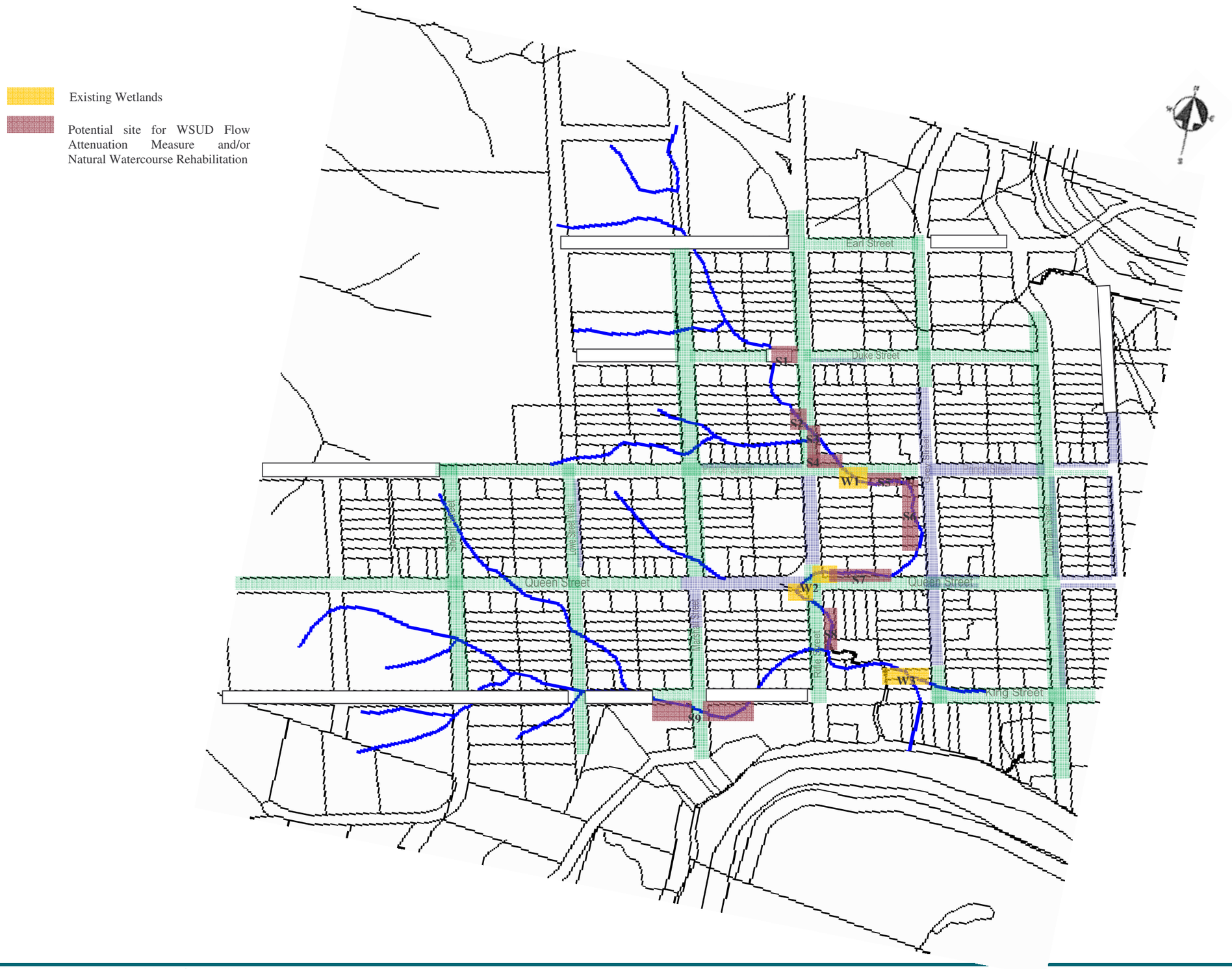
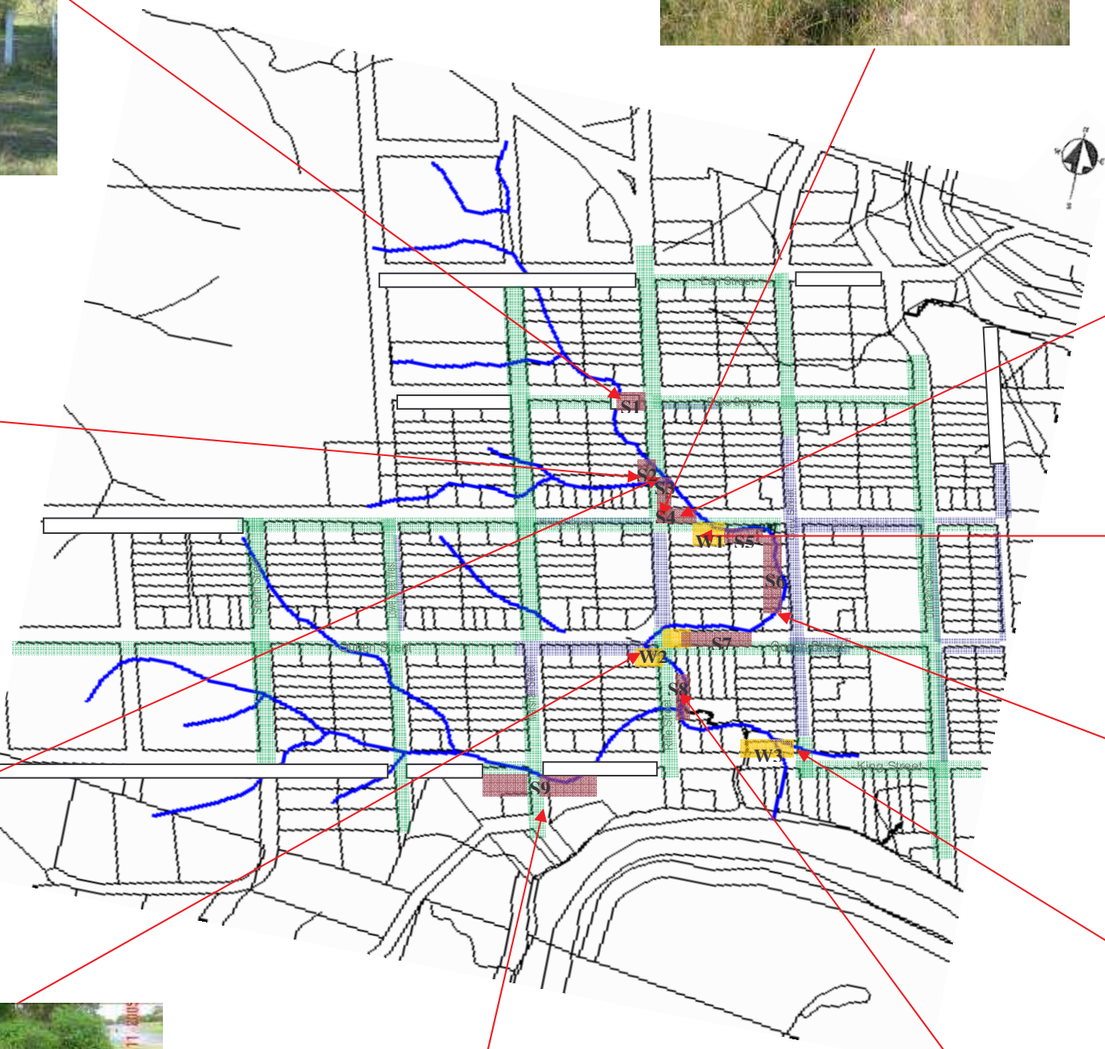


Figure 4. Images of Potential Sites for Stormwater related WSUD Measures in the Town Creek catchment



CONCLUSION

This catchment audit has identified areas where stormwater is impacting on the Clarence Town drainage system and the natural water course of Town Creek. Sites have also been identified where mitigation measures currently exist and where opportunities may exist to undertake activities to rehabilitate the Town Creek watercourse through remediation works and installation of Water Sensitive Urban Design (WSUD) measures to minimise the impacts of stormwater in the catchment.

A Town Creek Catchment Plan of Management based on the findings of this audit will develop guidelines for future stormwater work in the catchment, including recommending site specific WSUD measures.

Appendix B Key WSUD & Creek Remedial Measures

Key WSUD Measures

Measure	Description	Control Level
Vegetated Swales	Swales are formed, vegetated depressions that are used for the conveyance of stormwater runoff from impervious areas. They provide a number of functions including: • removing sediments by filtration through the vegetated surface; • reducing runoff volumes (by promoting some infiltration to the sub-soils); and • delaying runoff peaks by reducing flow velocities. Swales are typically linear, shallow, wide, vegetation lined channels. They are often used as an alternative to kerb and gutter along roadways but can also be used to convey stormwater flows in recreation areas and car parks.	Source and Transit
Vegetated Filter Strips	Vegetated filter strips (or buffers) are broad, sloped open vegetated areas that accept shallow runoff from impermeable areas as distributed or sheet flow. They provide a number of functions including: • removing sediments by filtration through the vegetation; • reducing runoff volumes (by promoting some infiltration to the sub-soils); and • delaying runoff peaks by reducing flow velocities.	
Sand Filters	Sand filters typically comprise of a bed of filter medium through which stormwater is passed to treat it prior to discharging to the downstream stormwater system. The filter media is usually sand, but can also contain sand/gravel and peat/organic mixtures. Sand filters provide a number of functions including: • removing fine to coarse sediments and attached pollutants by infiltration through a sand media layer; and • delaying runoff peaks by providing retention capacity and reducing flow velocities. Sand filters can be constructed as either small or large scale devices. Small scale units are usually located in below ground concrete pits (at residential/lot level) comprising of a preliminary sediment trap chamber with a secondary filtration chamber. Larger scale units may comprise of a preliminary sedimentation basin with a downstream sand filter basin-type arrangement.	
Bioretention Systems	Bioretention systems are essentially a surface and sub-surface water filtration system. They provide a number of functions including: • removing sediments and attached pollutants by filtering through surface vegetation and ground cover and through an underlying filter media layer; and • delaying runoff peaks by providing retention capacity and reducing flow velocities.	

	Bioretention systems are similar in function to sand filters. Whereas sand filters rely on water quality treatment via passage of stormwater through a sand medium, bioretention systems incorporate both plants and underlying filter soils for removal of contaminants. The vegetation enhances the filtration process as well as maintaining the porosity of the filter media. The filter media is usually the plant growing material, which may comprise soil, gravel, sand and peat mixtures. Bioretention trenches can be constructed as either small or large scale devices. Small scale units are usually located in residential planter boxes (sometimes refer to as "rain gardens"), which pass collected stormwater and percolates it through the filter media to the outlet. Larger scale devices work on the same methodology, however are located along the streetscapes and retarding basins over large open areas. There are two main types of bioretention systems: 1. Non-conveyance (off-line) systems – These use a freeboard for ponding above the bioretention surface to maximise the volume of runoff treated. Typically they contain the design inflow with higher flows discharged through overflow pits or bypass paths and are not required to convey flood flows. They are commonly installed in planting boxes or streetscapes as a landscape feature. 2. Conveyance (on-line) systems – These treat the design inflow but are also able to convey minor storm events along longitudinal channels. These systems are commonly used in streetscape applications in combination with vegetated swales, which are used to convey street runoff to the designated bioretention system.	
Permeable Pavements	Permeable pavements, which are an alternative to typical impermeable pavements, allow runoff to percolate through hard surfaces to an underlying granular sub-base reservoir for temporary storage until the water either infiltrates into the ground or discharges to a stormwater outlet. They provide a number of functions including: • removing some sediments and attached pollutants by infiltration through an underlying sand/gravel media layer; • reducing runoff volumes (by infiltration to the sub-soils); and • delaying runoff peaks by providing retention/detention storage capacity and reducing flow velocities. Commercially available permeable pavements include pervious/open-graded asphalt, no fines concrete, modular concrete blocks and modular flexible block pavements. There are two main functional types of permeable pavements: • infiltration (or retention) systems – temporarily holding surface water for a sufficient period to allow percolation into the underlying soils; and • detention systems – temporarily holding surface water for short periods to reduce peak flows and later releasing into the stormwater system.	

Infiltration Trenches	Infiltration trenches temporarily hold stormwater runoff within a sub-surface trench prior to infiltrating into the surrounding soils. Infiltration trenches provide the following main functions: • removing sediments and attached pollutants by infiltration through the sub-soils; • reducing runoff volumes (by infiltration to the sub-soils); and • delaying runoff peaks by providing detention storage capacity and reducing flow velocities. Infiltration trenches typically comprise of a shallow, excavated trench filled with reservoir storage aggregate. The aggregate is typically gravel or cobbles but can also comprise of modular plastic cells (similar to a milk crate). Runoff entering the system is stored in the void space of the aggregate material or modular cells prior to percolating into the surrounding soils. Overflow from the trench is usually to downstream drainage system. Infiltration trenches are similar in concept to infiltration basins, however trenches store runoff water below ground within a pit and tank system, whereas basins utilise above ground storage.	
Infiltration Basins	Infiltration basins are either sited in natural or excavated open areas, designed to temporarily hold stormwater runoff prior to infiltrating through the basin floor. Infiltration basins provide the following main functions: • Removing particulate and attached pollutants by infiltration through the sub-soils; • Reducing runoff volumes (by infiltration the sub-soils); and • Delaying runoff peaks by providing detention storage capacity and reducing flow velocities. Infiltration basins can be constructed as either small or large scale devices. Small scale units (catchment <5 ha) are usually excavated pits or ponds, with larger scale units (catchments up to 50 ha) are typically located within natural surface depressions or gullies within the site occupying a large open area (i.e. playing field or parkland).	
Detention Basins	Dry detention and dry extended detention (ED) basins are surface facilities intended to provide for the temporary storage of stormwater runoff to reduce downstream water quantity impacts. These facilities temporarily detain stormwater runoff, releasing the flow over a period of time. They are designed to completely drain following a storm event and are normally dry between rain events. • Dry detention basins should be sized to temporarily store the volume of runoff required to provide flood and channel protection and control storm event flows if required. • Dry ED basins are sized to provide extended detention of the channel protection volume and can also provide additional storage volume for normal detention (peak flow reduction). (Source www.georgiastormwater.com)	
Rainwater Tanks	Rainwater tanks are sealed tanks designed to contain rainwater collected from roofs. Rainwater tanks provide the following main functions: • allow the reuse of collected rainwater as a substitute for mains water supply, for use for toilet flushing, laundry, or garden watering; • when designed with additional storage capacity above the overflow, provide some on-site detention, thus	

	reducing peak flows and reducing downstream velocities; and • it may be permissible to use rainwater tanks for internal hot water supply. The water collected can be reused as a substitute for mains water supply either indoors (toilet flushing and laundry) or outdoors (garden watering). Rainwater tanks can be either above ground or underground. Above ground tanks can be placed on stands to prevent the need of installing a pump to distribute the water. Such systems are referred to as gravity systems. Pressure systems require a pump and can be either above or below ground tanks. Tanks can be constructed of various materials such as ColorbondTM, galvanised iron, polymer or concrete.	
Landscape Developments	The application of WSUD to landscape development involves the landscape design that aims to minimize irrigation water requirements and maximise the survival rate of plants during drought periods. It involves the application of the following seven principles: 1. Appropriate landscape planning and design; 2. Limiting the extent of lawn; 3. Ensuring irrigation efficiency; 4. Improving soil for plant growth; 5. Using surface mulches; 6. Selecting low water demand plants; and 7. Carrying out effective landscape maintenance. The selection of low water demand plants gives preference to locally indigenous species that are adapted to the local soils and climate. However, the use of non-indigenous species may be appropriate in some situations to achieve a particular landscape outcome.	
Baffle Boxes	Baffle boxes are primarily used for catching sediment but also for reducing water velocity at the discharge point of pipes or channels. Baffles create an obstacle for water, slowing water velocity and allowing sediment to settle on the bottom. Generally installed as a series of baffles, water builds up until it flows over the baffle and into the next partition.	

Sourced URS 2004

Creek Remedial Measures

Sourced from Waters and Rivers Commission, Stream Stabilisation, Report No. RR 10, 2001

Creek Stability

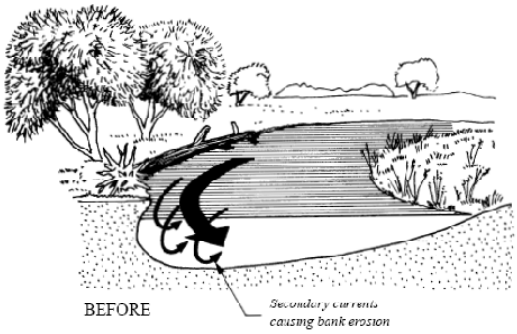
Riffles, snags and other channel controls are important to the stability and ecology of stream systems. The pool riffle sequence provides a variety of riverine habitats that are able to support a greater diversity of species than sections that have uniform characteristics. Riffles and meanders create variable water speeds and depths and maintain river pools that are important in providing summer refuges and breeding areas. Pool-riffle sequences contribute to channel stability by controlling the velocity of flow and reducing the downstream movement of sediments into the river. Stabilised bed material is important for the establishment of instream vegetation and habitat for aquatic fauna. Sediment accumulates behind the riffle and vegetation can be established on the flanks, stabilising the banks. By locking the sediment and reducing flow velocities, nutrients in the water column can be removed through biological processes or remain bound in the bed material. Water quality is also improved as the riffle creates turbulence that aerates the water, which in turn supports microbial activity that breaks down organic matter and assimilates nutrients.

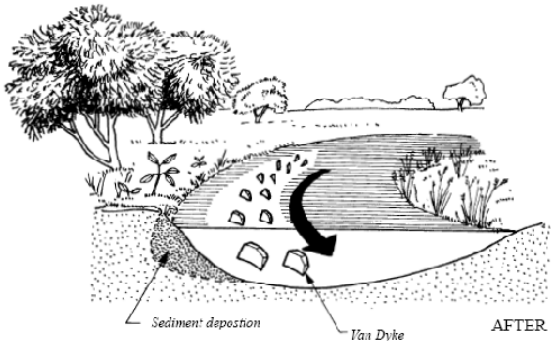
Riffles generally do not adversely affect the flood capacity of the river channel, which is often oversized due to erosion anyway. An assessment of the channel capacity should be undertaken when designing instream works. The structures will have negligible impact on flood levels if designed to obstruct less than 10 % of the cross-sectional area of the channel. The riffles are fully submerged during medium to high flows.

Bank Erosion Prevention

Van Dykes

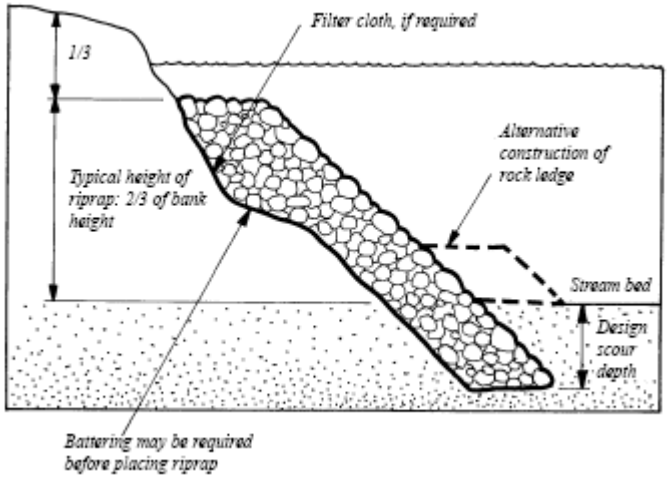
Vane dykes are used on meandering waterways to reduce bank erosion on outer bends and control channel alignment. A series of short vane structures are positioned mid-stream along an eroding bank to encourage sediment deposition. The shape and alignment of the vanes interrupt secondary currents that can cause bank erosion. An advantage of the technique is that the bank and bed of the river remain relatively undisturbed during installation as the structures do not require anchoring. Vanes can be used in deep water. The technique will not be as effective in straight or irregularly aligned rivers.





Rip rap

Rock riprap consists of a layer of rock which is placed on a stream bank to protect it from erosion. The stream bank is rock paved usually to above high water mark. Reinforcement with riprap of only the toe may be required in some cases to support the bank. The bank may require battering prior to placement of materials. Filter cloth can be placed on the bank beneath the rock to provide protection from undermining caused by flows getting above and behind the riprap, washing out sediment and destabilising the works. A trench should be excavated at the toe of the bank and the riprap laid to beneath bed level. Alternatively, on hard riverbeds, a rock ledge can be built along the toe of the bank.



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