City of Cape Town
Development Service

Transport, Roads & Stormwater Directorate

Catchment, Stormwater and River Management Branch

Stormwater Management Planning and Design Guidelines for New Developments

Version 1.0

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Executive Summary

This document provides guidelines for the planning and design of stormwater management systems with particular emphasis on new developments. It is however, equally applicable to stormwater management upgrading and rehabilitation projects.

The document has been structured into 5 broad sections, which cover the process from the initial concept design of stormwater systems through to the operational stage, as follows:

Section (1) – Preparation and Approach

It is widely recognised that developments impact negatively on drainage systems. By taking greater cognisance of natural hydrological patterns and processes it is possible, to develop stormwater management systems in manner that reduces these potentially negative impacts and mimic nature.

Cognisance should be taken of the following stormwater management objectives:

- Minimise threat of flooding
- Protect receiving water bodies
- Promote multi-functional use of stormwater management systems
- Develop sustainable stormwater systems

Section (2) - Planning

It is crucial to the successful implementation of an effective stormwater management system, to assemble consultants with the required multi-disciplinary expertise from the outset of the project and that they be briefed to operate as a team. The core members of the group would provide expertise in civil engineering, town planning and environmental consulting. Closely allied disciplines of freshwater ecology and landscape architecture should be added, if required, on the advice of the other professionals.

Various service delivery units with an interest or impact on the management of the drainage systems must be consulted by the design team at an early stage. This will ensure that the systems constructed meet their approval and address community needs.

The implications a number of legal and policy considerations on the development must be considered at an early planning stage.

A site analysis plan should be prepared in which the physical features of the site as well as ownership and spatial constraints, including adjacent and downstream areas, are assembled and evaluated. A conceptual layout together and a conceptual stormwater plan would then be prepared based on this information.

Section (3) - Design

In the design phase, various stormwater management facilities and techniques useful in achieving required design objectives are presented and grouped by generic function as follows:

- Conveyance
- Ponding

- Infiltration
- Filtration and Treatment

A number of examples with diagrams and additional design information, data sources and references are provided.

Section (4) - Construction

Construction of the stormwater management system should be carried out subject to the provisions of an environmental management programme (EMP).

Section (5) – Operation and Maintenance

It is of prime importance that the stormwater management system is well maintained and operated in accordance with the intentions of the design. The developer must consider the available maintenance resources and responsibilities when formulating designs.

This chapter furthermore, provides guidance regarding the allocation of responsibilities within the local authority. In addition, co-operation of the public and in particular local residents will ensure the success and optimal use of the system. Education programmes, projects in association with groups such as schools (e.g. "adopt-a-wetland") and Friends groups should be encouraged.

Effective monitoring based on the requirements of the operation management plan (OMP) is stressed.

In general, the aim should be to provide a stormwater management system which mimics nature, utilises natural features in the stormwater cycle, will be an asset to the community and will function efficiently with relatively little maintenance.

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Preface

Document Overview and Purpose

This guideline document, prepared in terms of Council's Catchment, Stormwater and River Management Strategy: 2002 – 2007 (May 2002) is intended to facilitate the development and extension of stormwater management systems on a rational and coherent basis within the Cape Town metropolitan area.

The Guidelines are provided to assist in the planning and design for stormwater management systems. Particular emphasis is placed on the development of innovative solutions that are cost effective, sustainable in terms of future maintenance requirements, environmentally sensitive and maximise, within these constraints, social as well as amenity value.

Applicability and Status of Document

Whilst the guidelines are focussed on new developments, they are equally applicable to other stormwater management upgrading and rehabilitation projects. They are intended to assist decision-making and should not be construed as standards or specifications.

These guidelines are intended to assist developers and their consulting teams in the planning and design of stormwater management systems as well as municipal officials involved in the approval and operation thereof.

Other Applicable Guidelines

This document is to be read and interpreted in conjunction with the Guidelines for Human Settlement Planning and Design (Red Book) prepared by the CSIR – Building and Construction Technology Division. In the event of conflict, this guideline will prevail.

Document Structure

Pertinent information and issues to be considered during the various phases of a stormwater management project, from project identification through to planning, design, construction and maintenance have been grouped under separate sections.

Glossary of Terms

Aquifer: A geological formation, which has structures or textures that hold water or permit appreciable water movement through them.

Base Flow: Flow occurring in a watercourse not attributable to a storm rainfall event, but to groundwater flow where the water table intersects the stream channels of a catchment.

Catchment: (in relation to a watercourse or watercourses or part of a watercourse) means the area from which any rainfall will drain into the watercourse or watercourses or part of a watercourse, through surface flow to a common point or common points

Catchment Management: simultaneously a philosophy, a process and an implementation strategy to achieve a balance between utilisation and protection of environmental resources in a particular catchment area

Council: means the municipal council of the City of Cape Town.

Detention facility: A structure, which temporarily stores excess stormwater for a length of time. The outlet of the structure is designed to release the stored water into the downstream watercourse at a rate less than the flow rate into the facility during storm events.

Development: means a man-made change to property, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation or drilling operations or storage of equipment or materials.

Environmental Impact Assessment: means a study of the likely effect on the environment of proposed activities or development.

Flood or Flood Waters: means a temporary rise in water level including ground water or overflow of water onto land not normally covered by water.

Flood Plain: The flood plain of a river is the valley floor adjacent to the incised channel, which may be inundated during high water.

Habitat Integrity: Habitat Integrity (Southern Waters 2001) is the degree of naturalness of a system, calculated as a percentage, and reported as one of six broad Habitat Integrity categories, ranging from Category A (unmodified) to Category F (critically modified). Habitat Integrity data allow the calculation of River Priority Rank – a measure of the conservation importance of a river, relative to that of other similar rivers. In terms of planning, the River Priority Rank of a system, influences the recommended buffer width between the riverbank and the development line.

Interception: Precipitation stored on vegetation as opposed to rain in surface depressions (termed depression storage).

Major drainage system: A stormwater drainage system, which caters for severe, infrequent storm events. Supported by the minor drainage system.

Management Plan: A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, problems, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.

Minor drainage system: A stormwater drainage system, which caters for frequent storms of a minor nature.

Pollution: means the direct or indirect alteration of the physical, chemical or biological properties of a water resource so as to make it less fit for any beneficial purpose for which it may reasonably be expected to be used; or harmful or potentially harmful to:

- the welfare, health or safety of human beings
- any aquatic or non-aquatic organisms
- soils and vegetation
- the resource quality
- property

Recurrence interval: Recurrence interval or return period is the average interval between events. The recurrence interval is usually expressed in years and is the reciprocal of the annual probability. That is, the event having an annual probability of occurrence of 2% (0,02) has a recurrence interval of 50 Years. This does not imply that such an event will occur after every 50 years, or even that there will necessarily be one such event in every 50 years. This does not imply that such an event will occur after every 50 years, but rather that over a much longer period (like a 1 000 year period) there will very likely be 20 events of equal or greater magnitude.

Retention Facility: A structure which retains runoff indefinitely should the capacity of the structure be sufficient to contain such runoff. Excess flow into the structure will be discharged via a spillway.

Riparian Habitat: includes the physical structure and associated vegetation of the areas associated with a watercourse which are commonly characterised by alluvial soils, and which are inundated or flooded to an extent and with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from those of adjacent land areas

Runoff: Water, which flows over surfaces.

Sheet flow: Overland stormwater runoff which is not confined to a channel but has a relatively shallow and wide flow pattern.

Stormwater: means water resultant from natural precipitation and/or accumulation and includes rainwater, groundwater and spring water.

Stormwater Management: involves both the quantitative and qualitative management of stormwater and the functions associated with planning, designing, constructing, operating, maintaining and financing stormwater management systems.

Stormwater Management Systems: means both constructed and natural facilities that collect, convey, store, control, treat, use and dispose of stormwater.

Sustainable development: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Watercourse: Lake, river, channel or other topographic feature in which water flows regularly or intermittently.

Water Resource: includes a watercourse, surface water, estuary or aquifer (National Water Act 1998)

Wetland: Land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil. Wetlands include lakes, salt marshes, coastal lakes, artificial impoundments, marshes, swamps, vleis, pools, ponds and pans.

Abbreviations

CMA	Cape Metropolitan Area
CCT	City of Cape Town
DECAS	Department of Environmental and Cultural Affairs and Sport
DWAF	Department of Water Affairs and Forestry
EIA	Environmental Impact Assessment
EMP	Environmental Management Programme
GIS	Geographical Information Systems
HEC	Hydrologic Engineering Centre
IMEP	City of Cape Town - Integrated Metropolitan Environmental Policy
OMP	Operation Management Plan
PAWC	Provincial Administration of the Western Cape
SCS	US Soil Conservation Service
USEPA	United States Environmental Protection Agency

1. Preparation and Approach

1.1 The Stormwater Management Service

Cape Town's stormwater management system comprises a complex mix of constructed infrastructure (underground pipes and culverts, lined and unlined canals, etc) and "natural" features (rivers, vleis, wetlands, groundwater reservoirs etc) with various diverse functions (stormwater drainage, recreation, nature conservation, wastewater effluent conveyance, water supply, etc). The stormwater service provided within the metropolitan area involves the management of urban catchments in respect of their hydrological functioning for drainage, flood control, ecological and social needs and as an important urban water resource.

1.2 Managing the Impact of Development on Natural Drainage Systems

It is widely recognised that developments impact negatively on natural drainage systems in several ways, including:

- Reduced permeability of catchment areas by introduction of impervious surfaces such as streets and buildings. This results in increased catchment runoff volumes.
- The introduction of efficient stormwater drainage results in reduced catchment response times with concomitant increased downstream flow peaks.
- Manipulation of groundwater tables, which can have severe effects on wetland functioning and the survival of many terrestrial plant communities.
- Alteration to the natural flow regimes in river systems resulting in both geomorphologic (e.g. channel / bank erosion) and aquatic ecosystem changes over time.
- Deteriorating water quality as a result of industrial fallout, fertilisers and other pollutants that are conveyed by stormwater systems directly to receiving water bodies, without any attempt to ameliorate en route.

These guidelines require greater cognisance to be taken of natural hydrological patterns and systems in the development of stormwater management systems and that the potential negative impacts highlighted above are reduced as far as is practically possible. This is illustrated by means of Figures 1 to 3 below, depicting both the traditional and recommended approaches to stormwater management within the urban context.

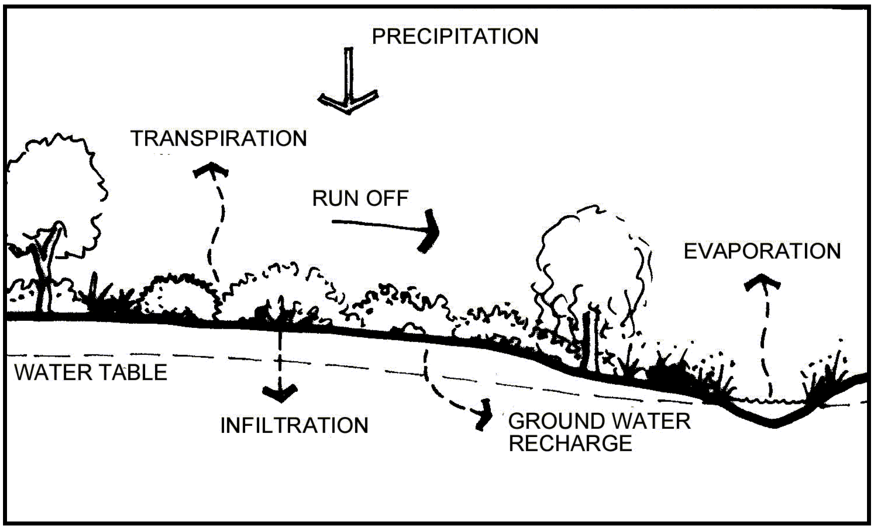


Figure 1: Natural hydrological system

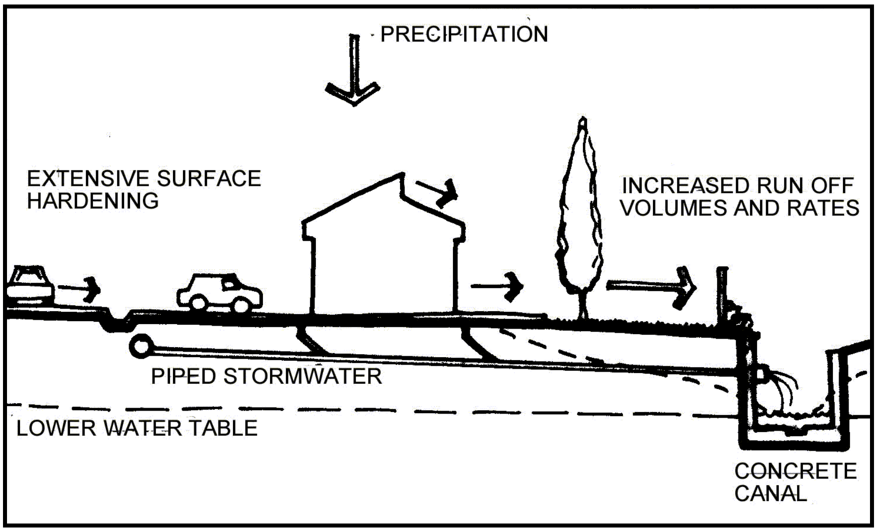


Figure 2: Stormwater management approach with little concern for the natural environment

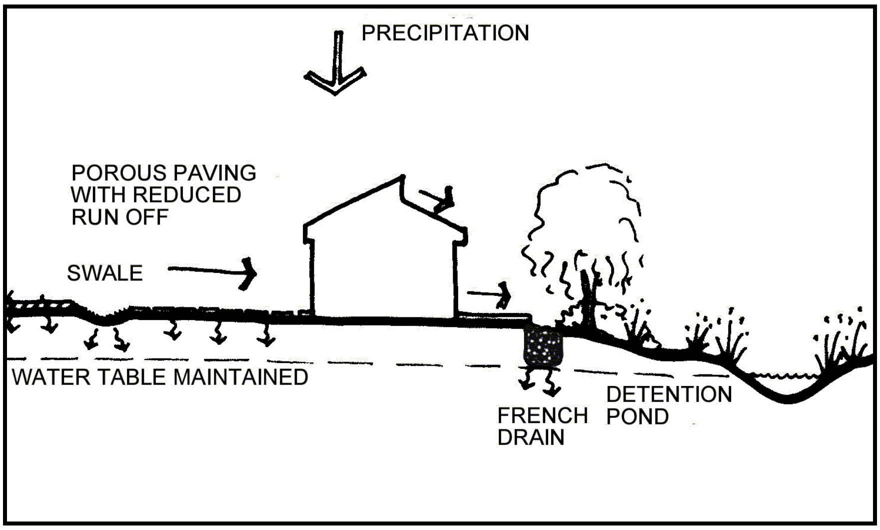


Figure 3 : Responsible approach to stormwater management

1.3 Stormwater Management Objectives

1.3.1 Minimise the Threat of Flooding

This remains a key objective of any stormwater management system. However the challenge when contemplating design of stormwater management systems is to consider the following:

- To mimic pre-development responses to storms
- To reduce the volume of runoff by promoting infiltration
- To reduce the peak flows and increase the time-to-peak through detaining the runoff and releasing it at a gradual rate
- Where necessary, to construct means to contain flood waters and safely convey them out of the urban area

1.3.2 Protection of Receiving Water Bodies

Receiving water bodies include the following:

- Rivers / streams
- Groundwater
- Wetlands which include vleis, lakes, seasonal marshes, and pans)
- The sea

It should be noted that the “receiving water body” is not necessarily the system into which stormwater is discharged directly, but can also be a natural system located further downstream in the catchment. Every endeavour should be made to achieve the following as far as possible:

- Maintain natural flow regimes and seasonality
- Prevent deterioration in water quality
- Prevent erosion or sedimentation of natural wetlands or rivers
- Preserve natural river channels, wetlands and vegetation, and preclude engineering interventions that may alter their physical and ecological characteristics.

The need to design appropriate stormwater management systems for new developments should be seen as an opportunity to preserve or, if possible, improve natural freshwater ecosystems that have suffered degradation as a result of past activities, and in some cases, to create additional freshwater habitats that will contribute to the availability of appropriate, high quality river and wetland habitat that mimics the natural condition.

1.3.3 Promote Multi-Functional Use of Stormwater Management Systems

Resources such as land and water are becoming increasingly scarce and multiple use of these must be strived for. Stormwater systems provide a wide range of opportunities for multi-functionality. These can have significant implications on:

- The initial and long term costs of development. Eg. Instead of constructing a detention pond and a sportsfield, these uses could be combined.
- The quality of the natural and urban environment. Eg. The pressure of private development requirements on land for public land use, conservation, etc can be alleviated by combining compatible land uses such as conservation, recreation and stormwater systems (including wetlands, vleis, dams and rivers) enabling an improved natural and urban environment.
- Maintenance efficiency. Eg. Instead of meeting the maintenance requirements of stormwater systems and public open space separately, they could be combined and could include walking/bicycle trails and parks.

1.3.4 Development of Sustainable Environments

Developers should think beyond their short-term involvement with the project and consider the sustainability of the stormwater management system that is to be implemented. All relevant factors that will impact on future operation and maintenance should be taken into account. Maintenance requirements should be minimised as far as possible in order to maximise the available local authority funding, personnel and equipment. Responsibilities for maintenance must be resolved with the relevant local authority department at an early stage of the design.

The possibility of developing public/private partnerships should be explored with local authorities (e.g. division of funding of capital versus maintenance costs between public and private sectors).

Environmental policies such as promoting the use of locally indigenous vegetation in planting programmes will also reduce the long-term maintenance requirements of the development.

2. Stormwater Planning

Adequate planning is crucial to the success of the project as a whole. This section endeavors to sketch out the areas where relevant information should be assembled and how this information may be integrated into a stormwater management plan, which will assist the design process, which follows.

2.1 The Need for Multi-disciplinary Expertise

In order to meet these objectives in designing an effective stormwater management system, the developer is urged to adopt a multi-disciplinary approach to the project from inception through to completion and acceptance by the City. This will enable the developer to maximise opportunities.

The roles that such a team could fulfil are set out in Table 2-1.

Table 2-1 : Recommended composition of multi-disciplinary design team

<table>
<tr><td colspan="2">Team Member</td><td>Role</td></tr>
<tr><td colspan="2">Town Planner</td><td>The town planner should plan the development layout to locate the stormwater system – attenuation dams, channels, and overland escape routes – to functionally blend with the development.</td></tr>
<tr><td colspan="2">Civil Engineer</td><td>An engineer skilled in the design of stormwater systems should determine runoff flows for the required recurrence intervals and proposed land uses and design appropriate measures to attenuate peak flows and safely convey the runoff.</td></tr>
<tr><td colspan="2">Environmental Consultant</td><td>The environmental consultant should alert the engineer and town planner at the conceptual stage of the development to crucial aspects of the environment, which are fulfilling an important role with respect to stormwater and should be taken into consideration, as well as opportunities for enhancement or rehabilitation of existing natural features.</td></tr>
<tr><td rowspan="2">If required</td><td>Freshwater Ecologist</td><td>The freshwater ecologist should provide specialist insight regarding the functioning of natural rivers, streams and wetlands and advise regarding the ecological aspects of the design of the components of the system, including water quality enhancement and the land needed for the system to function.</td></tr>
<tr><td>Landscape Architect</td><td>The landscape architect should provide a holistic site analysis of the existing natural and man-made landscape and advise on the opportunities, constraints and implications of the site on the development planning and design.</td></tr>
</table>

2.2 Interface with Municipal Service Delivery Units

Provision of stormwater management services within the City of Cape Town requires a multi-sectional approach dependent on the co-operation of various service delivery units as illustrated in Table 2-2 below.

Table 2-2 : City service delivery units with an interest and / or impact in the management of drainage systems

Service Delivery Unit	Interest / Impact
Roads	Roadways form part of the drainage system.
Water Services	Discharge of wastewater effluents into river systems. Also possible future abstraction of water from rivers and aquifers to augment water supply to the metropolitan area.
Waste Management	Effective street sweeping and area cleansing reduces pollution of watercourses, the marine environment and reduces flood risk.
Planning and Environment	Responsible for urban planning and environmental auditing.
Open Space, Nature and Coastal Management	Management of amenity and nature conservation aspects of riverine corridors, wetlands, vleis and beaches.
Health	Human health implications of poor water quality.
Housing	Responsible for informal settlements
Disaster Management	Management of flood disasters and pollution incidents

In addition, the certain external stakeholders also have an interest and / or impact on the service as illustrated in Table 2-3 below.

Table 2-3 : External stakeholders with an interest and / or impact in the management of drainage systems

Organisation	Interest / Impact
Department of Water Affairs and Forestry (DWAF)	Management and control of water resources in terms of National Water Act (Regulatory function)
Provincial Administration of the Western Cape (PAWC)	Control of activities that may have a detrimental effect on the environment in terms of Environmental Conservation Act (Regulatory function)
Academic and Research Institutions	Related research and education
Non Governmental Organisations and Catchment Forums	Advise and monitor activities of service

2.3 Legal and Policy Considerations

Although not exhaustive, the statutes, ordinances, regulations, by-laws, policies and guidelines listed in this section (Refer to Annexure A for details) have relevance, and should be considered by the developer at the planning stage. They should not however be seen as exhaustive as they are subject to ongoing amendments, revisions and additions.

Legal Status of Documents

It is essential that the developer ensure that he is aware of any amendments to the relevant acts as these can have substantial impact on a development project.

2.3.1 National level

- Constitution of the Republic of South Africa, 1996 (Act 108 of 1996)
- Local Government: Municipal Systems Bill (B27B-2000)
- National Water Act, 1998 (Act 36 of 1998)
- DWAF Water Quality Guidelines, 1996
- National Environmental Management Act, 1998 (Act 107 of 1998)
- Environmental Conservation Act, 1989 (Act 73 of 1989)
- Environmental Impact Assessment (EIA) Regulations (No.R1182 and R1183 – September 1997)
- Protected Natural Environments
- Conservation of Agricultural Resources Act, 1983 (Act 43 of 1983)
- Development Facilitation Act, 1995 (Act 67 of 1995)
- National Building Regulations and Building Standards Act, 1997 (Act 103 of 1977)

2.3.2 Provincial level

- Western Cape Planning and Development Act, 1999 (Act 7 of 1999)
- Land Use Planning Ordinance, 1985 (Ordinance 15 of 1985)

2.3.3 Municipal (City of Cape Town)

- Proposed by-law for Stormwater Management and Related Matters (In preparation)
- Policy for Control of Development Near Watercourses (City of Cape Town, 2002)
- Stormwater Land Identification Project (SLIP): a set of GIS plans covering the entire CMA which identifies all erven impacted by stormwater issues
- Integrated Metropolitan Environmental Policy (2001)
- Zoning Schemes

2.3.4 International Conventions

- Ramsar Convention on Wetlands, 1975

2.4 Incorporation of Existing Information into Planning Stage

The following information should be collated for each site, during the planning stage and used to feed into the more detailed site assessment:

- Catchment area in which site is located
- Catchment or river management plans - The overall management objectives and recommend key management actions with respect to runoff quantity, quality and other associated environmental and social issues, where such plans exist for the catchment in question, must be met in the design stage.
- Stormwater management master plan - This plan Identifies bulk infrastructure, including stormwater flow routes, required within developing areas and may identify particular issues such as pollution which must be addressed at a local level. The existence of a stormwater management master plan, which covers the area, to be developed should be established and its recommendations applied to the design.
- Existing reports relating to the sensitivity of known wetlands / rivers / other natural ecosystems on or associated with the study area.

Cognisance must be taken of the interdependencies that exist between the various water related services such as water supply, sanitation and stormwater management. This includes consideration of the impact of effluent discharges into or water abstraction from stormwater management systems.

If the developer is considering the implementation of educational type programmes, he should first consult with the Catchment, Stormwater and River Management Branch on the nature and status of their own current or planned educational programmes intended to promote basic awareness and appreciation of stormwater systems and the functioning and value of rivers, wetlands, vleis and the receiving coastal waters.

A useful resource which may be consulted is the library of Catchment, Stormwater and River Management Division of the City of Cape Town.

2.5 Site Analysis

The physical characteristics of the site reflect the existing course of runoff and stormwater. Working with the natural environment and processes has been found to be safer, more sustainable and easier to maintain in the long term than more traditional engineering approaches aimed at controlling these processes.

On sites that have been substantially disturbed, consideration should be made of what the natural drainage and runoff conditions would have been, as well as the existing situation. This will enable potential problems, and opportunities, to be identified.

The following are some of the main features that should be considered and collated in the form of a site analysis plan that should be used to inform the design process.

2.5.1 Topography

The following topographical factors should be considered:

- Gradients dictate the direction of flow and runoff/drainage routes can be plotted over land, identifying areas of ponding and concentration of loads.
- In some areas which are very flat, earthworks may be required to provide sufficient grade for drainage.
- Topography influences the potential for erosion to occur.
- Topography informs the feasibility of different locations for stormwater routes, outlets and treatment areas. The main stormwater routes should be located along natural drainage routes.
- In ecological terms, different habitats, some of higher conservation value than others, are frequently associated with changes in topography.
- From an environmental and stormwater management perspective, as the slope increases, erf sizes should also increase to prevent excessive run-off and potential erosion. Road and planning layouts should also reflect the topography of an area, to enable integrated stormwater design and management.
- The commercial (and aesthetic) value of different sections of a development area is also frequently derived from different topographical characteristics.

2.5.2 Geology, Soils and Groundwater

A good understanding of the geology, soil and groundwater conditions is an important factor in assessing the infiltration potential of the site. The following factors should be considered:

- Soil types affect surface permeability and hence rate of runoff.
- The mapping of geology and soils will indicate areas of potential groundwater recharge.
- Geology and soils influence the potential for erosion to occur.

- Soil types should be identified, along with the characteristics of the different soils, such as levels of infiltration, permeability and their water-bearing capacity.
- The presence of contaminated soils, which may pose a threat to surface and groundwater quality should be identified and plotted.
- Areas of high groundwater levels can limit the possibilities and/or desirability of groundwater recharge and filtration methods. It should be noted that large-scale removal of certain vegetation types, such as Port Jackson (*Acacia saligna*) and Bluegums (*Eucalyptus sp*.), that consume large volumes of water, might significantly raise groundwater levels.
- Need to determine seasonal and longer term trends in groundwater level fluctuation (City of Cape Town, 2002 (in draft))
- Groundwater information available in the CMA
- Soil types indicate the likely occurrence of particular plant communities, some of which may play a role in the stormwater management plan.
- Assessing soils can also indicate the presence of both existing and even historic wetlands.
- Seasonal variation of groundwater levels should be taken into account.
- The geology and soils of a site will inform the feasibility of different locations for stormwater treatment areas and the potential for groundwater recharge.
- Different habitats (some with high conservation value) are associated with specific geological features and soils.

Determining Groundwater Levels

In the absence of sufficient documented groundwater information, the seasonal and long-term ground water fluctuations should be projected, based on the hydrological, geological and climatic information available.

2.5.3 Climate

The following climatic factors should be considered:

- Storm rainfall parameters are major design factors and must be carefully determined (Refer to Annexure E - Modeling Tools, Techniques And Parameters)
- The general climatic characteristics of an area will also impact on the site and stormwater systems implemented, ie whether the site is generally waterlogged or dry and if evaporation levels are high or low.
- Microclimate conditions can inform the spatial layout of water treatment and attenuation, particularly those associated with specific planting and multifunctional uses.

2.5.4 Hydrology

It is essential, for successful, sustainable and integrated stormwater management, that the existing and/or natural hydrological response and functions of the site are understood. The following factors should be considered:

- The natural drainage that was characteristic of the development area, to the extent that this is possible, should be determined and both the irreversible as well as less permanent changes that have taken place should be identified.
- The hydrology of the development area is a function of much of the other data, which is described under the Site Analysis section.

Tools for quantifying storm runoff quantity and quality are dealt with in Annexure E - Modeling Tools, Techniques And Parameters on page 74.

2.5.5 Natural Ecosystems, Flora and Fauna

The site should be assessed in terms of the natural ecosystems and habitat types that it supports. The following factors should be considered:

- Conservation (or improvement) of bio-diversity and ecosystem function must be one of the objectives of a management plan, as required by policies such as IMEP.
- Some habitats are afforded protection by existing legislation and guideline (e.g. wetlands; buffers around rivers and wetlands)
- Where the site intercepts natural corridors of movement between ecologically important areas, stormwater management should seek to retain or recreate such corridors.
- Endangered or threatened vegetation, animals and/or habitats should be identified and their opportunities and constraints for stormwater management assessed.
- Vegetation and animals that have roles or functions that can improve water quality, amelioration and/or infiltration should be identified, and their natural status and integrity determined.
- Healthy, diverse and/or relatively undisturbed natural systems should be identified and assessed in terms of their habitat integrity and importance (environmentally, socially and culturally), and, wherever possible, be accommodated within the future planning and development of the site.
- The presence of invasive alien animals (e.g. fish, birds) or plants should be discouraged from any developments. Alien flora or fauna associated with habitats created or maintained for the management of stormwater from a site should not be allowed to pass into any downstream or associated water bodies.

2.5.6 Ecological Characteristics of Freshwater Ecosystems

The occurrence of rivers, streams or other watercourses on the site should be identified. And the habitat integrity of each should be determined. The following ecological and ecosystem factors should be considered:

- The floodplains and ecological buffers (Annexure B) that relate to the site should be determined at an early stage in order to establish the broad development planning, and specific stormwater, implications they have for the site.
- The presence of wetlands within the development site should be red flagged, due to their global and nationally threatened status. Protection is accorded by certain policies and legislation. They also may play a useful role in natural hydrological functioning, with potential for integration in an integrated stormwater management plan (Refer Annexure C - Significance of Wetlands in Stormwater Planning on Page 54).
- The stormwater discharge and receiving capacity of rivers, channels and drainage courses should be determined to establish the levels of integration of the natural and proposed stormwater management systems.
- The use of these linear elements should form part of an integrated public open space and stormwater system, and promote the multifunctional use of space.
- Floodplains and ecological buffers provide open space systems within which the more space-consuming “soft technologies” of stormwater management can be accommodated, without posing a conflict with development pressures on land.
- Development sites that do not have floodplains and ecological buffers within the area should consider integrating a public open space system with an overland escape route for an extreme storm event, to maximise the opportunity for habitat corridors.
- Where ecologically important wetlands or rivers are recipients of stormwater discharge, the quality and quantity of stormwater discharges into such systems should be regulated to minimise downstream impacts. Cognisance should be taken of cumulative impacts to water bodies occurring, as a result of discharge from several

sources. (Refer to the DWAF Water Quality Guidelines listed in Annexure A - Acts, Regulations, Policies and other Relevant Documents on Page 47)

2.5.7 Cultural and Historical Landscapes and Archaeological Sites

Areas, routes, vegetation and landmarks that have a cultural and/or historical use or significance should be identified. Development and stormwater planning should avoid disturbing these areas where possible. Where possible they should generally be incorporated within the public open space of a development. This contributes a further function to the public open space system, and should be integrated into a network of public open space.

2.5.8 Development Requirements

The public open space and pedestrian access requirements of a development should be incorporated into the stormwater management planning of the site. The integration of public open space and access requirements with the spatial requirements of stormwater management not only reduces the conflict of pressure on land, but also enables the amalgamation of maintenance requirements, and maximises the use of resources.

The following factors should be considered:

- Land use planning should be done in relation to the natural context and characteristics of the site. The appropriate placement of land uses will enhance the multi-functionality of the stormwater systems and their use as an amenity by residents in the area.
- Innovative opportunities exist for future the stormwater management system to link-up and add value to educational initiatives (outdoor classroom), ownership (friends groups adopting the system), and water saving (re-use of stormwater/treated effluent for irrigation). These opportunities are also area specific need to be identified up front, rather than as nice to have after thought.
- The need for a safe environment must be taken into account (e.g. avoid of potential hiding places for criminal elements; do not create unnecessary hazards in the selection of stormwater management options).
- The cost of stormwater implementation, management and maintenance, as well as flood risk, can be greatly reduced by identifying, retaining and enhancing the natural areas along which runoff and natural habitat retain ecological integrity. The advantages of this approach are not limited to stormwater, but can increase the visual, amenity and ecological value of a development.

2.5.9 Ownership Opportunities and Constraints

A clear distinction should be made between public and privately owned land. The following factors should be considered:

- As a principle, stormwater should as far as possible be accommodated within public open areas or spaces under common ownership.
- Servitudes should always be registered in the favour of the controlling authority to ensure effective management and access at all times.
- Public open space used in the stormwater systems should be clearly demarcated to ensure that the stormwater functions are apparent and to enable monitoring and policing.
- Early identification of land ownership in potential stormwater treatment or conveyance areas outside of the development area will assist in identifying constraints, in some cases, as well as opportunities to provide additional space for stormwater management, through *inter alia* land swaps, use of public open space and local authority land.

- Servitudes and public rights of way can also be incorporated into the stormwater systems, for example use of road reserves for conveyance and/or infiltration, but these elements should not be critical to performance, as they may be relinquished for later development purposes (road widening, etc.). The servitudes may not however be relinquished if they are embodied in the title deeds, without legally altering or deleting the servitude which would require the local authority consent.

2.5.10 Spatial Opportunities and Constraints

The amount of appropriate public space that is available for stormwater management should be identified at an early stage in project planning, since this will largely dictate the extent to which different stormwater design elements are feasible in a development.

Where site analyses show that spatial constraints are likely to dictate stormwater design, attention should focus on identification of spatial opportunities outside of the development area (e.g. areas of public open space, local authority land; schools and other areas of open space), that might lend themselves, through negotiation, to more ecologically desirable stormwater design options.

2.5.11 Surrounding Developments

Stormwater management design options should take cognisance of developments in the upstream catchment that are likely to impact on the timing, quality or quantity of stormwater generated upstream of the development area. Identification of these issues will highlight potential problem areas in stormwater management. The following factors should be considered:

- It is important that site planning be done in context with the adjacent properties to ensure effective stormwater systems and integrated stormwater corridors. Sufficient retention facilities should therefore be planned and provided on site as part of an integrated open space system.
- Clarity on the stormwater management principles employed in upstream developments should also be obtained so that anticipated stormwater runoff from these areas can be quantified.
- The rate of growth and anticipated land-use of surrounding developments and areas that discharge onto the development site should also be taken into account to determine the future pressures on the stormwater systems.
- The general capacity of the stormwater systems of surrounding developments that lie downstream of the site, and the current rate of growth and pressure on these systems should be taken into account during site planning and design. Failure of systems downstream can cause failure and flooding upstream. As a principle, the post development runoff should not exceed the predevelopment runoff.

2.6 Maintenance Capacity

Before stormwater design options are considered in any detail, it is vital that the developer has a clear indication of the practical maintenance capacity, in terms of time, personnel and finance, of the final managing authority for the stormwater system. Aesthetically or ecologically complex designs that owe their sustainability to regular maintenance inputs on a permanent basis will fail in the medium to long term, if there is no capacity for ongoing and adequate maintenance.

Similarly, where public expectations centre on aesthetically pleasing design, adequate allowance must be made for basic maintenance activities, such as removal of litter or alien clearing. If this is neglected, the project as a whole may be deemed a failure in the eyes of the public. This may have ramifications for the rest of the project in question, as well as future projects requiring public buy-in and support.

2.7 Site Planning

2.7.1 Site Analysis

As part of the site analysis process, it is suggested that the developer prepare the following items to guide in the formulation of a stormwater management plan:

a) A checklist for easy identification of aspects to be considered as they emerge from the site analysis (Section 2.5 above)

- Topography
- Geology and Soils
- Groundwater
- Climate
- Hydrology
- Natural Ecosystems (flora and fauna)
- Cultural and Historical Landscapes and Archaeological Sites
- Development Requirements
- Ownership Opportunities and Constraints
- Spatial Opportunities and Constraints
- Surrounding Developments
- Maintenance Capacity

b) A Site Analysis Plan that maps out the informants that have implications for stormwater management.

2.7.2 Conceptual Layout

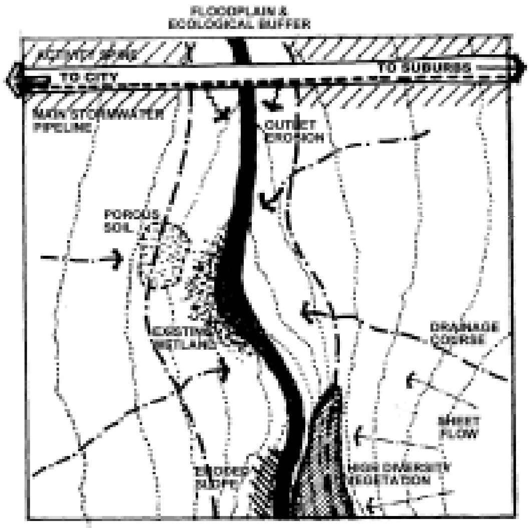
A general concept plan for the site layout should be developed, taking into account the legal and physical aspects of the site as developed through the site analysis process. This plan should indicate the location of different land-uses. This will influence the stormwater management conditions, and reflect some of the spatial requirements of the system.

2.7.3 Conceptual Stormwater Planning

The information gathered concerning the site and relevant legislation and policy documents as summarised in the Site Analysis Plan and Conceptual Layout Plan will then be used to draw up a Conceptual Stormwater Plan. This plan will indicate the major flow routes, natural features that will form a part of the stormwater system and areas, which are to be set aside for elements of the stormwater system such as attenuation ponds. It will then be modified and refined in the design phase.

Two examples of this process are presented in Table 2-4 and Figure 4 as well as Table 2-5 and Figure 5 on the following pages.

Table 2-4 : Site (A) – Planning Example

<table>
<tr>
<td>


</td>
<td>
In the Site Analysis Plan opposite, the river and topography provide substantial informants (opportunities and constraints) for planning. The floodplain and ecological buffers have legal, spatial and ecological implications for site development and stormwater management.

Existing infrastructure, and spatial development proposals will inform land use location and characteristics, and will provide an indication of future loading/capacity requirements.

Existing drainage courses indicate the existing characteristics of the run-off and should be incorporated into integrated site design.

Significant natural ecosystems should be identified, along with their implications for planning and stormwater management. And areas of existing or potential problems, such as erosion, should also be noted.
</td>
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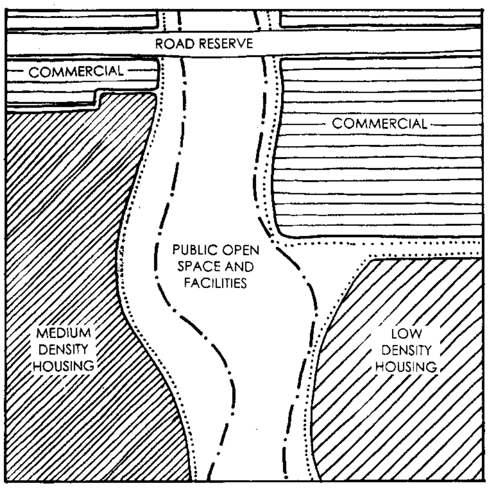

</td>
<td>
The Conceptual Layout will inform the character of development and subsequent implications for stormwater management.

Similarly, stormwater management requirements, and constraints may have implications on land use, densities and layout.
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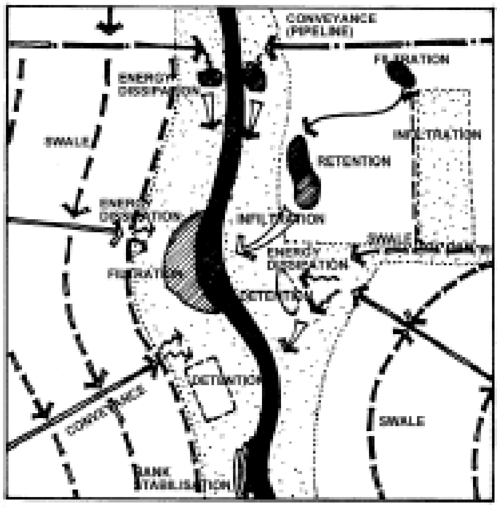
<td>


</td>
<td>
The development of a Conceptual Stormwater Layout should be an iterative process, informing and informed by the site analysis and conceptual layout of the development.

The conceptual layout should also accommodate storm events and allow for overland flow.
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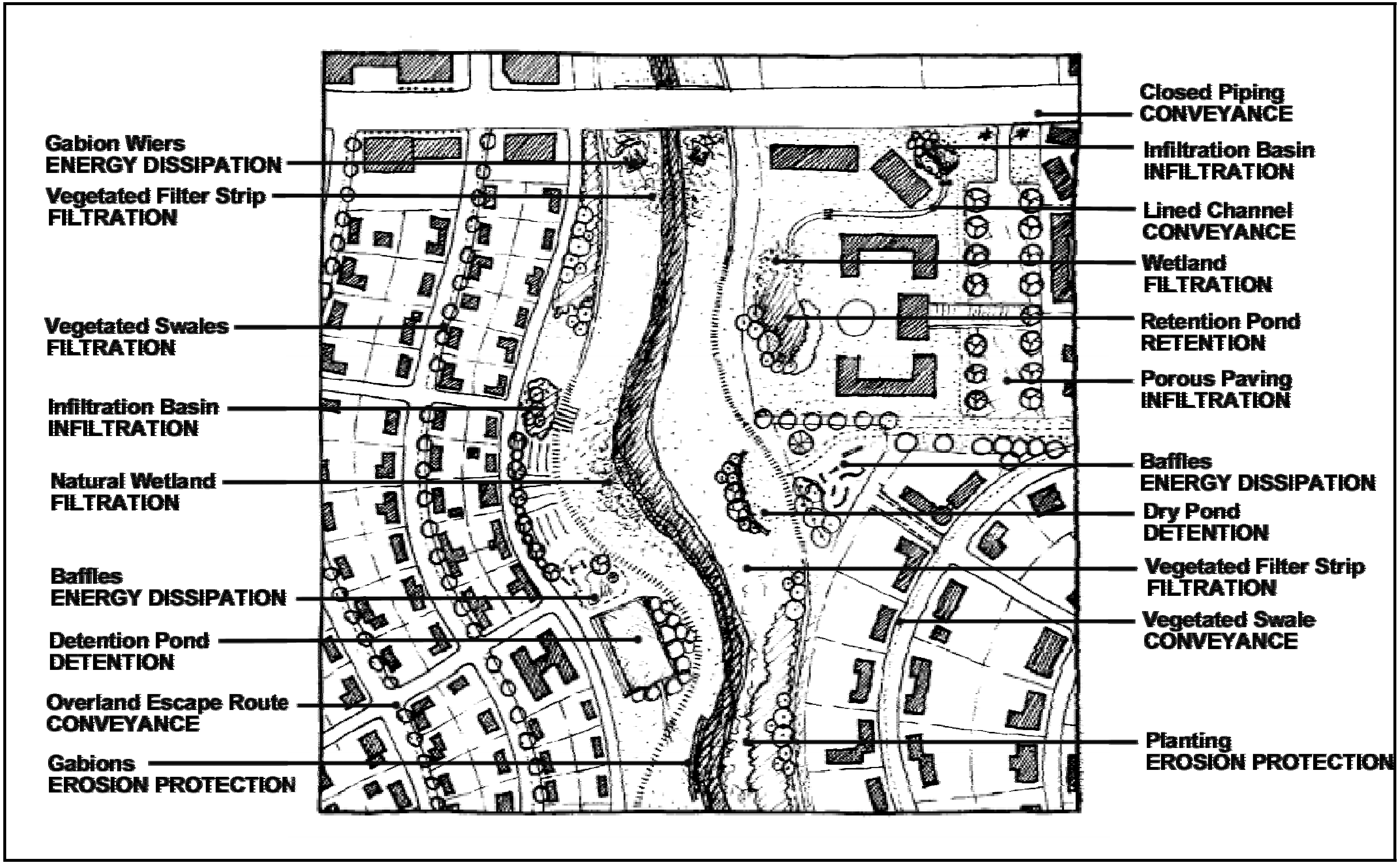
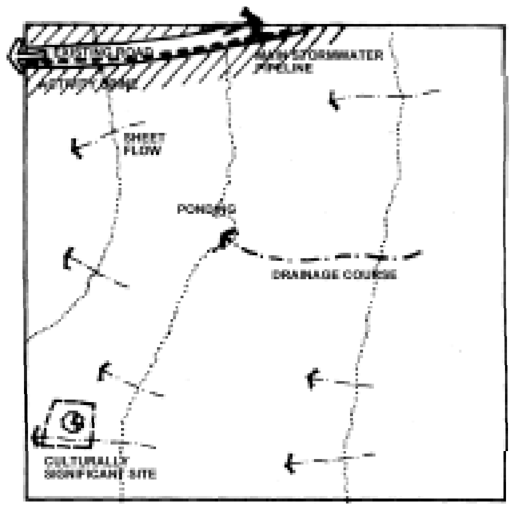
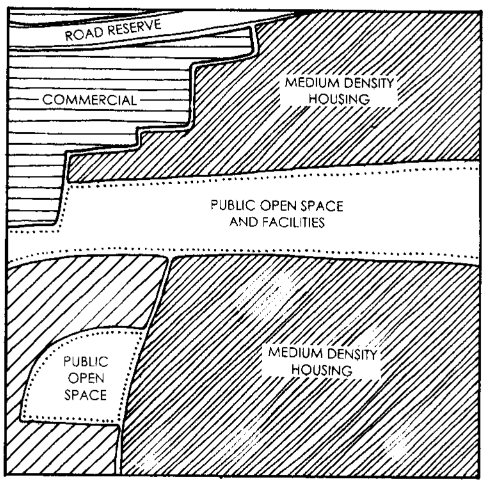
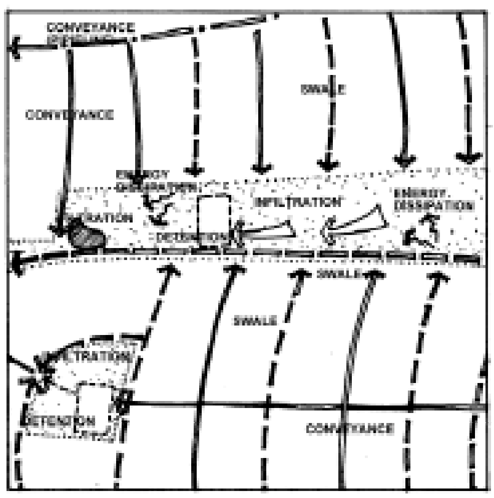


Figure 4 : Site A – Layout Plan incorporating Conceptual Stormwater Management Plan

Table 2-5 : Site (B) – Planning Example

	In the **Site Analysis Plan** opposite shows a relatively flat site with undefined drainage patterns (characteristic of many areas of the CMA), and has inherently different implications compared to Site A. For sites that are not directly related to a river corridor or floodplain, there still remains the potential to integrate the linear nature of a public open space system with stormwater management planning. Determining the sensitivity and capacity of the receiving body and the implications this has on stormwater planning remains applicable. Existing drainage courses, even if relatively undefined, do indicate the existing characteristics of runoff and have implications for stormwater management. They also indicate the importance of groundwater levels and soil characteristics on the site.
	Land use characteristics and intensities should respond to the landscape tolerances of the site and be reflected in the **Conceptual Layout**. Even on relatively flat sites, it is crucial that planning relate to the topography in terms of land use and road layout to enhance the stormwater functioning on the site.
	The iterative process of developing **a Conceptual Stormwater Layout** should take into account not only the spatial implications of site analysis and layout, but also the legal, social and economic implications.

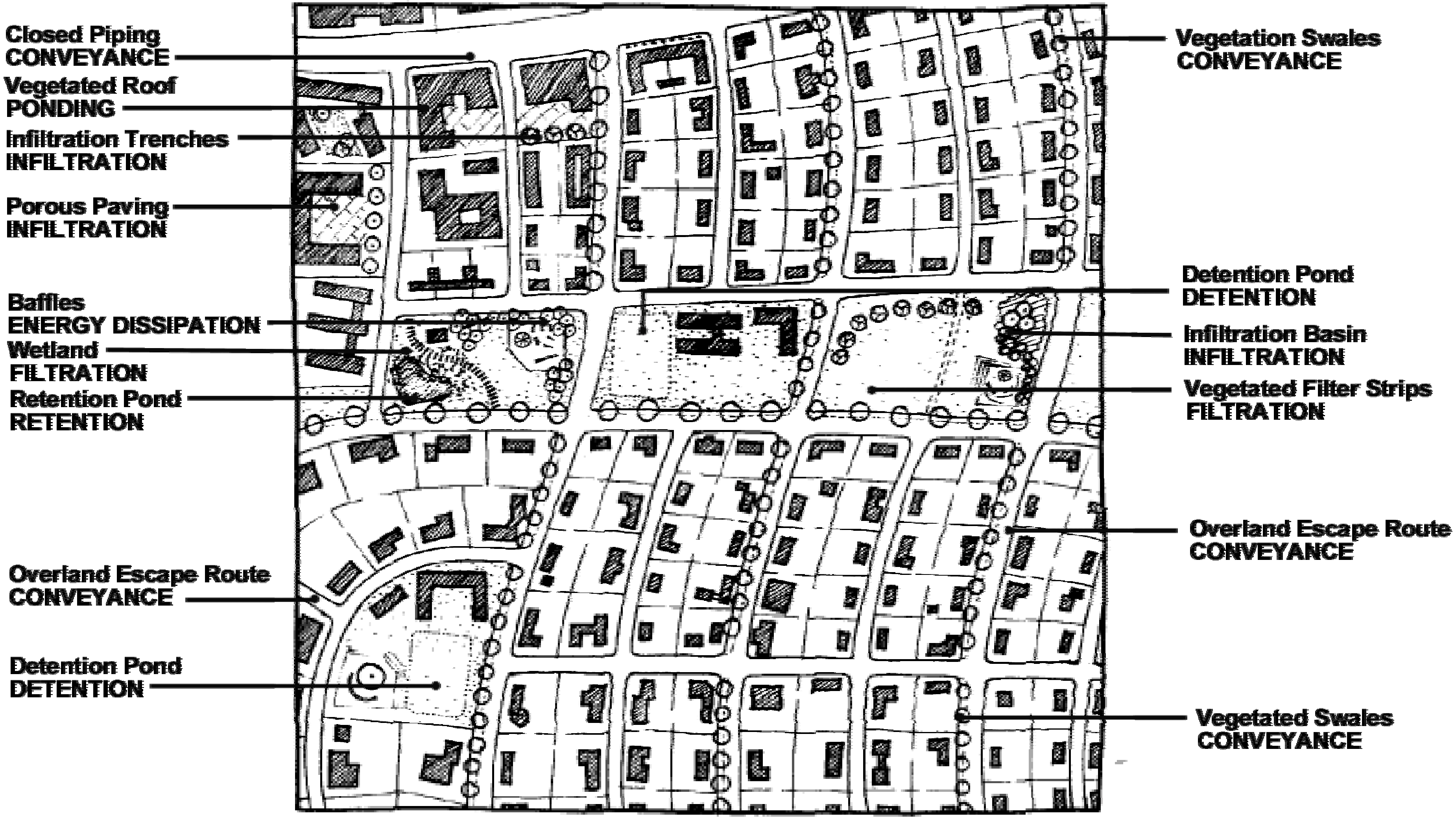


Figure 5 : Site B – Site Layout Plan incorporating Conceptual Stormwater Management Plan

3. Design

Once the planning phase process has developed a conceptual stormwater plan for the site, there is need for a design phase that develops site and context specific design of the stormwater management system. This section provides design guidelines to inform appropriate stormwater design for a development.

The key variables to be evaluated and managed are water quantity (volume and peak flow) and water quality. Suggested calculation methods and parameters are described in Annexure E - Modeling Tools, Techniques And Parameters on Page 74. Construction, operation and maintenance implications are dealt with in Sections 4 and 5.

3.1 System Design Objectives

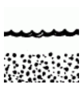
Various stormwater management facilities and techniques are presented and evaluated in terms of engineering, ecological, health, safety, aesthetic, social, construction and maintenance design objectives. The system design objectives listed in Table 3-1 below, should form the basis for the selection of appropriate design options.

Important

The developer would need to demonstrate, through submission of appropriate stormwater designs, the extent to which the proposed development would meet these system design objectives.

Monitoring requirements may be imposed on the development to measure long term performance and compliance.

Table 3-1 : Stormwater System Design Objectives

Symbol	Description
	**Flood Protection** Protect vulnerable areas against flooding, and locate development in areas which are not prone to flooding.
	**Volume** Minimise changes in the volume of runoff from the development. This will provide protection of human safety and property, as well as ecological resources.
	**Downstream Effects** Maintain the natural channel morphology and geometry of the receiving water body; where the system has been altered, the downstream effects and associated physical and ecological changes should be minimised.
	**Water Quality** Minimise negative impacts on water quality and improving, where possible, existing stormwater quality.
	**Velocity** Minimise the velocity of stormwater runoff and the likelihood of erosion of the catchment, including receiving water bodies.
	**Sedimentation** Minimise sedimentation of natural ecosystems by addressing erosion in the catchment or by trapping sediment. This will protect the natural ecosystems and help to prevent blockage of stormwater systems.
	**Peak** Minimise peak flows during storm events in order to mimic the natural pre-development condition.
	**Natural Habitats** Maximise the opportunities for the preservation, creation and/or rehabilitation of wetland and riverine habitats, by incorporating natural rivers/wetland into stormwater design where appropriate.
	**Multifunctionality** Maximise the use of resources in stormwater management by implementing multifunctional and dual-purpose strategies wherever possible.
	**Sustainability** Maximise the use of resources in stormwater management by considering both the long and short-term costs and implications of available design strategies. Strategies must be appropriate to their context, and be properly implemented and maintained.
	**Health & Safety** Minimise the risk of stormwater design and structures to humans and animals, through the appropriate choice of strategies and structures.
	**Maintenance** Design in such a way that the system will be effectively maintained and functional, and that the local community will appreciates its function, and where possible benefits in other ways, such as through creation of amenities.

3.2 Appropriate Stormwater Management Facilities and Techniques

Various facilities and techniques that may be utilised to manage stormwater runoff from the development have been grouped by generic function as follows:

a) Conveyance

Use of natural or artificial channels, natural or artificial wetlands or pipes and culverts for stormwater conveyance as well as the prevention of erosion.

b) Ponding

A form of flow rate control, this term usually refers to methods of infiltrating runoff into the ground or otherwise holding it back for a period, reducing peak runoff, contributing to extended base-flows, improving water quality and creating natural habitats.

c) Infiltration

Reduces runoff volume and contributes to groundwater recharge.

d) Filtration and Treatment

Water quality may be improved by a number of means including ponding and filtration and to a lesser extent conveyance facilities and techniques. By carrying out this function as close to source as possible impact on stormwater systems and habitat functioning may be minimised.

Table 3-2 below provides a quick reference index to locating possible facility options and techniques within the document. The tabulations that follow provide a brief description and appropriate application of the stormwater management option with a diagram depicting an example of its use. More in-depth information to assist in design is provided in Annexure F - Stormwater Management Facilities and Techniques on commencing on Page 78.

The effectiveness of various facility options and techniques presented in the following sections have been rated as follows:

H - High
M - Moderate
L - Low

Table 3-2 : Quick Reference Index to Stormwater Management Facility and Technique Options

Generic Function	Ref.	Option	Main Page	Annex. Page
Conveyance	**C 1**	Pipes and culverts	24	79
	C 2	Lined artificial channels	24	80
	C 3	Unlined artificial channels	24	83
	C 4	Unlined sheet flow	25	84
	C 5	Natural channels	25	85
	C 6	Gabion baskets and mattresses	25	87
	C 7	Energy dissipaters	26	88
	C 8	Planting	26	90
Ponding	**P 1**	Dry ponds	27	92
	P 2	Wet ponds	28	94
	P 3	Rooftop runoff management	28	97
Infiltration	**I 1**	French drain	29	99
	I 2	Hard porous surfaces – asphalt/concrete	30	100
	I 3	Hard porous surfaces – paving blocks	30	101
	I 4	Infiltration trenches	30	102
	I 5	Infiltration basins	31	103
	I 6	Swales	31	105
	I 7	Checks dams	31	106
Filtration and Treatment	**F 1**	Vegetated filter strips	33	108
	F 2	Natural and artificial wetlands	33	109
	F 3	Litter traps	34	111
	F 4	Sediment traps	34	112
	F 5	Oil separator	34	114

3.2.1 Conveyance

Some designs have in the past only applied “hard” stormwater conveyance techniques that facilitate the rapid and efficient removal of stormwater from a development, with little regard for other aspects such as improving water quality en route, providing social and aesthetic amenities such as water corridors, rehabilitation or creation of wetland and riverine habitat.

In this section, these “hard” type techniques are assessed in terms of their ecological and other (e.g. social, health and safety) implications, and a number of additional approaches to stormwater conveyance are also evaluated.

In general terms, the developer when selecting designs for stormwater conveyance should consider the following aspects:

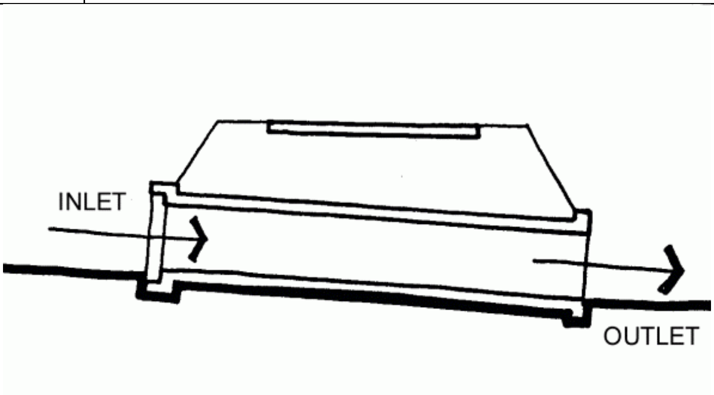
- The slopes of the development area – stormwater design on steep slopes will need to incorporate methods for reducing erosion.

- Soil type and stability in the development area – the former will affect infiltration rates, as well as the potential for establishment of different kinds of plant communities in unlined conveyance structures; the latter will affect the degree of stabilisation that may be necessary.
- Seasonal changes in water table height – groundwater should not be exposed by unlined conveyance structures during summer, as this will promote drainage of the groundwater resource; infiltration capacity will be reduced if the water table is above an unlined channel base during winter.
- The cost of land – where land is at a premium, use of large areas for stormwater conveyance may be prohibitively expensive. Nevertheless, the increase in aesthetic and other forms of amenity value that may be gained from sensitive and imaginative stormwater designs may make the use of such space more economically feasible.
- The anticipated quality of stormwater runoff – severely polluted water may constitute a health hazard to downstream residents and an ecological hazard to downstream aquatic ecosystems. Consideration should be given to the conveyance of such water off-site, and directly to water purification works, at least during low-flow periods when water quality is likely to be most impacted.
- Presence of natural water bodies that would lend themselves to the conveyance of stormwater - habitat integrity, priority ranking and/or ecological importance and sensitivity of the system should be considered – sensitive systems should be protected from, rather than incorporated into stormwater conveyance design.
- The volume of expected stormwater runoff, during within-year flood events, and during larger storm events.
- The availability of open space for stormwater conveyance – large areas of open public or private space often lend themselves to the creation of wide, artificial waterways, which may also have ecological, recreational and aesthetic value in addition to providing a stormwater function.
- The presence of litter and sediment which would result in blockages.

Erosion is unfortunately often associated with development as areas become disturbed or as stormwater runoff is concentrated at outlets. In order avoid these problems, options such as stabilisation, energy dissipation and the design of stormwater management systems, which do not concentrate flows, are recommended. A number of structures incorporated into stormwater design play a role in the dissipation of energy required to prevent erosion at outlet and inlet points, and at various points in different conveyance structures. This section provides brief commentary on the ecological, engineering and aesthetic function of each of these.

Soil which has been disturbed or from which the vegetation has been removed, should be stabilised to prevent erosion due to wind or runoff. Such erosion could cause the stormwater system to block, thereby resulting in the flooding of properties. Stabilisation would be short term, for the duration of the construction phase, followed by long term on completion of construction. Particular care should be taken of areas where development will not take place immediately on completion of the construction phase, e.g. wide verges in the road reserve which have been acquired to accommodate future road widening, or erven reserved for unspecified local authority use.

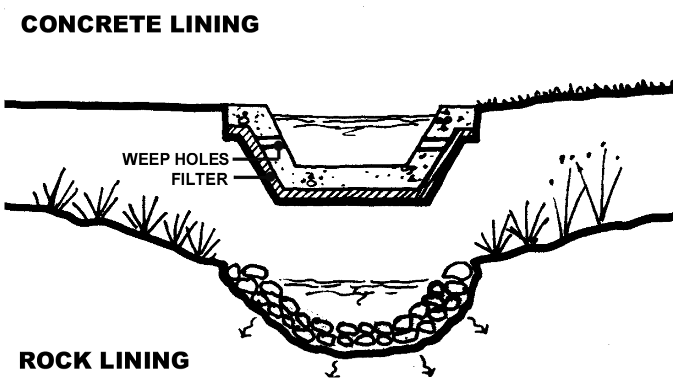
C 1	**Pipes and Culverts**	Refer Page 79 for additional details
Application	Stormwater reticulation in urban developments normally for conveyance of minor storm runoff and for major system where open channel flow is not practical; Road crossings.	



Effectiveness Rating

	H		M
	L		L
	L		L
	L		H
	H		H
	L		H

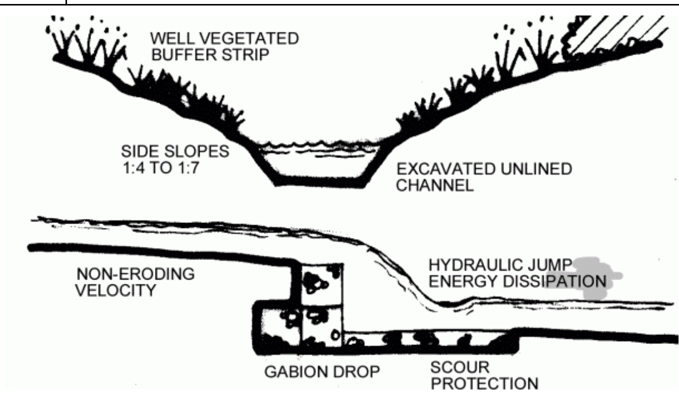
C 2	**Lined Artificial Channels (Concrete or Rock)**	Refer Page 80 for additional details
Application	For conveyance of runoff where severe space restrictions exist and where properties must be protected from flooding.	



Effectiveness Rating

	H		L
	M		L-M
	L-M		M
	M		H
	H		M
	L-M		H

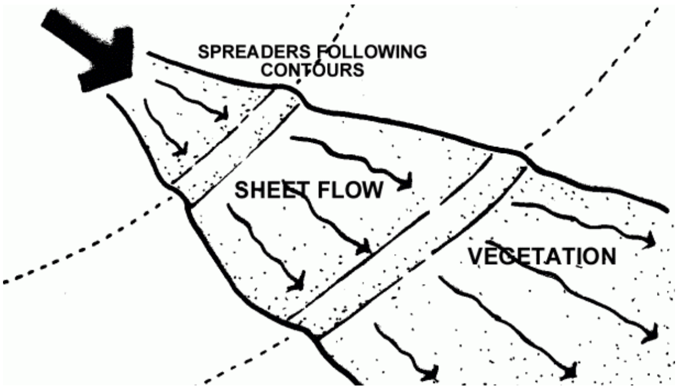
C 3	**Unlined Artificial Channels**	Refer Page 83 for additional details
Application	For conveyance of runoff where properties must be protected from flooding and where space restrictions are not severe.	



Effectiveness Rating

	H		M
	M		H-M
	H-M		H
	M-H		H
	H		M
	M		M

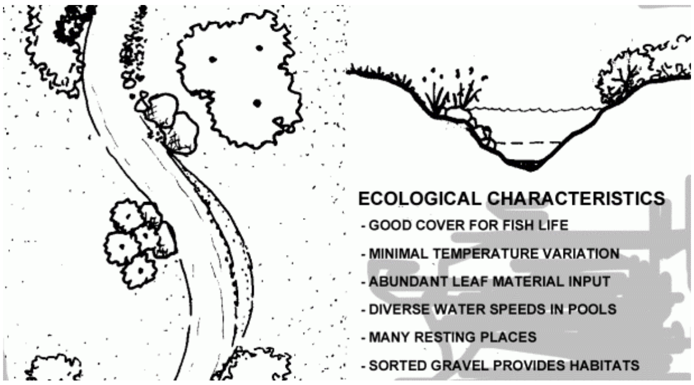
C 4	**Unlined Sheet Flow**	Refer Page 84 for additional details
Application	For conveyance of runoff in areas where wide extensive wetlands would have been the norm and space restrictions are not severe.	



Effectiveness Rating

	L		M
	M		M-H
	M-H		L
	H		M
	H		H
	M		M

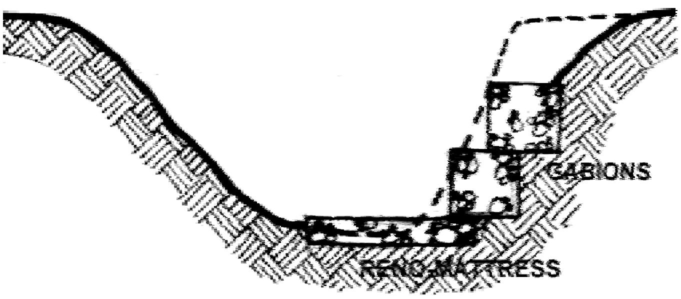
C 5	**Natural Channels**	Refer Page 85 for additional details
Application	Natural channels should be retained for stormwater drainage as a matter of course. Measures may be required to protect their integrity and function.	



Effectiveness Rating

	M		M
	M		L-H
	L-H		H
	H-M		H
	M		M
	M		M

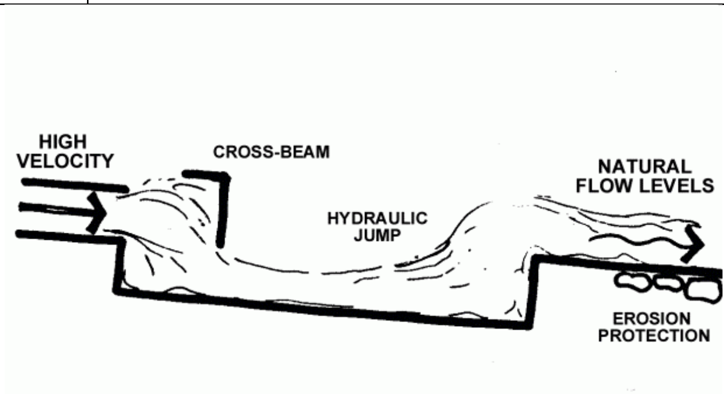
C 6	**Gabion Baskets and Mattresses**	Refer Page 87 for additional details
Application	Erosion protection, bank stabilisation, energy dissipation, weirs and earth retention.	



Effectiveness Rating

	H		M
	L-M		L-M
	M		H
	L-M		H
	H		M
	L		H

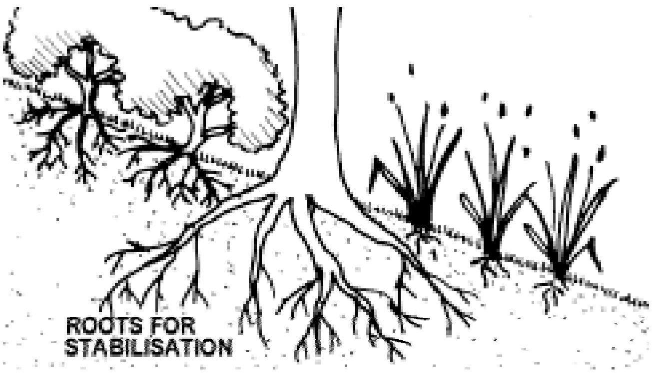
C 7	**Energy Dissipaters**	Refer Page 88 for additional details
Application	Points where high water velocity will occur, such as pipe and culvert outfalls, dam spillways and steeply sloping channels.	



Effectiveness Rating

	H		L
	L		M
	H		L
	L		H
	H		M
	M		M

C 8	**Planting**	Refer Page 90 for additional details
Application	Can enhance slope stabilisation and improve dissipation and spreading of flows downstream of an inlet/outlet structure (e.g. in a retention dam)	



Effectiveness Rating

	M		M
	H		M
	H		H
	H		H
	M		H
	L		H

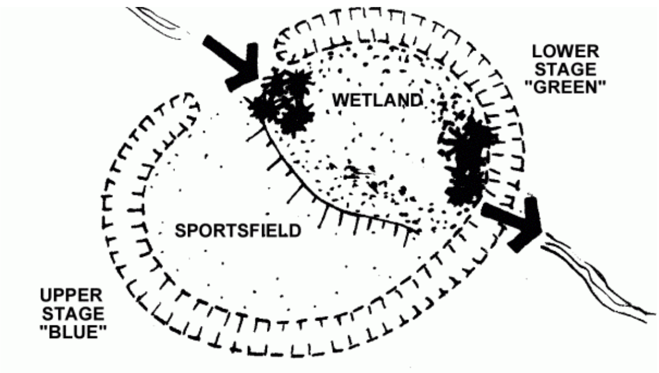
3.2.2 Ponding

Ponding is an important component of stormwater management, in countering the effects of urban development such as increased runoff (peak and volume) and diminished water quality. Ponding utilizes temporary storage of stormwater runoff for periods ranging from a few hours to a day or more. This is achieved by providing an outlet or outlets with a capacity which is smaller than the anticipated flow peaks, thus aiming to restore as far as possible the natural flow regime of the watercourse and also facilitating groundwater recharge. In some situations, in highly pervious soils, it may be possible to completely retain the stormwater runoff and only provide an emergency overflow. Such ponds could be termed “retention ponds”. Detention ponds may be “dry” – no water retained between storm events, or “wet” – permanent water body is retained.

Developers wishing to make use of ponding should take cognisance of the following:

- The purpose of these ponds in reducing runoff is to mimic nature (pre-development conditions) as far as possible over the full range of anticipated flows and not just a particular recurrence interval.
- In larger catchments the placement and design of ponds must be taken with cognisance of stormwater management throughout the catchment.
- Seasonal changes in water table height – ideally, ponding structures should not intercept groundwater, particularly during the low flow season. Where interception does occur, the effects of seepage on the functioning of the facility need to be investigated.
- Wet ponds should not be specified in areas where they might be utilised for swimming.

P 1	**Dry Ponds**	Refer Page 92 for additional details
Application	These structures hold water for a few hours to a day only, but may be used in combination with retention and infiltration facilities. Their purpose is to temporarily store stormwater runoff in order to restrict outflows to predetermined levels to reduce local and downstream flooding and to promote the settlement of pollutants.	



Effectiveness Rating

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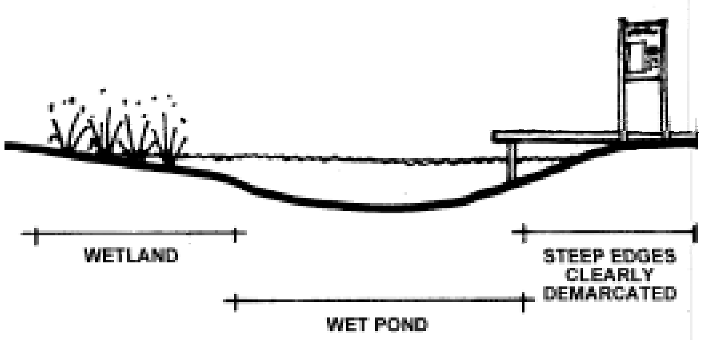
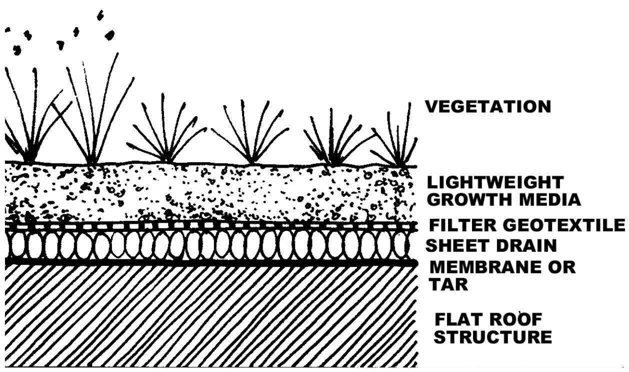
	H		L-M
	M-H		H
	M		H
	M		M
	M		M

P 2	**Wet Ponds**	Refer Page 94 for additional details
Application	The application is similar to that for dry ponds except that retention of a permanent water body also permits water quality treatment, through removal of sediments and reduction of pollutants (e.g. by exposure to sunlight and absorption / binding of nutrients /other pollutants by plants and soil particles.	



Effectiveness Rating			
	H		H
	H		M-H
	H		M
	H		H
	M		L-M
	H		M

P 3	**Rooftop Runoff Management**	Refer Page 97 for additional details
Application	Highly urbanised settings where the use of other facilities or techniques is limited – can effectively increase time of concentration and decrease runoff peaks and volumes, and improve water quality.	



Effectiveness Rating			
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	M		M
	M		H
	M		H
	M		H
	L		L

3.2.3 Infiltration

Infiltration devices are designed to reduce the amount of runoff produced and thereby achieve a reduction in the storm runoff volume and peak, to replenish ground water and to enhance water quality. This is achieved by the promotion of infiltration of runoff into porous media and into the soil, to reduce runoff volumes and peaks and to improve water quality.

Designs that rely primarily on infiltration for their successful function need to take cognisance of the following factors:

- Soil permeability – this affects the rate at which infiltration will occur
- Seasonal changes in water table height. It is recommended that at least 0,9m should remain between the working base of the infiltration device and the top of the high water table
- Site topography – infiltration devices are best used on level or gentle (<5%) slopes. Infiltration practices carried out on a steeper slope may result in water seepage from the sub grade to lower areas of the site, thus decreasing the actual amount of infiltration

- Infiltration practices are not recommended for infilled areas, due to the possibility of creating unstable, saturated sub grade.
- The proximity of sensitive groundwater resources including water supply wells will often make the use of infiltration devices unfeasible, particularly where stormwater is likely to be heavily polluted, containing high levels of organic or chemical pollution (e.g. runoff from industrial developments; market gardening areas and nurseries). Infiltration should not be used close to septic tanks.

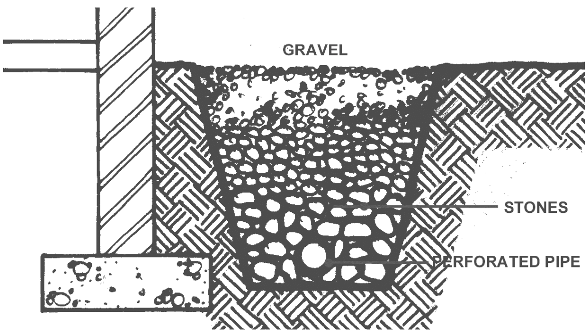
Where one of the intentions of infiltration is to recharge an aquifer, a groundwater specialist must be consulted during the design phase to ensure that stormwater is routed to the aquifer, and does not merely contribute to subsurface flows. This approach could be particularly useful in areas where water supplies rely heavily on abstraction from groundwater resources or where stormwater runoff is likely to be relatively unpolluted.

Sedimentation of infiltration surfaces will reduce the working life of the device. This has implications for both the construction and maintenance phases of such devices. Designs involving infiltration devices should only be brought into effect once sediment associated with the construction period has been stabilised, to prevent premature clogging of system and reduction in service period. This means that other means of temporary detention and sediment trapping will be required during the construction period.

Attention should also be paid to the timing of construction. Phases likely to involve destabilisation of sediments on receiving surfaces should be initiated at the end of the rainy season, and stabilisation methods should be in effect by the start of the next rainy season.

Maintenance costs may be reduced by filtering runoff prior to its entering an infiltration device. The passage of water over vegetated swales or other vegetation buffer areas, or ensuring that runoff passes directly off roofs only, before entering the infiltration area, will increase the working life of the infiltration device.

I 1	**French Drain**	Refer Page 99 for additional details
Application	Provides infiltration at localised scale, typically around individual buildings, and reduces flood volume and rate of runoff; to a lesser extent – some water quality improvement is usually associated with infiltration.	



Effectiveness Rating

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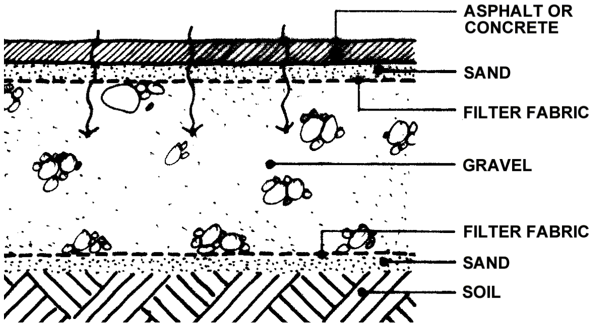
	L		L
	M		M
	L- M		H
	L		H
	L		H

I 2	Hard Porous Surfaces – Asphalt / Concrete	Refer Page 100 for additional details
Application	Reduces the impact of surface hardening on stormwater runoff by allowing infiltration. Infiltration is associated with a degree of filtration, particularly of sediments. For parking lots, footways, other areas of open space.	



Effectiveness Rating			
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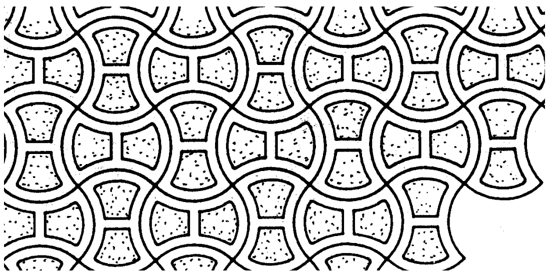
	L-M		H
	M		H
	L		H

I 3	Hard Porous Surfaces – Paving Blocks	Refer Page 101 for additional details
Application	For parking lots, footways, other areas of open space.	



Effectiveness Rating			
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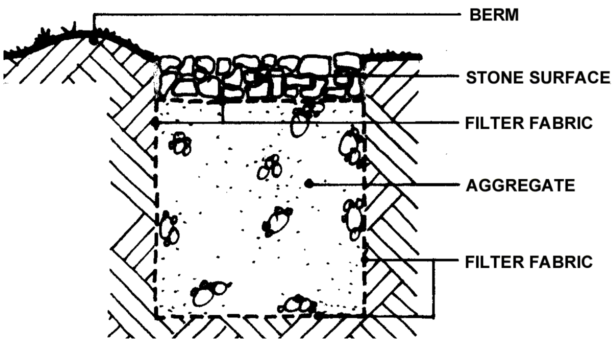
	L-M		H
	L-M		H
	M		H
	L		H

I 4	Trenches	Refer Page 102 for additional details
Application	Generally used on relatively small drainage basins (e.g. residential plots; parking areas).	



Effectiveness Rating			
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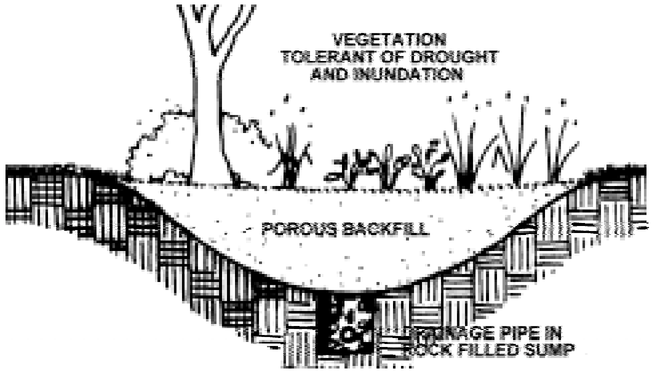
	M		M
	M		M
	L		L

I 5	**Infiltration Basins**	Refer Page 103 for additional details
Application	Temporarily stores surface runoff for a selected design storm; maintains or increases groundwater recharge by infiltration through the bed and sides of the basin.	



Effectiveness Rating			
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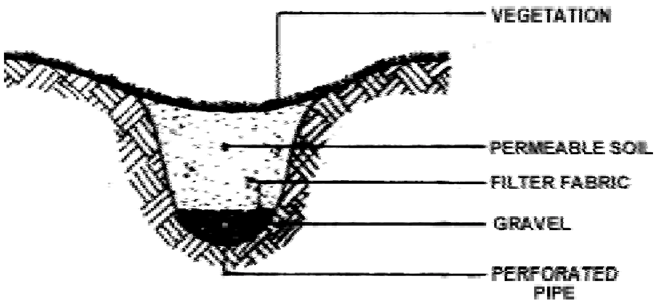
I 6	**Swales**	Refer Page 105 for additional details
Application	Slow flowing grassed channel, which reduces runoff volumes and peaks and traps pollutants.	



Effectiveness Rating			
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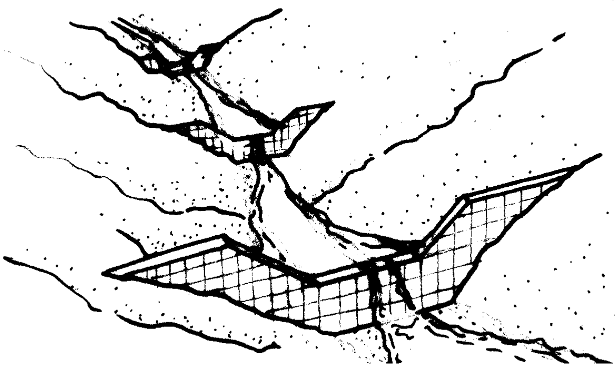
	M		H
	M		H

I 7	**Check Dams**	Refer Page 106 for additional details
Application	Erosion control/sedimentation in steeply sloping channels	



Effectiveness Rating			
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	M		M
	M		L
	L-M		H
	H		H
	H		M

3.2.4 Filtration and Treatment

In addition to structural designs, stormwater management design should also provide for more subtle forms of stormwater control, which allow a reduction in quantity or improvement in quality of stormwater at source, rather than symptomatic management of stormwater produced. This approach should include ongoing education of local residents regarding water demand management principles, the effects of allowing sources of pollution to enter stormwater systems, and the value of adhering to strategic stormwater guidelines at the level of the individual property or residence. Examples include, passing water from gutters onto grassed surfaces, rather than directly into road stormwater drains or minimising areas of impervious surfaces at a development scale.

Residential streets and green open space would ideally be incorporated into stormwater design to enable temporary storage and infiltration, at the same time as providing a visual amenity. Minor streets in a development should be considered as areas for construction of swales and for detention.

As a general principle litter, silt and other pollutants emanating from a catchment should be trapped as close to source as possible. This is of particular importance when the stormwater discharges into a sensitive environment, and where damage may result if the pollutant is not trapped and removed.

Note that although plastic litter is a highly visible and unsightly pollutant, the problems it poses, unless it is such that blockages occur, are usually aesthetic and social, rather than ecological. Excessive plastic pollution may however have indirect negative ecological impacts, in that it contributes to a perception of freshwater systems as neglected, useless and unhealthy, which in turn results in a vicious cycle of neglect, where more harmful pollution of the system (e.g. dumping of organic waste, toxic runoff) is also tolerated.

Filtration of pollutants from stormwater is a vital component of stormwater management, although its prominence in the overall stormwater management plan of a development will depend on the extent to which water quality is likely to be a problem, either within the development area, or to freshwater ecosystems and human users in the catchment downstream.

Pollutants addressed during filtration include: sediment, nutrients, heavy metals, petrol- and oil-based compounds and numerous other pollutant types, depending on land use within the development area and in the upstream catchment. Filtration is best by passage of water across vegetated areas. A degree of filtration (particularly of sediments) does however take place in infiltration systems. Where plants are used to provide filtration, it should be noted that different plant species have different capacities for absorption or assimilation of different pollutants.

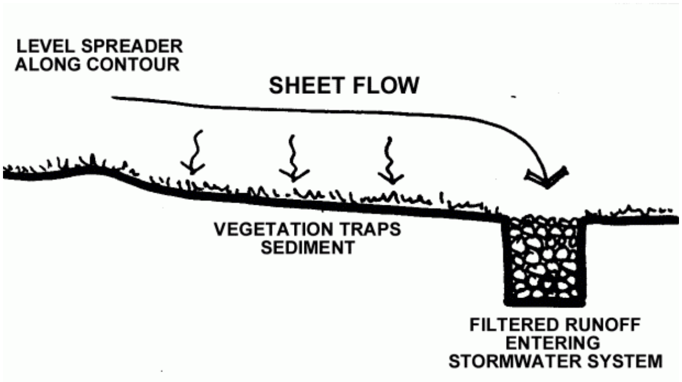
Designs that rely primarily on filtration for their successful function need to take cognisance of the following factors:

- Site topography – filtration is best achieved at very gentle gradients
- Plant species utilised – different species have different filtering capacities, as well as aesthetic qualities
- Soil type – highly porous soils are often more suited to infiltration than filtration systems, and do not always retain sufficient moisture to maintain plant growth; different soils have different
- Stormwater quality and water quality of receiving water body – the degree of filtering that can be realistically expected from a filtering device of a particular size and constitution should be calculated. In some circumstances, water quality in surface effluent may be too poor for treatment to acceptable standards to be a realistic option.

In such cases, and particularly where the natural receiving water body is a system with a high priority rank or conservation importance, consideration should be given to conveying this stormwater for treatment at a waste water treatment facility.

- Seasonal changes in water table height – groundwater should not be exposed by the swale during summer as this will promote drainage of the groundwater resource; filtration capacity will be reduced if water table is above swale base during winter; where high pollution loading of stormwater is anticipated, swale depth should be considerably higher than the high water table level.

F 1	**Vegetated Filter Strips**	Refer Page 108 for additional details
Application	Surrounding infiltration structures Adjacent to all water courses and water bodies Between parking lots and stormwater management structures where drainage is primarily sheet flow	



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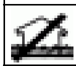
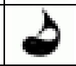
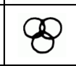
	L		L
	M		L-M
	H		M
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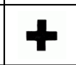
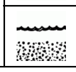
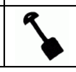
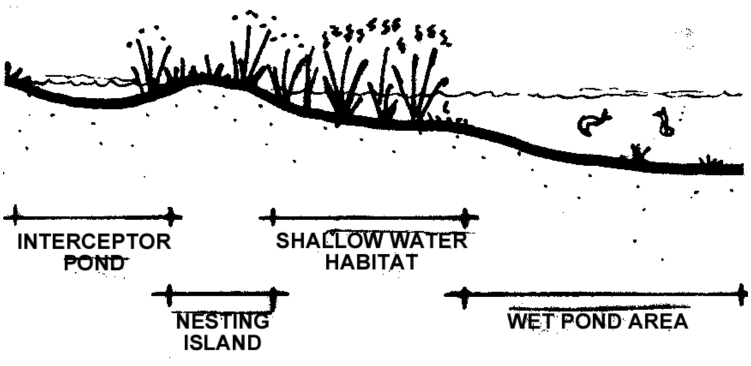
	L		H
	M		H

F 2	**Natural and Artificial Wetlands**	Refer Page 109 for additional details
Application	Effective pollution filter through absorptive and assimilative capacities of wetland plants and their soils. Sedimentation through filtration by plants and spreading out of flows. Retention of water in the wetland reduces stormwater volumes.	



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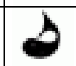
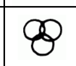
	M		H
	H		H
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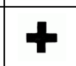
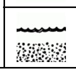
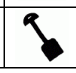
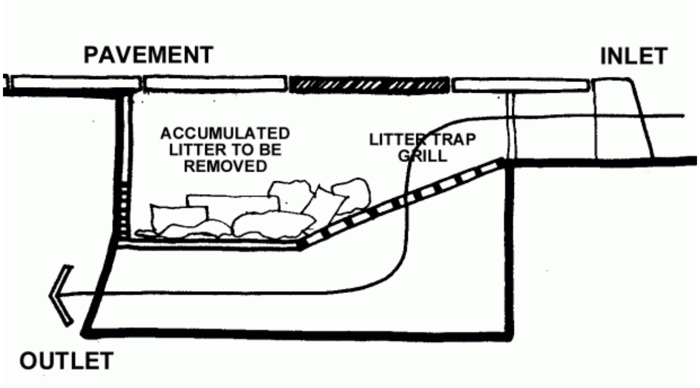
	M		H
	H		M

F 3	**Litter Traps**	Refer Page 111 for additional details
Application	Removal of litter and sediment from urban stormwater systems.	



Effectiveness Rating			
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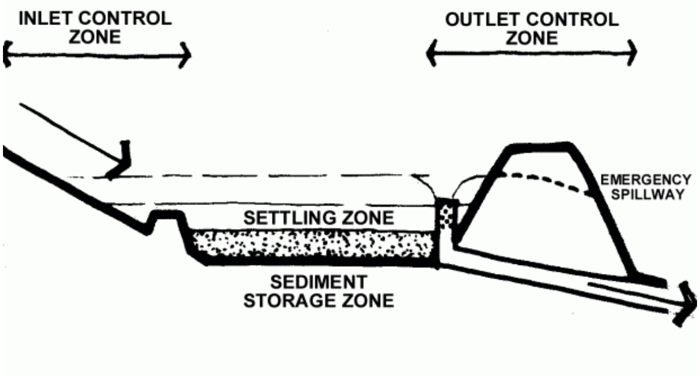
	L		M
	M		L

F 4	**Sediment Traps**	Refer Page 112 for additional details
Application	Trapping and removal of sediment from rivers and channels	



Effectiveness Rating			
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	M		L-M
	M-H		L
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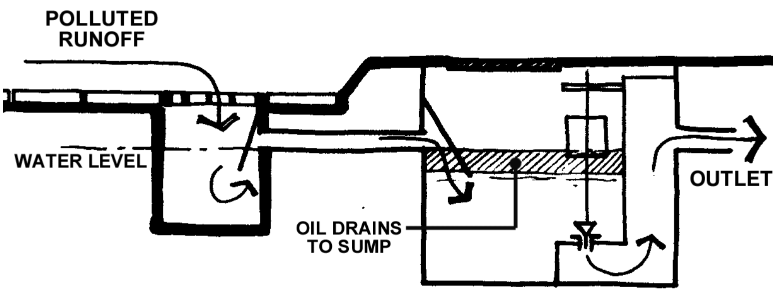
F 5	**Oil Separator**	Refer Page 114 for additional details
Application	Treatment of stormwater runoff polluted with oil.	



Effectiveness Rating			
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	L		H
	L		M

3.3 Design Reports

The City of Cape Town require that a design report, which might include a detailed stormwater management plan, to accompany the final design submission and must include the following design information:

- A plan of the catchment area showing all sub-catchments, pipe networks and pipe details where applicable.
- The relevant input data, such as: assumed landuse, runoff coefficients, hydraulic grade lines, catch pit capacities, pipe loadings
- Method of calculating or selecting parameters and assumptions made.
- Design hyetographs.
- Method of computing attenuation volumes (where applicable).
- Basic geohydrology and opportunities to infiltrate stormwater.
- Relevant flood levels shown on a topographical plan.
- Pre- and post-development stormwater runoff and quality.
- Where a computer programme has been used to calculate the various runoff volumes, sample manual check calculations may be called for.
- Other services and their effect on the system to be taken into account.
- Description of the major elements of the downstream outfall system for a distance specified by the local authority (if requested).
- Stormwater impact assessment

The design of attenuation facilities/wetlands/open channels and riverine areas must include input from planners, environmentalists and others, so that the final design satisfies all requirements.

3.4 Minimum Engineering Design Standards

Minimum engineering design standards for underground stormwater reticulation are contained in Annexure I - Minimum Design Standards for Underground Stormwater Reticulation and Associated Intakes

3.4.1 Flood Escape Routes

Trapped low points must be avoided at all possible through good layout planning. Where the road system cannot serve as the major flood escape route the most appropriate of the following options must be applied:

- Public open spaces provided along drainage route.
- Underground system capacities upgraded to cater for 50 year storm events.
- Flood escape servitudes must be registered over private properties. Servitudes must prohibit all surface development, including construction of solid boundary walls. Escape routes located within road reserves or public open space are preferable.

4. Construction

4.1 Standard Civil Engineering Specifications

All materials and workmanship shall comply with the South African Bureau of Standards Standardised Specification for Civil Engineering Construction (SABS 1200 Series) as amended.

4.2 Environmental Management Programmes

The City of Cape Town, Environmental Management Department, has prepared a guideline document for Environmental Management Programmes for Private Development Projects. The document is presently in draft format (City of Cape Town 2002b).

This generic EMP will enable the City of Cape Town to ensure that private development projects comply with current environmental regulations and that environmental “best practice” procedures and governance are incorporated into the construction phases. It is important to note that it is currently a working document aimed specifically at the construction phase (earthworks, bulk services & road works, and building and home construction).

The document is divided into five different sections:

- Contextual information
- Roles, responsibilities and communication procedures w.r.t. the Developer (and the Engineer’s Representative), relevant Consultants, the Contractor, the ESO, the Environmental Reference Group (ERG) and the ECO from CCT.
- Standard environmental management programme – earthworks, bulk services and roadworks, i.e. including the stormwater management system.
- Standard environmental management programme – building and home construction
- Long term environmental management of private developments: It is recommended that an Operational Phase Environmental Management Programme for the development be compiled which will provide a set of guidelines for the managers of the development to ensure that general management of the development takes environmental factors into consideration.

4.3 As-Built Information

Specific requirements are stated in Annexure J - GIS Protocols for Stormwater As-Built Drawings and Data Capture Projects

4.4 Protection of Stormwater Systems during Construction

Sediment-laden stormwater should not be allowed to pass directly off the development during the establishment phase. It should be routed into areas where sediment can settle out and be removed.

In some cases, infiltration structures may be used as temporary sedimentation areas during the stabilisation phase, if they are not dug down to their final design depth. Sediment can therefore accumulate on material that will be excavated at the end of the stabilisation phase, thus exposing the filtration surface.

4.5 Vegetation and Stabilisation

Structures that rely on infiltration for their efficacy should not come into operation until their runoff areas have been stabilised, following construction. This will prevent the need for early and costly maintenance of structures.

If stabilisation by planting is envisaged, plants should be established before the onset of the winter rains. A phased approach to construction should be considered, where the extent of the water course is such that planting of the whole area will take too long for stabilisation to be effective, or where construction activities are likely to take longer than the period between the end of the wet season (early summer) and the end of the dry season (autumn), when planting should take place.

In some cases, delays in the design or tender stages of a project result in delaying construction such that plants are unlikely to be established before the start of the rainy season. Planting during the rainy season is likely to result in the costly loss of plants, due to washout, as well as the erosion of banks, often resulting in the destruction of careful landscaping of bank slopes and profiles. In such cases, it is suggested that planting be delayed until after the end of the rainy season – either until spring, or until the following autumn. Planting in late spring would allow a longer period for the establishment of plants before the next rainy season. However, for all zones except for permanently wetted zones, frequent irrigation would be necessary to ensure the survival of the plants over summer.

Delays in planting are likely to have cost implications for the project as a whole: survival of pre-ordered, potted plants is often not good over a whole year; in addition, regrading and shaping of eroded banks may be necessary. Nevertheless, it should also be noted that there are advantages to such delays in planting – for one thing, it allows water levels and rates of flow to be observed over one year, and these observations can be used to guide plant zonation.

It is strongly recommended that any planting programmes carried out in stormwater management systems make use of locally indigenous plant species. Indigenous species tend to require less costly nurturing than do exotics. Moreover, they are often less prone to disease and, from an ecological perspective, can also provide areas of indigenous habitat, potentially linking areas of natural indigenous habitat, across the development area.

Refer to Annexure G - Planting Schedules on page 115 for recommended plants for revegetation of river courses/water bodies.

Multifunctional Planting

Planting in a stormwater system should be multifunctional. This influences the choice of plant itself, such as those with edible fruit or seeds, medicinal properties or commercial value; and how the plant is used: for shade, screening, security, bank stabilization, infiltration and habitat. Plants can have historic and cultural importance, as well as aesthetic and recreational appeal.

4.6 Enhancing Ecological Function

Where enhanced ecological function is one of the objectives of a project, a freshwater ecologist should participate in on-site supervision of landscaping, to maximise the opportunities for habitat creation. The methodologies underlying implementation of designs to enhance ecological functioning of water bodies are in many cases in their infancy in the Cape Metropolitan Area (Day and Ractliffe 2002).

Aspects of the above mentioned ecological recommendations should be regarded as experimental, and a flexible approach should be taken to their practical implementation. However, where changes in design suggested for ecological reasons are required, it is strongly recommended that alternatives should be discussed with a river ecologist prior to implementation, so that the objective, where relevant, of optimising opportunities for ecological enhancement can be maintained in future versions of the design.

5. Operation and Maintenance

5.1 Allocation of Responsibilities

Responsibility for the operation and maintenance of the stormwater system normally rests with the local authority. These duties are allocated to a number of different departments as described in Table 5-1 below.

Table 5-1 : Co-operative operation and maintenance of stormwater management systems

Department	Activity
Catchment Stormwater and River Management	Operation and repair of stormwater systems, watercourses
Open Spaces and Nature Conservation	Maintenance of public open space including wetlands and conservation areas, within which stormwater system is located
Sport and Recreation	Maintenance of sportsfields which form part of dry ponds
Solid Waste Services	Cleaning of certain litter traps; removal of dumped material
Health	Monitoring health and safety risks posed by stormwater systems

Responsibility for maintenance of a particular area could also be carried out in cooperation with residents and businesses in the form of a public-private partnership. Local residents and/or businesses could take responsibility for maintenance of their stormwater system through a funding mechanism such as a surcharge on rates to the benefit of the whole community. It is recommended that incorporation of the above measures be considered when planning the long-term operation of a stormwater management system.

5.2 Education

It is important for the local community to "take ownership" of their local river system in the sense of becoming aware of its purpose and benefits and the way in which it is intended to function. An awareness of the benefits of an environmentally friendly system will hopefully start to reverse the pressures exerted at present to introduce greater amounts of impervious paving, drain wet ponds, provide culverts for river etc. The formation of Friends of Rivers groups should be encouraged.

It is also important that education programmes are put in place to train staff with the appropriate skills to carry out the correct operation and maintenance of each different area. It is imperative that the specific functions and objectives of the stormwater system components are understood, along with the implications and requirements of each. Maintenance personnel, for example, should not mow areas where natural habitat is to be established.

5.3 Maintenance

5.3.1 Operation Management Plan

The developer of each new development should be required to submit an approved Operation Management Plan (OMP) for the stormwater system. The OMP manual should include "as-built" drawings of the stormwater system and clearly set out the detailed functions, objectives, actions and responsibilities required for the maintenance of the stormwater system and associated habitats. It should also provide specific guidelines for monitoring maintenance and performance. The local authority may require an annual audit in selected areas.

It should also be noted that the information supplied in the Operational Management Plan will be captured in the Catchment, Stormwater and River Management Department's River Maintenance Database.

Operation Management Plan
A Plan, which organises and coordinates maintenance and monitoring measures in order to guide the operation of the stormwater management system and associated natural habitats.

5.3.2 Recognition of maintenance capacity

It is critically important that the ongoing maintenance needs of a project should match the capacity of the maintaining authority. Where this does not occur, structures may, as a result, lose part or all of their intended functions, amounting to wastage of the capital costs of installing the structure in the first place. For example, where planting takes place, but short-term maintenance through irrigation and weeding does not occur, costly plant specimens may be lost, and areas intended to be aesthetic amenities may become degraded, eroding and regarded by local communities as eyesores. During the design phase of a project, the maintenance needs of each structure should be assessed. Where these are unlikely to be met, it is recommended that alternative treatment methods be sought.

It should also be noted that well designed ecological alternatives can be less costly to maintain than the “hard” solutions. As part of the assessment of maintenance needs, the short-term costs of vandalism and threats to structures, and particularly to planted areas, should not be underestimated (Day and Ractliffe 2002). Costs of replacement of plants and structures such as wooden railings, platforms, poles should be built into the maintenance budget of a project.

Measures should be introduced during the design stage of the project to reduce the impact of theft and vandalism. For example, the purchase of fewer, large trees, rather than many small specimens, should be encouraged, since these are harder to steal and less readily vandalised by uprooting.

5.3.3 Training of Maintenance Staff

Training of maintenance workers needs to recognise that too much maintenance may be as counter-productive as too little. For example, dredging of planted wetlands, resulting in channelisation and drainage; and continued dredging of rivers, to remove aquatic weeds, resulting in bank destabilisation and increased channelisation and deepening of the system (Day and Ractliffe 2002). Manual removal of invasive vegetation from water courses is recommended, and comparisons of the relative costs of mechanical versus manual removal of plants should take into account the long-term costs in terms of bank destabilisation, loss of habitat and general disturbance caused by mechanical removal.

5.3.4 Maintenance Period

A period of intensive, short-term establishment maintenance should be agreed upon between the developer and the final controlling authority. This should involve both a time component and parameters such as plant cover. The time component should allow for a mimimum of one year, preferably for maintenance over two summers (when irrigation is critical). The parameters would relate to the planting material to be maintained, as indicated in Table 5-2 below.

Table 5-2 : Plant Establishment Parameters

Plant Material	Requirements
Indigenous Seed	A minimum of 60% cover (with acceptable plants) No bare patches with a maximum dimension greater than 800mm (except where rocks and boulders are present)
Commercial Grass Seed	A minimum of 75% cover (with acceptable plants) No bare patches with a maximum dimension greater than 500mm (except where rocks and boulders are present)
Grass Sodding	Full area covered with live grass after 3 months
Planting	A minimum of 90% cover (with acceptable plants)

The developer must ensure that the works contract includes and ensures the following:

- The landscape subcontractor (lsc) visits the site often enough to ensure that maintenance is sufficiently undertaken.
- The maintenance team of the landscape subcontractor is sufficient to undertake and complete the maintenance required. This would depend on the specific site, particularly with regard to the size of the area to be maintained, and whether irrigation is manual or automatic. In general, a 2ha site requires a team of 3 labourers full time with 1 supervisor making daily inspections.
- The maintenance requirements and tasks should be clearly specified and understood, along with other site specific requirements, and would generally include watering, weeding, litter control, erosion control and replanting.
- The maintenance time period and establishment requirements are sufficiently understood and defined.
- The budget is allowed for and that payment agreement is put in place to provide the landscape subcontractor with an incentive to complete the works. For example, the lsc could be paid monthly, with a retention held back until the end of the maintenance period and that this is released if the cover aspects have been achieved.

Where a project is to be phased, there is the opportunity to extend the maintenance period of the contract, to run concurrently with the following phases, so that the contractor is maintaining one phase of a project, whilst present on the site implementing subsequent phases.

Best management practices for river maintenance are summarised in the document City of Cape Town, 2002a.

5.4 Monitoring Performance

Monitoring of performance of the stormwater management system should be carried out by the body responsible for the functioning of the stormwater system, or by delegation. Effective monitoring will be based on the operation management plan as described above.

The local authority may then use the reports from the monitoring body to enforce compliance with its requirements.

5.4.1 Use of Community "Watch Dogs"

The services of local residents / local communities as community "watch dogs" should be encouraged. Reporting of ecological or problems associated with poor maintenance or employment of stormwater structures (e.g. blocked drains or channels; erosion; evidence of polluted runoff, sewers leaking into the stormwater system, etc) should be encouraged, and local communities informed of where to lodge reports of such incidents.

5.4.2 Monitoring and modification

Where stormwater structures have been set in place specifically to address particular environmental (or human health) requirements (e.g. improvement in stormwater quality; reduction of erosion), monitoring of the effectiveness of such structures should be carried out on a regular basis. Where they are found not to have met their design objectives, modifications to their structure, or to the stormwater management plan, should take place.

5.4.3 Ongoing assessment and refinement of stormwater design

Day and Ractliffe (2002) recommended that assessment of the ecological impact, and degree to which structures meet their stated objectives, should form an integral part of all projects carried out in the CMA, and which involve wetlands and rivers. This recommendation, currently being considered by CMCA, would apply equally to stormwater management structures – their efficacy, ecological impact, strengths and weaknesses, should all form the basis of assessments, carried out immediately after implementation, and again after the elapse of up to 2 years. This would assist in the dissemination of knowledge of different design applicability to other practitioners, improving the overall quality of stormwater design being carried out in the CMA.

5.5 Resources

There is clearly a limit on the financial resources available for the adequate maintenance of stormwater systems due to pressing demands from a wide range of needs in the community. It is therefore essential to make the best long-term use of the available funds. This set of guidelines strives to promote the development of stormwater systems in such a manner as to provide the best value for money. Care of the environment is a key component together with well-planned multi-use of facilities and effective maintenance of structures.

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Annexure A - Acts, Regulations, Policies and other Relevant Documents

National Water Act 1998 (No36 of 1998)

The National Water Act controls water use. The enforcing authority is the Department of Water Affairs And Forestry (DWAF). The local municipal authority generally controls the provision of water. The act recognises that water is a scarce resource in South Africa and its provisions are aimed at achieving sustainable use of water to the benefit of all users. The provisions of the Act are thus aimed at discouraging pollution and waste of water resources.
The Act focuses on the protection of water resources. Pollution prevention is covered in part 4 (section 19). Any person who owns, controls, occupies or uses land is deemed responsible for taking measures to prevent pollution of water resources.
The Act defines water use as the abstraction, consumption and discharge of water. Use of water includes the discharge of water containing waste into a water resource and the disposal of water containing waste from an industrial process in any manner. (section 39).

Sections 117 to 123 deal with the safety of dams with a safety risk. If such dams fall on the property then cognisance should be taken of the potential impact of the development on the dam.

Section 144 specifies the requirement to indicate the 1:100 year flood levels.

Section 145 deals with flood risk information which the local water management institution must make available to the public.

The National Water Act can be viewed at: http://www.dwaf.gov.za

Department of water Affairs and Forestry: Water Quality Guidelines - 1996

While the National Water Act legislates a set of water quality standards that must be met by discharged water, a second set of standards, or target water quality guidelines also exist. These are recommended by the Department of Water Affairs and Forestry (DWAF), and aim at minimising negative impacts of poor water quality on aquatic ecosystems in South Africa, by setting target ranges for a series of different water quality constituents, including various heavy metals (DWAF 1996). Unlike the General Authorisations for discharge of effluent, specified in the National Water Act, the DWAF guidelines apply to the quality of water occurring in rivers, rather than to the quality of water found in the final effluent. The guidelines also include estimates of “acute effect values” and “chronic effect values” for different variables.

The Water Quality Guidelines can be viewed at: http://www.dwaf.gov.za

National Environmental Management Act (Act 107 OF 1998)

The National Environmental Management Act (NEMA) provides for co-operative environmental governance by establishing principles for decision-making on matters affecting the environment, institutions that will promote co-operative governance and procedures for co-ordinating environmental functions exercised by organs of the state/ and to provide for matters connected therewith.
The following Sections of the Act have relevance:
Section 2 of the Act establishes a set of principles that apply to the activities of all organs of state that may significantly affect the environment. These include the following:

- development must be sustainable
- pollution must be avoided or minimised and remedied
- waste must be avoided or minimised, reused or recycled
- negative impacts must be minimised

Responsibility for the environmental health and safety consequences of a policy, project, product or service exists throughout its life cycle.
The above principles are taken into consideration when a government department exercises its powers, for example, during the granting of permits and the enforcement of existing legislation or conditions of approval.
Section 23 identifies the general objective of Integrated Environmental Management.
Section 24(1) provides that the "potential impact …… of activities that require authorisation or permission by law and which may significantly affect the environment must be considered, investigated, and assessed prior to their implementation and reported to the organ of state charged by law with authorising, permitting, or otherwise allowing the implementation of an activity".
Section 24(7) provides that procedures for the investigation, assessment and communication of the potential impact of activities meet certain minimum requirements.
Section 24 provides that all activities that may significantly affect the environment and require authorisation by law must be assessed prior to approval. In addition, it provides for the minister of environmental affairs and tourism or the relevant MEC's to identify:

- New activities that require approval
- Areas within which activities require approval
- Existing activities that should be assessed and reported on

The Act also provides for the minister to make regulations with respect to the manner in which investigations should occur. No regulations have been issued under section 24 as yet.

Section 28(1) states that "every person who causes, has caused or may cause significant pollution or degradation of the environment must take reasonable measures to prevent such pollution or degradation from occurring, continuing or recurring". If such pollution cannot be prevented then appropriate measures must be taken to minimise or rectify such pollution. These measures may include:

- assessing the impact on the environment
- informing and educating employees about the environmental risks of their work
- and ways of minimising these risks
- ceasing, modifying or controlling actions which cause pollution/degradation
- containing pollutants or preventing movement of pollutants
- eliminating the source of pollution; and
- remedying the effects of the pollution

The authorities may direct an industry to rectify or remedy a potential or actual pollution problem. If such a directive is not complied with, the authorities may undertake the work and recover the costs from the responsible industry.

The National Environmental Management Act can be viewed at:
http://www.polity.org.za/govdocs/legislation/1998/act98-107.html

Environment Conservation Act 1989 (Act 73 Of 1989)

The following Sections of the Act have relevance:

- Section 21(1) makes provision for the identification of activities that may have a substantial detrimental effect on the environment.
- Section 26 makes provision for regulations to be promulgated regarding any activity identified in terms of Section 21(1).

These provisions of the Act culminated in the promulgation of the so-called EIA Regulations (refer to insert below).

The Environment Conservation Act can be viewed at: http://www.acts.co.za/enviro/

Environmental Impact Assessment (EIA) Regulations (GN No R1182 And R1183 Of 5 September 1997)

In terms of Section 1(i) of Schedule 1 of R1182, the “construction or upgrading of canals and channels” is a listed activity which may have a substantial detrimental effect on the environment, and it is therefore necessary to apply for authorisation of such an activity in terms of the provisions of R1183.

Protected Natural Environments

Watercourses may be given Protected Natural Environment (PNE) status in terms of the Environment Conservation Act 73 of 1989 (there are currently only five in existence in South Africa). The declaration of a watercourse as a PNE affords it one of the highest forms of legal protection available to a natural environment.

Nature Reserves

Nature reserves, under the jurisdiction of the provincial or local authority or private reserves, may be impacted by urban stormwater and special cognisance should taken of these.

Conservation Of Agricultural Resources Act 1983 (Act 43 Of 1983)

Key aspects include legislation that allows for:

- Protection of land against water erosion: 4 (1) suitable soil conservation work is required to divert/restrict runoff water and to prevent excessive soil loss
- Protection of land against wind erosion: 5 (1) land should be protected against excessive erosion by wind
- Utilisation and protection of vleis, marshes, water sponges and water courses: 7 (1) subject to the Water Act of 1956 (since amended to the Water Act 36 of 1998), no land user shall utilise the vegetation of a vlei, marsh or water sponge or within the flood area of a water course or within 10m horizontally outside such flood area in a manner that causes or may cause the deterioration of or damage to the natural agricultural resources. (3) and (4) unless written permission is obtained, no land user may drain or cultivate any vlei, marsh or water sponge or cultivate any land within the flood area or 10m outside this area (unless already under cultivation)
- Regulating flow patterns: No user shall divert run-off water away from a water course except with written permission, or may effect an obstruction which will disturb the natural flow pattern of run-off water on his farm, unless such obstruction will not cause excessive soil loss due to action of water or restoration of the natural agricultural resources.

Land Use Planning Ordinance 1985 (Ordinance 15 Of 1985) And Associated Planning Policies, Zoning Schemes And Scheme Regulations

No specific reference is made to stormwater management in the Ordinance. The purpose of the Ordinance is however to provide a legal framework for future planning policy (e.g. structure plans and spatial development frameworks) as well as for the evaluation and approval of future development applications.

In terms of the requirements of the Ordinance a development application can only be considered on the grounds of:

- desirability as far as guideline proposals in terms of a relevant structure plan
- the effect of an application on existing rights concerned
- the safety and welfare of the members of the community as well as
- on the potential impact of an application on the natural and developed environment

Section 42 of the Ordinance provides an authority with the right to impose conditions of approval that will ensure that the abovementioned criteria are met. These conditions are however usually imposed as a result of comment received from the various engineering and environmental departments involved in the evaluation of an application. Existing procedures therefore allow for stormwater planning and management to be dictated by the engineering and environmental departments at the relevant authority.

Proposed By-Law For Stormwater Management And Related Matter (In Preparation)

In terms of the Constitution of South Africa, Act 108 of 1996, municipalities have the executive authority and the right to administer listed local government matters, including stormwater management systems in built-up areas. The City of Cape Town is currently in the process of adopting a by-law covering stormwater management and related matters. Once approved, all developments will have to comply to this by-law.

Integrated Metropolitan Environmental Policy 2001

The City of Cape Town's Integrated Metropolitan Environmental Policy (IMEP) forms the basis of a series of strategies and programmes to ensure that the fundamental principles of, and approaches to, sustainable development are adhered to.

IMEP is a statement of intent, a commitment to certain principles and ethics and to the development of sectoral strategies, which will detail goals, targets, programmes and actions needed to ensure sustainable resource use and management of the city's unique environment for all communities.
Section 4.2 Water Resources of IMEP deals with the City's commitment to ensuring that the quality of coastal, marine and inland waters is suitable for the maintenance of biodiversity and the protection of human health.

IMEP can be viewed at: http://www.capetown.gov.za/imep

Integrated Environmental Management Guidelines Series 1992

The following basic principles underpinning IEM have relevance:
- A broad meaning to the term environment (i.e. one that includes physical, biological, social, economic, cultural, historical and political components)
- An open, participatory approach in the planning of proposals
- Due consideration of alternatives options
- Mitigation of negative impacts and enhancement positive aspects of proposals
- Ensuring that the social costs of development proposals are outweighed by the social benefits

The RAMSAR Convention On Wetlands 1975

South Africa became a signatory of the Convention on Wetlands in December 1975. The obligations of each signatory of the convention include the following:

- to promote the conservation of listed wetlands, and as far as possible the wise use of wetlands in their territory (South Africa presently has 17 listed sites; none of these fall within the CMA area, although Rietvlei Nature Reserve is in the process of being proclaimed a listed site)
- to promote the conservation of wetlands and waterfowl by establishing nature reserves on wetlands, whether they are listed or not.

Wetlands are one of the most threatened habitats in South Africa, where nearly half of natural wetlands have already been destroyed (Cowan 1995). As such, they are accorded a high conservation status, and even degraded wetlands are viewed as important systems, warranting conservation (REF: Working for Wetlands)

Annexure B - River And Wetland Buffer Widths

Recommended Buffer Widths between Rivers and Developments

A range of different minimum buffer widths have been recommended for rivers within the CMA, depending on the river zone (sub region) and relative importance of the river (referred to as the river priority ranking) City of Cape Town (2002a). These widths are outlined in the following table – calculated buffer widths are available for a number of assessed rivers in the CMA, and are listed in City of Cape Town (2002a).

River zone/ sub region	Importance Category	No-go zone (on either side of the river)	Special sanction buffer width (on each side of the river)
Mountain stream	1 & 2	10 m	10 m per 1 m of mean bankfull width, no less than 10 m and up to a maximum of 40 m.
	3	10 m	10 m per 1 m of mean bankfull width, no less than 10 m and up to a maximum of 30 m.
	4	10 m	10 m per 2 m of mean bankfull width, no less than 10 m and up to a maximum of 20 m.
	5	10 m	10 m per 3 m of mean bankfull width, no less than 10 m and up to a maximum of 20 m.
Foothill	1 & 2	10 m	10 m per 2 m of mean bankfull width, no less than 10 m and up to a maximum of 40 m
	3	10 m	10 m per 2 m of mean bankfull width, no less than 10 m and up to a maximum of 30 m
	4	10 m	10 m per 2 m of mean bankfull width, no less than 10 m and up to a maximum of 20 m
	5	10 m	10 m
Wetland transitional	1 & 2	10 m	10 m per 2 m of mean bankfull width, no less than 10 m and up to a maximum of 40 m
	3	10 m	10 m per 2 m of mean bankfull width, no less than 10 m and up to a maximum of 30 m
	4	10 m	10 m per 3 m of mean bankfull width, no less than 10 m and up to a maximum of 25 m
	5	10 m	10 m
Lower	1 & 2	10 m	10 m per 2 m of mean bankfull width, no less than 10 m and up to a maximum of 40 m
	3	10 m	10 m per 2 m of mean bankfull width, no less than 10 m and up to a maximum of 30 m
	4	10 m	10 m per 3 m of mean bankfull width, no less than 10 m and up to a maximum of 25 m
	5	10 m	10 m
Note that these parameters are subject to on-going revision.			

Buffer Widths Between Wetlands And Developments

A draft protocol for assigning buffer widths to urban wetlands has also been formulated (Southern Waters 2001). The protocol suggests buffer widths of between 25 and 75m width, except where there is an identified need to provide wider zones. Buffer widths are determined based on assessments of a number of criteria, particularly the Ecological Importance and Sensitivity of the wetland.

Annexure C - Significance of Wetlands in Stormwater Planning

Significance of Wetlands in Stormwater Planning

The following aspects of wetlands should be considered:

- Consideration of wetlands at an early stage of a project could lessen conflict between environmental and developmental priorities at a later stage in the project, and enable a far more integrated planning solution.
- Wetlands can play a significant and diverse role in stormwater management, including infiltration, water quality improvement, and amelioration of flood events.
- Not all wetlands lend themselves to the receipt of stormwater, and sensitive wetland areas should be protected from contaminated flows, while changes (even increases) in the natural flow regimes of some wetlands can result in severe ecological degradation. This is particularly true for the seasonal wetlands that once characterised the area now included in the Cape Metropolitan Area but which today are threatened, and accorded a high conservation importance.
- Although not able to form part of an integrated stormwater management system, an environmentally sensitive wetland would continue to play an important role in the natural hydrological functioning of the site.

Why Are Wetlands Important?

Wetlands can perform a number of important functions:

- absorption of nutrients
- buffering of riverine ecosystems
- prevention of erosion
- flood attenuation
- retention of water, and hence
  - improvement in soil structure
  - reduction in drying and subsequent erosion of soil
  - maintenance of most habitats
- provision of habitat – including to juveniles of insect pollinators of other conservation-worthy ecosystems (e.g. fynbos)
- provision of longitudinal corridors, linking patches of relatively natural terrestrial habitat.

Annexure D - Hydrological and Water Quality Data Sources

Rainfall Monitoring Stations with Intensity-Duration-Frequency Relationships

Rain Monitoring Station		Location		Source Of IDF Data (Note 1)
No.	Name	Lat.	Long.	
-	Molteno	33° 56'	18° 26'	CCT
-	Camps Bay	33° 57'	18° 23'	CCT
-	Table Mountain	33° 58'	18° 25'	CCT
-	Newlands	33° 58'	18° 27'	CCT
-	Cecilia	33° 58'	18° 22'	CCT
-	Wynberg	33° 60'	18° 27'	CCT
-	Kendal	34° 02'	18° 27'	CCT
-	Southfield	34° 03'	18° 29'	CCT
-	Strandfontein	34° 05'	18° 31'	CCT
-	Mitchell's Plain	34° 03'	18° 37'	CCT
-	Groenvlei	34° 00'	18° 32'	CCT
-	D.F.Malan	33° 58'	18° 37'	CCT
-	Athlone	33° 57'	18° 29'	CCT
-	Tygerberg	33° 53'	18° 36'	CCT
-	Tokai	34° 04'	18° 25'	CCT
004/723	Tokai	34° 03'	18° 25'	WB
005/605	Somerset West	34° 05'	18° 51'	WB
020/649	Robben Island	33° 49'	18° 22'	WB
020/689	T.MT.(Woodhead)	33° 59'	18° 23'	WB
020/715	C.T.(Sig.Hill)	33° 55'	18° 24'	WB
020/716	C.T.(Tambrsklf)	33° 56'	18° 24'	WB
020/746A	T.MT.(Reserve)	33° 56'	18° 25'	WB
020/747	T.MT.(Plattekp)	33° 57'	18° 25'	WB
020/776	C.T.(Fire STN.)	33° 56'	18° 26'	WB
020/839	Claremont	33° 59'	18° 28'	WB
020/866	C.T.(Observtry)	33° 56'	18° 29'	WB
020/896	C.T.(Pinelands)	33° 56'	18° 30'	WB
021/055	C.T.(Maitland)	33° 55'	18° 32'	WB
021/130	Vanschoorsdrift	33° 40'	18° 35'	WB
021/230	Altydgedacht	33° 50'	18° 38'	WB
021/235	Bellville	33° 55'	18° 38'	WB
021/260	Durbanville	33° 50'	18° 39'	WB
021/330	Eersterivier	34° 0'	18° 41'	WB
021/441	Kraaifontein	33° 51'	18° 45'	WB
021/621	Klapmuts	33° 51'	18° 51'	WB
021/655	Stellenbosch	33° 55'	18° 52'	WB

Note 1: SOURCE OF IDF DATA
CCT – City of Cape Town, Aug. 1992: "Rainfall intensity-duration-frequency curves"
WB – Analysis of Weather Bureau data by Directorate of Hydrology, Department of Water Affairs and published with revised time distributions in Schmidt, EJ and Schulze, RE, 1987a and 1987b and Schmidt, EJ, Schulze, RE and Dent, MC, 1987.

City of Cape Town - Rainfall Monitoring Stations

Station Name	Location	Catchment	Code	X Co-ord	Y Co-ord
Atlantis WWTW	Atlantis WWTW	Atlantis	Atla17aR	-47001	-3717732
Camps Bay PS	Camps Bay Pump Station, Victoria Road, Camps Bay	City	City11aR	-57444	-3758168
Molteno Reservoir	Moltino Dam , Molteno Road, Oranjezicht	City	City11bR	-54193	-3757054
Devil's Peak	Devil's Peak, High Cape	City	City11cR	-52530	-3757535
Klein Welmoed G2H040	Klein Welmoed Farm, Baden Powell Road, R310	Eerste / Kuils river	Eers02aR	-21611	-3763251
Kleinplaas G2H005	Jonkershoek Dam, Stellenbosch	Eerste / Kuils river	Eers02cR	-5207	-3761049
Macassar road	Macassar road at Kuils crossing	Eerste / Kuils river	Kuil02aR	-23314	-3770583
Waldemar road	Waldemar road, Oakdene, Kuils river	Eerste / Kuils river	Kuil02bR	-30262	-3756774
UWC	UWC, Modderdam road, Bellville	Eerste / Kuils river	Kuil02cR	-34289	-3756160
Table Mountain	At Kloofnek Circle take the gravel road to the top	Hout Bay	Diep05eR	-54079	-3762843
Disa@Princess	Princess Road, Hout Bay	Hout Bay	Disa09aR	-59437	-3768467
Disa@Longkloof	Longkloof Road	Hout Bay	Disa09bR	-56567	-3765116
Lour@Vergelegen	Vergelegen Farm, Vergelegen road, Somerset West	Lourens river	Lour06bR	-9327	-3771284
Lour@Waterval	Lourensford Farm, Lourensford road, Somerset West	Lourens river	Lour06cR	-3702	-3766531
Lour@Langklippie	Vergelegen Farm, Vergelegen road, Somerset West	Lourens river	Lour06dR	-4667	-3770392
Lour@Blinksberg	Lourensford Farm, Lourensford road, Somerset West	Lourens river	Lour06eR	-7595	-3766674
Mitchells Plain WWTW	Mitchells Plain Sewage Work, off Spine Road, Strandfontein	Mitchells Plain / Khayelitsha	MPla12aR	-37652	-3771219
Avondrust road, Noordhoek	Avondrust road, Forestry station, Noordhoek	Noordhoek	Norh08bR	-57965	-3774710
Wildevoelvlei WWTW	Wildevoelvlei WWTW, Kommetjie Main Road, Kommetjie	Noordhoek	Wild08aR	-58558	-3778773
Maastricht Farm	Maastricht Farm, Durbanville Road,	Salt River	Elsi03aR	-38138	-3746067
Dagbreek Reservoir	Dagbreek Reservoir, Paardeberg Road, Durbanville Hills Ext16	Salt River	Elsi03bR	-33552	-3747035
Tygerberg Reservoir	Tygerberg Reservoir, Java Oos Straat, Avondale	Salt River	Elsi03cR	-36693	-3751856
Goodwood Greens	c/o Milton & Alice Rds Goodwood	Salt River	Elsi03dR	-41767	-3753295
Pinelands	Pinelands Maintenance Yard, Princess Path, Pinelands	Salt River	Elsi03eR	-45536	-3756977
Marshalling Yards	Marshalling Yards	Salt River	Elsi03pR	-35328	-3755026
Newlands Res	Newlands Reservoir, Rhode Drive, Newlands	Salt River	Lies03fR	-50844	-3760171
Observatory	National Observatory	Salt River	Lies03hR	-48288	-3756398
Athlone WWTW	Athlone Treatment Works, Jan Smuts Ave, Athlone	Salt River	Vyge03gR	-44878	-3758584
Constantia	Constantia	Sand River	Diep05iR	-50947	-3767259
Kendal Road	Water Work Depot (SPM), Kendal Road, Meadowridge	Sand River	Diep05aR	-50921	-3767021
Wynberg Reservoir	Wynberg Reservoir, Wynberg Park, Trovato Road, Wynberg	Sand River	Diep05cR	-50634	-3763650
Cecilia Forest	Cecilia Forest, Rhodes drive	Sand river	Diep05dR	-53742	-3763865
Keyser@M3	Next to the Simon Van Der Stel Freeway	Sand River	Keys05dR	-51064	-3769806
Tokai Forest	At the SAFCOL office at Tokai Forest	Sand River	Keys05fR	-53608	-3770346

Silvermine@Dam	Silvermine Nature Reserve, Ou Kaapse Weg, Silvermine	Silvermine	Silv16cR	-55520	-3772163
Simonstown	Brooklyn Water Treatment Plant, Red Hill, Simonstown	South Peninsula	SPen13aR	-55392	-3782344
Southfield	Southlfield Depot, Alduwa Road, Southfield	Zeekoe	Diep05bR	-47965	-3767536
Groenvlei / Hanover Park	Cleansing Department, Downberg Road, Hanover Park	Zeekoe	Lotu04aR	-43528	-3763757
Cape Flats WWTW	Cape Flats Treatment Plant, off Strandfontein Road	Zeekoe	MPla12bR	-44622	-3772432

City of Cape Town – River Flow Monitoring Stations

Name	Location	Catchment	Code	X Co-ord	Y Co-ord
Marshalling Yards			Elsi03pS	-35404	-3755946
Tygerberg			Elsi03qS	-36590	-3753464
Rietvlei@Outlet(R27)	Upstream of R27 bridge over Diepriver, Milnerton	Diep river	Diep01aS	-46310	-3748055
Disa@Princess	Princess road / Disa river crossing	Hout Bay	Disa09aS	-59446	-3768476
Disa@Longkloof	Longkloof road / Disa river crossing	Hout Bay	Disa09bS	-56568	-3765126
Klein Welmoed G2H040	Klein Welmoed Farm, off Baden Powell Raod (R310)	Kuils Eerste	Eers02aS	-21700	-3763306
Plankenberg G2H020	Libertas Farm, Van Rheede Raod, Stellenbosch	Kuils Eerste	Eers02bS	-14847	-3757957
Kleinplaas G2H005	Jonkershoek Dam, Stellenbosch	Kuils Eerste	Eers02cS	-5286	-3760947
Kleinvlei@Old Faure	Kleinvlei Canal downstream of Old Faure road	Kuils Eerste	Klei02eS	-24922	-3766543
Kuils@Macassar	Macassar road / Eersteriver crossing, Macassar	Kuils Eerste	Kuil02aS	-23293	-3770614
Kuils@Waldemar	Waldemar Street, Oakdene, Kuils River	Kuils Eerste	Kuil02bS	-30296	-3756725
Kuils@Driftsands Dam	Driftsands Dam	Kuils Eerste	Kuil02dS	-31034	-3764099
Lourens@Main road	Main Road / Lourens river crossing at historic bridge	Lourens River	Lour06aS	-13304	-3773346
Lourens@Lourensford	Vergelegen Farm, Vergelegen Raod, Somerset West	Lourens River	Lour06bS	-9334	-3771315
Mitchells Plain	Sewage Pump Station, Alps Circle, Tafelsig, Mitchells Plain	Mitchells Plain / Khayelitsha	MPla12aS	-33889	-3771212
Black@SybrandPk	Sybrand Road, Sybrand Park	Salt River	Blac03kS	-46451	-3758960
Black@SybrandPk	Sybrand Road, Sybrand Park	Salt River	Blac03xS	-46560	-3759236
Blomvlei@Stadium	Ebrahim Hadji / Blomvlei canal crossing	Salt River	Blom03mS	-44212	-3760737
Elsies@Pinelands	Cora Avenue, Pinelands (Close to Howard Centre)	Salt River	Elsi03aS	-45153	-3756759
Elsies@Conradie	Jan Smuts / Elsieskraal crossing near Conradie Hospital	Salt River	Elsi03bS	-44224	-3755797
Elsies@Coleman	Coleman Street, Elsies River	Salt River	Elsi03cS	-39264	-3754009
Elsies@Jack Muller	Jack Muller Park, Frans Conradie Drive, Boston	Salt River	Elsi03dS	-34259	-3751460
Elsies@Quarry	Durbanville Quarry, Carl Cronje Drive, Durbanville	Salt River	Elsi03eS	-34214	-3750593
Maastricht Farm		Salt River	Elsi03fS	-38136	-3746064
Elsies@Pinelands	Cora Avenue, Pinelands (Close to Howard Centre)	Salt River	Elsi03xS	-45265	-3756947
Jakkals@N2	Next to Settlers Way (Few Kms past the cooling towers from	Salt River	Jakk03mS	-43948	-3758208

Liesbeek@Paradise	At the Paradise Road intersection	Salt River	Lies03gS	-50603	-3761757
Liesbeek@Durban	Next to Liesbeeck Parkway, Mobray	Salt River	Lies03hS	-48291	-3758093
Salt@Glamis Close	Next to M5 Black River Parkway, Maitland	Salt River	Salt03iS	-48214	-3755001
Vygekraal@Athlone	Vygekraal opposite ATWWTW	Salt River	Vyge03jS	-45190	-3758296
Diep@Doordrift	Doordrift Road, Plumstead	Sand River	Diep05cS	-49903	-3766070
Keyser@M3	Next to the Simon Van Der Stel Freeway	Sand River	Keys05dS	-51063	-3769813
Little Princess Vlei	Consort Road, Retreat	Sand River	Lpvl05aS	-48478	-3769327
Diep@Maynardville	Maynardville Park c/o Wolfe & Church Street, Wynberg	Sand River	Wynb05bS	-49515	-3764298
Zandvlei@railway	Under the railway bridge at the inlet to the vlei	Sand River	Zvin05eS	-49582	-3773159
Zandvlei@Thesens	Thessen Bridge, Sandvlei	Sand River	Zvou05fS	-48560	-3775170
Silvermine Golf Club	Clovelly Golf Club, Clovelly raod, Clovelly	Silvermine	Silv16bS	-52895	-3777729
Silvermine@Dam	Silvermine Nature Reserve, Ou Kaapse Weg, Silvermine	Slivermine	Silv16cS	-55490	-3772171
Lotus@Springfield road	Springfield road / Lotus river crossing	Zeekoe	Lotu04aS	-44085	-3764932
Lotus@Sixth Ave	Sixth Avenue / Lotusriver crossing, Lotus river	Zeekoe	Lotu04cS	-44559	-3768433
Zeekoe@yachtclub	Zeekoevlei Yacht Club, Peninsula Road, Zekoevlei	Zeekoe	Zeek04dS	-45149	-3770736

City of Cape Town – Inland Waters: Chemical and Bacteriological Sampling Locations

Location	Catchment	Code	X Co-ord	Y Co-ord
Maastricht Canal u/s WWTW	Diep	MOS01	0	0
Maastricht canal d/s WWTW	Diep	MOS02	0	0
Mosselbank trib d/s Fisantkraal	Diep	MOS03	0	0
Diep River at Blauwberg Road bridge	Diep	RTV01	-44230	-3744943
Rietvlei - sample collected from pier in watersport area of vlei	Diep	RTV02	-46919	-3745422
Stormwater outfall from Theo Marais Park (Montagu Gardens)	Diep	RTV03	-44385	-3746601
Stormwater channel from Bayside Mall (into Rietvlei)	Diep	RTV04	-47355	-3744062
Outlet from Rietvlei at Otto du Plessis Drive bridge	Diep	RTV05	-46299	-3747678
Diep River downstream of N7 road bridge	Diep	RTV06	-41799	-3740180
Diep River at end of Raats Road	Diep	RTV07	-43974	-3743327
Duikersvlei Stream u/s of confluence with Theo Marais Park stormwater canal	Diep	RTV08	-44365	-3746533
Diep River estuary at Woodbridge Island (Loxton Rd)	Diep	RTV09	-47075	-3750389
Diep River estuary at mouth	Diep	RTV10	-47582	-3751275
Kuils River on Brackenfell Boulevard / De Bron Rd	Eerste / Kuils	EK01	-30692	-3747628
Kuils River at Old Paarl Rd	Eerste / Kuils	EK02	-30043	-3750828
Bottelary River at Amandel Rd	Eerste / Kuils	EK03	-28816	-3754104
Kuils River at Carinus street bridge	Eerste / Kuils	EK04	-29908	-3755350
Kuils River in canal u/s of Stellenbosch Arterial Rd	Eerste / Kuils	EK05	-30498	-3757919
Kuils River d/s of Hindle Rd bridge	Eerste / Kuils	EK06	-30829	-3761260
Kuils River u/s of Old N2 / Faure Rd bridge	Eerste / Kuils	EK07	-30177	-3764719
Kuils River d/s of Baden Powell Drive bridge	Eerste / Kuils	EK08	-25623	-3768164
Belville WWTW discharge at Rietvlei Rd	Eerste / Kuils	EK09	-30141	-3755892
Effluent discharge from Kuils R WTW	Eerste / Kuils	EK10	-30827	-3758324
Kuils River d/s of Zandvliet discharge (dirt road bridge)	Eerste / Kuils	EK11	-24768	-3769067
Eerste River u/s of Macassar WTW (d/s of Kuils confluence)	Eerste / Kuils	EK12	-21677	-3771151

Eerste River on N2 Freeway (u/s of Kuils confluence)	Eerste / Kuils	EK13	-24113	-3768228
Eerste River in Stellenbosch near Dorp Street bridge	Eerste / Kuils	EK14	-13542	-3756876
Kleinvlei canal	Eerste / Kuils	EK15	-24938	-3766103
Zandvliet WWTW Final discharge	Eerste / Kuils	EK16	-25675	-3768834
Eerste River estuary	Eerste / Kuils	EK17	-21814	-3772240
Moddergatspruit - Macassar Rd	Eerste / Kuils	EK18	-21312	-3770688
Elsies River u/s of vlei at Gordon's Camp bridge	Glencairnvlei	GC01	-53317	-3780708
Vlei centre - at concrete berm	Glencairnvlei	GC02	-52705	-3780939
Weir - near road bridge	Glencairnvlei	GC03	-52497	-3781237
Disa River at Princess St	Hout Bay	DR01	-59386	-3768206
Disa River at Victoria Rd	Hout Bay	DR02	-59641	-3766909
Pond overflow from World of Birds	Hout Bay	DR03	-58856	-3765565
Disa River at Longkloof Rd	Hout Bay	DR04	-56457	-3764800
Hout Bay River Estuary	Hout Bay	DR05	-59482	-3768621
Lourens at Vergelegen Estate	Lourens	LOU01	-10515	-3772175
Lourens in P.O.S., Hillcrest Rd	Lourens	LOU02	-11898	-3772566
Lourens at Main Rd - Somerset West	Lourens	LOU03	-13185	-3773024
Lourens at Broadway Rd	Lourens	LOU04	-15904	-3774216
Lourens on Beach Road	Lourens	LOU05	-16935	-3774580
Lourensford Estate at "Red Bridge"	Lourens	LOU06	-6720	-3768319
Bokramspruit upstream of Aries Street	Noordhoek	BOK01	-59154	-3780899
Bokramspruit upstream of Slangkop Road	Noordhoek	BOK02	-60230	-3779777
Bokramspruit a short distance downstream of Flamingo Road	Noordhoek	BOK03	-61283	-3778685
Elsieskraal River on Claredon Road	Salt	ELS01	-36653	-3753456
Elsieskraal River at Connaught Rd	Salt	ELS02	-38047	-3754317
Elsieskraal River on Coleman Road	Salt	ELS03	-39124	-3753671
Elsieskraal River on Chelsea Street	Salt	ELS04	-40472	-3753839
Elsieskraal River at end of Paul Kruger Rd	Salt	ELS05	-41247	-3753938
Elsieskraal River on Forest Drive Extension - Thornton	Salt	ELS06	-43211	-3754587
Elsieskraal River on Ringwood Drive	Salt	ELS07	-44337	-3755597
Elsieskraal River at Nightingale Way	Salt	ELS08	-45417	-3756942
Elsieskraal at Diemersdal Rd	Salt	ELS09	-34357	-3747477

Elsieskraal at Carl Cronje Rd	Salt	ELS10	-34178	-3750690
Blomvlei Canal at Koodoo Street u/s of Vygekraal River confluence	Salt	NR01	-44426	-3758694
Vygekraal River at Cornflower Street u/s of Blomvlei Canal conflunence	Salt	NR02	-43960	-3758801
Vygekraal River u/s of Athlone WTW	Salt	NR03	-44845	-3758012
Vygekraal River d/s Athlone WTW	Salt	NR04	-45940	-3758013
Black River at Raapenberg Road bridge	Salt	NR06	-47429	-3757564
Black River on Footbridge to Alexandra Institute	Salt	NR07	-47841	-3756376
Liesbeek River downstream of Lake weir opp. Hartleyvale	Salt	NR08	-48353	-3756424
Salt River Canal at Voortrekker Road bridge	Salt	NR09	-48365	-3755148
Salt River Canal at Marine Drive Bridge - Paarden Eiland	Salt	NR10	-48669	-3753342
Black River in Rdbosch Golf Course	Salt	NR11	-46523	-3758334
Liesbeek River on Sans Souci Rd	Salt	NR12	-49596	-3760571
Liesbeek River - old canal next to River Club	Salt	NR13	-48680	-3756025
Jakkalsvlei Canal at N2	Salt	NR15	-43945	-3757918
Langa Canal on N2	Salt	NR16	-44489	-3757909
Kalksteenfontein canal nr Netreg Stn	Salt	NR17	-40231	-3758224
Nyanga Canal at Duinefontein Road outside GF Jooste Hospital	Salt	NR18	-40584	-3761926
Downstream of Elsieskraal but upstream of Black River confluences	Salt	NR19	-46474	-3758303
Near Borcherd's Quarry outfall	Salt	NR21	-39047	-3759849
Liesbeek River on Paradise Rd	Salt	NR22	-50462	-3761369
Liesbeek River on Winchester Rd - Kirstenbosch	Salt	NR23	-51996	-3762219
Westlake River cnr Main and Chenel Roads	Sand	CR01	-50168	-3772526
Westlake River at Orange St - Kirstenhof	Sand	CR02	-50679	-3771841
Westlake River Altenburg Rd - Kirstenhof	Sand	CR03	-50961	-3771734
Westlake River in Pollsmoor Prison grounds	Sand	CR04	-51637	-3771667
Westlake River at Steenberg Rd	Sand	CR05	-52597	-3771889
Prinskasteel River in greenbelt off Lismore Rd (close to M3)	Sand	CR06	-51121	-3769517
Tributary of Prinskasteel River (just u/s of CR06)	Sand	CR07	-51182	-3769524
Prinskasteel at Orpen Rd	Sand	CR08	-52907	-3769381

Grootboschkloof River on Soetvlei Rd (where M3 runs parallel to river)	Sand	CR09	-51189	-3768981
Grootboschkloof on Spaanschemat River Rd	Sand	CR10	-52433	-3768122
Grootboschkloof on Klein Constantia (Hope of Constantia gates)	Sand	CR11	-53198	-3767658
Spaanschemat River on Constantia Main Road to Hout Bay	Sand	CR12	-52221	-3766274
Spaanschemat River on Gilmour Circle	Sand	CR13	-52603	-3765900
Diep River at Doordrift Road	Sand	CR14	-49859	-3765746
Diep River in Greenbelt off Alphen Drive (LHS of road)	Sand	CR15	-50656	-3764977
Diep River at Alphen Rd in canal d/s of CR15	Sand	CR16	-50585	-3764994
Diep River cnr Brommersvlei & Rathvelder Rds	Sand	CR17	-51662	-3764862
Diep River in dip on Hohenhort Drive	Sand	CR18	-51962	-3764010
Diep River at T-junction Southern Cross & Rhodes Drive	Sand	CR19	-53711	-3764339
Keysers River at Military Rd	Sand	CR20	-49491	-3771896
Sand River at Oudevlei Road (d/s of conf Langvlei & Sand River canal	Sand	CR21	-48677	-3772348
Diep River at Roscommon Road	Sand	DRRSC	-48834	-3768414
Little Princessvlei - north	Sand	LPVN	-48434	-3768382
Little Princessvlei - south	Sand	LPVS	-48409	-3769020
Langevlei - vlei inlet	Sand	LVI	-49292	-3769688
Langevlei - vlei oulet	Sand	LVO	-49226	-3770055
Die Oog at Midwood Avenue, Bergvliet	Sand	OOG01	-50952	-3768864
Westlake Wetland opp. Rutter Rd	Sand	WLW	-49652	-3773158
Zandvlei - north	Sand	ZA01B	-49139	-3772937
Zandvlei - north	Sand	ZA01S	-49139	-3772937
Zandvlei - centre (opp Imperial Y.C.)	Sand	ZA02B	-48948	-3773529
Zandvlei - centre (opp Imperial Y.C.)	Sand	ZA02S	-48948	-3773529
Zandvlei - south (opp Playwaters)	Sand	ZA03B	-48889	-3774077
Zandvlei - south (opp Playwaters)	Sand	ZA03S	-48889	-3774077
Outlet channel - midway to mouth	Sand	ZA04B	-48800	-3774518
Outlet channel - midway to mouth	Sand	ZA04S	-48801	-3774518
Outlet channel near Royal Rd bridge	Sand	ZA05B	-48374	-3774944
Outlet channel near Royal Rd bridge	Sand	ZA05S	-48374	-3774944

South entrance to Marina da Gama canals	Sand	ZA06B	-48602	-3773671
South entrance to Marina da Gama canals	Sand	ZA06S	-48602	-3773671
North entrance to Marina da Gama canals	Sand	ZA07B	-48775	-3772940
North entrance to Marina da Gama canals	Sand	ZA07S	-48775	-3772940
Marina da Gama canal near "The Anchorage"	Sand	ZA08S	-48140	-3773889
Marina da Gama canal	Sand	ZA09S	-48030	-3773551
Downstream of Silvermine Dam	Silvermine	SIL01	-55339	-3771915
Near Sunbird Environmental Centre - Silvermine NR	Silvermine	SIL02	-54419	-3775851
At top of Clovelly Country Club	Silvermine	SIL03	-53637	-3776718
At pipe gantry near Winkle Rd - Clovelly	Silvermine	SIL04	-52449	-3777747
At footbridge on dam near Clovelly Beach	Silvermine	SIL05	-52073	-3777939
Sir Lowrys at Wedderwill Farm	SirLowrys	SIR01	-7253	-3775646
Sir Lowrys d/s N2	SirLowrys	SIR02	-10156	-3777168
Sir Lowrys at Gustrouw Rd	SirLowrys	SIR03	-11355	-3779294
Sir Lowrys original river channel at Dolphin Rd	SirLowrys	SIR04	-11665	-3779518
Sir Lowrys at Hendon Park	SirLowrys	SIR05	-12293	-3780426
Sir Lowrys d/s of WWTW	SirLowrys	SIR06	-11698	-3779341
Sir Lowrys at Lancaster Rd	SirLowrys	SIR07	-13175	-3779407
Soet River u/s of Boundary Rd	Soet	SOE01	-14293	-3777063
Soet R u/s of Greenways Rd	Soet	SOE02	-14948	-3777527
Sout at R27	Sout	SOU01	0	0
Sout at Otto du Plessis Drive	Sout	SOU02	0	0
Schusters River at Main Road crossing	South Peninsula	SCH01	-55301	-3786284
Schusters River at Schusterskraal Reserve entrance	South Peninsula	SCH02	-57585	-3785981
Wetland adjacent to Schusters River	South Peninsula	SCH03	-57556	-3785938
Pound River canal	South Peninsula	SCH04	-57736	-3785580
Tributary of Schusters at Main Rd	South Peninsula	SCH05	0	0
SE side of EAST vlei nr stormwater outlet	Wildevoelvlei	WV01	-58745	-3778535
Centre of EAST vlei	Wildevoelvlei	WV02	-58969	-3778524
NW side of EAST vlei	Wildevoelvlei	WV03	-59199	-3778562
SE side of WEST vlei	Wildevoelvlei	WV04	-59625	-3778796
Centre of WEST vlei	Wildevoelvlei	WV05	-59752	-3778695
NW side of WEST vlei	Wildevoelvlei	WV06	-59839	-3778558
Middle of canal leading to beach and lagoon	Wildevoelvlei	WV07	-60323	-3778368

Wildevoelvlei mouth to sea	Wildevoelvlei	WV08	-60463	-3777701
Backshore lagoon nr old shipwreck	Wildevoelvlei	WV09	-59969	-3777348
E end of EAST vlei nr WWTW outfall	Wildevoelvlei	WV10	-58735	-3778441
W end of EAST vlei nr interconnecting channel	Wildevoelvlei	WV11	-59213	-3778675
E end of WEST vlei	Wildevoelvlei	WV12	-59535	-3778724
W end of WEST vlei	Wildevoelvlei	WV13	-59949	-3778621
S shore of EAST vlei	Wildevoelvlei	WV14	-58920	-3778636
N shore of EAST vlei	Wildevoelvlei	WV15	-59032	-3778372
S shore of WEST vlei	Wildevoelvlei	WV16	-59773	-3778797
N shore of WEST vlei	Wildevoelvlei	WV17	-59720	-3778582
Mussel beds on rocks in sea	Wildevoelvlei	WVMussel	-60573	-3777577
Lotus River on Airport Approach Road opposite Borcherd's Quarry final effluent ponds	Zeekoe	LR01	-38722	-3759913
Lotus River on Settler's Way (N2) about 500m from Airport Approach Road	Zeekoe	LR02	-38891	-3760305
Lotus River at corner Duinefontein and Lansdowne Roads	Zeekoe	LR03	-40765	-3763628
Lotus River at Lansdowne Road	Zeekoe	LR04	-43414	-3763542
Lotus River at Plantation Road (near Hillstar Traffic Department)	Zeekoe	LR05	-44349	-3765171
Lotus River at New Ottery Road (near Ottery Hypermarket)	Zeekoe	LR06	-44492	-3765415
Lotus River at Klip Road	Zeekoe	LR07	-44586	-3767171
Lotus River at Fisherman's Walk bridge (just u/s of vlei body)	Zeekoe	LR08	-44396	-3768738
Little Lotus River at Klip Road (near Montagues Gift Road)	Zeekoe	LR09	-45669	-3767349
Little Lotus River at Eighth Avenue	Zeekoe	LR10	-45503	-3768781
Little Lotus River at Fifth Avenue Grassy Park	Zeekoe	LR11	-45572	-3768224
Lotus River at Fifth Avenue - Grassy Park	Zeekoe	LR12	-44521	-3767959
NY3A u/s stormwater outlet	Zeekoe	LR13	-39654	-3762073
NY3A d/s stormwater outlet	Zeekoe	LR14	-39674	-3762095
NY3 u/s stormwater outlet	Zeekoe	LR15	-40353	-3762874
NY3 d/s stormwater outlet	Zeekoe	LR16	-40374	-3762903
Lansdowne Road opposite Sherwood Park	Zeekoe	LR17	-40993	-3763589
Lotus River at Springfield Rd Turfhill Estate	Zeekoe	LR18	-43688	-3764596

Princessvlei - vlei inlet	Zeekoe	PV01	-47481	-3768576
Princessvlei - north	Zeekoe	PV02	-47746	-3768628
Princessvlei - centre	Zeekoe	PV03	-47733	-3768843
Princessvlei - south	Zeekoe	PV04	-47738	-3769094
Princessvlei near outlet weir	Zeekoe	PVWEIR	-47524	-3768998
Italian Rd canal leading to Rondevlei	Zeekoe	RVIRD	-46604	-3770162
Perth Rd canal leading to Rondevlei	Zeekoe	RVPRD	-46151	-3769973
Rondevlei Weir	Zeekoe	RVWEIR	-45789	-3770622
Southfield Canal at Victoria Road	Zeekoe	SCV	-47095	-3767570
Home Bay in front of Zeekoevlei Yacht Club	Zeekoe	ZEV1S	-45403	-3770329
Opposite inlet of Big Lotus River	Zeekoe	ZEV2S	-44572	-3769327
In front of Cape Peninsula Aquatic Club	Zeekoe	ZEV3S	-44719	-3771282
SW corner approx 200m from weir	Zeekoe	ZEV4S	-45526	-3771178
Vlei sample at Zeekoevlei weir - occasional	Zeekoe	ZEWEIR	-45649	-3771415
Zoarvlei at corner of Vrystraat and Grey St	Zoarvlei	PEV1	-48302	-3753289
Zoarvlei (centre) at Wemmys Rd footbridge	Zoarvlei	PEV2	-47847	-3752558
Zoarvlei at Bancroft St	Zoarvlei	PEV3	-47416	-3751574

City of Cape Town – Coastal Bathing Areas: Bacteriological Sampling Locations

Coastline	Location	Code	X Co-ord	Y Co-ord
Atlantic	Table Bay Docks - off breakwater	cn02a	-52590	-3752266
Atlantic	Granger Bay - off beach before	cn03	-54497	-3752267
Atlantic	Mouille Point Beach - surf zone	cn04	-55057	-3752338
Atlantic	Green Point Outfall - off sea wall inshore	cn05	-55489	-3752472
Atlantic	Park Road Green Point - sea wall opposite	cn05a	-55614	-3752828
Atlantic	Three Anchor Bay - off NW rocks	cn06	-55684	-3753107
Atlantic	Rocklands - off sea wall opp. Shoreham flats	cn06a	-55997	-3753336
Atlantic	Rocklands stormwater pipe discharge	cn06b	-56069	-3753390
Atlantic	Rocklands Beach - surf zone	cn06c	-56040	-3753366
Atlantic	Graafs pool - rocks near concrete apron	cn07	-56614	-3753805
Atlantic	Sunset Tidal Pool - outside pool	cn08o	-57278	-3754672
Atlantic	Clifton 4th Beach - surf zone at south end	cn09	-57782	-3756953
Atlantic	Maidens Cove - off rocks	cn10	-57990	-3757250
Atlantic	Camps Bay Beach - surf zone	cn11	-57555	-3758073
Atlantic	Camps Bay Tidal Pool inside west wall	cn12a	-57686	-3758520
Atlantic	Camps Bay Tidal Pool inside near pump stn	cn12b	-57627	-3758562
Atlantic	Camps Bay Tidal Pool - sea outside the pool	cn12o	-57716	-3758525
Atlantic	Horne Bay Beach - rocks east	cn14	-57525	-3758843
Atlantic	In front of Bakoven Bungalows - NW rocks	cn15	-57851	-3759012
Atlantic	Saunders Rocks - surf zone off beach	cn16a	-57524	-3755131
Atlantic	Saunders Rocks stormwater discharge	cn16b	-57498	-3755122
Atlantic	Saunders Rocks Tidal Pool - inside pool	cn16i	-57538	-3755143
Atlantic	Saunders Rocks Tidal Pool - outside pool	cn16o	-57559	-3755136
Atlantic	Three Anchor Bay stormwater A	cn17a	-55684	-3753130
Atlantic	Three Anchor Bay - stormwater B	cn17b	-55686	-3753130
Atlantic	Three Anchor Bay - stormwater C	cn17c	-55688	-3753129
Atlantic	Three Anchor Bay stormwater E ????	cn17e	-55626	-3753058
Atlantic	Milton Tidal Pool - inside pool	cn18i	-56704	-3754041
Atlantic	Milton tidal pool - outside pool	cn18o	-56714	-3754029
Atlantic	Maidens Cove Tidal Pool 1 - inside pool	cn19i	-57748	-3757454
Atlantic	Maidens Cove Tidal Pool 1 - outside pool	cn19o	-57757	-3757469

Atlantic	Maidens Cove Tidal Pool 2 - inside pool	cn20i	-57849	-3757420
Atlantic	Maidens Cove Tidal Pool 2 - outside pool	cn20o	-57840	-3757446
Atlantic	Beach in front of Bakoven Pump Station	cn21	-57884	-3759151
Atlantic	Near Rietvlei Outlet - +/- 50m south of	cn22	-47933	-3751525
Atlantic	Horne Bay stormwater discharge on beach	cn23	-57562	-3759019
Atlantic	Graafs Pool stormwater 1 discharge	cn24	-56641	-3753978
Atlantic	Graafs Pool stormwater 2 discharge	cn25	-56574	-3753905
Atlantic	Graafs Pool stormwater 3 discharge	cn26	-56524	-3753788
Atlantic	Bakoven stormwater discharge	cn27	-57873	-3759106
Atlantic	Camps Bay stormwater discharge	cn28	-57712	-3758399
Atlantic	The Kom, Kommetjie	xcn01	-62389	-3779293
Atlantic	Long Beach Kommetjie	xcn02	-61876	-3778695
Atlantic	Llandudno Beach	xcn03	-60875	-3764492
Atlantic	Milnerton Lighthouse	xcn04	-47464	-3750300
Atlantic	Blouberg, small bay	xcn05	-50124	-3741026
Atlantic	Tableview	xcn06	-48511	-3743647
Atlantic	Melkbosstrand	xcn07	-51575	-3732660
Atlantic	Silwerstroom Tidal Pool	xcn08	-59376	-3718209
Atlantic	Oudekraal Resort	xcn09	-60019	-3762138
Atlantic	Hout Bay Beach	xcn10	-59043	-3768831
Atlantic	Scarborough Beach	xcn11	-57839	-3785634
False Bay	Kalk Bay	cs01	-50646	-3777532
False Bay	Kalk Bay Harbour Beach	cs01a	-50819	-3777762
False Bay	Kalk Bay Tidal Pool	cs02	-50629	-3777504
False Bay	Dalebrook Tidal Pool	cs03	-50391	-3777229
False Bay	St James Tidal Pool	cs04	-49798	-3776680
False Bay	ex Sandown Hotel site	cs05	-49025	-3775775
False Bay	Muizenberg Station	cs06	-48956	-3775647
False Bay	Sunrise Beach	cs07	-47710	-3775101
False Bay	Opposite lifebox 21	cs08	-46733	-3774715
False Bay	Opposite lifebox 23	cs09	-45905	-3774381
False Bay	Sonwabe	cs10	-45109	-3774174
False Bay	Ribbon Parking area	cs11	-44454	-3773994
False Bay	Lifebox 30	cs12	-42758	-3773546
False Bay	Strandfontein Point	cs13	-41710	-3773357

False Bay	Lukannon Drive WW pumping station	cs14	-37905	-3772298
False Bay	Mnandi Beach west	cs15	-35129	-3771824
False Bay	Muizenberg Pavilion	cs16	-48583	-3775476
False Bay	Strandfontein Tidal Pool	cs17	-41109	-3773356
False Bay	Mitchells Plain WW effluent discharge	cs18	-37046	-3772094
False Bay	Mnandi Beach east	cs19	-34770	-3771757
False Bay	Muizenberg Station stormwater	cs22	-49027	-3775693
False Bay	Mitchells Plain stormwter west discharge	cs23	-35847	-3771826
False Bay	Surf zone 50m east of MPSTW.W disch	cs23e	-35777	-3771847
False Bay	Surf zone 50m west of MPSTW.W disch	cs23w	-35894	-3771862
False Bay	Mitchells Plain stormwter east discharge	cs24	-33291	-3771530
False Bay	Surf zone 50m east of MPSTW.E disch	cs24e	-33228	-3771565
False Bay	Surf zone 50m west of MPSTW.E disch	cs24w	-33342	-3771570
False Bay	Muizenberg side of Baileys Cottage strmw	cs25	-49130	-3775921
False Bay	Baileys Cottage stormwater	cs26	-49167	-3776021
False Bay	St James side of Baileys Cottage	cs27	-49258	-3776163
False Bay	Dalebrook side of Baileys Cottage	cs28	-50052	-3776916
False Bay	Gordon Bay WWTW 20m from outlet	xcs01	-13582	-3779645
False Bay	Near Sir Lowrys Pass River Outlet 50m east	xcs04	-12389	-3780680
False Bay	Van Riebeek Hotel	xcs05	-12198	-3781055
False Bay	Gordons Bay Harbour centre	xcs07	-12953	-3781600
False Bay	Bikini Beach	xcs08	-13013	-3781681
False Bay	Kogel Bay Beach life savers tower	xcs09	-13648	-3789617
False Bay	Millers Point	xcs11	-48582	-3788977
False Bay	Fishermans Beach	xcs12	-49861	-3786311
False Bay	Seaforth Beach	xcs13	-50895	-3785003
False Bay	Long Beach Simons Town	xcs14	-52794	-3784281
False Bay	Glencairn Beach	xcs15	-52300	-3781204
False Bay	Fish Hoek Beach	xcs16	-52257	-3779067
False Bay	Silvermine River Mouth	xcs17	-51694	-3778291
False Bay	Monwabisi Tidal Pool	xcs18	-28653	-3771550
False Bay	Macassar Beach	xcs19	-23000	-3772051
False Bay	Simonstown Harbour	xcs21	-51426	-3784335
False Bay	Simonstown Diving School	xcs22	-52068	-3784822
False Bay	Gordons Bay Harbour Island	xcs23	-12976	-3780135

False Bay	Strand opposite Woltemade Street	xcs26	-16865	-3775161
False Bay	Strand opposite Burnard St (Springbok Café)	xcs27	-16425	-3775759
False Bay	Strand Pavilion jetty	xcs28	-15888	-3776598
False Bay	Strand Harmonie Park	xcs29	-14182	-3778918
False Bay	Monwabisi Beach	xcs30	-28541	-3771532
False Bay	Boulders Beach	xcs32	-50430	-3785463
False Bay	Strand near Lourens River Mouth	xcs33	-17225	-3774620

Department of Water Affairs and Forestry: River Flow, Level and Water Quality Monitoring Stations in the Cape Town Metropolitan Area

Monitoring Station		Location		Components Measured (Note 1)
No.	**Name**	**Lat.**	**Long.**	
G2H011	Macassar	34° 04'	18° 46'	W, WL
G2H014	Vissershoek	33° 47'	18° 32'	W, WL, Q
G2H015	Faure	34° 01'	18° 44'	W, WL, Q
G2H016	Somerset West	34° 05'	18° 51'	W, WL, Q
G2H021	Kuils River	33° 56'	18° 40'	W, WL, Q
G2H029	Strand	34° 06'	18° 49'	W, WL, Q
G2H038	Strand	34° 05'	18° 50'	Q
G2H040	Klein Welgemoed	34° 00'	18° 45'	W, WL, Q

Note 1: COMPONENTS MEASURED
F – flow
WL – water levels
Q – water quality

Annexure E - Modeling Tools, Techniques And Parameters

Basis for Design

a) Acceptable Flood Risk

One of the primary objectives of stormwater management planning is to achieve an acceptable flood risk within the developed area and to avoid increasing the downstream flood risk. The flood risk may be addressed within two main components of the stormwater management system: the major system and the minor system. The major system addresses conditions during large infrequent events and the minor system provides a means of handling the runoff from the smaller more frequent storms.

b) Major System

Major floods relate to the less frequent events, with a recurrence interval of 1:20 years and greater. The stormwater management system for all new developments should be designed to safely contain floods up to the 1:50 year flood without the flooding of properties. Conditions should also be checked for the 1:100 year event to ensure that floor levels will not be inundated. In terms of the National Water Act (Act 36 of 1998) the 1:100 year floodline must be indicated on the layout of all new townships.

The location of new developments within floodplain areas is described in the Guidelines for Development Control in Floodprone Areas. (City of Cape Town (2002a)), and is summarised in the tabulation below.

Flood Zone	Permissible Development
1:100 year flood level	Floor levels not permitted below 1:100 year flood level
1:50 year flood level	New development not permitted below the 1:50 year flood level
1:20 year flood level	The area below this level is known as the floodway and should remain unobstructed to permit the passage of floods.

c) Minor System

This system is to be designed to accommodate the more frequent events so as to eliminate inconvenience to pedestrian and vehicular traffic. Guidelines for the design frequencies for the minor system are given in the tabulation below. The minor system should therefore be designed with sufficient capacity to accommodate flows of this magnitude.

Land-Use	Design Flood Recurrence Interval
Residential	1:2 – 1:5 years
Institutional (e.g. schools)	1:2 – 1:5 years
General commercial and industrial	1:5 years
High value central business districts	1:5 – 1:10 years

Storm Rainfall

a) IDF Curves

For design purposes, storm rainfall is defined i.t.o. an intensity-duration-frequency relationship (IDF) and time distribution. IDF relationships have been determined for a number of rain monitoring stations in the Cape Town Municipal Area by the City of Cape Town and the Department of Water Affairs and Forestry (Weather Bureau monitoring stations) as modified and published by Schmidt, E.J., Schulze, R.E. and Dent, M.C. (1987) and Smithers and Schulze (2000). The rain stations in the CMA are listed in Table D.1 (Annexure D). In selecting an appropriate monitoring station to represent the catchment to be analysed both station proximity to the catchment and location relative to nearby hills or mountains should be taken into account.

Smithers and Schulze (2000) recommend the use of the Type 2 storm distribution while the triangular storm shape or the Chicago storm shape (based on nested critical depths for increasing durations all at the same recurrence interval) is favoured by many local engineers. In a study by Berg et al (2000) a number of recorded storms were analysed and it was concluded that the use of the Type 1 storm distribution is most appropriate for the CMA. Designers should exercise judgement in this regard.

b) Time Distribution

When stormwater runoff modelling is carried out it is also required to define the shape of the storm hyetograph, i.e. a time distribution of the storm rainfall. Two main distribution types are used in the CMA, viz. a triangular shaped storm and the more conservative Chicago type storm with a centrally placed peak.

The Chicago type storm is derived directly from the IDF relationship and requires the selection of a minimum time increment (typically 5 –15 minutes) and a storm duration (typically 24 hours). The average intensity over any period of time centred on the peak equals the intensity from the IDF relationship for that particular duration.

c) Areal Reduction Factor

It is recommended that the Alexander (1991) area reduction factors (ARFs) be used.

d) Autographic Rain Monitoring Stations

A number of other autographic rain monitoring stations are operated in the Cape Town metropolitan area and are listed in Annexure D - Hydrological and Water Quality Data Sources.

Stormwater Modeling

a) Modeling Tools and Techniques

Storm peak flow runoff may be conveniently computed for small catchments (up to 8 km^2) by means of the Rational or the SCS methods (Rooseboom et al (1993), and Schmidt, E.J. and Schulze, R.E. (1987a and b). For larger catchments the area should be discretised into sub-catchments and the peaks lagged and summed. A simple time lag method may be employed based on estimated flow velocities in the river channels.

These methods are open to criticism of being over-simplistic and for assuming that storm event probability equals runoff event probability, e.g. James (1992). If calibration data (rainfall with corresponding flow data) is available and the proposed development is large and must accommodate runoff from upstream and/or may have consequences downstream, then a modelling approach is justified.

Statistical methods based on recorded flow data (Alexander (1991)) are normally not appropriate because of the lack of specific long flow records.

Simple methods to compute pollutant export from a developing community have been derived e.g. Schueler (1987), however applicability to local conditions has not been tested.

Flow, water level and water quality data is collected at a number of points in the Cape Town metropolitan area and these data should be taken into account at every opportunity. A list of measuring points is listed in Table D.2 (Annexure D).

b) Stormwater Modeling

A number of models are available for modeling stormwater runoff in urban areas. The most commonly in use in South Africa are listed in Table 5.

Various processes may be modeled and these can be categorised as follows:

- Hydrological
- Hydraulic
- Water quality

The City of Cape Town recently commissioned a study to evaluate a wide range of models for more complex stormwater modeling, both quantity and quality. The SWMM model was recommended in the form of either the Visual Hydro or PCSWMM packages.

Comparison Of Selected Stormwater Models In Use In South Africa				
Model Name	**Modeling Capability**			**Normal Application**
	Hydrological	**Hydraulic**	**Water Quality**	
Stormwater	Time-area	Routing (channel and reservoir); Manning (normal flow)	-	Design or analysis of stormwater system
HEC-HMS	SCS method, Unit hydrograph	Routing (channel and reservoir); pumping; diversion	-	Master planning; modeling of attenuation ponds
HEC-RAS	-	Calculates water surface profiles for steady and unsteady gradually varied flow in network of channels, dendritic system or single river reach	Sediment Transport	Floodlines; hydraulic analysis
PCSWMM2000	USEPA SWMM method	Models steady and unsteady flows, pressure flows and full hydrodynamic routing	Multiple constituents	Design or detailed analysis of stormwater system with option of modeling water quality
VISUAL HYDRO	USEPA SWMM, SCS, Unit hydrograph methods	Models steady and unsteady flows, pressure flows and full hydrodynamic routing	Multiple constituents	Design or detailed analysis of stormwater system with option of modeling water quality
PONDPACK	SCS, Rational, Unit hydrograph methods	Routing (channel and reservoir); pumping; diversion	-	Master planning; modeling of attenuation ponds.

Annexure F - Stormwater Management Facilities and Techniques

Conveyance

C 1	**Pipes and Culverts**	Illustration: Page 24

Application

For conveyance of storm runoff where open channel flow is not practical, as well as for road crossings.

Engineering Design Considerations

Pipes and culverts are the primary components of any stormwater management system. They efficiently and quickly collect surface runoff and convey it away from areas where it may cause flooding or inconvenience. They significantly reduce catchment response time and increase runoff peak and volume compared to natural conditions.

Normally designed to flow full at design discharge, however surcharge in manholes may be taken into account if depth of pipe/culvert permits.

In special cases it may be required to calculate the water surface profile and allow for all potential hydraulic head losses, e.g. at hydraulic jumps, expansions, contractions, sharp changes of direction, etc.

Special measures may be required at outfalls to dissipate energy or protect against erosion.

Volume reduction can be achieved to a certain extent if storage pipes are used. Pipe storage schemes would only be useful on small developments, and where costs of land are very high, due to the expense of installing larger pipes.

Safety objectives as well as protection of downstream resources would arguably be met if extremely poor quality water is piped off-site and directed to a treatment facility.

Ecological Implications

Piped conveyance provides ecologically sterile habitat and, where stormwater would normally feed into surface drainage routes, effectively deprives these systems of their natural flow regimes and water supply. Natural water cleansing (e.g. through exposure to sunlight) cannot occur in piped systems.

Concentration of stormwater flow into pipes may also result in erosion downstream of their release into other conveyance channels, either natural or artificial and inlet and outlet details should be carefully considered in this regard.

This option presents little opportunity for improving ecological function. Piping of water to a treatment facility should be considered in cases where extremely severe water quality impairment exists, and is realistically likely to remain a long-term problem of the area.

Effectiveness

Effective in conveyance of stormwater runoff and prevention of erosion. Low effectiveness w.r.t. ecological and water quality improvement.

Health and Safety Implications

Only a positive aspect when water quality degradation is such that it constitutes a severe human health risk, such that on-site treatment through measures such as wetlands or other filtration devices are unlikely to work. In such cases, positive benefits are only achieved if water is conveyed to a treatment facility – its release from closed pipes further downstream is likely to result in health risks to natural and human communities downstream.

Closed pipes are less hazardous in terms of drowning than many open canals. Inlet and outlet details should be carefully considered in this regard and designed for safety and visual impact

Aesthetic or Social Implications or Additional Functions

In certain degraded areas, closed pipes are more aesthetically pleasing than open watercourses, since litter and other waste cannot be dumped in them.

Construction Implications

None

Maintenance Implications

Closed pipes will not attract windblown litter from the surrounding catchment as readily as open systems; however, where blockages do occur, they will be more serious and location of blocked areas will be more difficult. Small pipes are prone to blocking by paper, rags, debris etc.

Regular emptying of catchpits is required in order to minimize blockages caused by debris or sediment.

Additional Resources

Ven te Chow (1985); Rooseboom et al, (1993)

C 2	**Lined Artificial Channels (Concrete Or Rock)**	Illustration: Page 24

Application

For conveyance of runoff where severe space restrictions exist and where properties must be protected from flooding.

Engineering Design Considerations

May have uniform concrete lining or composite linings, e.g. concrete low-flow channel with vegetated high-flow section.

The most efficient hydraulic shape is parabolic but for stormwater canals the most common would be trapezoidal or rectangular because of ease of construction.

Normally design velocities are such that some form of erosion resistant lining is required. Various examples are illustrated above. Those with a concrete base are often favored because of ease of maintenance, but have negative ecological implications. Alternative pervious linings are normally rougher and result in slower, deeper flow - these can be used to dissipate water energy and improve quality.

For safety reasons, designs resulting in high velocities should be avoided.

Ecological Implications

<u>Smooth Impervious linings</u>
Channels with concrete or similar linings are ecologically sterile, providing little or no habitat diversity, no protection to living organisms during periods of strong flow and, since few if any organisms are able to survive such conditions, natural cleansing functions performed by many riverine ecosystems do not occur.

<u>Rough, pervious linings</u>
Rock-lined channels for stormwater conveyance provide a far better option, although they too have problems. The rocky bed formed might not necessarily be the kind of habitat that would occur in natural rivers in the area, and the ecosystem thus created would not therefore mimic natural conditions. Nevertheless, such a substratum can provide a far more diverse range of habitats than a concrete canal and, if flood velocities are not too high to prevent sedimentation, is likely to support in-channel vegetation growth, creating, in time, in-stream habitats such as islands and sand bars.

As far as possible, variation of the basic trapezoidal shape should be incorporated to maximise the diversity of in-stream habitats (e.g.- varying the widths of the low flow section, the height and slope of the low flow section sides, and the high flow section, where non-concrete lined options are selected.)

<u>Riparian fringe</u>
Additional ecological benefits may be obtained by creating a wide riparian fringe and sloped sides along the edges of the channel, such as buffering of surface water entering the channel from the surrounding area, creation of a corridor of riparian vegetation, providing shelter and habitat (where appropriate indigenous vegetation is established, and where the fringe is wide enough – a width of at least 10m on either side of the channel is recommended).

<u>Habitat quality</u>
Habitat quality can be further enhanced along the channel through landscaping details designed to increase habitat heterogeneity. These include the provision of meanders, varied bank slopes, ranging from 1:4 to 1:7, provision of high flow and low flow sections, and creation of off-channel and in-channel wetland areas. Even where space is severely constrained, “nodes” can be created in the river corridor, where slightly more space is available.

Effectiveness

Effective in conveying large flows at higher velocities, small width requirements and relatively low maintenance.

Low effectiveness w.r.t. water quality improvement and ecological benefit, unless substantial modifications to structure (e.g. rock-lined channels with vegetated margins).

A negative aspect associated with rock-lined channels is the potential for growth of invasive vegetation.

Health and Safety Implications

Concrete canals are usually trapezoidal or rectangular, can be deep, and are often fast flowing during flood periods. They thus constitute safety risks to humans and animals – exit from the canals once fallen into is also often difficult.

Velocities and depths should be kept as low as possible. Special measures should be taken to prevent humans and animals that have fallen into the canal, from being carried into long culverts. Such measures could include sloped gratings over entrances of such culvert and protuberances on the sides of the canal to assist an exit.

Graded, rock-lined channels (as outlined above) by contrast permit ease of exit, provided that vegetation growth is not excessive.

In non-concrete lined channels, water quality improvements should be associated with the incorporation of wide riparian buffer strips and on-channel wetlands.

Growth of Typha capensis along non-concrete lined channels the river channel can be associated with the production of seeds, associated with respiratory problems and clogging of curtains etc. If residential areas are set well back from the channel area, these are unlikely to be serious problems. Cutting of T. capensis seems to prevent seeding over at least one season.

Aesthetic or Social Implications or Additional Functions

Rock-lined channels, or composite channels (small concrete lined low-flow section and vegetated flood-flow section), landscaped and planted appropriately can be used to enhance the character of the development and incorporated into the useable open space of a development.

Potential uses include, informal sports activities in high flow sections (this use may however be in conflict with the creation of a substantially vegetated indigenous buffer strip) or adjacent to the riparian fringes; walkways; hiking trails; picnic areas; bird watching areas; educational resources.

The use and design of concrete channels must be appropriate to the context and location. Concrete channels frequently become little more than sewers, associated with pollution, litter loading and criminal elements. Conversely, in some areas they can form an important part of local movement networks and/or recreational systems, or act as deterrents to criminals, by forming the barriers to movement between sections of a community or between communities.

Construction Implications

Construction should not take place during the rainy season. If stabilisation by planting is envisaged, plants should be established before the onset of the winter rains and a phased approach to construction should be considered.

Where enhanced ecological function is an objective, a freshwater ecologist should participate in on-site supervision of landscaping, to maximise opportunities for habitat creation.

Maintenance Implications

Where extensive planting is envisaged, for aesthetic, bank stabilisation or ecological purposes, provision should be made for irrigation over at least one full year, as well as for weeding and replacement of plants lost to vandalism, drought, flooding.

Cutting of Typha capensis seems to prevent seeding over at least one season.

In rock-lined channel regular maintenance would be required to remove invasive vegetation.

Additional Resources

Ven te Chow (1985) Rooseboom et al (1993); Davies and Day (1998)

C 3	**Unlined Artificial Channels**	Illustration: Page 24

Application

For conveyance of runoff where properties must be protected from flooding and where space restrictions are not severe.

Engineering Design Considerations

Channels should be designed to achieve non-eroding velocities by appropriate selection of cross-sectional shape and longitudinal gradient.

Side slopes should be 1:4 to 1:7. Non-uniform edges may be used provided hydraulic capacity is maintained.

Utilising steps, e.g. gabions, may reduce gradients. Local erosion protection may be required at these points.

The channel base could be flat or have a depressed central section. A low-flow channel could be formed with rock protection, however it is likely to quickly silt up.

Vehicular access points should be provided for maintenance purposes.

Ecological Implications

Where steps (drops) are included in channel design, these should be <1m in height and/ or tied in to graded channel sides to allow for longitudinal migration of fish. The specific requirements for fish passage should be established where pertinent to that environment.

Where channels are lined, this should be covered by at least 300mm of soil to encourage establishment of vegetation. Planting should allow the establishment of a range of plants, adapted to seasonal or permanent inundation. At least some of these should be efficient at nutrient and other pollutant absorption, so that filtration is also enhanced. Vegetated buffer areas around planted channels will contribute to improving surface runoff quality from the surrounding areas

Channels may support unsightly blooms of algae at times (particularly in standing water areas) as well as invasion by T. capensis. The latter is effective in filtration, and it should be controlled, rather than eradicated from an area.

Effectiveness

Effective in conveying small or large flows at low velocities where sufficient width can be provided. Effective w.r.t. attenuation because of wider slower flow regime. Effective in sedimentation, groundwater recharge and provision of natural habitats.

Health and Safety Implications

Invasion by T. capensis may be associated with respiratory problems in some adjacent residential areas – this can be controlled by annual cutting or burning of the bulrush, to reduce seeding.
Improved water quality will have positive safety implications for downstream users.

Open channels may constitute safety threats to children and some adults. Warning signs should be posted, and local residents educated regarding potential dangers associated with these and other water bodies.

Aesthetic or Social Implications or Additional Functions

May be incorporated into P.O.S. to provide a focus point; could include walking, cycling, running tracks.

Construction Implications

Construction should be carried out during periods of anticipated low flow and special precautions should be taken to prevent sediment being washed downstream.

Maintenance Implications

Regular maintenance would include removal of sediment and vegetation, which reduces the hydraulic capacity below the design requirement, and removal of alien vegetation and litter. Irrigation may be required initially in order to establish vegetation.

C 4	**Unlined Sheet Flow**	Illustration: Page 25

Application

For conveyance of runoff in areas where wide extensive wetlands would have been the norm and space restrictions are not severe.

Engineering Design Considerations

Area to be shaped to achieve ecological objectives while maintaining hydraulic capacity. These design options provide opportunities for the creation of seasonal wetland habitat. Many sheet flow wetlands have been lost from development areas by changes in drainage and infilling. They are more vulnerable to development than discrete river channels, since during the dry season, their function as seasonal wetlands is often not obvious. It is only during the wet season that they are associated with broad seepage areas and surface shallow, surface flows after rainfall. Their creation in appropriate areas of new developments, would therefore be very positive from an ecological perspective.

Depending on the choice of design, landscaping and planting should be structured to create systems that are as diverse as possible. Attention should be paid to wetland shapes, which should meander longitudinally, and have side slopes that range between 1:4 and 1:7. Shallow irregular depressions on the base of wetlands will provide patches of differentially wetted habitat; shallow wetland areas will enhance water quality improvements through filtration.

Ecological Implications

Planting should ideally allow the establishment of a range of plants, adapted to seasonal or permanent inundation. At least some of these should be efficient at nutrient and other pollutant absorption, so that filtration is also enhanced.

Vegetated buffer areas around wetlands will contribute to improving surface runoff from the surrounding areas.

Wetlands may support unsightly blooms of algae at times (particularly in standing water areas) as well as invasion by T. capensis. The latter is however effective in increasing filtration and it should be controlled, rather than annihilated from an area.

Effectiveness

Effective in conveying small flows at low velocities where sufficient width can be provided. Effective in sedimentation, groundwater recharge and provision of natural habitats.

Health and Safety Implications

Invasion by T. capensis may be associated with respiratory problems in some adjacent residential areas – annual cutting of the bulrush, to reduce seeding, can control this.

Improved water quality will have positive safety implications for downstream users.

Areas of shallow standing water may constitute safety threats to children and some adults. Warning signs should be posted, and local residents educated regarding potential dangers associated with these and other water bodies.

Aesthetic or Social Implications or Additional Functions

Litter carried by stormwater tends to catch on plants, making wetland areas unsightly. This problem can be addressed by incorporation of litter traps into stormwater outlets (provided that maintenance of such traps occurs at appropriate intervals); alternatively, local ratepayers or body corporate should consider funding cleansing programmes.

Wetlands such as these lend themselves to use as community amenities, providing aesthetically pleasing natural areas in urban settings; providing bird watching areas and walking trails.

Construction Implications

Construction should not take place during the rainy season; plants should be established before the onset of the winter rains and a phased approach to construction should be considered. Where enhanced ecological function is an objective (e.g. as outlined in ecological section above), a freshwater ecologist should participate in on-site supervision of landscaping, to maximise opportunities for habitat creation.

Maintenance Implications

Where extensive planting is envisaged, provision should be made for irrigation over at least one full year, as well as for weeding and replacement of plants lost to vandalism, drought, flooding.

Erosion nicks between berm overflow areas in sheet wetland designs should be attended to – planting may be more effective than hard engineering designs, although the latter might include grass blocks and gabion -mattresses.

C 5	**Natural Channels**	Illustration: Page 25

Application

Natural channels should be retained for stormwater drainage as a matter of course. Measures may be required to protect their integrity and function.

Engineering Design Considerations

Developments tend to alter runoff behavior by reducing infiltration and increasing volume, rate of runoff and pollution. The sediment transport regime is also altered.

These consequences may all negatively impact on natural channels. Care should therefore be taken to address these effects before the runoff enters the natural channel.

Certain in-stream measures may be necessary if this cannot be fully achieved prior to runoff entering the channel. Such measures could include erosion protection, planting, introduction of wetlands, sediment, oil or litter traps.

Ecological Implications

The impacts of incorporating natural channels into a stormwater system need to be carefully determined and analysed. Substantial changes in the hydrological regime of the channel will have negative impacts ecologically and functionally, and inappropriate use may lead to severe undercutting erosion, undercutting, increased flood risk and eventual canalisation of courses.

The use of natural channels should be part of an integrated stormwater management plan that aims to ameliorate development impacts close to source. For example, vegetated buffer areas around planted channels/wetlands will contribute to improving surface runoff quality from the surrounding areas

Wetlands and channels may support unsightly blooms of algae at times (particularly in standing water areas) as well as invasion by T. capensis. The latter is however effective in filtration, and it should be controlled, rather than eradicated from an area. Measures to prevent erosion at inlet areas should be put in place.

Natural river ecosystems should be protected from the influence of the poor stormwater quality by creation of substantial wetland areas at inlet points. Where natural channels have high ecological importance, or are likely to be negatively impacted by receipt of stormwater, their use as stormwater conduits should not automatically be assumed, without incorporation of substantial mitigatory measures.

Effectiveness

Most effective in achieving all design objectives, provided the system is regularly monitored and not over-stressed.

Health and Safety Implications

Invasion by T. capensis may be associated with respiratory problems in some adjacent residential areas – this can be controlled by annual cutting or burning of the bulrush, to reduce seeding.

Improved water quality will have positive safety implications for downstream users.

Areas of shallow standing water and open channels may constitute safety threats to children and some adults. Warning signs should be posted, and local residents educated regarding potential dangers associated with these and other water bodies.

Aesthetic or Social Implications or Additional Functions

Litter carried by stormwater tends to catch on plants, making planted channels and wetland areas unsightly. This problem can be addressed by incorporation of litter traps into stormwater outlets (provided that maintenance of such traps occurs at appropriate intervals); alternatively, local ratepayers or body corporate should consider funding cleansing programmes.

Wetland and channel systems such as these lend themselves to use as community amenities, providing aesthetically pleasing natural areas in urban settings; providing bird watching areas and walking trails.

Construction Implications

Limited erosion protection may be required from time to time.

Maintenance Implications

Annual cutting of the bulrush, to reduce seeding, may control invasion by T. capensis.
If possible mechanical dredging of sediment invasive vegetation from channels should not be carried out, as this leads to the creation of unstable steep-sided, deep channels, with reduced ecological function. Manual weed/ other vegetation clearing should take place, where such clearing is necessary.

Litter carried by stormwater tends to catch on plants, making planted channels and wetland areas unsightly. A cleansing programme will be required.

C 6	**Gabion Baskets And Mattresses**	Illustration: Page 25

Application

Erosion protection, bank stabilisation, energy dissipation, weirs and earth retention.

Engineering Design Considerations

<u>Erosion protection</u>
Gabion mattresses suitable for erosion protection where water has high velocity or impact e.g. channel lining, downstream of weirs, culvert or pipe outlets. Suitable thickness mattress should be selected for the anticipated velocity or measures taken to first reduce the velocity.

<u>Weirs</u>
Gabions may be stacked to form weirs of various heights. Although flexible, measures must be taken to prevent undermining of structure.

Ecological Implications

Gabions and mattresses may be covered with topsoil on completion and vegetated. Where appropriate larger openings may be retained between gabions baskets to provide space for vegetation with larger root system.

Gabion weirs can be effective structures in terms of dissipating energy and thus preventing erosion. However, like gabion channel linings, they are ecologically barren, supporting little quality vegetation and, in low-income areas, serving as traps for the collection of unsightly litter.

Where gabion weirs are necessary, consideration should be given to packing soil in spaces between stones along the length of the gabion, other than at the overflow lip of the structure. Planting is possible in such areas, albeit little but camouflaging vegetation, rather than hanging vegetation capable of providing marginal vegetation or other cover, is likely to be established here.

Where the natural template of a channel would actually be closer to a wide shallow wetland than a flowing channel, construction of a wide, shallow gabion weir would allow spreading of flows upstream of the weir, and the creation of a swathe of wetland, rather than a defined channel in this area. Such a wetland would probably have a more substantial effect on water quality improvement through filtration.

Gabion baskets and mattresses are often installed in the short reaches immediately downstream of inlet and outlet points. These play an important engineering role, by preventing erosion and scour, however fast flows prevent the accumulation of sediment necessary for the establishment of screening vegetation. The use of such structures should be minimised.

Where gabions are used on channel sides, stepped gabions, with the lowest step set at bed level, may allow planting to be carried out behind the gabion, or even in sediment that accumulates on the edge of the gabion, outside of the main flow. Such planting, if successful and sensitively carried out, using appropriate, indigenous riverine species, both screens gabion structures, and provides a degree of sheltered marginal vegetation habitat at wetted bank level.

Where sporadic flows only discharge from a structure, establishment of plants other than hardy weeds is often difficult.

Effectiveness

Effective if baskets are correctly designed and filled.

Health and Safety Implications

Aesthetic or Social Implications or Additional Functions

Direct benefits through the prevention of scour. These structures do however tend to accumulate litter.

Construction Implications

Important that good controls are maintained during construction. Careful selection and placement of stones in the front face can result in an attractive product.

Maintenance Implications

Damaged wires and subsequent loss of fill stone must be promptly repaired to prevent total loss of structure.

Additional Resources

Stephenson; Manufacturers’ handbooks

C 7	**Energy Dissipaters**	Illustration: Page 26

Application

Points where high water velocity will occur, such as pipe and culvert outfalls, dam spillways and steeply sloping channels.

Engineering Design Considerations

Normally energy dissipation is required when supercritical flow has occurred and the associated high velocities are likely to result in scour damage or create unsafe conditions. Various means may then be employed to force a hydraulic jump to occur at a predetermined location where erosion protection may be provided. Excess energy is dissipated in the hydraulic jump and the flow regime changes to sub-critical flow in which the velocity is slower and less likely to cause erosion. Downstream conditions should be evaluated to ensure that sub-critical flow would be maintained.

Examples of energy dissipaters are:

- Rip rap basins
- Stilling basins
- In-channel weirs
- Impact basins

Energy dissipaters, which rely on high velocities to scour out accumulated sediment in order to function, should be avoided.

The concentration of flows with high energy should ideally be avoided by the distribution of storm runoff among multiple outlets, each discharging relatively small flows.

Ecological Implications

Positive in that velocities and resultant scour of natural habitat is reduced but in themselves often ecologically sterile and should be kept to a minimum.

Effectiveness

Effective in preventing high velocities and scour if appropriately designed and maintained. Sediment and debris tends to accumulate at energy dissipators because of the sudden reduction in velocities. This should be regularly removed in order to maintain function.

Health and Safety Implications

High velocity flows can be dangerous and should therefore be reduced through the use of energy dissipators or eliminated by avoiding the concentration of runoff (refer to Engineering design considerations).

Aesthetic or Social Implications or Additional Functions

Construction Implications

As construction may take place within a river, special precautions to prevent the discharge of eroded material downstream. Construction during the dry season is advised.

Maintenance Implications

Sediment and debris will tend to accumulate at energy dissipators and should be regularly removed.

Additional Resources

ASCE, (1992); Rooseboom, (1993); Ven te Chow, (1985), Environmental Protection Authority 1999

C 8	**Planting**	Illustration: Page 26

Application

Can enhance slope stabilisation and improve dissipation and spreading of flows downstream of an inlet/outlet structure (e.g. in a retention dam)

Engineering Design Considerations

Vegetation may be an effective means of erosion control in channels and where sheet flow occurs.

The relative erosion resistance depends on the type and density of vegetation cover, the erodibility of the soil and the silt content of the water.

Fine sands are more erodible for example than clayey soils or gravel. Depending on conditions velocities of up to 2 m/s may be permitted.

Vegetation also fulfils a role of improving water quality through the uptake of nutrients and the deposition of sediment.

Ecological Implications

Where slopes and discharge rates permit, stabilisation of slopes by planting with indigenous vegetation, in the case of permanently or seasonally flowing channels, with riparian/wetland vegetation is an ecologically preferred option to the use of hard stabilising structures.

Plants, if selected carefully, provide a quality, sheltered habitat, with additional properties such as moisture retention, pollution filtration and soil binding.

Plants also play a role in the vicinity of inlet and outlet structures. Most inlets and outlets need to be designed to withstand fast, often concentrated flows. These sections of the structure can appear stark and unsightly. However, they are also often adjacent to areas that can be prone to sedimentation, e.g. immediately downstream of inlet structures and upstream of outlets. Sedimentation can, if maintenance is not carried out, result in blockages of structures. It also encourages the growth of vegetation.

Whilst excessive vegetation across inlet and outlet points can be problematic, in that it blocks flows, it can also provide a useful ecological function, by filtering sediment, and absorbing nutrients.

In retention ponds for example, clusters of dense reed growth in the vicinity of inlets are to be encouraged in that they can play a positive role in filtering stormwater discharge as it enters the water body. This can potentially reduce the likelihood of algal blooms and other problems in the water body associated with poor water quality. Reeds are, however, unlikely to have any noticeable impact on stormwater quality in severely impacted stormwater discharges.

Effectiveness

Most effective provided the flow conditions and the quality of the vegetation remain within the capacity of the design.

Health and Safety Implications

Aesthetic or Social Implications or Additional Functions

The use of planting can form part of the green open space system, both visually and physically.

Planting is often more aesthetically pleasing than ‘hard’ engineering solutions, and the benefits of a planted system are greater than purely stormwater function.

Construction Implications

Protective measures during the initial growing period may be required, e.g. various types of biodegradable netting, stakes, horizontally secured logs etc. Planning should take place such that plants have established themselves before the rainy season starts. Allowance should be made for irrigation over short hot, dry periods, and during summer, if planting occurs early.

Maintenance Implications

Where the objectives of planting have included provision of a functioning riparian buffer and natural habitat corridor, the maintenance needs of the area must be carefully defined and controlled. This should prevent impacts such as routine mowing of indigenous planted areas, or alternatively, lack of watering / weeding during establishment phases, with the result that plant densities are insufficient to meet any of their required objectives.

Ponding

P 1	**Dry Ponds**	Illustration: Page 27

Application

These structures hold water for a few hours to a day only, but may be used in combination with retention and infiltration facilities. Their purpose is to temporarily store stormwater runoff in order to restrict outflows to predetermined levels to reduce local and downstream flooding and to promote the settlement of pollutants.

Engineering Design Considerations

The pond will be most effective in reducing flood peaks by being placed off-channel, i.e. the maximum permissible flow is designed to bypass the pond, and only the excess flow enters the pond and is temporarily stored. The inlet and outlet would be placed in close proximity as opposed to a low flow channel, which crosses the pond.

To achieve effective reduction in peak rates of runoff, pond must be located so as to intercept a major proportion of the site runoff.

Suggested two stage design to achieve greater water quality benefits - Lower stage (incorporating a small permanent wetland) to be sized to accommodate mean annual storm so that the upper section normally remains dry. Upper stage to accommodate the design storm, and have an emergency overflow to accommodate storms which exceed this. This recommendation has implications for the size and depth of the facility.

One of the main purposes is to achieve attenuation of storm runoff and anticipated hydrographs should be routed through the pond to confirm its effectiveness. The length of time that the pond takes to drain and the required storage volume are determined by the outlet capacity. Multiple storms with different durations or a Chicago type storm (Annexure E) should be used to determine maximum required storage. Maximum ponding duration should be determined after evaluating the primary purpose of pond e.g. if the dry portion of the pond is used for sport then ponding duration should be minimised. However, water quality benefits may be achieved if ponding can be extended to at least 24 hours.

The purpose of the outlet control is to significantly reduce downstream flows, ideally to those, which occurred prior to development. The outlet should be configured to achieve this for a range of frequencies and not only for the major less frequent events. Outlets should be protected with grids or other means for safety and to trap debris. Special measures should be taken to ensure that debris will not cause the pond to malfunction or fail.

Side slopes should ideally be 1:7 but no steeper than 1:4. This to promote safety and ease of maintenance. Overall cost savings may be achieved in an area by having fewer larger ponds as opposed to numerous smaller ponds. This may however have reduced effectiveness of water quality treatment.

Embankments and base should be made irregular to provide diverse habitat and maintain ecological integrity.

Ecological Implications

Positive, in terms of design objectives addressed, but less so than in the case of wet ponds.

Tendency for the location of the structure within natural drainage systems means that inundation periods are often associated with “drowning” of natural river or wetland habitats.

Effectiveness

One of the most effective means of attenuating peak flows if designed correctly. Not highly effective in addressing water quality, ecosystem functioning, bio diversity etc

Health and Safety Implications

Flat side slopes (1:7 – 1:4) and protected outlet to guard against danger of drowning.

Aesthetic or Social Implications or Additional Functions

Aesthetically pleasing vegetation of dry ponds is often difficult to achieve, since conditions in them range from brief periods of inundation, to long periods of dryness.

Dry ponds often have recreational/ public amenity value, as they are dry for most of the year, and thus lend themselves to use as sports fields, other forms of public open space. However, since their primary flood control function is often not obvious, they also lend themselves to invasion by informal settlements, or inappropriate use/maintenance.

The safety implications of human settlements in flood-control areas, and reduced functioning of an essential component of a major stormwater system are very serious. There is a need either for costly policing and evictions from such areas and/or alternative means of clear demarcation, education, awareness and signage.

Construction Implications

The basin may be constructed and used before the development area has been stabilised, but allowance should be made to remove the additional sediment load, which may be trapped.

Maintenance Implications

Maintenance responsibilities must be confirmed up-front with the local authority.

Wet-weather inspections annually, with as-built plans in hand. Performance of outlet control device and condition of wetland to be noted. Outlet structures require regular clearing. Dry-weather inspections annually, with as-built plans in hand.

A site access road should be stabilised to withstand heavy equipment.

Dry sections to be mowed 3-4 times per year.

Sediment to be cleared out of wetland section approximately every 5 years depending on catchment. Maintenance costs can be reduced by filtering inflows to the facility, (e.g. by passage of stormwater through swales or filter strips).

Address adequate drainage of dry portion of pond, vegetation should not become overgrown, any dumped material to be removed.

Additional Resources

ASCE 1993; Scheuler, 1987, Environmental Protection Authority 1999, “Catalog of Stormwater Best Management Practices (Idaho)”, http://www2.state.id.us, New Jersey Departments of Environmental Protection 2000

P 2	**Wet Ponds**	Illustration: Page 27

Application

The application is similar to that for dry ponds except that retention of a permanent water body also permits water quality treatment, through removal of sediments and reduction of pollutants (e.g. by exposure to sunlight and absorption / binding of nutrients /other pollutants by plants and soil particles.

Engineering Design Considerations

A permanent water body is usually achieved by either excavating a pond below natural ground level or by raising the outlet in a dam wall. The permanent water body is formed by excavating below the seasonal water table level or by retaining runoff or both.

In view of maintenance requirements it is preferred by the local authority that a single large detention in a development is preferable to a number of smaller ones. For the sake of safety it is preferable not to place the wet pond in a location where children are likely to have easy unsupervised access.

Short-circuiting should be prevented by increasing the length to width ratio (say 3:1 or greater) and placing the inlet and outlet as far apart as possible.

Depths of approximately 1,2 - 1,5m are recommended. This is to make provision for sediment and also to act as a safety measure. This also allows more successful establishment of vegetation around the fringes only.

Appropriate aquatic vegetation should be established in the shallower perimeter of the pond. This will enhance pollutant removal, provide an attractive habitat for birds and other wildlife, act as erosion protection, and trap incoming sediment if situated at the inlet. Shrubs should be placed on the buffer around the pond in order to enhance the wildlife habitat. However caution should be exercised so that hiding places for criminal elements are not created.

Side slopes should ideally be 1:7 or flatter but no steeper than 1:4. This to promote safety and ease of maintenance.

Inlet pipes should be approximately 300mm below the permanent water level. Outlets should be protected against erosion.

Variable side slopes and base, both in terms of steepness as well as roughness will facilitate a more diverse plant community and increase habitat diversity for wetland fauna.

Ecological Implications

Potentially very positive ecological implications associated with the use of this option. Wetted ponds can provide substantial filtration/water purification if designed carefully, at the same time as affording valuable wetland habitat. Bias in design towards a filtration/purification function, versus a diverse wetland habitat, would be determined by the anticipated quality of stormwater runoff into the structure.

Shallow systems, with high length: width ratios will be most efficient at filtration (although these have greater spatial requirements to achieve the same storage capacity). The type of plants established in the system will also affect the function of the wetland as a filtration device. Refer to plant list in Annexure G.

Where water quality improvements are not accorded over-riding significance, habitat quality and diversity should be maximised. Choice of wetland plants so as to create a variety of habitat patches, of plants with different size structures and densities, contributes to physical diversity within the wetland. Attention should also be paid to the creation of areas of seasonal wetland areas – a threatened wetland type in the metropolitan area. Islands and sandbars, while reducing storage capacity of the wetland, do provide sheltered roosting, nesting and feeding areas for wetland birds and other animals.

Side slopes should be varied, and range between 1:4 and 1:7 – again, to maximise habitat diversity and mirror natural systems; the overall shape of the wetland should be irregular, rather than geometrical, and should provide a diversity of sheltered inlets and exposed areas, including seasonally inundated fringes in permanent wetted ponds. Note that such considerations have implications for the spatial requirements of these ponds.

As a general rule, locally indigenous plants should be utilised and the use of invasive alien plants should be strictly discouraged, even in artificial wetlands, as the likelihood of contamination of other water bodies from these source areas is great.

In the metropolitan area, nutrient-enriched runoff from many developments, coupled with the high availability of wind blown seed, means that many wetted ponds are prone to invasion by Typha capensis. While it is efficient in terms of nutrient absorption and is able to bind many pollutants into its root system, it is also perceived as a pest plant, choking shallow waterways and producing many fine seeds that clog curtains and can cause respiratory problems. Creation of deeper areas of standing water (ca 1.5m depth) is recommended as a way of reducing invasion by T. capensis (Hall 1993). Alternatively, manual control by cutting or burning.

Other potential nuisance species associated with the creation of wetted ponds include provision of habitat for midge larvae (chironomids) and mosquitoes, and the proliferation of floating and rooted complex plants and/or algae, including potentially toxic blooms of cyanobacteria, or blue-green algae. Nutrient enrichment in the pond encourages proliferation of nuisance species, particularly unsightly algal blooms.

Establishment of stands of plant species that are particularly efficient at nutrient uptake (e.g. T. capensis) should be considered in the vicinity of inlets into the pond; prior passage of incoming stormwater through vegetated swales / across vegetated filter strips would also improve incoming water quality.

Effectiveness

Wet ponds are one of the most effective stormwater management tools to achieve peak flow rate attenuation and water quality improvement. More effective way of attenuating floods and simultaneously addressing ecological issues. Recommended where this may be adjacent to existing remnant patches of natural wetland or linked to watercourses.

Health and Safety Implications

Wet ponds may be associated with, or are perceived by local communities, to be associated with particular health and safety risks. These include the danger of drowning to small children and non-swimming adults that is associated with the proximity of an open body of water. This problem can be reduced through careful location of play areas away from retention facilities; use of sign boarding to warn of dangers; attention to predominance of gently sloped wetland side slopes (1:7 to 1:4) to facilitate ease of access and egress, as well as be designing larger, shallower ponds.

Health risks are associated with wetted ponds where they give rise to algal blooms, particularly potentially toxic blue-green algal or cyanobacterial blooms in open water habitat.

Aesthetic or Social Implications or Additional Functions

Device lends itself to multiple (but sometimes mutually exclusive) uses, including recreational water sports; attraction of birds and other wetland animals; fishing; supply of irrigation water.

Unlike in the case of dry ponds, the function of wet ponds is obvious, and they do not lend themselves to purposes such as informal settlements.

Construction Implications

Provision should be made for on-site input from a wetland ecologist during the landscaping phase of construction.

Although use of the basin for treatment should be deferred until the development area has been stabilised, the partially excavated basin can be used as a temporary sediment trap / detention facility during construction.

Construction should take place during the dry season, and allow for planting of wetlands during late autumn, so that they are established before the onset of winter rains; irrigation is usually necessary during the first year of establishment.

Maintenance Implications

Maintenance responsibilities must be confirmed upfront with the local authority.

Site access - access road should be stabilised to withstand heavy equipment.

Wetland section - sediment to be cleared out approximately every 5 years depending on catchment. Pond should not be constructed until upstream catchment has stabilised.

Wet-weather inspections annually, with as-built plans in hand. Performance of outlet control device and condition of wetland to be noted.

Dry-weather inspections annually, with as-built plans in hand. Address the following: vegetation not overgrown, removal of any dumped material, debris and litter, ensure that the outlet has not been blocked by debris. Design should include sediment trap portion that can be cleared out- otherwise maintenance will undermine the ecological benefits of this option

Additional Resources

Environmental Protection Authority 1999, “Catalog of Stormwater Best Management Practices (Idaho)” ” http://www2.state.id.us , New Jersey Departments of Environmental Protection 2000

P 3	**Rooftop Runoff Management**	Illustration: Page 28

Application

Highly urbanised settings where the use of other ponding facilities is limited – can effectively increase time of concentration and decrease runoff peaks and volumes, and improve water quality.

Engineering Design Considerations

In high density urban areas there may be little opportunity to implement some of the other stormwater management facilities or techniques described in this report. However by treating the rooftops, which have virtually 100% runoff, it may be possible to achieve significant reduction in runoff peak and volume and an improvement in water quality. Three alternative approaches are described:

<u>Vegetated Roof Covers</u>

These comprise a relatively thin, uniform layer of vegetation over the entire surface of a flat roof.

The vegetated roof cover is made up of a sheet drain placed on the waterproofed surface of the roof, on which is placed the growth media and the vegetation (refer to diagram).

Light rainfall would be totally absorbed by the vegetation and growth media, while heavier rain would be delayed and filtered as it passes through the vegetated roof cover. When the water reaches the sheet drain it would quickly drain away and not remain ponding on the roof surface.

Normally such a vegetated cover would be light enough to be retrofitted to a roof without structural changes.

Roofs with vegetated covers are not intended to accommodate traffic by people.

A normal garden irrigation system would be required.

<u>Roof Gardens</u>

Roof gardens are similar in concept and purpose to vegetated roof covers, but are intended to create a landscaped environment which could include planters, potted shrubs, walkways etc. The extra weight involved would necessitate that provision be made for this in the design.

<u>Roof Ponding</u>

Roof ponding may be feasible in buildings where this would not result in high additional costs, e.g. where the roof support structure does not have long spans, or where the additional reinforcement required in the roof slab would not add greatly to costs.

Special measures must be taken to ensure that the ponding area remains waterproof.

Ponding may be provided on existing flat roofs by restricting and raising the flow to downpipes.

Ecological Implications

Positive, due to filtering effect and the reduction in runoff peak flows and volumes.

Effectiveness

These practices could be highly effective in achieving the objectives of reduction of rate and volume of discharge and improving water quality, depending on how widely they are implemented.

Health and Safety Implications

N/A

Aesthetic or Social Implications or Additional Functions

Very positive implications in a high density urban environment. Vegetated roof covers may be attractive if well maintained and roof gardens provide entertainment/recreational areas.

Construction Implications

Roofs that are retrofitted with rooftop gardens or ponds may require modification/strengthening.

Maintenance Implications

Vegetated roof covers/gardens: Relatively low maintenance if hardy indigenous plants are selected; will require periodic irrigation, fertilisation and weeding.

Vegetated roof covers protect roofs from UV rays and wide variations in temperature and could thereby prolong the life of the roof.

Ponding: Regular inspection required.

Additional Resources

New Jersey Departments of Environmental Protection
http://www.state.nj.us/dep/watershedmgt/bmpmanual.htm

Infiltration

I 1	**French Drain**	Illustration: Page 29

Application

Provides infiltration at localised scale, typically around individual buildings, and reduces flood volume and rate of runoff; to a lesser extent – some water quality improvement is usually associated with infiltration.

Engineering Design Considerations

"French Drain" is a term used as a synonym for a subsurface drain. A subsurface drain is gravel filled trench with a perforated pipe installed in the bottom. (A true French Drain is the same gravel filled trench, but without the perforated pipe installed in the trench bottom.)

A geotechnical investigation is required to determine relative soil characteristics such as porosity, heave potential and tendency to collapse. It should be established that the level of the winter (rainy season) water table is low enough to permit infiltration, as this will not occur if the surrounding ground is saturated.

A subsurface drain is usually placed at the same elevation as the bottom of the item to be protected. For example, if we are to intercept and divert water away from a basement, the perforated pipe should be placed no higher than the top of the basement floor. Ideally it shall be placed slightly below the floor to intercept all water and allow for some slope on the pipe.

Ecological Implications

Positive, insofar as it reduces stormwater volume and flow rate and thus reduces effects on downstream freshwater systems; it may also contribute to groundwater recharge, although in some cases this may be at the expense of natural areas of recharge for other groundwater resources.

May be associated with problems in establishing vegetation cover above the drain area, due to over-drying of surface soil during non-rainfall periods. Drought-tolerant vegetation should be used.

Effectiveness

Effective in handling small flows where soil conditions are favourable.

Health and Safety Implications

If the French drain is used to discharge poor quality stormwater to the groundwater then care must be taken that pollution of the groundwater will not occur, particularly if it is a potable water source.

Aesthetic or Social Implications or Additional Functions

Groundwater replenished.

Construction Implications

See general notes. Guard against ingress of sediment.

Maintenance Implications

Regular monitoring of performance to ensure that blockage does not occur.

Additional Resources

DrainPro http://drainpro.com/french.htm

I 2	Hard Porous Surfaces - Asphalt / Concrete	Illustration: Page 30

Application

Reduces the impact of surface hardening on stormwater runoff by allowing infiltration. Infiltration is associated with a degree of filtration, particularly of sediments. For parking lots, footways, other areas of open space.

Engineering Design Considerations

Specifically designed paving comprising open graded asphalt or concrete with large proportion of normal fine aggregate material excluded, e.g. no-fines concrete, on a prepared base. The base should be formed from suitably selected crushed stone and an impervious layer may be placed below this if discharge to the groundwater is to be prevented.

Requirements include permeable soil, a fairly flat slope, relatively deep water table and bedrock levels are required unless special measures are taken.

Ecological Implications

Positive - some filtration occurs, particularly of sediments, and pollutants are retained close to source; reduces stormwater volume and flow rate and thus reduces effects on downstream freshwater systems.

Positive, insofar as it reduces stormwater volume and flow rate to a limited extent and thus reduces effects on downstream freshwater systems.

Effectiveness

Reduces the amount of land needed for stormwater management; replenishes groundwater; reduces runoff volumes and peaks to a limited extent; provides safer driving surface.
Sediment clogging will lead to failure.

Health and Safety Implications

Risk of groundwater pollution and potential health risks to be evaluated.

Aesthetic or Social Implications or Additional Functions
N/a

Construction Implications

See general notes for infiltration. During construction phase, when on-site sediment availability is high, water should not be conveyed onto these areas from elsewhere on the site; attention should be paid to timing of construction outside of the rainy season.

Maintenance Implications

Accumulation of sediment can cause failure through loss of infiltration capacity. Regular maintenance is essential for the removal of accumulated pollutants / surface layer is essential

Additional Resources

Bond et al, 1999; ASCE 1993; Scheuler TR, 1987, Environmental Protection Authority 1999

I 3	Hard Porous Surfaces-Paving Blocks	Illustration: Page 30

Application

For parking lots, footways, other areas of open space.

Engineering Design Considerations

Design possibilities include paving modules, which present large 'gaps' between impervious paved areas for infiltration – these can be integrated with grass or groundcover.
Where excessive wear is not likely, grassed surfaces may be considered.

Ecological Implications

Positive, in so far as it reduces stormwater volume and flow rate and thus reduces the effects of hardening on downstream freshwater systems; also contributes to groundwater recharge – but need to ascertain whether this is at expense of natural areas of recharge for other groundwater resources.

Although grass blocks fulfil a useful function, in terms of erosion protection, thus arguably fulfilling an ecological role in protection of the downstream catchment, in themselves they tend to be ecologically barren structures, supporting little but weedy vegetation and, in well-watered areas, grasses and low groundcover species (Ractliffe and Day 2002).

Where this recommendation will not interfere with the primary function of grass blocks (i.e. erosion control), scope for establishment of larger plants, and thus creation of more diverse and sheltered habitat can be achieved by leaving out alternate blocks, and thus creating a matrix structure, with larger holes at intervals.

Effectiveness

Depending on volume of vehicular traffic and resultant surface compaction, infiltration may be relatively low.

Health and Safety Implications
N/a

Aesthetic or Social Implications or Additional Functions

Where integrated with grass or groundcover planting, softer or greener appearance created

Particularly appropriate for natural sites where obtrusive road surfaces and artificial stormwater infrastructure are undesirable and where natural paving materials may be appropriate

Establishment of larger plants in grass block structures improves screening, and allows creation of a less barren, weedy structure.

Construction Implications

During construction phase, when on-site sediment availability is high, water should not be conveyed onto these areas from elsewhere on the site.

Maintenance Implications

Regular mowing of vegetation and prompt replacement of damaged blocks required. Irrigation often necessary to maintain grass cover.
Irrigation is usually necessary to establish plants and grasses in grass blocks that are above permanently wetted or moistened areas.

Additional Resources

Environmental Protection Authority 1999

I 4	**Infiltration Trenches**	Illustration: Page 30

Application

Generally used on relatively small drainage basins (e.g. residential plots; parking areas).

Engineering Design Considerations

This structure comprises a shallow excavated trench, backfilled with coarse stone aggregate, and which allows for temporary storage of runoff in the voids between the aggregate. A filter fabric should enclose the stone. Water percolates from here into the surrounding soil. The design can incorporate a surface that is either covered in gabion, stone or sand, or comprises a grass covered area with a surface inlet – in this case, inflow into the trench is only by means of the pipe.

Its use in combination with wide (at least 4m width recommended) vegetated swale strips between a hardened receiving surface and the trench allows trapping of sediment, and thus contributes to extending the working life of the structure, reducing maintenance requirements and increasing storage capacity.

Not suitable in areas with high, uncontrolled sediment yields, best suited for urban areas.

Ecological Implications

Ecological implications of the structure are positive, in so far as it reduces stormwater volume and flow rate and thus reduces effects on downstream freshwater systems; this option does not however contribute to wetland/ riverine habitat creation or rehabilitation (compare to retention ponds and “natural” vegetated conveyance channels.

May improve stormwater quality through provision of temporary storage of typically highly polluted runoff associated with the first storms of the rainy season.

Effectiveness

Effective as long as permeability is retained. Should be protected from siltation by surrounding grassed areas, which are well maintained.

Health and Safety Implications

If the infiltration trench is used to discharge poor quality stormwater to the groundwater then care must be taken that pollution of the groundwater will not occur, particularly if it is a potable water source.

Aesthetic or Social Implications or Additional Functions

Location of infiltration trenches close to built structures might result in seepage into foundation areas.

Construction Implications

The area should be well marked during surveying and protected during construction. Heavy equipment, vehicles and sediment-laden runoff should be kept out of infiltration areas to prevent compaction and loss of infiltration capacity.

Maintenance Implications

Sedimentation of the trench will result in gradual loss of function. Installation of observation wells at intervals along the trench will allow observation of rate of dewatering of the trench after a storm, as well as how rapidly the trench fills up with sediment. This will allow predictions of the frequency of maintenance activities to be made.

If sedimentation can be prevented maintenance requirements will be relatively low.

Additional Resources

ASCE 1993, Scheuler TR 1987, Environmental Protection Authority 1999, New Jersey Departments of Environmental Protection 2000

I 5	**Infiltration Basins**	Illustration: Page 31

Application

Temporarily stores surface runoff for a selected design storm; maintains or increases groundwater recharge by infiltration through the bed and sides of the basin.

Engineering Design Considerations

The underground basins temporarily store runoff and slowly release it. Infiltration basins may be either on-line or off-line with respect to the natural drainage route. Off-line basins are more effective both in attenuating the peak flow but also in capturing, detaining and treating the most polluted first flush of runoff.

These basins may be incorporated into landscaped areas, or islands in parking areas. Long-narrow (length: width ration =2:1 – 3:1), shallow structures are most effective; structures with sections for sedimentation, or which allow for sedimentation prior to entry into the basin, have longer working lives.

Energy dissipators are required at inlets, to increase sedimentation and decrease resuspension of sediment in the basin itself.

Ecological Implications

Positive, in so far as it reduces stormwater volume and flow rate and thus reduces effects on downstream freshwater systems; also contributes to groundwater recharge – but need to ascertain whether this is at expense of natural areas of recharge for other groundwater resources; this option does not however contribute to wetland/ riverine habitat creation or rehabilitation (compare to retention ponds and "natural" vegetated conveyance channels.

May improve stormwater quality through provision of temporary storage of typically highly polluted runoff associated with the first storms of the rainy season. Not suitable where stormwater likely to be highly polluted and contamination of sensitive/ important groundwater resources is likely.

Effectiveness

Effective as long as permeability is retained. Should be protected from siltation by surrounding grassed areas, which are well maintained.

Health and Safety Implications

If the infiltration basin is used to discharge poor quality stormwater to the groundwater then care must be taken that pollution of the groundwater will not occur, particularly if it is a potable water source.

Aesthetic or Social Implications or Additional Functions

The visual appeal of the structure can be enhanced by shaping and contouring to reflect the natural topography – a curvilinear basin edge is preferable to a geometric edge, and may be planted with appropriate vegetation, capable of withstanding occasional inundation and long periods of exposure/dry conditions. Establishment of dense vegetation on the base of the structure will reduce potential for erosion and contribute to maintaining high infiltration rates

Construction Implications

Although use of the basin for infiltration should be deferred until the development area has been stabilised, the partially excavated basin can be used as a temporary sediment trap / detention facility during construction.

Maintenance Implications

Filtration of grease, oil, solid organic material and sediment from stormwater prior to entry into the basin will reduce clogging and thus extend the working life of the infiltration system and lessen maintenance requirements.

Maintenance requirements depend on whether the system is vegetated or not; unvegetated structures may be tilled and re-excavated; vegetated systems require little maintenance: grassed surfaces for example grow up through sediment deposits, forming a porous turf and preventing the formation of an impermeable layer.

Additional Resources

Environmental Protection Authority 1999, Russell, Z 2000

I 6	**Swales**	Illustration: Page 31

Application

Slow flowing grassed channel, which reduces runoff volumes and peaks and traps pollutants.

Engineering Design Considerations

A swale, or grassed waterway, is a shallow trench which has the following characteristics:

- side slopes 1:3 or flatter; the cross-section should normally be trapezoidal with as wide a base as possible, so as to maximise contact of the water with the vegetation
- contains areas of standing or flowing water only after rainfall
- contains vegetation suitable for soil stabilisation, stormwater treatment and nutrient uptake.

It performs a dual role of conveying stormwater runoff, which is in excess of that flowing in the underground system, and improving water quality through the uptake of nutrients and the trapping of sediments. It should normally be used in conjunction with an underground stormwater system.

Swales should be designed to achieve shallow depths and slow flow to maximise efficiency. Check dams will improve efficiency. These may be created at driveway crossings by raising the culverts at these points.

Ecological Implications

Positive implications – water quality improvements likely through passage of water across vegetated area; may function as buffer between stormwater source areas and natural receiving bodies; may also be used to trap sediment upstream of infiltration devices;

Where space is available, the ecological value of swales can be vastly improved if efforts are made to mimic natural stream channels, for example by varying side slopes and channel shape, so as to create a meandering system, with a variety of hydraulic habitats.

Side slopes should vary between 1:4 and 1:7, with the latter effectively forming gently graded riparian wetlands.

Use of indigenous wetland and riparian vegetation further contributes to habitat quality and diversity, and allows the swale to function as a habitat corridor, providing shelter and aquatic and riparian habitat through the development, potentially linking upstream and downstream areas. The latter would be an important factor in developments that potentially segment drainage corridors.

Attention must be paid to the seasonality of flows in the system – where the catchment area is small, runoff may be limited to short periods following rainfall events and creation of a riparian corridor might not be feasible. In such cases, simple grassed swales would be more appropriate.

Stormwater quality would also influence the extent to which a high quality habitat might be created. In the CMA, nutrient-enriched runoff from many developments, coupled with the high availability of aerially-carried seed, means that many drainage channels are prone to invasion by the bulrush (Typha capensis). While this species is efficient in terms of nutrient absorption and is able to bind many pollutants into its root system, it is also perceived as a pest plant, choking shallow waterways and producing many fine seeds that clog curtains and can cause respiratory problems.

Effectiveness

Effective in increasing infiltration, reducing runoff and improving water quality.

Health and Safety Implications

See ecological implications
Roadside swales keep flow away from street surfaces during rainstorms, reducing the potential for car hydroplaning.

Aesthetic or Social Implications or Additional Functions

Can be used as softer, more environmental and aesthetic alternative to kerbs.

Provides green linkages through an area, along roads, but less compatible with sidewalk systems, except where space not limited.

Roadside swales become less feasible as the number of driveway and other entrances requiring culverts increases.

Construction Implications

Relatively inexpensive (cheaper than kerbs and drains).

Swale outlets (often into another open channel) must be constructed and stabilised before operation of the swale commences.

Maintenance Implications

Vegetation requires regular maintenance to maintain swale capacity. This may vary from cutting, to burning or dredging, depending on vegetation type and degree to which filtration capacity of soil has been exceeded; where large amounts of sediment are carried by stormwater and deposited in the swale. Dredging of sediment may be required, resulting in short-term reduction in filtering capacity.

Swales subject to damage by off-road parking and precautions should be taken to discourage this.

Additional Resources

Environmental Protection Authority 1999, "Catalog of Stormwater Best Management Practices (Idaho)" www2.state.id.us

I 7	**Check Dams**	Illustration: Page 31

Application

Erosion control/sedimentation in steeply sloping channels

Engineering Design Considerations

May be designed to be porous or impervious: Constructed from rock or gabions (pervious) or earth with core or concrete (impervious).

Serve as dissipaters of flow energy.

Can be used as filters and impoundments that trap sediments

Frequently constructed in series to stabilise riverbed and promote aggradatiion instead of erosion.

Size distribution of inflow sediment required in order to determine dam size.

Ecological Implications

Creation of series of dams can have a major impact on natural stream function. Needs to take account of River Priority Rank of system and its incorporates into natural systems should be undertaken with caution. Effective in artificial conveyance channels.

Effectiveness

Effective in decreasing channel erosion. Associated channel shallowing and sedimentation can result in creation of more diverse in stream habitat in previously channelised areas. In areas where natural situation would have been broad sheet flow wetlands, check dams at expense of recreating natural habitat.

Health and Safety Implications

For safety reasons check dams should be constructed with relatively low wall height.
Pervious check dams will fill more slowly than impervious dams – this is important where flash floods may occur.

Aesthetic or Social Implications or Additional Functions

The nature of the channel with the check dams may result in a varied habitat for fauna and flora and if well maintained can form attractive recreational area.

Construction Implications

Construction of check dams from downstream in an upstream direction may help to minimize transport of sediment downstream.

Maintenance Implications

Ongoing dredging of channels, wetland areas created by sedimentation of channels should not take place, save in demarcated areas.

If the check dams are to act primarily as a sediment trap, then regular dredging will be required. The frequency is dependant on the basin sizes, the flow regime and the sediment size distribution and loading. If however the check dams are to stabilise against further erosion then relatively little maintenance will be required.

Additional Resources

ASCE, (1993); Agostini, (1985)

Filtration and Treatment

F 1	Vegetated Filter Strips	Illustration: Page 33

Application

Surrounding infiltration structures. Adjacent to all water courses and water bodies. Between parking lots and stormwater management structures where drainage is primarily sheet flow.

Engineering Design Considerations

During its passage across the filter strip, water may lose sediment and other pollutants by filtration, infiltration, absorption and gravity sedimentation, associated with reduction in flow velocity.

Vegetation also reduces rate of erosion as a result of rainfall impact.

Where filter strips exposed to concentrated flows (e.g. low points in parking lots) then level spreaders should be used to establish sheet flow.

Effectiveness in terms of water quality control limited by slope – not effective at slopes > 17% - preferred slope <5%; not considered effective in terms of water quality control where water discharged onto the strip from a pipe, rather than as sheet flow.

Positive implications may be enhanced where space is available, through use of indigenous plant species to create riparian corridors associated with drainage corridors.

Ecological Implications

Traps sediment, promotes infiltration, some pollutants removed, protects downstream wetlands/streams from sedimentation.

Effectiveness

Effective in removing pollutants particularly sediment and in prolonging the effectiveness of stormwater management devices such as infiltration trenches and basins and porous paving.

Health and Safety Implications

Positive in both respects

Aesthetic or Social Implications or Additional Functions

Vegetated areas may serve an important stormwater management function if correctly located w.r.t. receiving bodies.

Construction Implications

Area must be stabilised and vegetated before being exposed to stormwater flows; irrigation will probably be necessary.

Maintenance Implications

Provision should be made for mowing of grassed areas. The presence of alien annual grasses should be kept to a minimum.

Additional Resources

Scheuler TR, (1987); ASCE, (1993)

F 2	Natural And Artificial Wetlands	Illustration: Page 33

Application

Effective pollution filter through absorptive and assimilative capacities of wetland plants and their soils. Sedimentation through filtration by plants and spreading out of flows. Retention of water in the wetland reduces stormwater volumes.

Engineering Design Considerations

An artificial wetland should be designed according to specifications of a freshwater ecologist.

Artificial wetlands may be established around the perimeter of a wet pond, the lower stage of a “dry” pond, or off-channel. The wetland must then be suitably landscaped and planted.

Ecological Implications

Positive implications, in that water purification should occur. The degree of water purification will depend on wetland design – e.g. shallow systems, with high length: width ratios will be efficient at filtration; retention time should be maximised, to allow uptake of pollutants, and expose pathogens (e.g. Escherichia coli bacteria) to sunlight, which destroys them.

The type of plants established in the system will also affect the function of the wetland as a filtration device. However, in ecological terms, a compromise can often be considered between design of a wetland exclusively for use in water purification, and incorporation of other ecological functions, such as provision of diverse wetland habitat. Where this is seen as an additional objective, choice of wetland plants might focus more on establishment of a diverse range of species, with different size structures and densities, to maximise diversity within the wetland.

Attention should also be paid to the creation of areas of seasonal wetlands – a threatened wetland type in the CMA. Islands and sandbars, while reducing storage capacity of the wetland, provide sheltered roosting, nesting and feeding areas for wetland birds and other animals. Side slopes should be varied, and range between 1:4 and 1:7 – again, to maximise habitat diversity and mirror natural systems. A wetland ecologist should participate in the landscaping phase of project construction, to ensure that habitat diversity is optimised.

The use of natural wetlands for the discharge of stormwater should not be at the expense of natural habitat diversity or biodiversity. Many wetlands support sensitive plants and animals, which are lost once the system is impacted. Impacts resulting from stormwater inflows are as likely to revolve around changes in flow regime (e.g. seasonal wetlands becoming perennial) as in water quality (e.g. many fynbos wetlands are naturally low in nutrients with a high pH; additions of nutrient-enriched water, of lower pH, and potentially bearing other toxins, could have devastating impacts on the natural wetland flora and fauna.

As a general rule, locally indigenous plants should be utilised and the use of invasive alien plants should be strictly discouraged, even in artificial wetlands, as the likelihood of contamination of other water bodies from these source areas are great. Anticipated stormwater quality would also influence the extent to which a high quality habitat might be created – stormwater with high levels of toxins such as heavy metals may create a system in which levels of these toxins are too high for survival of any but the most pollution-tolerant species; by contrast, in the CMA, nutrient-enriched runoff from many developments, coupled with the high availability of aerially-carried seed, means that many drainage channels are prone to invasion by the bulrush (Typha capensis). While this species is efficient in terms of nutrient absorption and is able to bind many pollutants into its root system, it is also perceived as a pest plant, choking shallow waterways and producing many fine seeds that clog curtains and can cause respiratory problems. Creation of deeper areas of standing water (ca 1.5m depth) is recommended as a way of reducing invasion by T. capensis (Hall 1993).

Effectiveness

Highly effective in improving water quality – refer to Ecological implications. Depending on storage capacity, runoff volumes and peaks may also be significantly reduced.

Health and Safety Implications

Positive in that water quality purification will occur, lessening health risks in downstream receiving water bodies (e.g. as a result of toxic algal blooms thriving in nutrient-enriched open water bodies)

Wetlands, particularly if they incorporate areas of deep standing water may be perceived as safety risks – these risks may be reduced by education and sign boarding of potentially dangerous areas; ensuring that slopes out of wetlands are gentle, to facilitate exit;

Aesthetic or Social Implications or Additional Functions

Multiple-function wetlands may also provide valuable recreational amenities – e.g. picnic or bird watching sites; water sport facilities (where water quality and water depth permit). However, any body of water, even relatively shallow systems, can constitute a safety hazard to small children. Play areas should not therefore be located in the vicinity of such wetlands.

Litter is often associated with stormwater, and tends to accumulate on wetland plants, creating a highly visible, unsightly structure. Installation and maintenance of a litter trap upstream of the wetland, or at the inlet structure, would reduce this problem.

Construction Implications

Provision should be made for the appointment of a freshwater ecologist to the site during landscaping, to ensure optimisation of habitat.

Construction should take place during the dry season, and allow for planting of wetlands during late autumn, so that they are established before the onset of winter rains; irrigation is usually necessary during the first year of establishment.

Maintenance Implications

Maintenance requirements centre on controlling invasive plant species (preferably by manual rather than more destructive mechanical means) and the need for periodic removal of wetland plants and soil as the absorptive and retentive capacity of the wetland is used up. Note that most nutrients and other pollutants are bound in sediment and root material, rather than in surface plant material, and although cutting back of plants is likely to promote plant growth, it is not usually an effective way of increasing the filtration capacity of a wetland.

Sedimentation of a filtration wetland reduces its capacity and in the long-term results in a change in state from wetland towards terrestrial ecosystems. Maintenance requirements in terms of sediment removal might be lessened by passage of stormwater through vegetated swales, or through a sediment trap, prior to entry into the wetland area.

Additional Resources

Environmental Protection Authority 1999, “Catalog of Stormwater Best Management Practices (Idaho)” ” http://www2.state.id.us , New Jersey Departments of Environmental Protection 2000

F 3	Litter Traps	Illustration: Page 34

Application

Removal of litter and sediment from urban stormwater systems.

Engineering Design Considerations

Litter traps should be strategically selected and located within urban catchments in order to effective. Normally this basic criterion for the litter trapping system would be established as a part of the overall catchment management plan. A basic best management practice is to trap pollutants as close to source as possible.

Various trapping devices have been developed and may be categorised as follows (Armitage, 1998):

- Low flow, low head structures
  - Small - side-entry catchpit traps (SECTs)
  - Medium - In-line Litter Separator (ILLS)
  - Large - Continuous Deflective Separation (CDS)
- Low flow, high head structures
  - Medium - North Sydney Litter Control Device (LCD)
  - Large - Baramy Gross Pollutant Trap (BGPT)
- High flow, low head structures
  - Small - fences, nets, booms or baffles installed across slow flowing streams or ponds
  - Large – CDS, Urban Water Environmental Management (UWEM)
- High flow, high head structures
  - Medium - BGPT
  - Large – side channel spillway option (SCS)

Trap efficiency is typically 70% and therefore a combination of the trapping points listed above should be implemented.

Care should be taken that flooding of properties will not result if trap becomes overloaded with litter, i.e. if a trap becomes blocked with litter, the required rate of flow must be able to bypass or overtop without flooding properties.

The use of grids over catchpit inlets is to be encouraged (except in very leafy areas) as it is in line with the policy of trapping litter as close to its source as possible. The use of these grids also places a responsibility on the street cleaning services and on residents to regularly clean these grids.

Ecological Implications

If litter is not efficiently removed by traps then it tends to accumulate on vegetation, e.g. in wetlands where removal is more costly. The removal of litter upstream ponds and wetlands makes the functioning of these devices more effective.

Effectiveness

The litter traps listed above are all reasonably effective provided that the litter is regularly removed. Different communities tend to generate different types and quantities of litter and specific local conditions should therefore be taken into account.

Health and Safety Implications

Certain litter is hazardous to health if handled and can also result in water pollution. Items such as plastic bags could pose a threat to animals and birds.

In channel litter traps can result in blockages, leading to raised water levels and increased flooding/drowning hazards.

Aesthetic or Social Implications or Additional Functions

Litter removal improves the aesthetics of an area and can increase a community's pride in their township. Presence of litter in a multi-functional stormwater management facility such as an open channel in a green belt would diminish its value as a recreational amenity.

Construction Implications

Construction should take place in the dry season.

Maintenance Implications

Ease and safety of maintenance required.

Effectiveness in trapping debris, particularly that which could cause blockages downstream. Local experience indicates that grid openings should not be smaller than 70mm in order to prevent grids from clogging up to rapidly.

Additional Resources

Armitage 1998, Environmental Protection Authority 1999

F 4	Sediment Traps	Illustration: Page 34

Application

Trapping and removal of sediment from rivers and channels

Engineering Design Considerations

Typically a basin is created along a flow path in which the sediment-laden water is caused to flow at a slow uniformly distributed velocity at a predetermined depth and for a sufficient length of time to settle out a large proportion of the sediment. Alternative designs, which require relatively less area, utilise artificial bends within the basin

Typical data requirements needed for design would include the particle size distribution of inflow sediment and the flood hydrograph frequency distribution.

Means of efficient sediment removal and areas for temporary or permanent stockpiling must be provided.

Ecological Implications

Where space permits, the ecological benefits of sediment traps can be increased, through the provision of wetland habitat adjacent to the "working" surface of a large sediment trap. This would be achieved by grading of gentle (and varied) slopes, ranging between 1:4 and 1:7; planted with appropriate indigenous wetland and terrestrial vegetation. Islands and sand bars can also be created within the sediment collection area. These areas should be demarcated (e.g. by bollards or raised concrete sills, so that dredging machinery does not disturb them.

Growth of wetland plants on accumulated sediment within the "working" area of the sediment trap will add a filtration / water purification function to the structure.

Effectiveness

Effective if designed according to accurate and appropriate data.

Health and Safety Implications

Flat side slopes (1:7 to 1:4) and protected outlet to guard against danger of drowning.

Aesthetic or Social Implications or Additional Functions

Frequent maintenance of sediment traps may result in unsightly, disturbed and largely bare structures.

Litter is often associated with stormwater, and tends to accumulate on wetland plants, creating a highly visible, unsightly structure. Installation and maintenance of a litter trap upstream of the sediment trap would reduce this problem.

Construction Implications

As construction may take place within a river, special precautions to prevent the discharge of eroded material downstream.

Maintenance Implications

Regular maintenance required, removing accumulated sediment and maintaining capacity. Maintenance is usually destructive and results in a temporarily unsightly structure.

Additional Resources

ASCE 1993, Environmental Protection Authority 1999

F 5	Oil Separator	Illustration: Page 34

Application

Treatment of stormwater runoff polluted with oil

Engineering Design Considerations

Anticipated maximum flows should be determined and the unit sized accordingly.
Provision should be made for an adequately sized sump to which the oil drains prior to removal.

A high proportion of the oil in runoff may be removed provided the unit is regularly maintained and that the flow remains below the maximum flow capacity.

Ecological Implications

It is vital to remove oil and grease at source; facilities which generate polluted runoff should be compelled to treat it prior to discharge to the stormwater system.

Health And Safety Implications

The removal of oil polluting runoff is has positive health implications for humans as well as fauna and flora. Prevention of pollution is far better than having to clean it up at a later stage.

Maintenance Implications

Regular removal of oil from sump and periodic checking that the mechanism is functioning correctly.

Annexure G - Planting Schedules

Recommended Plants for Re-vegetation of Watercourses and Water-bodies

Key to Table					
Habitat		**River Reach**		**Function**	
DB	Dry bank	MS	Mountain streams	C	Cover
SW	Seasonally wet	MR	Middle reach	E	Erosion control
WB	Wet bank	LR	Lower river	S	Shade
AQ	Aquatic	W	Wetlands	V	Economic value
		C	Coast	O	Ornamental

Scientific Name	Common Name	Habitat	River Reach	Function
TREES				
Brabejum stellatifolium	cape bitter almond	WB/DB	MS-LR	S,O,C
Brachylaena neriifolia	water white alder	WB	MS/MR	O,C
Canthium inerme	turkey berry	DB	MR/LR	O,C
Chionanthes foveolata				
Celtis africana	white stinkwood	WB	W	
Colpoon compressum				
Cryptocarya angustifolia	blue laurel	DB	MS/MR	O
Cunonia capensis	butterspoon tree; red alder	DB	MS-LR	S,O, C
Curtisia dentata	assegai wood	DB	MS	C
Diospyros whyteana	blackbark	DB	MS/MR	O, C
Euclea racemosa				
Halleria lucida	mountain fuchsia	DB	MS/W	O,C
Hartogiella schinoides	spoonwood	DB	MS	O,C
Ilex mitis	cape holly	DB	MS-LR	O,C
Kiggelaria africana	wild peach; pork wood	DB	MS-LR	O,C
Maurocenia frangularia	aasvoelbessie			
Maytenus heterophylla	gewone pendoring		LR	
Maytenus oleoides	rock candlewood	DB	MS-LR	S,O,C
Myrica serrata	lance-leaved waxberry	SW	W	
Ocotea bullata	stinkwood	WB	W	
Olea capensis subsp. macrocarpa	ironwood; black ironwood	DB	MS	C
Olea europaea subsp. africana	wild olive; olive wood	DB	MS-C	S,O,C
Olea exasperata				
Olinia ventosa	hard pear			
Olinia ventosa	hard pear	DB	MS	S,O,C
Platylophus trifoliatus	white alder	DB	MS	S,C
Podocarpus elongatus	Breede River yellowwood	DB	MS-LR/W	S,O,C
Podocarpus falcatus	Outeniqua yellowwood	DB	W	
Pterocelasirus tricuspidatus	cherry wood			
Rhus glauca				
Rhus lancea	willow rhus	WB	W	
Rapanea melanophloeos	cape beech	WB/DB	MS-LR	S,O,C
Salix mucronata	cape / bush willow	WB	MR/LR/W	E
SHRUBS				
Agathosma ovata	false buchu	DB	MS	O
Berzelia lanuginose	vlieebos	WB		
Buddleia saligna	bastard olive	DB	MR/W	O
Cassine maritima		DB	C	
Cliffortia odorata	wilde wingerd	DB	MR/LR	C
Cliffortia strobilifera Murray	bog rice-bush	WB/DB	MR/LR	FC,FE
Crotalaria capensis Jacq.	cape laburnum	DB	MR/LR	O
Diospyros glabra	blueberry bush	DB	MS-C	C
Erica caffra	sweet scented heath	WB	MS/MR	C
Freylinia lanceolata	honey-bell bush	DB	MR/LR	O,E,C
Gnidia oppositifolia	gonnabos; basbos	DB	MS/MR	O,C
Grewia occidentalis	cross-berry	WB		

Scientific Name	Common Name	Habitat	River Reach	Function
Halleria elliptica	notsun; bush honeysuckle	DB	MS/MR	O,C
Helichrysum crispum	hottentotskooigoed	DB	MS-LR	C
Leucospermum conocarpodendron	pincushion; kreupelhout	DB	MS	O
Maytenus lucida.	cape maytenus	DB	MS/MR	C
Metrosideros angustifolia	lance-leaved myrtle	WB/DB	MS/MR	E,C
Myrica cordifolia	waxberry		C	
Myrsine africana	cape myrtle; mirting	DB	MS/MR	O,C
Osmitopsis asteriscoides	belskruie	WB		
Othonna quinquedentata	5-point daisy	DB	MS/MR	C
Passerina vulgaris	gonnabos; bakkerbos	WB	MS-C	C,O
Plecostachys serpyllifolia	vaaltee	WB		
Podalyria calyptrata	water blossom pea	DB	MS/MR	O
Podalyria sericea	keurtjie	WB		
Polygala myrtifolia	septemberbos	WB		
Protea repens	sugar bush	DB	MS/MR	O
Psoralea aphylla	fonteinbos	WB		
Psoralea pinnata	fountain bush	WB	MS-LR	O
Senecio halimifolius	tabakbos	WB		
Stoebe plumose	slangbos	WB		
Rhus angustifolia	willow currant	DB	MS-LR	C
Rhus rosmarinifolia	rosemary wild currant	DB	MS/MR	C
Rhus tomentosa	woolly berry; real wild currant	DB	MS-LR	C
Secamone alpinii	monkey rope	DB	MS	C
Stoebe plumosa	slangbos	DB	MS-LR	C
Tetragonia fruticosa	klimopkinkelbossie			
RESTIOS, FERNS, GRASSES AND SEDGES				
Agrostis lachnantha	bent grass	WB	MR/LR	E,C
Andropogon appendiculatus	vlei bluestem	WB		
Asplenium sp.	mother fern	DB	MS	C
Blechnum . attenuatum	hard fern	WB	MS	O,C
Blechnum cf. punctulatum	hard fern	WB	MR	O,C
Calopsis paniculata	besemriet	WB/DB	MS-LR	O,E
Carpobrotus edulis	sour fig	DB	LR/C	
Commelina benghalensis	blouselblommetjie	WB	LR	C
Cyperus brevis	sedge	WB	MS/MR	E
Cyperus longus	water sedge	WB	MR/LR	E
Cyperus textilis	gaint cape sedge	WB	MR/LR	E,C,O
Cynodon dactylon	fyn kweek couch grass	SW/DB	w	
Digitaria eriantha	finger grass	WB		
Echinochloa colona	jungle grass	WB	w	
Ehrharta calycina	rooisaadgras	DB	MS-C	C
Ehrharta delicatula	watergrass	DB	MS-LR	C
Ehrharta erecta	-	DB	MS-LR	C
Ehrharta villosa	pypgras		LR/C	
Eragrostis curvula	blue seed grass	DB	MR/LR	C
Eragrostis capensis	heart seed love grass	WB		
Festuca scabra	munniksgras	DB	MS-LR	C
Helictotrichon turgidulum	small oat grass	WB		
Hypodiscus aristatus	cape reed	DB	MS	C
Imperata cylindrical	cottonwool grass	WB		
Ischyrolepis subverticillata	cape reed	DB	MS-LR	E,C,O
Isolepis prolifer	sedge	WB	MS-C	E,C
Jordaaniella dubia	strandvygie		C	
Juncus capensis	rush	WB	MS	C
Juncus kraussii	rush/biesie	SW/WB	W/C	
Juncus lomatophyllus	sedge	WB	MS-LR	E,C
Juncus punctorius	rush	WB	C	C
Lagurus ovatus	hares tail	WB		
Paspalum distichum	couch paspalum	WB		
Prionium serratum	palmiet	WB	MS/MR	E,C
Schoenoxiphium lanceum	forest sedge	WB	MS	C
Setaria incrassata	vlei brittle grass	WB		
Setaria megaphylla	ribbon bristle grass	DB	MR/LR	E,C
Setaria sphacelata	common bristle grass	WB		

Scientific Name	Common Name	Habitat	River Reach	Function
Spartina maritime	cord grass/strandkweek	WB	W/C	
Sporobolus africanus	ratstail dropseed	WB		
Sporobolus virginicus	brakgras	DB	W/C	
Stenotaphrum secundatum	coastal buffalo grass	SW/DB	W/C	
Zostera capensis	seegras/eelgrass	WB/AQ	W/C	
Stenotaphrum secundatum	coastal buffalo grass	SW/DB		E
Typha capensis	bulrush	WB	LR/W/C	E
GROUNDCOVERS				
Commelina benghalensis	blouselblommetjie	WB	LR	C
Chenolea diffusa	soutbossie	DB	W/C	
Erica chamissonis			LR/C	
Eriocephalus racemosus	kapkoppie	DB	LR/C	
Gazania maritime			C	E
Geranium incanum	horlosies		C	
Helichrysum cymosum subsp. cymosum	everlasting	DB	MS	C
Helichrysum orbiculare			LR/C	
Jordaaniella dubia	strandvygie		C	
Kniphofia uvaria	red hot poker			
Knowltonia capensis	katjiedrieblaar	DB	MS	O
Lobelia erinus	wild lobelia	WB	MS	O
Lycium campanulatum			LR/C	
Orphium frutescens			LR/C	
Putterlickia pyracantha	basterpendoring		MR-C	
Sarcocornia perennis		SW/WB	W/C	
Scuroys bidisys		WB		
Selago sp. (genus under revision)	-	WB	MR/LR	O
SUCCULENTS				
Carpobrotus edulis	sour fig	DB	LR/C	
BULBS				
Amaryllis belladonna	march lily	DB	MS/MR	O
Aponogeton distachyos	waterblommetjie	AQ	MR/LR	O
Aristea macrocarpa	suurkanol	DB	MS	O,C
Asparagus racemosus	wild asparagus	DB	LR/C	C
Asparagus suaveolens sensus	katdoring	DB	MS-LR	C
Chasmanthe aethiopica	suurkanol	DB	MS-C	O,C
Chondropetalum tectorum		SW	LR/W/C	
Myrsiphyllum scandens	creeping asparagus	DB	MS/MR	C
Watsonia spp.	iris	WB		
Zantedeschia aethiopica	arum lily; pig lily	DB	MS-C	O,C

Annexure H - City of Cape Town Stormwater Land Identification Database

Stormwater Land Identification Database

The Catchment, River and Stormwater Branch has prepared a set of GIS plans covering the entire CMA which identifies all erven impacted by stormwater issues. The aim is to alert planners, developers, development control officers and anyone else involved in land use management to the stormwater implications of erven.

The plans indicate the following stormwater features:

- Known flood prone areas demarcated by a flood line
- Flood prone rivers and canals
- Existing stormwater detention ponds, vleis and open water bodies
- Planned detention ponds

These plans, which are as yet are only available from the Catchment, River and Stormwater Branch, should be referred to prior to any planning so that potential major stormwater drainage problems can be quickly identified and the consequences for the proposed development can evaluated.

Annexure I - Minimum Design Standards for Underground Stormwater Reticulation and Associated Intakes

Pipes

The minimum pipe diameter shall be 300mm for catchpit connections and 375mm for longitudinal lines.

Pipes are to be in accordance with SABS (1200) loading criteria, while the minimum class of stormwater pipe shall be 100D for 300mm pipes.

Cutting of pipes - pipes must be clean cut with any exposed reinforcing adequately treated.

Pipes Joints

Pipes with spigot and socket (and rubber ring seal) joints must be used, while interlocking (ogee) joints may only be used in public open space. Where interlocking pipes are used the joints must be wrapped with a 400mm width of a suitable non-polyester geotextile with a 300mm overlap secured with nylon straps.

Where stormwater pipes cross sewers or watermains, the minimum clearance is to be 150mm.

Bedding

Bedding shall be Class B (SABS 1200).

Gradients

Minimum pipe gradients are to ensure a self-cleaning velocity of at least 0,9 m/s. Increased gradients must be used near the head of the system prior to the development of full flows.

The gradient of catchpit connections should not be less than 1:60.

Where possible design velocities should not exceed 3,5 m/s.

Where pipes of 375mm diameter to 450mm diameter exceed grades of 1:6, they must be anchored at alternate collars.

Where the pipe diameter exceeds 450mm and the grade exceeds 1:8 anchor blocks must be provided as above.

Anchor blocks must be 300mm long, protrude 150mm from either side of the socket and must extend 200mm below the bottom of the socket.

Where pipes enter canals, rivers or ponds the following criteria shall apply:

- The invert level must be above the normal wet season water level.
- The soffit must be above water level achieved during minor storms.

Catchpits / Gullies

Catchpit depths should not be less than 750mm and not greater than 1,0m less special circumstances exist.

Benching to be in accordance with the standard drawings.

Catchpit to catchpit connections are not acceptable.

The distance between catchpits shall not exceed 90,0m unless hydraulic calculations indicate that an alternative distance should be accommodated.

The percentage flow past a catchpit should not exceed 20% of the total approach channel flow.

The apron slope adjacent to the catchpit should be increased for greater efficiency and the upstream channel kicked where required.

Catchpit grids and frames are to be cast iron but other approved material for grids will be considered provided that SABS standard are complied with.

Skew kerb inlets/catchpits are to be used where road gradients exceed 8% (1:12,5).

Catchpit connection lengths may not exceed 15,0m.

Kerb inlet opening to be 100mm in height.

Catchpits may not be positioned on intersection radii as these are prone to damage by heavy vehicles.

Where Watereco grids are considered at planing stage, consideration should be given to increasing the length of the inlet.

Manholes

Manholes shall be provided at all horizontal and vertical changes in direction.

The distance between manholes shall not exceed 90m.

Manholes must be located in the roadway unless the verge is sufficiently wide to allow for repairs to the stormwater system to be undertaken without interference to cable and /or the kerb and channel.

SABS Type 2A cast iron covers and frames are to used. Covers of alternative materials may be used in high theft risk areas, providing the loading as specified in SABS 558-1973 can be met.

Only crown to crown pipe connections will be accepted.

Manhole access shafts are to be located in such a manner as to permit the cable for a bucket cleaning machine direct free access to the machine.

Widening must be provided on outside curves (benching) to allow for bucket cleaning.

Junction Boxes/Non Accessible Junctions

Junction boxes/non accessable junctions are not permitted unless the main line is larger than 600mm in diameter (man entry).

The end of the connecting pipe must be cut to follow the wall of the larger pipe and the connection protrusion must be kept to a minimum.

Annexure J - GIS Protocols for Stormwater As-Built Drawings and Data Capture Projects

Required Data Formats

All as-built information must be provided both on paper / film as well as in electronic format in accordance with the formats specified in the GIS Protocols for Sewer and Stormwater Data Capture and Data Management (City of Cape Town – September 1999) as amended.