DEVELOPMENT DESIGN SPECIFICATION 0074

STORMWATER DRAINAGE (DESIGN)

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Hornsby Shire Council
ABN 20 706 996 972
PO Box 37, Hornsby NSW 1630
Phone 02 9847 6666
Email hsc@hornsby.nsw.gov.au
296 Peats Ferry Rd, Hornsby 2077
Fax 02 9847 6999
Web hornsby.nsw.gov.au

SPECIFICATION 0074 – STORMWATER DRAINAGE (DESIGN)

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0074 STORMWATER DRAINAGE (DESIGN)

1 GENERAL

1.1 RESPONSIBILITIES

Scope

The work to be executed under this Worksection consists of the design of stormwater drainage systems for urban and rural areas.

Objective

Design requirements: Provide stormwater drainage systems design and documentation to meet the following requirements:

- Reduced frequency of flooding of private and public buildings in flood-prone areas.
- Control of surface flows to prescribed velocity/depth limits.
- Control of surface flows to minimise the effect on pedestrians and traffic in more frequent stormwater conditions.
- Within each catchment, retention of incident rainfall and runoff consistent with the planned use of the area.
- Conformance with the Australian Rainfall & Runoff (ARR) ‘major/minor’ system concept.
- A constant average recurrence interval (ARI) for existing and reconstructed works.
- Adoption of Water Sensitive Urban Design (WSUD) principles.

In General, the following principles will apply to all stormwater drainage design-

- To retain major creeks, streams and watercourses in a condition that minimises interference to stormwater flows especially those from major storms.
- To minimise the exposure of people and property to stormwater inundation.
- To minimise erosion and sedimentation problems.
- To protect and enhance the environmental quality and social well-being of residents.
- To ensure that supportive, preventative and remedial measures are consistent with Council’s principles, goals and objectives.
- To protect the natural environment against degradation from changes to stormwater runoff patterns and the transportation of pollutants.

1.2 CROSS REFERENCES

General: Conform to *0110 Quality requirements for design.*

Related worksections: The following worksections are related to this worksection:

- *0041 Geometric road layout.*
- *0042 Pavement design.*
- *0043 Subsurface drainage (Design).*
- *0075 Control of erosion and sedimentation (Design).*
- *1121 Open drains including kerb and channel (gutter).*
- *1351 Stormwater (Construction).*
- *1352 Pipe drainage.*
- *1353 Precast box culverts.*
- *1354 Drainage structures.*

1.3 REFERENCED DOCUMENTS

The following documents are incorporated into this worksection by reference:

Standards

AS/NZS 1254: 2010	PVC pipes and fittings for storm and surface water applications.
AS 1289	Methods of testing soils for engineering purposes
AS 1289.4.2.1-1997	Soil chemical tests - Determination of the sulfate content of a natural soil and the sulfate content of the groundwater - Normal method
AS 1289.4.3.1-1997	Soil chemical tests - Determination of the pH value of a soil - Electrometric method
AS 1289.4.4.1-1997	Soil chemical tests - Determination of the electrical resistivity of a soil - Method for sands and granular materials
AS/NZS 2032: 2006	Installation of PVC pipe systems
AS 2200-2006	Design charts for water supply and sewerage
AS/NZS 2566	Buried flexible pipelines
AS/NZS 2566.1: 1998	Structural design
AS/NZS 2566.2:2002	Installation
AS/NZS 3500	Plumbing and drainage
AS/NZS 3500.3: 2003	Stormwater drainage
AS/NZS 3725: 2007	Design for installation of buried concrete pipes
AS/NZS 4058: 2007	Precast concrete pipes (pressure and non-pressure)
AS 4139-2003	Fibre reinforced concrete pipes and fittings
AS/NZS 5065: 2005	Polyethylene and polypropylene pipes for drainage and sewerage applications

Other publications

Austroads

AGRD05-2008	Guide to road design – Drainage design
AP-R232: 2003	Guidelines for treatment of stormwater runoff from the road infrastructure

Council

Urban Drainage Design Manual

Engineers Australia

Australian Rainfall and Runoff (ARR) Volume 1 - A guide to flood estimation

- Book II - Design rainfall considerations
- Book III - Choice of flood estimation methods and design standards
- Book IV - Estimation of design peak discharges
- Book VII – Aspects of hydraulic calculations.
- Book VIII - Urban stormwater drainage.

ARQ 2006 Australian runoff quality – A guide to Water Sensitive Urban Design

Concrete Pipe Association of Australasia

Hydraulic Design Manual for precast concrete pipes

Refer to www.concpipe.asn.au for the design of steel reinforced concrete pipelines

Australian National Conference On Large Dams, Leederville WA

ANCOLD, Guidelines on Acceptable Flood Capacity for Dams (2007)

Australian and New Zealand Environment and Conservation Council

ANZECC- 2000 National Water quality management strategy No.10 Guidelines for urban stormwater management

NSW RTA

Model analysis to determine hydraulic capacities of kerb inlets and gully pit gratings

1.4 STANDARDS

General

Standard: Conform to the following:

- Rainfall and runoff: To ARR.
- Water sensitive urban design: To ARQ.
- To Council's Urban Drainage Design Manual.

1.5 INTERPRETATIONS

Abbreviations

General: For the purposes of this worksection the abbreviations given below apply:

- ARI: Average Recurrence Interval.
- ARR: Australian Rainfall and Runoff.
- ARQ: Australian Runoff Quality.
- BPP: Best Planning Practices.
- BMP: Best Management Practices.
- GPT: Gross Pollutant Trap.
- IFD: Intensity-Frequency-Duration.
- HGL: Hydraulic Grade Line.
- JP: Junction pits.
- OSD: On-site detention.
- SEP: Side entry pit.
- SMP: Stormwater Management Plan.
- SQID: Stormwater quality improvement devices.
- WSUD: Water Sensitive Urban Design.

Definitions

General: For the purposes of this worksection the definitions given below apply:

<u>Stormwater</u>: Water that drains off the land surface after rainfall forming part of the water cycle. Stormwater flows are highly variable and, in the natural environment, shape the landscape through flooding, erosion and deposition. In urban areas stormwater is carried via the drainage system and discharged untreated directly into the receiving waters.

<u>Receiving Waters</u>: Any natural water body to which the stormwater system discharges. This could be a creek, river, lake or the ocean. The primary receiving waters for stormwater runoff from Hornsby Shire are Berowra Creek, Cowan Creek and the Hawkesbury River to the north and the Lane Cove River to the south.

<u>Catchment</u>: The land surface area which contributes to the supply of stormwater in a common receiving water. Each catchment is separated by hills or ridges beyond which stormwater is directed away from the catchment. Hornsby Shire forms part of 2 major catchments, the Hawkesbury River catchment, (comprising of Berowra Creek, Cowan Creek and the Hawkesbury River) and the Lane Cove River catchment. Within these major catchments Hornsby Shire is broken up into 14 sub catchments, eg. Georges Creek catchment. Each of these sub catchments can be further broken down into smaller catchments appropriate to the area under consideration, eg. Verney Drive catchment. Most natural processes and environmental disturbances have their greatest impact within the boundaries of a catchment.

<u>Total Catchment Management</u> (TCM): The coordinated and sustainable use and management of land, water and vegetation and other natural resources on a water catchment basis so as to balance resource utilisation and conservation.

TCM gives priority to:
- coordination and integration of environmental and natural resource policies, programs and activities
- community participation and active, effective partnerships
- using water catchments as a principal focus for restoring and enhancing ecological assets and services.

<u>Ecologically Sustainable Development</u> (ESD) Using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained and restored, and the quality of life, now and in the future, can be increased. ESD gives priority to:
- intergenerational equity
- intragenerational equity
- conservation of biodiversity and ecological integrity

- dealing cautiously with risk
- global accountability
- integration of social and environmental considerations into decision making.

Minor storm: Storm of low rainfall intensity that occurs frequently.

Major storm: Storm of high rainfall intensity that occurs rarely.

Minor flow: Stormwater runoff resulting from a minor storm that would generally be carried in the pipe system.

Major flow: Stormwater runoff resulting from a major storm that in almost all instances would exceed the capacity of the pipe system.

Average Recurrence Interval (ARI): A measure of the frequency of rainfall which indicates the average number of years between occurrences of a storm of given intensity. For example a 100 year ARI storm will occur on average once every 100 years. However, as the estimation of the ARI is based on a statistical approach, it is important to understand that the periods between storms of any severity are generally random.

Q2: Stormwater runoff resulting from a 2 year ARI storm.

Q5: Stormwater runoff resulting from a 5 year ARI storm.

Q20: Stormwater runoff resulting from a 20 year ARI storm.

Q100: Stormwater runoff resulting from a 100 year ARI storm.

On-Site Detention (OSD): The temporary storage of stormwater on the site where it is generated. The storage is discharged at a controlled rate to avoid increasing downstream peak flows for all storm events.

Permissible Site Discharge (PSD): The rate set by Council as the maximum allowable stormwater discharge from OSD systems. The permissible site discharge has been generally limited for developments in Hornsby Shire to the Q5 discharge from the property prior to the proposed development unless varied by Council.

On-Site Retention/ Infiltration: The temporary storage of stormwater on site and the permanent retention of silt, debris and pollutants. The system encourages infiltration to promote groundwater recharge, improves water quality and prevents erosion and weed spread to downstream lands.

Drainage Easement: A section of privately owned land (commonly along a side or rear boundary) in which Council has the legal right to drain stormwater either in a piped system, an open channel or a combination of both. In areas where there are no easements however and public stormwater runoff drains through the subject site, Council will have the legal right to drain water under the Local Government Act 1993 as amended.

Interallotment Drainage Easement: A section of privately owned land (commonly along a side or rear boundary) in which upstream properties enjoy the right to drain stormwater generating from these properties.

Natural Watercourse: A natural open channel that may or may not have been modified/improved by man made actions. Council has the legal right for stormwater to pass through a natural watercourse and to carry out maintenance on the natural watercourse, if required. The owner of the land on which a natural watercourse exists must not obstruct stormwater flow. Often the width required for stormwater flow is not defined.

Drainage Reserve: A section of land owned by Council for the express purpose of stormwater control. These usually exist in older developed areas of the shire and run between two private properties.

Retarding Basins: Retarding Basins are used to control the increased peak rates of flow from development by temporarily storing stormwater runoff. The discharge is controlled to suit the capacity of the downstream trunk drainage system. Between storms the basin is typically empty and dry.

Primary treatment SQID: Removal of the majority of gross pollutants and coarse-medium grained sediments by screening or sedimentation e.g. GPT's, trash racks, sediment trap.

- Redevelopment site: A site which had (or was originally zoned to have) a lower density development than is proposed.

Secondary treatment SQID: Removal of the majority of coarse, medium and fine grained sediments, as well as a significant proportion of the pollutants attached to sediments, by enhanced sedimentation and filtration e.g. Infiltration basins and wet ponds.

- Stormwater Management Plan: Plan to manage the stormwater quantity and quality within a catchment and protect receiving water features, such as the protection of existing waterways, lakes and wetlands.
- Sub-catchment: A topographically defined area drained by a tributary or branch drain of a primary stream or main drain draining a catchment.
- Tertiary treatment SQID: Removal of the majority of sediments, attached pollutants and dissolved pollutants by sedimentation, filtration and biological uptake e.g. Constructed wetlands.
- Time of concentration: The time required for storm runoff to flow from the most remote point on the catchment to the outlet of the catchment or to the inlet of a drainage structure within the catchment.
- Treatment train: Sequencing of SQID's to optimise treatment performance.
- Trunk drains: Large capacity channels or conduits which carry runoff from local street drainage systems to receiving waters. For example, natural or artificial channels, transitions and hydraulic structures, culverts and road crossings, naturally occurring ponds and lakes, artificial detention or retention storages.
- Water Sensitive Urban Design (WSUD): Design principles aimed at improving the sustainable management of the urban water cycle. It integrates the planning and design of urban water cycle, water supply, waste water, stormwater and groundwater management, urban design and environmental protection.

2 DESIGN

2.1 CONSULTATION

Calculations

Certified design calculations: Engage a qualified hydrologic and hydraulic design professional to perform all required calculations.

Major structures

Certified structural design: Engage a professional engineer for all bridges, major culvert structures and specialised structures in conformance with *0160 Quality (Design).*

2.2 PLANNING

Best Planning Practices (BPP)

General: Carry out BPP including the following:

- Capability assessment: Assess the existing physical and natural attributes of the site including the following:
  - Area and shape of the catchment area.
  - Slopes and existing channels.
  - Vegetation affecting run-off and/or loss factors.
  - Existing works at risk of inundation.
  - Existing drainage works location and capacity.
  - Sensitive inhabited locations to be protected.
  - Services and transport works to be protected.
  - Any tidal considerations.
  - Pollution control requirements.
- Planning and design for WSUD.

Best Management Practices (BMP)

General: Evaluate the structural and non-structural elements of a design that perform the prevention, collection, treatment, conveyance, storage and re-use functions of a water management scheme.

BMP: Include the following:

- BPP:
  - . Land and water use planning.
  - . Regulation assessment.
  - . Urban design.
- Source control:
  - . Land management.
  - . Enforcement.
  - . Education and awareness.
- System management measures:
  - . Stormwater management plan.
  - . Stormwater treatment.
  - . Flow management.

Water Sensitive Urban Design

General: Plan and design stormwater drainage using WSUD principles including the following:

- On-site detention (OSD).
- Capture and use of stormwater as an alternative source of water to conserve potable water.
- Use of vegetation for filtering purposes.
- Water-efficient landscaping.
- Protection of water-related environmental, recreational and cultural values.
- Localised water harvesting for re-use.
- Localised wastewater treatment systems.

2.3 PRINCIPLES

There are four underlying principles that Hornsby Shire embraces in the design of stormwater management systems. These principals are:

1. <u>The Drainage System is Part of a Larger Environmental System</u>.

The influence of planned new developments and redevelopment within a catchment must be analysed and, where necessary, adjustments made to minimise the creation of new drainage and stormwater inundation and degradation problems. Where practicable, drainage works must be integrated with other community demands on watercourses and associated lands.

2. <u>Watercourses and Flow Paths are Natural Storage Areas</u>

The primary natural function of each watercourse and its associated flow path is the collection, storage and transmission of stormwater runoff. This function should not be subordinated to any other use of the flow path without compensating measures.

3. <u>Stormwater Requires Space</u>

If the time of concentration or natural storage is reduced by urban or other land use practices without appropriate compensatory measures, then additional space will be claimed by stormwater at some other location.

4. <u>Reduce, Remove, Recycle</u>

By reducing the amount and velocity of runoff the design goals will be easier to achieve. Preventing the entry of pollutants into the system is far more efficient and effective than attempting to get them out of the system. Stormwater must be considered a resource and whenever possible recycled and reused.

3 STORMWATER DRAINAGE SYSTEMS

3.1 GENERAL

Stormwater drainage

Design requirements: Consider the following elements in designing the stormwater drainage system:

- Determination of design flows.
- Hydraulic design of pipelines.
- Appropriate inlet and discharge structures.
- Structural elements of the drainage system.

Easements

Easements over private property: Do not surcharge major system flows across private property. Contain flows of ARI 100.

Collaboration: Plan services layout to avoid clashes with other services.

Control of erosion and sedimentation

Requirement: To *0075 Control of erosion and sedimentation.*

3.2 WATER CYCLE MANAGEMENT

Design for stormwater harvesting and re-use

General: Design for re-use of locally generated roof water, stormwater and wastewater. Adopt BPP and BMP systems to integrate the urban water cycle for collection, drainage and re-use.

Stormwater re-use scheme: Design the re-use scheme for ease of operation and maintenance. Consider the following when designing for collection, storage, treatment and distribution:

- End use requirements for water quality and quantity.
- Reliability of supply (varies with local climate and rainfall).
- Estimated demand for water with regard to peak flow. (Depends on the variable rainfall pattern).
- Assessment of water balance for sizing and storage.
- Storage requirements considering average annual volume and diversion flow rates.
- Treatment system based on:
  - Diversion flow rates before storage.
  - Distribution flow rates both before and after storage.

Roofwater: Provide an integrated design with rainwater tanks, coordinate with the appropriate engineering consultation and comply with the requirements of any authorities or local government.

Stormwater runoff: Design for the utilisation of stormwater runoff at the following scales:

- Allotment scale.
- Subdivisional/regional scale.

Wastewater and grey water: Design for wastewater and grey water re-use where it impacts the stormwater drainage design. Utilise professional engineering input where appropriate.

Stormwater collection

Requirement: Design the stormwater collection system to meet the following objectives:

- Extraction of sufficient water to meet the end use requirements without compromise to downstream aquatic eco systems.
- Potential to stop collection in the event that stormwater is contaminated by an incident within the catchment.
- Minimisation of the risk and/or impact of upstream flooding.

Stormwater storage

Requirement: Design the stormwater storage system to meet the following objectives:

- Storage of sufficient water to balance supply and demand.
- Above-ground storage: Minimisation of mosquito habitat (virus control), risks to public safety and risks to water quality and maximisation of dam safety.

Stormwater treatment

Treatment: Design appropriate stormwater treatment techniques to meet the following objectives:

- Minimisation of public health risks for the adopted public access arrangements.
- Minimisation of environmental risks.

Stormwater distribution

Requirement: Minimise the potential for:

- Contaminant inputs downstream of the final treatment facilities.
- Public exposure to untreated stormwater.
- Cross-contamination with mains water distribution networks or confusion with mains water supplies.

Irrigation: Design the irrigation system to the following requirements:

- Minimise run off, groundwater pollution and soil contamination.
- Minimise spray to areas outside the access control zone where access control is adopted to reduce public health risks.
- Application rate of stormwater: Uniform for the irrigation scheme and at a rate less than the nominal infiltration rate to avoid surface runoff.

3.3 STORMWATER MANAGEMENT

General

Requirement: Integrate management activities at the catchment, waterway and local development level in conformance with the *Guidelines for urban stormwater management* and the following:

- Restore of existing stormwater systems.
- Minimise the impacts of stormwater from new developments.
- Hydrological: Minimise the impacts of urbanisation on the hydrological characteristics of a catchment including wet weather and low flows. Mitigate pre-development inappropriate flows where practical.
- Water quality: Minimise the amount of pollution entering the stormwater system and remove residual pollution by implementing stormwater management practices.
- Vegetation: Maximise the value of indigenous riparian, floodplain and foreshore vegetation.
- Aquatic habitat: Maximise the value of physical habitats to aquatic fauna within the stormwater system.
- Processes for management: Submit processes for management for the following as applicable:
  - Runoff.
  - Water quality.
  - Riparian vegetation.
  - Watercourse and aquatic habitat.
  - Urban bushland.
  - Bridges and culverts across waterways.
  - Water sensitive urban design.

Stormwater management plan

Requirement: Provide a stormwater management plan in conformance with the *Guidelines for urban stormwater management* and the following:

- Describe the catchment or sub-catchment area.
- Identify stakeholders and partnership mechanisms.
- Outline agreed values, issues and management objectives.
- Identify management strategies for land and water use and practices.
- Address implementation instruments and programs including education and training, planning, infrastructure provision, operation and maintenance, regulation and economic incentives.
- Address assessment and performance review including monitoring of values and conditions, monitoring of strategy implementation and review time frames.
- Link water quantity controls with water quality controls.
- Integrate permanent stormwater management features into overall development.
- Identify legal point(s) of discharge (prior to Development Approval).

- Address ecological protection issues that are influenced by the management of stormwater (e.g. waterway corridor vegetation and habitat management issues).
- Clearly identify pollutants of concern and their sources for both the construction and operational phases of development.
- Identify an optimum combination of structural and non-structural Stormwater Quality Best Management Practices to limit the pollutant export potential of the site for both the construction and operational phases of development.
- Address the management of specific water quality issues (where relevant).
- Specify a water quality monitoring program where necessary.
- Outline maintenance requirements.
- Ensure site-based measures complement regional water quantity and water quality management measures already planned through Council Stormwater Management Plans or Waterway Management Plans.

3.4 GENERAL GUIDELINES

The requirements of this specification are generally in accordance with AR&R (1997) Book 8, however in keeping with the objectives and underlying principles of stormwater management in Hornsby Shire, the following summarises some of the key requirements of stormwater design.

Stormwater drainage systems consist of pipelines, pits, channels, overland flow paths and natural watercourses.

The design of stormwater drainage systems will be based on the current (1997) edition of the Institution of Engineers, Australia publication "Australian Rainfall and Runoff" (AR&R) or any revision of the publication.

It is not economically justifiable to construct a drainage system that will collect every drop of water from the most extreme storm. For this reason AR&R requires the use of a major/minor design philosophy, i.e. pipes be designed to carry minor flows while major flows be routed overland along streets and through drainage easements. Once the design capacity of a pipeline is exceeded the additional runoff will flow overland. The method of control of this overland flow will depend on its magnitude. With any new drainage construction, due regard must be given to the capacity of the downstream system.

Many old stormwater drainage systems do not meet the revised standards for stormwater drainage systems. It is financially prohibitive to upgrade all existing drainage systems to these standards.

Reconstruction of existing drainage systems will have regard to the standards for new areas but emphasis will be placed on the provision of overland routes and maximising the efficiency of the existing system. This will be achieved by:

- improving pit geometry
- improving inlet capacity
- regrading footways in road sag points
- improving pipe configuration.

Once the improvements to the existing pipe system are assessed the capacity of the pipeline and the magnitude of the overland flow will be calculated using the methods outlined in AR&R. and this specification. Council may then give consideration to the undertaking of other works along the pipe system if the project meets the criteria in Table 3.1 and 3.2.

TABLE 3.1 - DRAINAGE WORKS CATEGORIES FOR EXISTING PIPELINES.

Category	**Pipe Capacity less than Q20 but...**	**20 Year ARI Overland Flow (m^3/s)**
1	> Q2	< 1
2	> Q5	1 - 2
3	> Q5	2 - 10
4	> Q5	> 10

Where pipe capacity does not meet these standards consideration may be given to reconstructing the pipeline.

For each of the categories detailed above the actions described in the following table will apply:

TABLE 3.2 - ACTION PLAN FOR DIFFERENT PIPE CATEGORIES

Category	**Action**
1	Some minor works may be undertaken in the case where water is likely to enter any dwelling.
2	Consideration for the requirement of an overland flow path.
3	The following alternatives need to be considered:
(i)	-Upgrade the pipeline
(ii)	-Construct an overland flow path
(iii)	-A combination of the above alternatives
(iv)	-Determine an appropriate design capacity for the system. To be determined by Council's Engineer Investigation.
4	Council's Engineer Investigation must be consulted.

4 HYDROLOGY

4.1 PEAK FLOWS

The Rational Method is used to calculate the expected peak stormwater discharge "Q" from a catchment area. This peak discharge is calculated from the formula:

$$Q = C.I.A/360 \qquad \textbf{(4.1)}$$

where

Q = peak discharge (m^3/s)

C = co-efficient of runoff

I = rainfall intensity (mm/hr)

A = catchment area (ha.)

To apply the method, it is necessary to define the catchment area, sketching its boundaries on a plan and measuring the area (usually in hectares, 1 ha = 10,000 sq. m.). The longest flow path to the outlet of the catchment is established to determine the time of concentration.

The basic assumption of the Rational Method is that the maximum instantaneous stormwater runoff from a catchment occurs due to a rainfall of uniform intensity over the whole catchment for a duration equal to the time of concentration of the catchment.

The rainfall intensity for a storm duration equal to the time of concentration is selected for the design Average Recurrence Interval (ARI).

Generally, a suitable runoff co-efficient "C" for the particular catchment area is selected and used with the calculated intensity to find the expected discharge (see Section 4.5).

4.2 AVERAGE RECURRENCE INTERVALS

The first considerations in any drainage design are the nature of the surrounding land use, both existing and proposed, and the determination of the average recurrence intervals appropriate to the drainage structure being designed.

The average recurrence intervals given in Table 4.1 should be used unless otherwise directed.

TABLE 4.1 - RECOMMENDED DESIGN AVERAGE RECURRENCE INTERVALS

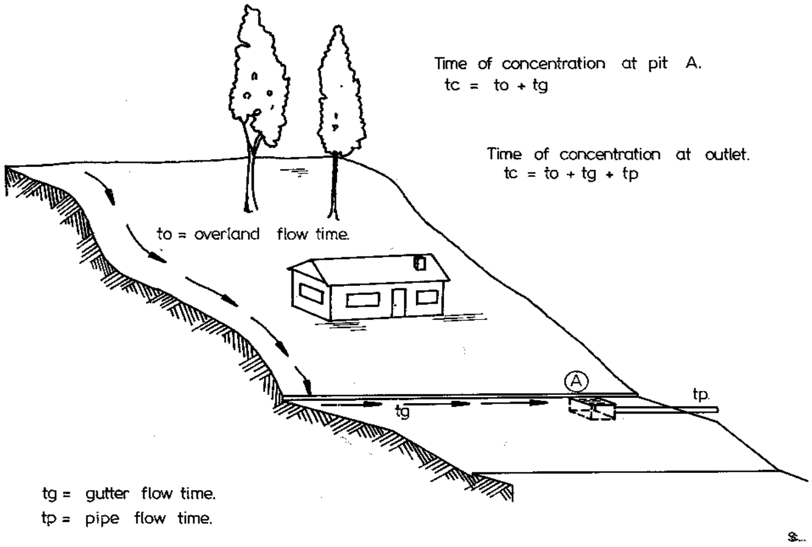
FLOW TYPE	DESIGN ARI
Roof, interallotment & household drainage:	
All residential, commercial, industrial, retail and service areas	20 year ARI
Flow in pipe or channel system along:	
Roads, pathways and easements through residential areas	20 year ARI
Trunk systems where Q20>3m^3/s	
Commercial, industrial, retail and service areas	
Overland Flow:	
For overland flows of Q100 < = 3m^3/s the flow may be routed through private property. A "restriction as to user" shall be placed on the Certificate of Title covering the overland flow path and setting a minimum floor RL for dwellings outside the flow path. Where appropriate, Council may require a drainage easement and/or a Positive Covenant on the Certificate of Title.	100 year ARI
For overland flow of Q100 > 3m^3/s the flow must be contained within public reserves, or drainage reserves. The drainage system will depend on the use of these areas and may not require a pipe system.	100 year ARI

4.3 TIME OF CONCENTRATION

The Rational Method generally determines the peak flow at various locations in a system by assuming that the whole catchment area is contributing to the flow at that location. The time that it takes for the runoff from the whole catchment to be contributing to the flow is called the time of concentration, and this is assumed to be the design storm duration.

Generally, the time of concentration for a particular location in the drainage system is the time of flow of the longest (i.e. slowest flow path to that location) (see figure 4.1).

FIGURE. 4.1 - TIME OF CONCENTRATION



NOTE: In some situations, the time of concentration determined from the longest flow path may not produce the peak discharge at a particular location. A peak discharge occurring before the normal time of concentration may occur because of partial area effects. Thus the critical time of concentration (i.e. the time of concentration which produces the peak discharge from a catchment) for each structure must be carefully determined. Partial area effects are discussed later in this section.

There are three different flow regimes encountered in urban drainage design for which it is required to calculate flow times. These are overland flow, gutter flow and pipe flow. The methods to be used to determine the flow times for these three situations are given in .this section.

The time of concentration for a pit inlet is taken as the longest travel time to that inlet. However, at the outlet pipe from this pit, the time of concentration to be used is the greater of either:

(i) the pit inlet time of concentration, or
(ii) the longest time of concentration for any upstream pit including the time of travel in that upstream pipe**.**

OVERLAND FLOW TIME

The 1987 Edition of AR&R requires the use of the Kinematic Wave Equation for the determination of overland flow times. The form of this equation is:

$$t = 6.94\,(L.n^*)^{0.6} / I^{0.4} S^{0.3} \qquad (4.2)$$

where
t = overland flow time (minutes)
L = flow path length (m)
n* = surface roughness co-efficient
I = rainfall intensity (mm/hr)
S = slope (m/m)

Typical values for the co-efficient n* are given in Table 4.2.

Appropriate values of this co-efficient for use in drainage design are given Table 4.2.

TABLE 4.2 - SURFACE ROUGHNESS FACTORS - n*

Surface Type	**Roughness Co-efficient n***
Dense Urban Development	0.012
New Urban Development	0.080
Average Urban Development	0.120
Average Grassed	0.170

For additional roughness coefficients, refer to AR&R table 14.4

As equation 4.2 involves both time of flow and rainfall intensity, it must be solved iteratively using the relation between time and intensity given in Table 4.5. in Section 4.4. Alternatively, equation 5.2 can be re-written as:

$$t\ I^{0.4} = 6.94(L\ n^*)^{0.6} / S^{0.3} \qquad (4.3)$$

The time of overland flow can then be found from Table 5.5, which contains values of t I0.4 for times up to sixty minutes. Once a value of t I0.4 has been determined, the corresponding time of overland flow is read from the table for the appropriate ARI.

Equations 4.2 and 4.3 apply only to catchments which are homogeneous in slope and surface roughness. For catchments that do not meet this criterion, the computer program given as Figure 14.6 in AR&R should be used.

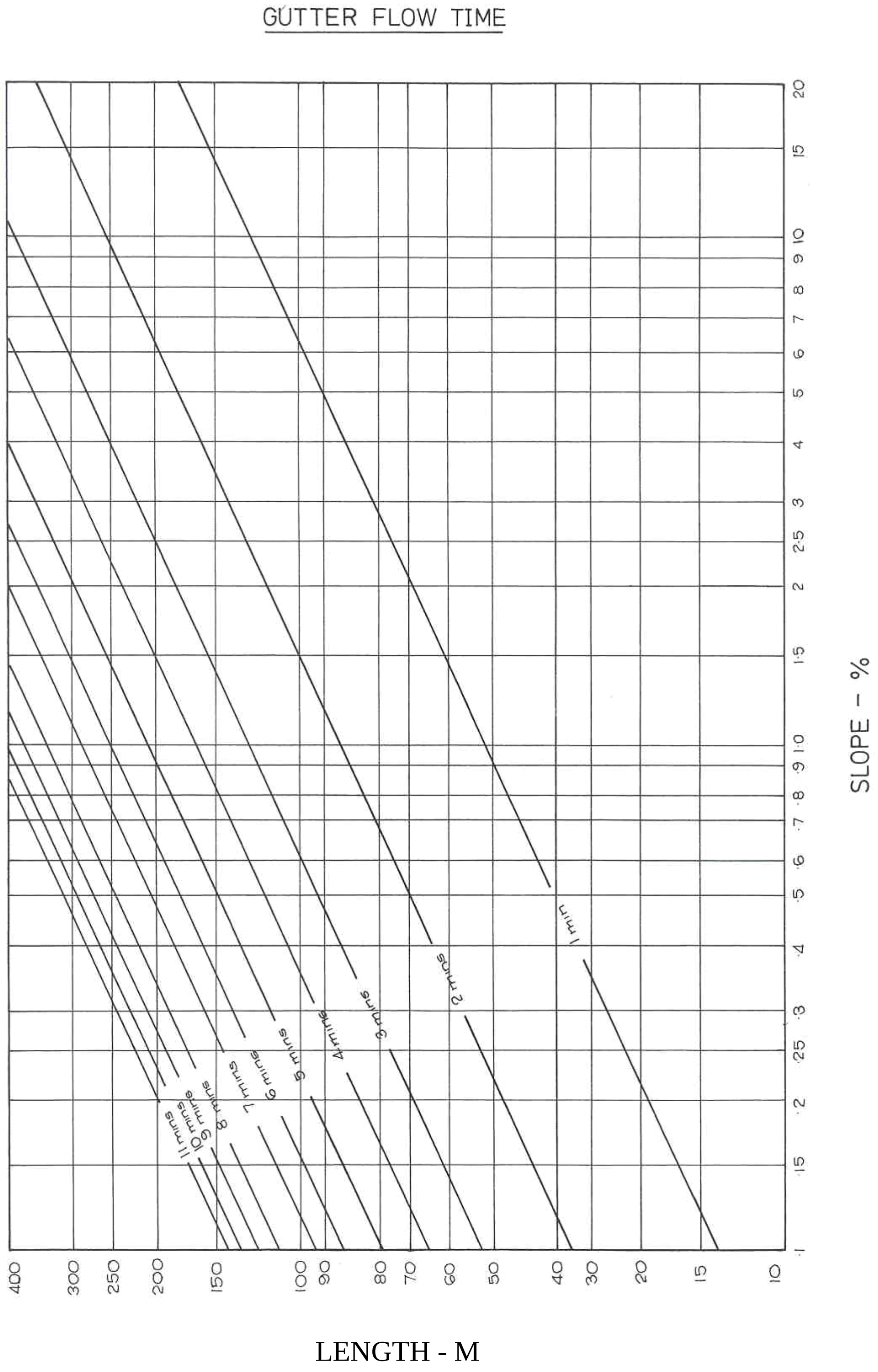
TABLE 4.3 – VALUES OF $Ti^{0.4}$

Time Minutes	Average Recurrence Interval (Years)						
	1	2	5	10	20	50	100
5	30.1	33.3	36.6	38.4	40.5	43.1	44.8
6	35.2	38.9	42.9	44.9	47.4	50.4	52.5
7	40.2	44.3	48.9	51.2	54.1	57.6	60.0
8	45.0	49.7	54.8	57.4	60.6	64.5	67.2
9	49.6	54.8	60.5	63.4	67.0	71.3	74.3
10	54.2	59.9	66.1	69.3	73.2	77.9	81.2
11	58.6	64.8	71.5	75.0	79.2	84.3	87.9
12	63.0	69.6	76.9	80.6	85.2	90.7	94.5
13	67.3	74.4	82.1	86.1	91.0	96.9	101.0
14	71.5	79.0	87.3	91.6	96.8	103.0	107.4
15	75.6	83.6	92.4	96.9	102.4	109.0	113.7
16	79.7	88.1	97.4	102.1	108.0	115.0	119.9
17	83.7	92.6	102.3	107.3	113.5	120.8	126.0
18	87.7	97.0	107.2	112.4	118.9	126.6	132.0
19	91.6	101.3	112.0	117.5	124.2	132.3	138.0
20	95.4	105.6	116.7	122.5	129.5	137.9	143.8
21	99.2	109.8	121.4	127.4	134.7	143.5	149.6
22	103.0	113.9	126.0	132.2	139.9	149.0	155.4
23	106.7	118.1	130.6	137.1	145.0	154.4	161.1
24	110.4	122.1	135.1	141.8	150.0	159.8	166.7
25	114.0	126.2	139.6	146.5	155.0	165.2	172.3
26	117.7	130.2	144.0	151.2	160.0	170.5	177.8
27	121.2	134.1	148.4	155.9	164.9	175.7	183.3
28	124.8	138.1	152.8	160.4	169.7	180.9	188.7
29	128.3	141.9	157.1	165.0	174.6	186.0	194.1
30	131.7	145.8	161.4	169.5	179.4	191.2	199.4
31	135.2	149.6	165.7	174.0	184.1	196.2	204.7
32	138.6	153.4	169.9	178.4	188.8	201.3	210.0
33	142.0	157.2	174.1	182.8	193.5	206.3	215.2
34	145.4	160.9	178.2	187.2	198.1	211.2	220.4
35	148.7	164.6	182.3	191.6	202.7	216.1	225.6
36	152.0	168.3	186.4	195.9	207.3	221.0	230.7
37	155.3	172.0	190.5	200.2	211.9	225.9	235.7
38	158.6	175.6	194.6	204.4	216.4	230.7	240.8
39	161.9	179.2	198.6	208.7	220.9	235.5	245.8
40	165.1	182.8	202.6	212.9	225.3	240.3	250.8
41	168.3	186.4	206.5	217.0	229.8	245.0	255.8
42	171.5	189.9	210.5	221.2	234.2	249.8	260.7
43	174.7	193.4	214.4	225.3	238.6	254.4	265.6
44	177.9	196.9	218.3	229.5	242.9	259.1	270.5
45	181.0	200.4	222.2	233.5	247.3	263.7	275.3
46	184.1	203.9	226.1	237.6	251.6	268.4	280.1
47	187.2	207.3	229.9	241.7	255.9	273.0	284.9
48	190.3	210.8	233.7	245.7	260.2	277.5	289.7
49	193.4	214.2	237.5	249.7	264.4	282.1	294.5
50	196.4	217.6	241.3	253.7	268.6	286.6	299.2
51	199.5	220.9	245.1	257.6	272.8	291.1	303.9
52	202.5	224.3	248.8	261.6	277.0	295.6	308.6
53	205.5	227.6	252.5	265.5	281.2	300.0	313.2
54	208.5	231.0	256.2	269.4	285.4	304.5	317.9
55	211.5	234.3	259.9	273.3	289.5	308.9	322.5
56	214.5	237.6	263.6	277.2	293.6	313.3	327.1
57	217.5	240.9	267.3	281.0	297.7	317.7	331.7
58	220.4	244.1	270.9	284.9	301.8	322.0	336.2
59	223.3	247.4	274.6	288.7	305.8	326.4	340.8
60	226.3	250.7	278.2	292.5	309.9	330.7	345.3

<u>Gutter Flow Time</u>

The time of flow in street gutters is to be estimated from Figure 4.2.

FIGURE 4.2 - GUTTER FLOW TIME



Pipe Flow Time

This can initially be calculated by assuming a velocity of pipe flow of 3m/s and dividing the length of the pipe reach (in metres) by this velocity to obtain the time (in seconds) of pipe flow. the assumed velocity is checked and the calculations revised if necessary.

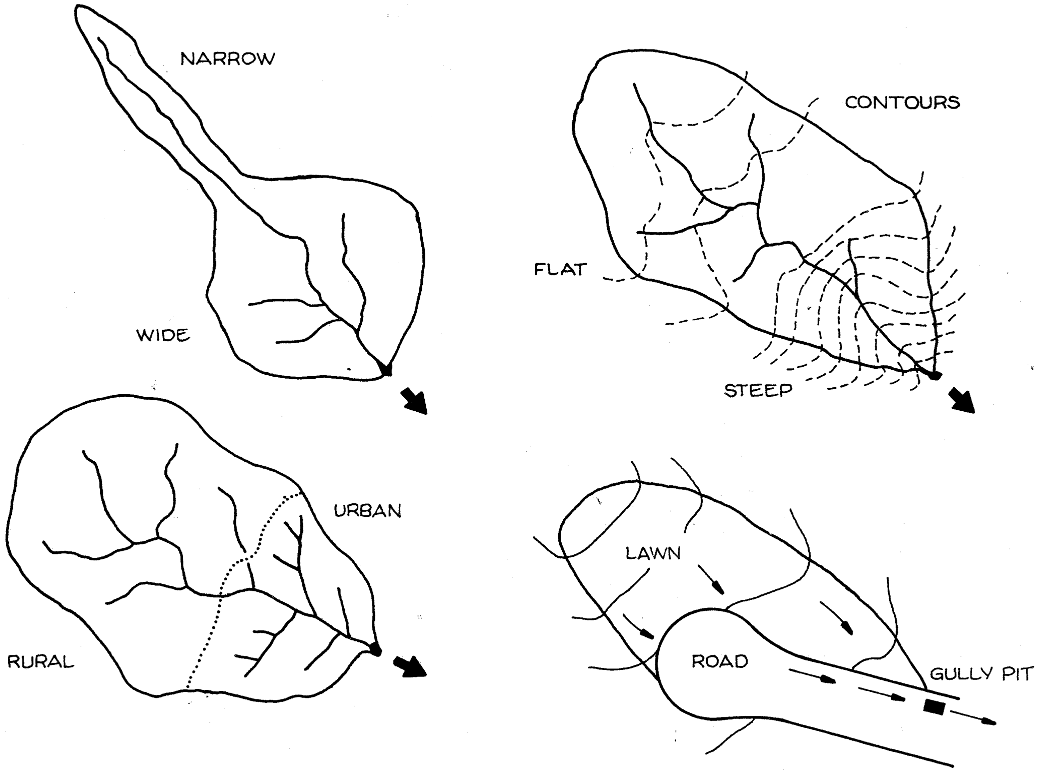
Partial Area Effects

A partial area effect occurs when the Rational Method produces a greater runoff from part of a catchment than from the entire catchment. This may occur where sharp changes occur in the catchment shape, slope or land-use as illustrated in Figure 4.3.

The designer must be aware of the possibility of partial area effects and should run checks where it appears likely to occur. Such checking would involve the calculation of the flow rate from a lower part of the catchment (say road surfaces only), using the appropriate time of concentration and hence rainfall intensity and comparing this flow rate with the flow rate calculated for the total catchment area. Particular care must be taken where there is a large variation in the time of concentration between pits and branches on a drainage line.

Where partial area effects are encountered, the time of concentration adopted would be the one which gives the highest rate of discharge.

FIGURE 4.3 - CATCHMENT LIKELY TO EXHIBIT PARTIAL AREA EFFECT



4.4 RAINFALL INTENSITY – "I"

Once the recurrence interval and time of concentration of a component are determined, the rainfall intensity is read from Table 5.7. This table gives intensities for duration from 6 minutes to 60 minutes. These intensities apply for the area around Hornsby itself but may be used for other areas in the Shire as the differences between areas in the Shire are minimal.

The Bureau of Meteorology in accordance with the methods described in AR&R has provided a formula:

$$Ln(I) = a+b(\ln(T))+c(\ln(T))^{2}+ d(\ln(T))^{3}+ e(\ln(T))^{4}+ f(\ln(T))^{5}+ g(\ln(T))^{6} \qquad \mathbf{(4.4)}$$

where
I = Intensity in millimetres per hour
T= Time in hours
Coefficients: a, b, c, d, e, f and g are shown in table 4.4

TABLE 4.4 - POLYNOMIAL COEFFICIENTS FOR RAINFALL INTENSITY CALCULATION.

Return period	a	b	c	d	e	f
1	3.3185	-0.5653	-0.0168	0.00841	-0.001184	-0.0003318
2	3.5743	-0.5621	-0.0173	0.00846	-0.001106	-0.0003439
5	3.8348	-0.5533	-0.0186	0.00753	-0.000692	-0.0002162
10	3.9606	-0.5488	-0.0191	0.00747	-0.000582	-0.0002138
20	4.1047	-0.5449	-0.0198	0.00718	-0.000413	-0.0001778
50	4.2672	-0.5405	-0.0205	0.00672	-0.000199	-0.0001194
100	4.3753	-0.5376	-0.0206	0.00656	-0.000138	-0.0000978

TABLE 4.5 RAINFALL INTENSITIES FOR HORNSBY (mm/hr)
(See next page)

Time Minutes	**Average Recurrence Interval (Years)**						
	1	**2**	**5**	**10**	**20**	**50**	**100**
5	89.0	114.1	145.1	163.0	186.6	217.5	240.9
6	83.4	106.9	136.4	153.2	175.5	204.8	226.9
7	78.8	101.0	129.0	145.0	166.1	193.9	215.0
8	74.8	96.0	122.7	137.9	158.1	184.6	204.7
9	71.4	91.6	117.1	131.7	151.0	176.4	195.6
10	68.3	87.7	112.2	126.2	144.8	169.2	187.7
11	65.6	84.2	107.9	121.4	139.3	162.7	180.5
12	63.2	81.1	103.9	117.0	134.3	156.9	174.1
13	61.0	78.3	100.4	113.0	129.7	151.7	168.3
14	59.0	75.7	97.1	109.4	125.6	146.9	163.0
15	57.1	73.4	94.1	106.0	121.8	142.5	158.1
16	55.4	71.2	91.4	103.0	118.3	138.4	153.6
17	53.8	69.2	88.8	100.1	115.1	134.6	149.5
18	52.4	67.4	86.5	97.5	112.1	131.2	145.6
19	51.0	65.6	84.3	95.1	109.3	127.9	142.1
20	49.7	64.0	82.2	92.8	106.7	124.9	138.7
21	48.6	62.5	80.3	90.6	104.2	122.0	135.5
22	47.4	61.0	78.5	88.6	101.9	119.3	132.6
23	46.4	59.7	76.8	86.7	99.7	116.8	129.8
24	45.4	58.4	75.2	84.9	97.7	114.4	127.2
25	44.5	57.2	73.7	83.2	95.7	112.2	124.7
26	43.6	56.1	72.2	81.6	93.9	110.0	122.3
27	42.7	55.0	70.9	80.1	92.2	108.0	120.1
28	41.9	54.0	69.6	78.6	90.5	106.1	117.9
29	41.1	53.0	68.3	77.2	88.9	104.2	115.9
30	40.4	52.1	67.1	75.9	87.4	102.5	114.0
31	39.7	51.2	66.0	74.6	86.0	100.8	112.1
32	39.1	50.3	64.9	73.4	84.6	99.2	110.3
33	38.4	49.5	63.9	72.3	83.2	97.7	108.6
34	37.8	48.7	62.9	71.1	82.0	96.2	107.0
35	37.2	48.0	62.0	70.1	80.8	94.8	105.4
36	36.7	47.3	61.0	69.1	79.6	93.4	103.9
37	36.1	46.6	60.2	68.1	78.5	92.1	102.5
38	35.6	45.9	59.3	67.1	77.4	90.8	101.1
39	35.1	45.3	58.5	66.2	76.3	89.6	99.7
40	34.6	44.6	57.7	65.3	75.3	88.5	98.4
41	34.2	44.1	57.0	64.5	74.4	87.3	97.2
42	33.7	43.5	56.2	63.7	73.4	86.2	96.0
43	33.3	42.9	55.5	62.9	72.5	85.2	94.8
44	32.9	42.4	54.8	62.1	71.6	84.2	93.7
45	32.4	41.9	54.2	61.4	70.8	83.2	92.6
46	32.1	41.4	53.5	60.6	70.0	82.2	91.5
47	31.7	40.9	52.9	59.9	69.2	81.3	90.5
48	31.3	40.4	52.3	59.3	68.4	80.4	89.5
49	30.9	39.9	51.7	58.6	67.6	79.5	88.5
50	30.6	39.5	51.2	58.0	66.9	78.7	87.6
51	30.3	39.1	50.6	57.4	66.2	77.8	86.7
52	29.9	38.6	50.1	56.8	65.5	77.0	85.8
53	29.6	38.2	49.6	56.2	64.8	76.2	84.9
54	29.3	37.8	49.1	55.6	64.2	75.5	84.1
55	29.0	37.5	48.6	55.0	63.6	74.7	83.3
56	28.7	37.1	48.1	54.5	62.9	74.0	82.5
57	28.4	36.7	47.6	54.0	62.3	73.3	81.7
58	28.2	36.4	47.2	53.5	61.8	72.6	80.9
59	27.9	36.0	46.7	53.0	61.2	72.0	80.2
60	27.6	35.7	46.3	52.5	60.6	71.3	79.5

4.5 COEFFICIENT OF RUNOFF – "C"

The 1987 Edition of AR&R specifies a method of calculating the co-efficient of runoff based on the values of "C" for the 10 year ARI storm (C_{10}) and the impervious fraction of the catchment.

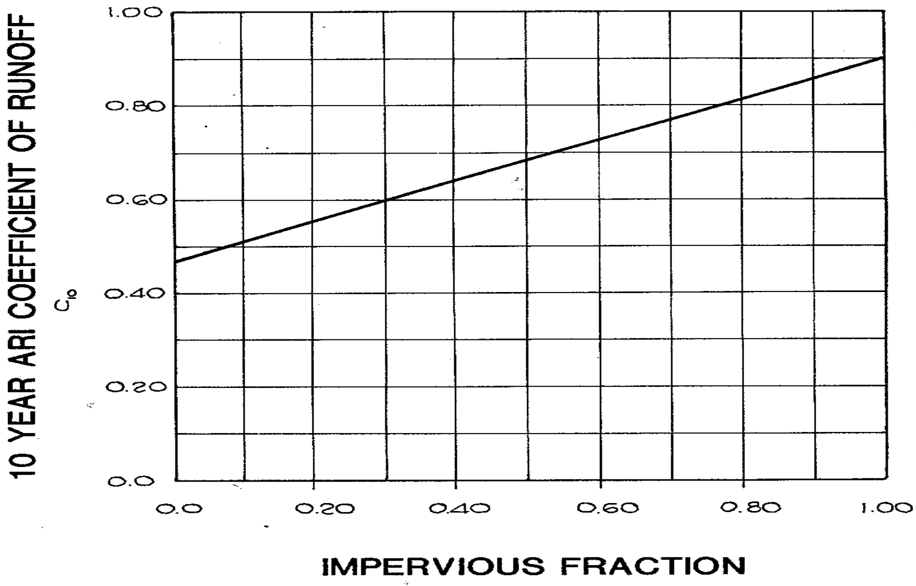
For Hornsby Shire, the following formula can be used:

$$C_{10} = 0.434f + 0.466 \qquad \textbf{(4.5)}$$

where
f = impervious fraction

The appropriate value of "C" is determined by finding the value of "C_{10}" from Figure 4.4 for the value of impervious fraction appropriate to the catchment. For average recurrence intervals other than 10 years the value of "C_{10}" is multiplied by a frequency factor "Fy" found in Figure 4.4. Where runoff co-efficients given by this method exceed 1.0, they should arbitrarily be set equal to 1.0.

FIGURE4.4 - CO-EFFICIENT OF RUNOFF



ARI (YEARS)	FREQUENCY FACTOR - Fy
1	0.80
2	0.85
5	0.95
10	1.00
20	1.05
50	1.15
100	1.20

NOTE : FOR 10 YEAR ARI $C = C_{10}$
FOR "Y" YEAR ARI $C = C_{10} \times Fy$

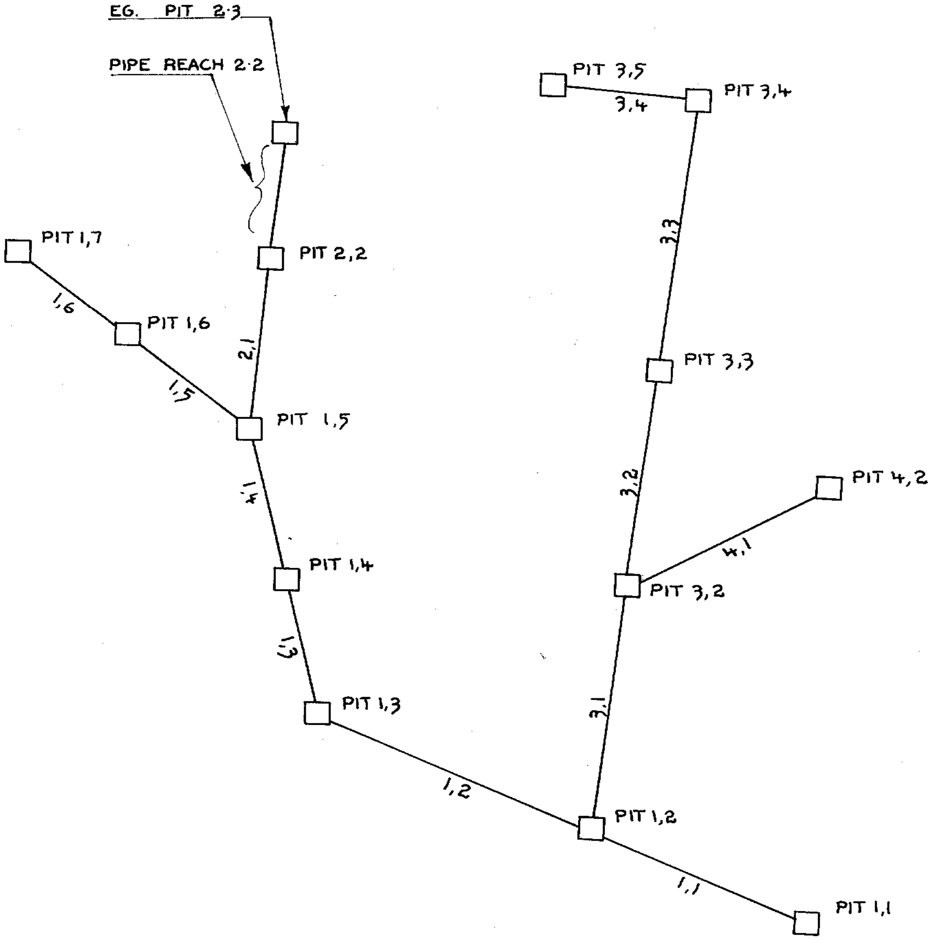
COEFFICIENT OF RUNOFF

4.6 NETWORK DESIGN

This section describes the method to be used to label stormwater drainage networks. Pipe systems will consist of a number of interconnected drainage lines, each line consisting of individual pipe reaches. Each drainage line must be given a line number and the pipe reaches are to be numbered 1, 2, 3, etc. in the upstream direction. An example of the labelling system is given in Figure 4.5.

Each pipe reach, pit and contributing sub-catchment area is then identified by a combination of the line number and reach number. For example, line 3 reach 2 would be referred to as "Pipe 3.2", the pit at the downstream end of this pipe would be "Pit 3.2" and the sub-catchment area contributing to this pit would be "Area 3.2".

FIGURE 4.5 - EXAMPLE OF LABELLING FOR STORMWATER DRAINAGE SYSTEM



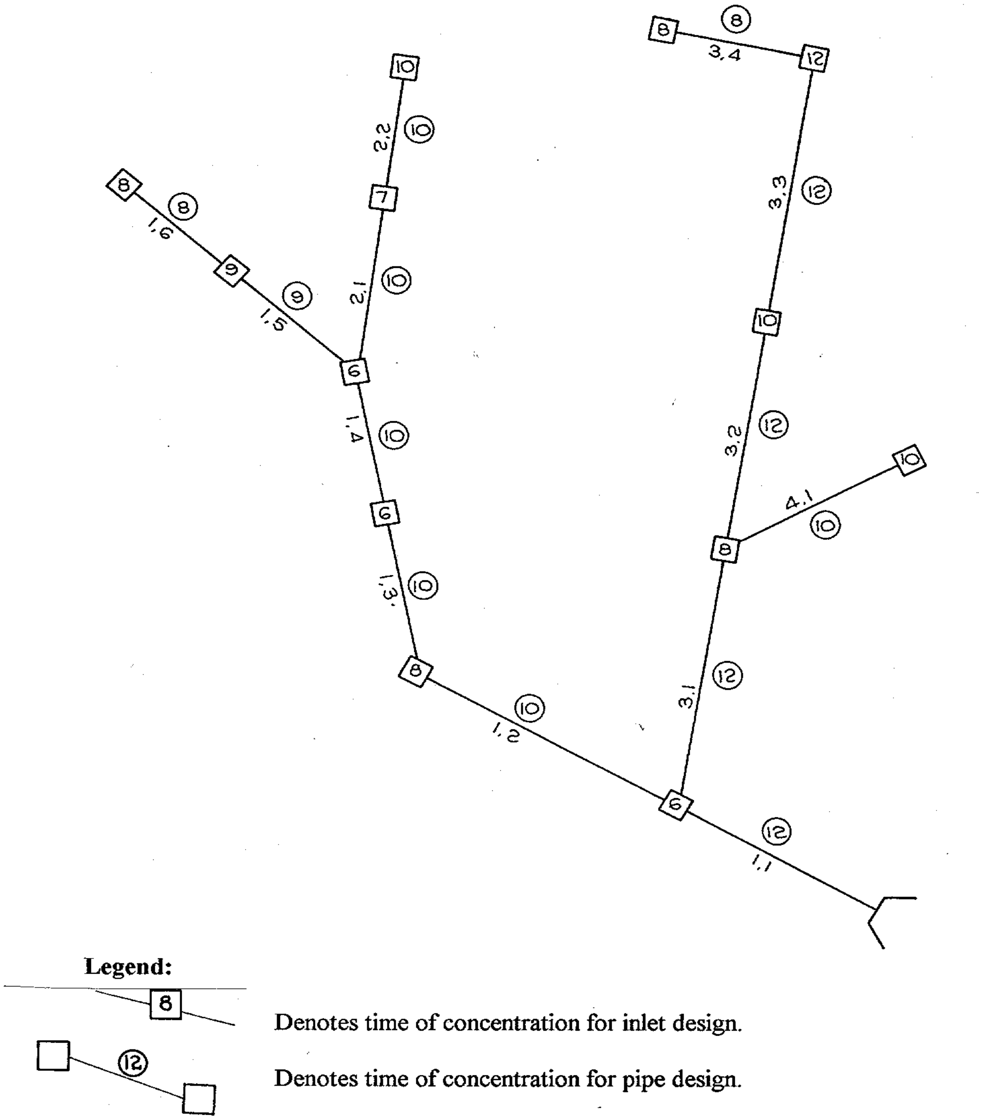
4.7 CRITICAL TIME OF CONCENTRATION

Figure 4.6 illustrates the principles of critical time of concentration in component design.

To determine the discharge at any point in the system, equivalent impervious areas for all upstream sub-catchments contributing to the flow are added rather than the discharges. Thus, for each pipe reach, the discharge is calculated using the sum of the equivalent impervious areas draining to it and the critical time of concentration for that pipe reach.

From Figure 4.6, it can be seen that the critical time of concentration for a pipe reach is the longest time of concentration of all of the sub-catchments contributing to the flow in that reach.

FIGURE 4.6 - CRITICAL TIME OF CONCENTRATION
(For Various Drainage System Components)



NOTE: Pipe length are assumed to be short and pipe flow time may therefore be ignored. Partial area effects are not critical in this example.

4.8 MAJOR SYSTEM CHECKS

Once the flows for the minor system have been determined and preliminary pipe sizes set, the ability of the system to safely handle the 100 year ARI storm must be checked. This means that the capacity of streets and drainage reserves must be checked to ensure that they can safely carry all the water that cannot enter the pipe system.

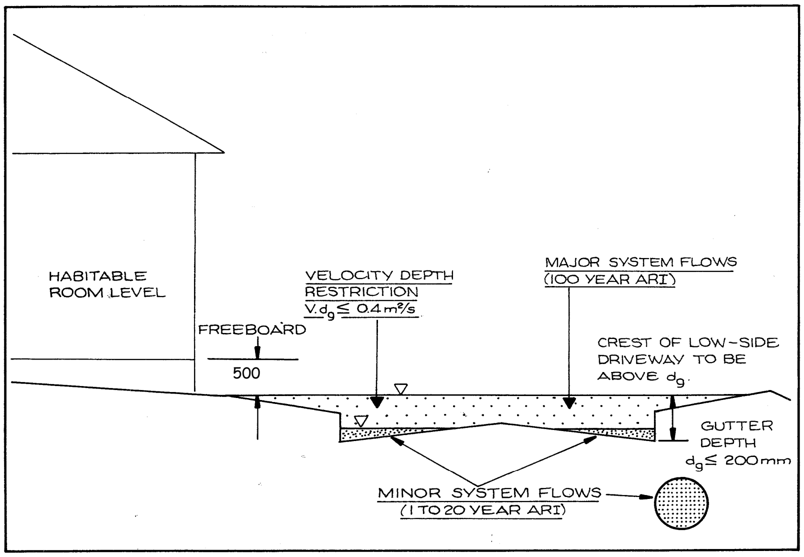
Figure 4.7 illustrates the design standard for the major system. If this standard cannot be achieved, consideration must be given to upgrading the pipe system.

The major system checks must allow for different flow paths taken by major and minor flows, and for overflows from other drainage systems entering the catchment under consideration.

The calculations involved are not as precise as those required for the minor system design. It is difficult to calculate pit entry capacities and pipe capacities with certainty under major flow conditions.

Major system checks are not required at every pit but should be carried out at critical points which will be different for each project. Checks are first made assuming that the "roadway" takes all the major flow. If the capacity of the "roadway" is sufficient to carry all the major flow, no calculations concerning pipe system capacity need be undertaken. If the capacity of the roadway is insufficient, an estimate is made of the capacity of the pipe system under major flow conditions. This estimate is based on pit capacities (assuming major flows approaching the pits and a suitable blocking factor), and pipe capacities based on overflowing pits with surface levels determining the available head.

FIGURE 4.7 - MAJOR SYSTEM DESIGN STANDARDS
(Source AR&R 1987 – amended))



4.9 DRAINAGE CALCULATIONS SHEET

The hydrologic information and calculations are inserted into Columns 1 to 14 of the Stormwater Runoff Calculations Sheet given as Figure 4.8. The major system checks are carried out in Columns 1 to 19 of the combined Major System Check Sheet/Hydraulic Check Sheet given as Figure 4.9.

Further details of the use of both sheets are given in Section 5.4 of this specification.

4.10 ALTERNATIVE MODELS AND COMPUTER ANALYSIS

Other hydrological models: Use of other hydrological models or computer analysis is permitted provided the following requirements are met:

- Satisfy the requirements of ARR.
- Submit summaries of calculations.
- Submit details of all program input and output.
- Submit copies of the final data files.

1.1 FIGURE 4.8 - STORMWATER RUNOFF CALCULATIONS

HORNSBY SHIRE COUNCIL
Works Division

STORMWATER RUNOFF CALCULATIONS

Basin: ....
Sub Area: ....
File No.: ....
Plan No.: ....

		OVERLAND FLOW			GUTTER FLOW									GUTTER FLOW PROFILE						INLET					PIPE SIZING						REMARKS
SUB CATCHMENT	SURFACE TYPE	LENGTH	SLOPE	TIME	LENGTH	SLOPE	TIME	SUB AREA TIME OF CONCENTRATION	RAINFALL INTENSITY - 1	COEFFICIENT OF RUNOFF - C	AREA -A	EQUIVALENT IMPERVIOUS AREA C & A	SUB-AREA DISCHARGE $Q = \frac{C \times A \times 1}{360}$	BYPASS FROM UPSTREAM	TOTAL GUTTER FLOW	ROAD CROSSFALL	GUTTER GRADE	WIDTH OF GUTTER FLOW	DEPTH OF GUTTER FLOW	INLET PIT NO.	INLET PIT TYPE	INFLOW	BYPASS	BYPASS TO PIT NO.	CRITICAL TIME OF CONCENTRATION	RAINFALL INTENSITY -I	TOTAL EQUIVALENT IMPERVIOUS AREA $\Sigma(C \times A)$	OUTFLOW $Q = \frac{\Sigma C \times A \times 1}{360}$	GRADE OF OUTLET PIPE	TRIAL DIAMETER	
		m	%	mins.	m	%	mins.	mins	min/hr		ha	ha	m^3/sec	m^3/sec	m^3/sec	%	%	m	mm			m^3/sec	m^3/sec		mins	min/hr	ha	m^3/sec	%	mm	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

SURFACE TYPES:-
1. DENSE URBAN DEVELOPMENT = 0.012
2. NEW URBAN DEVELOPMENT = 0.080
3. AVERAGE URBAN DEVELOPMENT = 0.120
4. AVERAGE GRASSED = 0.170

PIT TYPES:
(LINTEL SIZES REFER)
(TO LENGTH OF OPENING)

A. D.G.G.P. 1.8m LINTEL
B. D.G.G.P. 2.4m LINTEL
C. D.G.G.P. 3.0m LINTEL
D. D.G.G.P. 3.8m LINTEL
E. JUNCTION PIT
F. LETTERBOX PIT

RECURRENCE INTERVAL: 1 in .... YEARS	ROUGHNESS K_s...........	DATE 11 September, 1998	PLAN NO. 448.36	6/87

1.2

1.3

FIGURE 4.9 - MAJOR SYSTEM CHECK SHEET/HYDRAULIC CHECK SHEET

HORNSBY SHIRE COUNCIL
Works Division

MAJOR SYSTEM CHECK SHEET

HYDRAULIC CHECK SHEET

		OVERLAND FLOW			GUTTER FLOW																											
SUB CATCHMENT	SURFACE TYPE	LENGTH	SLOPE	TIME	LENGTH	SLOPE	TIME	SUB AREA TIME OF CONCENTRATION	RAINFALL INTENSITY - 1	COEFFICIENT OF RUNOFF - C	AREA -A	EQUIVALENT IMPERVIOUS AREA C & A	SUB-AREA DISCHARGE $Q = \frac{C \times A \times 1}{360}$	CUMULATIVE PIT CAPACITIES	DOWNSTREAM PIPE CAPACITY	ROAD FLOWRATE	ROAD CAPACITY CHECK	REMARKS	PIPE REACH	LENGTH L	FLOWRATE	DIAMETER	VELOCITY - V	$\frac{V^2}{2g}$	D/S HGL LEVEL	PIPE FRICTION LOSS - SoL	HGL JUST BELOW U/S PIT	OBVERT LEVEL AT UPPER END OF PIF	PIT LOSS COEFFICIENT - K	K - $\frac{V^2}{2g}$	ADOPTED U/S PIT HGL	U/S PIT SURFACE LEVEL
		m	%	mins.	m	%	mins.	mins	min/hr		ha	ha	m^3/sec	m^3/s	m^3/s	m^3/s				m	m^3/s	mm	m/s	m	m	m	m	m		m	m	m
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33

SURFACE TYPES:- 1. PAVED = 0.012
2. BARE SOIL = 0.022
3. AVERAGE URBAN DEVELOPMENT = 0.040
4. POORLY GRASSED SURFACE = 0.050
5. AVERAGE GRASSED SURFACE = 0.100
6. DENSEY GRASSED SURFACE = 0.170

RECURRENCE INTERVAL: 1 in .... YEARS
ROUGHNESS K_s...........
DATE 11 September, 1998
PLAN NO. 448.38
6/88

5 HYDRAULICS

5.1 GENERAL

Design concept: To the ARR major/minor drainage concept as defined in AGRD05 and ARR Book VII.

5.2 INLET DESIGN

Gutter Flow Width and Depth

Inlet spacing should be chosen to restrict the width and/or depth of gutter flow to acceptable limits. The normal criterion is to keep the gutter flow width less than 2.5 metres for the minor system design, however, it may be necessary to restrict the depth of flow on the low side of a street to a height below that of the kerb laybacks (depending on the vehicular crossing profiles) for the major system storm.

The desirable maximum length of any pipe reach should be 50 metres to enable access to clear blockages.

Flow widths and depths may be determined from Table 5.2 - Road & Gutter Capacity. Values may be interpolated for pavement crossfalls other than those given in the charts.

Pit Inlet Capacity

Inlet spacing and the number of pits is also dependant on inlet capacity. For a given gutter flow the theoretical amount of water which can be expected to enter a pit can be calculated from Figures 5.1, 5.2 & 5.3. It is clear from these Figures that the longer the kerb inlet, the higher the inlet capacity. Kerb inlets are to be specified by length of opening rather than overall length.

At each pit there will generally be some by-pass flow to the next downstream pit. For each pit, the by-pass flow from upstream pits should be added to the gutter flow arriving at that pit. By-pass can also result from blockages to the kerb inlet &/or the grate of a pit. Table 5.1 shows the allowances that need to be made.

Sag pits have a larger theoretical capacity than pits on grade. The width and depth of ponding at sag pits is found from Table 5.3. The width of ponding across a road pavement should be less than 2.5 metres for the minor system design. Capacity for grates in depressions are given in Table 5.4.

TABLE 5.1 - ALLOWANCES TO BE MADE FOR BLOCKAGES

PIT LOCATION	INLET TYPE	PERCENTAGE OF THEORETICAL CAPACITY ALLOWED
Sag	Kerb Inlet Only	80%
Sag	Grate Only	50%
Sag	Combination	80% Kerb Inlet and 50% of Grate
Sag	Letterbox Pit	50%
On Grade	Kerb Inlet Only	80%
On Grade	Grate Only	50%
On Grade	Combination	80% Kerb Inlet and 50% of Grate

TABLE 5.2 - ROAD & GUTTER CAPACITY

ROADWAY / GUTTER CAPACITY TABLES

ROADWAY / GUTTER CAPACITY BASED ON 2.5m WIDTH OF FLOW or TOP OF KERB (cum/s)

	< 2.5m	< 0.15m	LONGITUDINAL GRADES								
X-fall	**width**	**depth**	**0.5%**	**1%**	**3%**	**5%**	**7%**	**10%**	**12%**	**15%**	**20%**
1%	2.50	0.06	0.02	0.02	0.04	0.05	0.06	0.07	0.08	0.08	0.10
2%	2.50	0.08	0.04	0.05	0.09	0.11	0.13	0.16	0.17	0.19	0.23
3%	2.50	0.10	0.06	0.09	0.15	0.20	0.23	0.28	0.31	0.34	0.40
4%	2.50	0.12	0.10	0.14	0.23	0.30	0.36	0.43	0.47	0.52	0.60
5%	2.50	0.14	0.13	0.19	0.33	0.42	0.50	0.60	0.66	0.73	0.85
6%	2.28	0.15	0.14	0.20	0.35	0.45	0.53	0.63	0.69	0.77	0.89
7%	2.02	0.15	0.13	0.19	0.32	0.41	0.49	0.59	0.64	0.72	0.83
8%	1.83	0.15	0.12	0.17	0.30	0.39	0.46	0.55	0.61	0.68	0.78
9%	1.67	0.15	0.12	0.17	0.29	0.37	0.44	0.53	0.58	0.65	0.75
10%	1.55	0.15	0.11	0.16	0.28	0.36	0.42	0.51	0.55	0.62	0.72

NOTE: Roadway/ Gutter Capacity must be reduced at low lying Driveways

░ Velocity Depth Criteria >0.4
▓ Velocity Depth Criteria >0.6

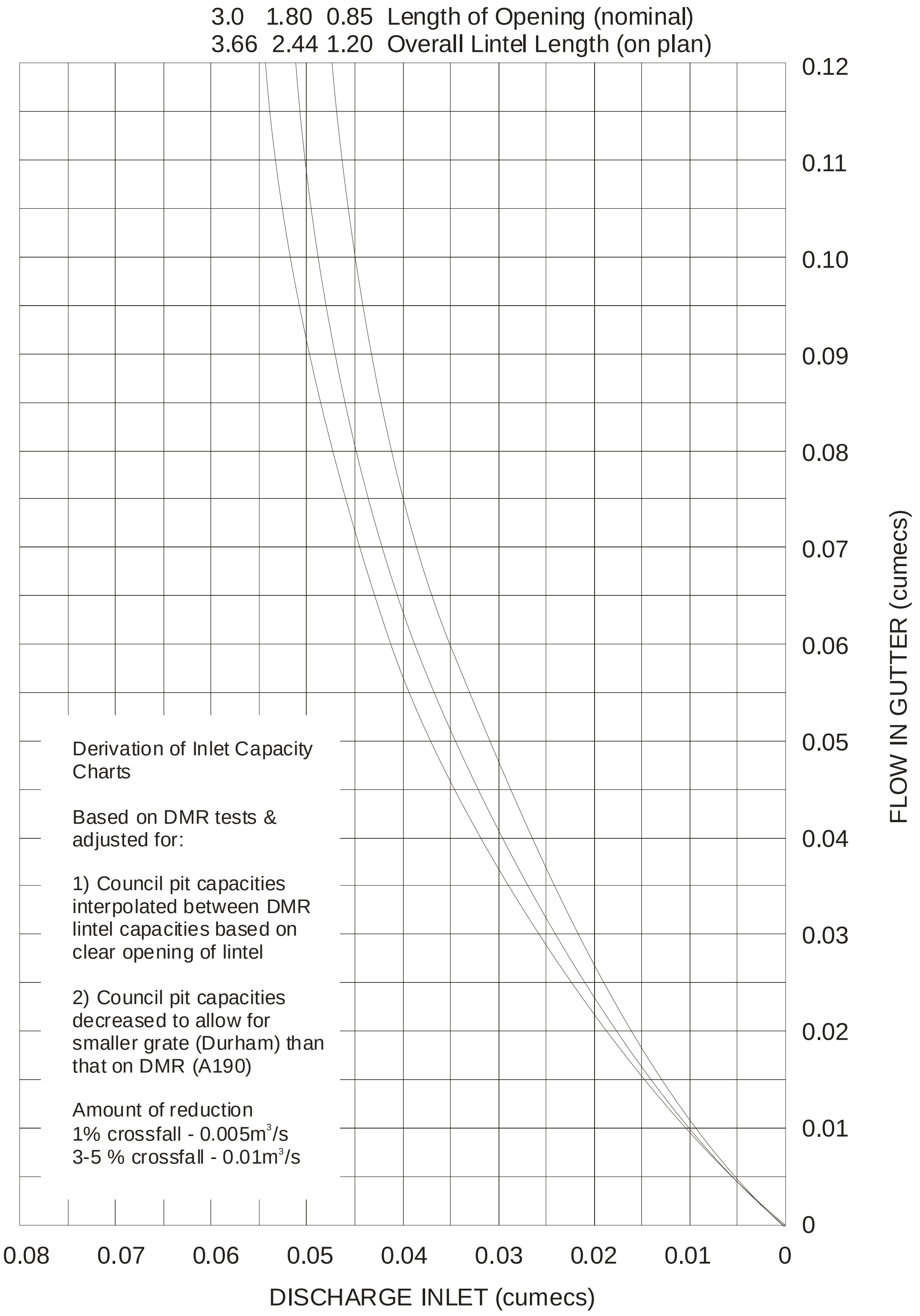
ROADWAY / GUTTER CAPACITY BASED ON 2.5m WIDTH OF FLOW or Top of Standard Layback (cum/s)

	< 2.5m	< 0.15m	LONGITUDINAL GRADES								
X-fall	**width**	**depth**	**0.5%**	**1%**	**3%**	**5%**	**7%**	**10%**	**12%**	**15%**	**20%**
1%	2.50	0.06	0.02	0.02	0.04	0.05	0.06	0.07	0.08	0.08	0.10
2%	2.50	0.08	0.04	0.05	0.09	0.11	0.13	0.16	0.17	0.19	0.23
3%	2.45	0.10	0.06	0.08	0.15	0.19	0.22	0.27	0.29	0.33	0.38
4%	1.95	0.10	0.05	0.07	0.13	0.17	0.20	0.24	0.26	0.29	0.33
5%	1.65	0.10	0.05	0.07	0.12	0.15	0.18	0.22	0.24	0.27	0.31
6%	1.45	0.10	0.05	0.06	0.11	0.14	0.17	0.20	0.22	0.25	0.29
7%	1.31	0.10	0.04	0.06	0.11	0.14	0.16	0.20	0.21	0.24	0.28
8%	1.20	0.10	0.04	0.06	0.10	0.13	0.16	0.19	0.21	0.23	0.27
9%	1.12	0.10	0.04	0.06	0.10	0.13	0.15	0.18	0.20	0.23	0.26
10%	1.05	0.10	0.04	0.06	0.10	0.13	0.15	0.18	0.20	0.22	0.25

ROADWAY / GUTTER CAPACITY BASED ON 2.5m WIDTH OF FLOW or Top of Cut-Down Kerb (cum/s)

	<=2.5m	<0.15m	LONGITUDINAL GRADES								
X-fall	**width**	**depth**	**0.5%**	**1%**	**3%**	**5%**	**7%**	**10%**	**12%**	**15%**	**20%**
1%	2.50	0.06	0.02	0.02	0.04	0.05	0.06	0.07	0.08	0.08	0.10
2%	2.20	0.08	0.03	0.04	0.07	0.09	0.10	0.12	0.13	0.15	0.17
3%	1.62	0.08	0.02	0.03	0.06	0.08	0.09	0.11	0.12	0.13	0.15
4%	1.33	0.08	0.02	0.03	0.05	0.07	0.08	0.10	0.11	0.12	0.14
5%	1.15	0.08	0.02	0.03	0.05	0.07	0.08	0.10	0.10	0.12	0.13
6%	1.03	0.08	0.02	0.03	0.05	0.07	0.08	0.09	0.10	0.11	0.13
7%	0.95	0.08	0.02	0.03	0.05	0.06	0.08	0.09	0.10	0.11	0.13
8%	0.89	0.08	0.02	0.03	0.05	0.06	0.07	0.09	0.10	0.11	0.13
9%	0.84	0.08	0.02	0.03	0.05	0.06	0.07	0.09	0.10	0.11	0.12
10%	0.80	0.08	0.02	0.03	0.05	0.06	0.07	0.09	0.09	0.11	0.12

FIGURE 5.1 – INLET PIT CAPACITY – 1% Crossfall



Derivation of Inlet Capacity Charts

Based on DMR tests & adjusted for:

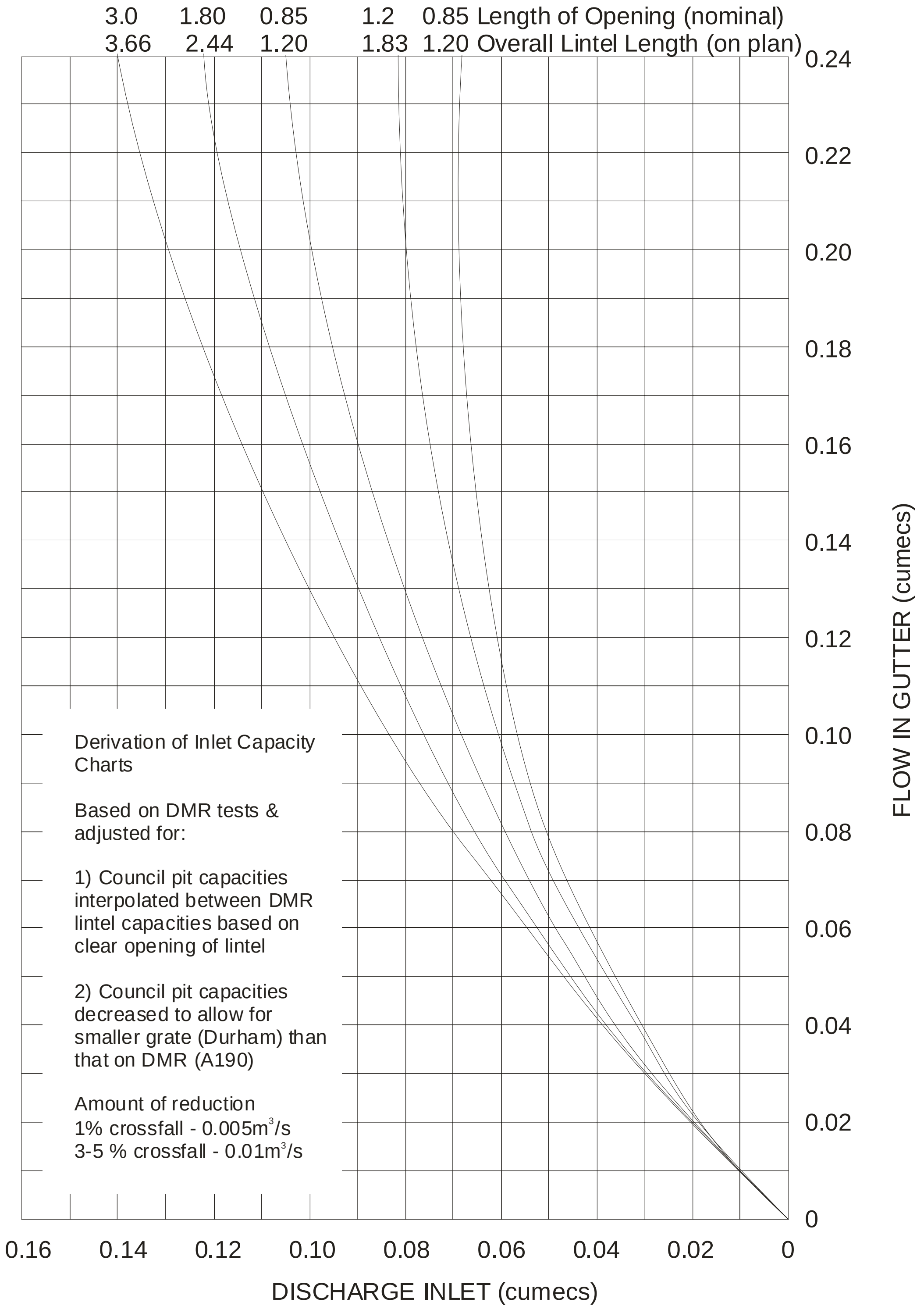
1) Council pit capacities interpolated between DMR lintel capacities based on clear opening of lintel

2) Council pit capacities decreased to allow for smaller grate (Durham) than that on DMR (A190)

Amount of reduction
1% crossfall - 0.005m^3/s
3-5 % crossfall - 0.01m^3/s

INLET PIT CAPACITIES - 1% CROSSFALL
Source Sutherland Shire Council

FIGURE 5.2 – INLET PIT CAPACITY – 3% Crossfall



Derivation of Inlet Capacity Charts

Based on DMR tests & adjusted for:

1) Council pit capacities interpolated between DMR lintel capacities based on clear opening of lintel

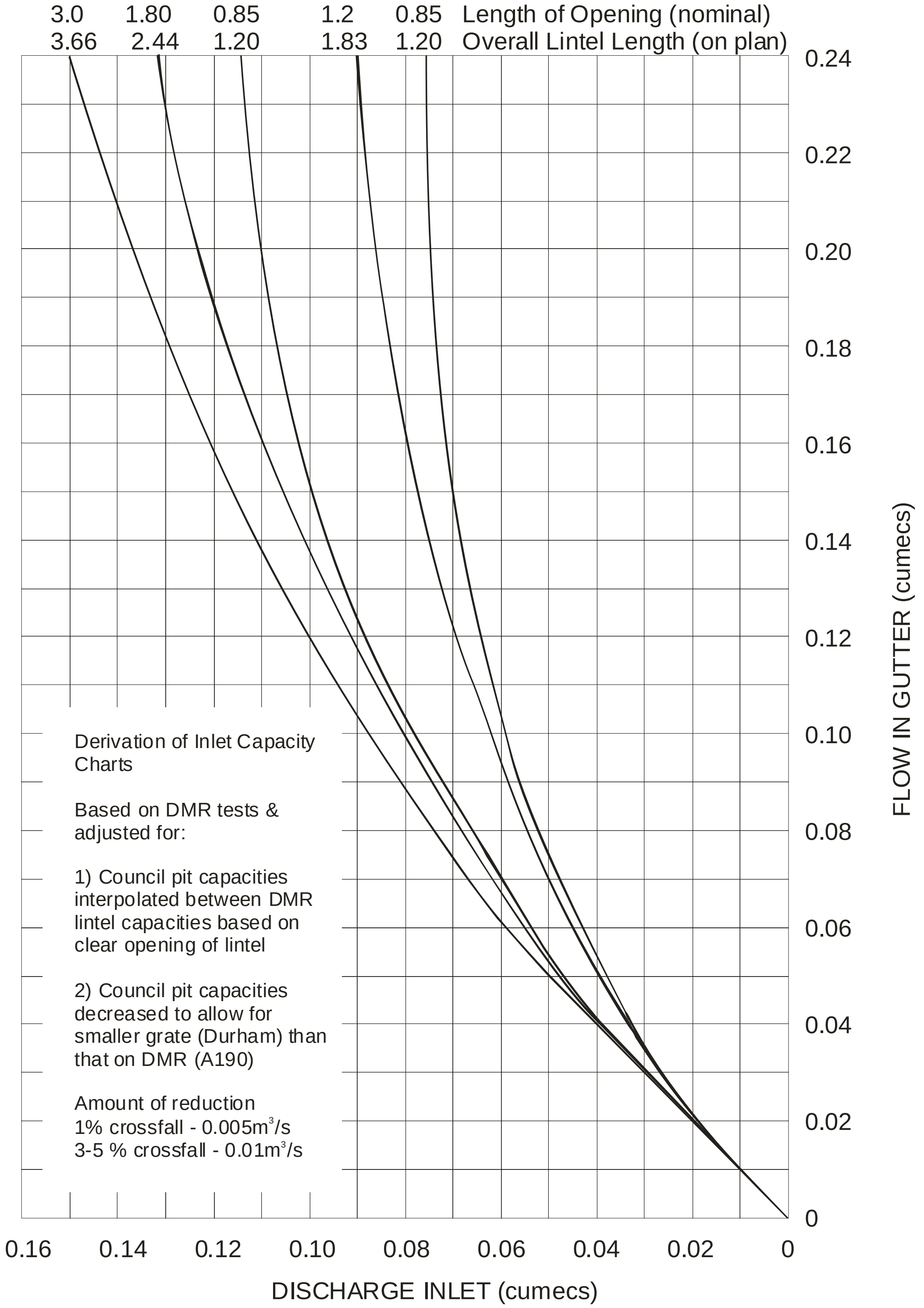
2) Council pit capacities decreased to allow for smaller grate (Durham) than that on DMR (A190)

Amount of reduction
1% crossfall - 0.005m^3/s
3-5 % crossfall - 0.01m^3/s

INLET PIT CAPACITIES - 3% CROSSFALL

Source Sutherland Shire Council

FIGURE 5.3 – INLET PIT CAPACITY – 5% Crossfall



Derivation of Inlet Capacity Charts

Based on DMR tests & adjusted for:

1) Council pit capacities interpolated between DMR lintel capacities based on clear opening of lintel

2) Council pit capacities decreased to allow for smaller grate (Durham) than that on DMR (A190)

Amount of reduction
1% crossfall - 0.005m^3/s
3-5 % crossfall - 0.01m^3/s

INLET PIT CAPACITIES - 5% CROSSFALL

Source Sutherland Shire Council

TABLE 5.3 - CAPACITY OF SAG PITS

LINTEL & GRATE CAPACITY FOR SAG PITS ONLY

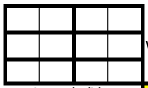
the lesser of Q1 or Q2

Q1=1.66Pd$^{1.5}$ (weir eqn) for d<0.43m

Q2= 0.67*Ag*(2gd)$^{0.5}$ (orifice eqn) for d>0.43m

pg 303 AR&R

GRATE GEOMETRY



Width (W) 0.45

Length (L) = 0.9

Grate EFFICIENCY factor= 0.5

ie 50% blocked

Area grate Ag=LxW 0.405

Perimeter P=2W+L 1.8

KERB GEOMETRY

Qk=1.66Ld^(1.5) for d<1.4h

Qk=0.67A(2g(d-h/2)^(0.5) for d>1.4h

kerb EFFICIENCY factor = 0.8

ie 20% blocked

h= Height of kerb inlet = 0.15

x 1.4 = 0.21

GRATE inlet capacity

	weir eqn	orifice eqn	
d (m)	Q1	Q2	Qmin
0.050	0.017	0.134	0.017
0.060	0.022	0.147	0.022
0.070	0.028	0.159	0.028
0.080	0.034	0.170	0.034
0.090	0.040	0.180	0.040
0.100	0.047	0.190	0.047
0.110	0.055	0.199	0.055
0.120	0.062	0.208	0.062
0.130	0.070	0.217	0.070
0.140	0.078	0.225	0.078
0.150	0.087	0.233	0.087
0.160	0.096	0.240	0.096
0.170	0.105	0.248	0.105
0.180	0.114	0.255	0.114
0.190	0.124	0.262	0.124
0.200	0.134	0.269	0.134
0.210	0.144	0.275	0.144
0.220	0.154	0.282	0.154
0.230	0.165	0.288	0.165
0.240	0.176	0.294	0.176
0.250	0.187	0.300	0.187
0.260	0.198	0.306	0.198
0.270	0.210	0.312	0.210
0.280	0.221	0.318	0.221
0.290	0.233	0.324	0.233
0.300	0.245	0.329	0.245
0.310	0.258	0.335	0.258
0.320	0.270	0.340	0.270
0.330	0.283	0.345	0.283
0.340	0.296	0.350	0.296
0.350	0.309	0.356	0.309
0.360	0.323	0.361	0.323
0.370	0.336	0.366	0.336
0.380	0.350	0.370	0.350
0.390	0.364	0.375	0.364
0.400	0.378	0.380	0.378
0.410	0.392	0.385	0.385
0.420	0.407	0.389	0.389
0.430	0.421	0.394	0.394
0.440	0.436	0.399	0.399
0.450	0.451	0.403	0.403
0.550	0.609	0.446	0.446
0.650	0.783	0.485	0.485
0.750	0.970	0.520	0.520
0.850	1.171	0.554	0.554
0.950	1.383	0.586	0.586
1.050	1.607	0.616	0.616
1.150	1.842	0.644	0.644
1.250	2.088	0.672	0.672
1.350	2.343	0.698	0.698
1.450	2.609	0.724	0.724
1.550	2.883	0.748	0.748
1.650	3.166	0.772	0.772
1.750	3.459	0.795	0.795
1.850	3.759	0.817	0.817
1.950	4.068	0.839	0.839
2.050	4.385	0.860	0.860

KERB inlet capacity

	Lintel Opening					
d (m)	1.2	1.8	2.4	3	3.6	4.2
0.050	0.018	0.027	0.036	0.045	0.053	0.062
0.060	0.023	0.035	0.047	0.059	0.070	0.082
0.070	0.030	0.044	0.059	0.074	0.089	0.103
0.080	0.036	0.054	0.072	0.090	0.108	0.126
0.090	0.043	0.065	0.086	0.108	0.129	0.151
0.100	0.050	0.076	0.101	0.126	0.151	0.176
0.110	0.058	0.087	0.116	0.145	0.174	0.203
0.120	0.066	0.099	0.132	0.166	0.199	0.232
0.130	0.075	0.112	0.149	0.187	0.224	0.261
0.140	0.083	0.125	0.167	0.209	0.250	0.292
0.150	0.093	0.139	0.185	0.231	0.278	0.324
0.160	0.102	0.153	0.204	0.255	0.306	0.357
0.170	0.112	0.168	0.223	0.279	0.335	0.391
0.180	0.122	0.183	0.243	0.304	0.365	0.426
0.190	0.132	0.198	0.264	0.330	0.396	0.462
0.200	0.143	0.214	0.285	0.356	0.428	0.499
0.210	0.153	0.230	0.307	0.383	0.460	0.537
0.220	0.163	0.244	0.325	0.407	0.488	0.570
0.230	0.168	0.252	0.336	0.421	0.505	0.589
0.240	0.174	0.260	0.347	0.434	0.521	0.608
0.250	0.179	0.268	0.358	0.447	0.536	0.626
0.260	0.184	0.276	0.368	0.460	0.551	0.643
0.270	0.189	0.283	0.377	0.472	0.566	0.660
0.280	0.193	0.290	0.387	0.484	0.580	0.677
0.290	0.198	0.297	0.396	0.495	0.594	0.694
0.300	0.203	0.304	0.405	0.507	0.608	0.709
0.310	0.207	0.311	0.414	0.518	0.622	0.725
0.320	0.212	0.317	0.423	0.529	0.635	0.740
0.330	0.216	0.324	0.432	0.540	0.647	0.755
0.340	0.220	0.330	0.440	0.550	0.660	0.770
0.350	0.224	0.336	0.448	0.560	0.672	0.784
0.360	0.228	0.342	0.456	0.570	0.684	0.799
0.370	0.232	0.348	0.464	0.580	0.696	0.812
0.380	0.236	0.354	0.472	0.590	0.708	0.826
0.390	0.240	0.360	0.480	0.600	0.720	0.839
0.400	0.244	0.365	0.487	0.609	0.731	0.853
0.410	0.247	0.371	0.495	0.618	0.742	0.866
0.420	0.251	0.377	0.502	0.628	0.753	0.879
0.430	0.255	0.382	0.509	0.637	0.764	0.891
0.440	0.258	0.387	0.516	0.645	0.775	0.904
0.450	0.262	0.393	0.523	0.654	0.785	0.916
0.550	0.295	0.442	0.589	0.736	0.884	1.031
0.650	0.324	0.486	0.648	0.810	0.972	1.134
0.750	0.351	0.527	0.702	0.878	1.053	1.229
0.850	0.376	0.564	0.752	0.941	1.129	1.317
0.950	0.400	0.600	0.800	0.999	1.199	1.399
1.050	0.422	0.633	0.844	1.055	1.266	1.477
1.150	0.443	0.665	0.886	1.108	1.329	1.551
1.250	0.463	0.695	0.926	1.158	1.390	1.621
1.350	0.483	0.724	0.965	1.206	1.448	1.689
1.450	0.501	0.752	1.002	1.253	1.503	1.754
1.550	0.519	0.779	1.038	1.298	1.557	1.817
1.650	0.536	0.804	1.073	1.341	1.609	1.877
1.750	0.553	0.830	1.106	1.383	1.659	1.936
1.850	0.569	0.854	1.139	1.423	1.708	1.993
1.950	0.585	0.878	1.170	1.463	1.756	2.048
2.050	0.601	0.901	1.201	1.501	1.802	2.102

COMBINED Kerb & Grate Capacity

	Lintel opening					
d (m)	1.2	1.8	2.4	3	3.6	4.2
0.050	0.035	0.043	0.052	0.061	0.070	0.079
0.060	0.045	0.057	0.069	0.081	0.092	0.104
0.070	0.057	0.072	0.087	0.101	0.116	0.131
0.080	0.070	0.088	0.106	0.124	0.142	0.160
0.090	0.083	0.105	0.126	0.148	0.169	0.191
0.100	0.098	0.123	0.148	0.173	0.198	0.224
0.110	0.113	0.142	0.171	0.200	0.229	0.258
0.120	0.128	0.161	0.195	0.228	0.261	0.294
0.130	0.145	0.182	0.219	0.257	0.294	0.331
0.140	0.162	0.203	0.245	0.287	0.329	0.370
0.150	0.179	0.226	0.272	0.318	0.365	0.411
0.160	0.198	0.249	0.300	0.351	0.402	0.453
0.170	0.216	0.272	0.328	0.384	0.440	0.496
0.180	0.236	0.297	0.357	0.418	0.479	0.540
0.190	0.256	0.322	0.388	0.454	0.520	0.586
0.200	0.276	0.347	0.419	0.490	0.561	0.633
0.210	0.297	0.374	0.450	0.527	0.604	0.681
0.220	0.317	0.398	0.480	0.561	0.642	0.724
0.230	0.333	0.417	0.501	0.585	0.670	0.754
0.240	0.349	0.436	0.523	0.610	0.696	0.783
0.250	0.366	0.455	0.544	0.634	0.723	0.812
0.260	0.382	0.474	0.566	0.658	0.750	0.841
0.270	0.398	0.493	0.587	0.681	0.776	0.870
0.280	0.415	0.512	0.608	0.705	0.802	0.899
0.290	0.431	0.531	0.630	0.729	0.828	0.927
0.300	0.448	0.550	0.651	0.752	0.854	0.955
0.310	0.465	0.569	0.672	0.776	0.879	0.983
0.320	0.482	0.588	0.694	0.799	0.905	1.011
0.330	0.499	0.607	0.715	0.823	0.931	1.039
0.340	0.516	0.626	0.736	0.846	0.956	1.066
0.350	0.533	0.646	0.758	0.870	0.982	1.094
0.360	0.551	0.665	0.779	0.893	1.007	1.121
0.370	0.568	0.684	0.800	0.917	1.033	1.149
0.380	0.586	0.704	0.822	0.940	1.058	1.176
0.390	0.604	0.724	0.844	0.963	1.083	1.203
0.400	0.622	0.743	0.865	0.987	1.109	1.231
0.410	0.640	0.763	0.887	1.011	1.134	1.258
0.420	0.658	0.783	0.909	1.034	1.160	1.285
0.430	0.649	0.776	0.903	1.031	1.158	1.285
0.440	0.657	0.786	0.915	1.044	1.173	1.302
0.450	0.665	0.796	0.927	1.057	1.188	1.319
0.550	0.740	0.887	1.035	1.182	1.329	1.477
0.650	0.809	0.971	1.133	1.295	1.457	1.619
0.750	0.872	1.047	1.223	1.398	1.574	1.749
0.850	0.930	1.118	1.306	1.495	1.683	1.871
0.950	0.986	1.185	1.385	1.585	1.785	1.985
1.050	1.038	1.249	1.460	1.671	1.882	2.093
1.150	1.088	1.309	1.531	1.752	1.974	2.195
1.250	1.135	1.367	1.598	1.830	2.062	2.293
1.350	1.181	1.422	1.663	1.905	2.146	2.387
1.450	1.225	1.475	1.726	1.976	2.227	2.478
1.550	1.267	1.527	1.786	2.046	2.305	2.565
1.650	1.308	1.576	1.845	2.113	2.381	2.649
1.750	1.348	1.625	1.901	2.178	2.454	2.731
1.850	1.387	1.671	1.956	2.241	2.525	2.810
1.950	1.424	1.717	2.010	2.302	2.595	2.887
2.050	1.461	1.761	2.062	2.362	2.662	2.962

TABLE 5.4 – GRATE CAPACITIES IN DEPRESSIONS

GRATE CAPACITY IN DEPRESSIONS - (not located at a gutter)

the lesser of Q1 or Q2 *pg 10.8 UTS*

Q1=1.66Pd^1.5 (weir eqn)
Q2= 0.60*Ag*(2gd)^0.5 (orifice eqn)

ASSUMPTIONS:
Grate is only 50% efficient (50% blocked)
Grate is Square in Shape

GRATE CAPACITY IN DEPRESSIONS - (not located at a gutter) in cum/s

	GRATE SIZE (m)							
d (m)	0.45	0.60	0.75	0.90	1.20	1.50	1.80	2.00
0.050	0.017	0.022	0.028	0.033	0.045	0.056	0.067	0.074
0.060	0.022	0.029	0.037	0.044	0.059	0.073	0.088	0.098
0.070	0.028	0.037	0.046	0.055	0.074	0.092	0.111	0.123
0.080	0.034	0.045	0.056	0.068	0.090	0.113	0.135	0.150
0.090	0.040	0.054	0.067	0.081	0.108	0.134	0.161	0.179
0.100	0.047	0.063	0.079	0.094	0.126	0.157	0.189	0.210
0.110	0.055	0.073	0.091	0.109	0.145	0.182	0.218	0.242
0.120	0.062	0.083	0.104	0.124	0.166	0.207	0.248	0.276
0.130	0.070	0.093	0.117	0.140	0.187	0.233	0.280	0.311
0.140	0.078	0.104	0.130	0.157	0.209	0.261	0.313	0.348
0.150	0.087	0.116	0.145	0.174	0.231	0.289	0.347	0.386
0.160	0.096	0.127	0.159	0.191	0.255	0.319	0.382	0.425
0.170	0.105	0.140	0.175	0.209	0.279	0.349	0.419	0.465
0.180	0.114	0.152	0.190	0.228	0.304	0.380	0.456	0.507
0.190	0.117	0.165	0.206	0.247	0.330	0.412	0.495	0.550
0.200	0.120	0.178	0.223	0.267	0.356	0.445	0.535	0.594
0.220	0.126	0.206	0.257	0.308	0.411	0.514	0.617	0.685
0.240	0.132	0.234	0.293	0.351	0.468	0.586	0.703	0.781
0.260	0.137	0.244	0.330	0.396	0.528	0.660	0.792	0.880
0.280	0.142	0.253	0.369	0.443	0.590	0.738	0.885	0.984
0.300	0.147	0.262	0.409	0.491	0.655	0.818	0.982	1.091
0.320	0.152	0.271	0.423	0.541	0.721	0.901	1.082	1.202
0.340	0.157	0.279	0.436	0.592	0.790	0.987	1.185	1.316
0.360	0.161	0.287	0.448	0.645	0.861	1.076	1.291	1.434
0.380	0.166	0.295	0.461	0.664	0.933	1.167	1.400	1.555
0.400	0.170	0.303	0.473	0.681	1.008	1.260	1.512	1.680
0.420	0.174	0.310	0.484	0.698	1.084	1.356	1.627	1.807
0.440	0.178	0.317	0.496	0.714	1.163	1.453	1.744	1.938
0.460	0.183	0.324	0.507	0.730	1.243	1.554	1.864	2.072
0.480	0.186	0.331	0.518	0.746	1.325	1.656	1.987	2.208
0.500	0.190	0.338	0.529	0.761	1.353	1.761	2.113	2.348
0.550	0.200	0.355	0.554	0.798	1.419	2.031	2.438	2.708
0.600	0.208	0.371	0.579	0.834	1.482	2.314	2.777	3.086
0.650	0.217	0.386	0.603	0.868	1.543	2.411	3.132	3.480
0.700	0.225	0.400	0.625	0.901	1.601	2.502	3.500	3.889
0.750	0.233	0.414	0.647	0.932	1.657	2.589	3.729	4.313
0.800	0.241	0.428	0.669	0.963	1.712	2.674	3.851	4.751
0.850	0.248	0.441	0.689	0.992	1.764	2.757	3.969	4.900
0.900	0.255	0.454	0.709	1.021	1.815	2.836	4.084	5.043
0.950	0.262	0.466	0.729	1.049	1.865	2.914	4.196	5.181
1.000	0.269	0.478	0.747	1.076	1.914	2.990	4.305	5.315

5.3 HYDRAULIC GRADE LINE

Once a trial stormwater drainage system has been established (i.e. pipe layout and sizes) the system has to be designed so that it operates hydraulically.

The calculation of the hydraulic grade line (H.G.L) is used to determine the size, grade and level of the drainage system components to ensure that water does not flow out of pits (surcharge) instead of into them.

The H.G.L. method evaluates the energy (head) levels through the system and the losses in energy (head losses) due to friction and turbulence.

The calculation of head loss due to frictional losses is explained in this section. The calculation of head loss due to turbulence of flow through pits is explained in also explained with a brief outline of the general steps used to determine the levels below which the pipe obvert must be located and revising the trial pipe sizes and possibly the pipe layout to satisfy the constraints detailed below.

The primary aims of the design are to determine the minimum pipe size allowable (to reduce material costs) and to determine the minimum depth at which a pipe can be laid (to reduce excavation costs) so that the stormwater system does not surcharge during the selected design storm.

The design is constrained by the following factors:

i) Minimum pipe size is 375 mm nominal diameter.

ii) Downstream pipe sizes must be the same or larger than upstream pipes unless pipe sizes are equal to or larger than 750 mm diameter.

iii) A minimum and maximum cover must be maintained to all pipes to avoid structural failure. Refer to Pipe Cover Requirements below. If in doubt see the Design Engineer.

iv) The pipe system must be located clear of any existing public utility services or other permanent obstruction that will not be relocated. The depth of any service crossed by a pipeline must be checked to ensure no conflict occurs.

v) The longitudinal grade of the pipeline must be steep enough to maintain sufficient velocity for self cleansing. If a pipeline is laid at a grade which is too flat, it will tend to silt up. The minimum grade for all pipe sizes is 0.5%.

vi) Flow velocities in pipes must be kept below 6m/s under normal conditions. Velocities greater than this cause excessive abrasion, scouring and can result in cavitation damage. Velocities may be permitted to exceed this limit by a maximum of 10% (i.e velocities up to 8.0m/s) where it can be demonstrated that the intended discharge does not carry a high loading of abrasive matter. In new developments this will be difficult to demonstrate. In some situations pipes may only flow part full (usually when laid at steep grades). When this occurs, the partial depth velocity must be determined as this could exceed the full bore velocity. Partial depth velocities can be calculated using Figure 5.4.

vii) The obvert level of the inlet shall be no lower than that of the outlet pipe in all pits. Wherever possible, however, the obvert levels of the inlet and outlet pipes are to be the same.

viii) The minimum freeboard to be provided at all on-grade pits is 150 mm. This is to be provided so that the effects of turbulence at the pit inlet do not interfere with the assumed hydraulic regime of the system. No freeboard needs to be provided at sag pits, the water may rise to the maximum allowable pond level at the sag point.

ix) The H.G.L. must not rise above natural surface level except at sag inlet pits where ponding is permitted.

Head Loss in Pipes

For full flow conditions, the quantity of flow "Q" in a pipe reach depends on the average flow velocity "V" and the cross-sectional area of the pipe "A". The relation is:

$$Q = V.A \qquad \textbf{(5.1)}$$

The loss of head "h_f" in a pipe reach depends on the flow velocity "V" and the pipe diameter "D". The relation is:

$$h_f = f.L.V^2 / 2.g.D \qquad \textbf{(5.2)}$$

where
h_f = head loss in the pipe reach (m)
f = friction factor
L = length of pipe reach (m)
V = flow velocity (m/s)
g = acceleration due to gravity (9.81m/s^2)
D = pipe diameter (m)

The hydraulic gradient "S_o" is the head loss per unit length of flow i.e.:

$$S_o = h_f / L \qquad \textbf{(5.3)}$$

Equation 5.8 can be rewritten as:

$$h_f = S_o.L \qquad \textbf{(5.4)}$$

The hydraulic gradient "S_o" can be read directly from Figure 5.5 for Reinforced Concrete Pipes (K=0.60mm) or Table 5.6 for FRC pipes (K=0.06mm).

Pit Losses

At each junction within the system, there will be a loss in head known as a "shock loss" caused by turbulence created as water flows out of a pipe into a pit and then out of the pit into the next pipe reach. It is important to design pits so that these losses will be minimised. Figure 5.7 shows the desirable layout of a pit with the centrelines of the inlet and outlet pipes intersecting on the downstream face of the pit.

Pit losses are best determined from charts such as the Missouri Charts or those prepared by Hare (see references below). However, for most designs, provided the designer appreciates the principles of hydraulic head losses, it will be satisfactory to obtain head loss co-efficients from Figure 5.8, which is a simplification and rationalisation of these charts. For a particular pit configuration, the head loss "h_l" is obtained from the equation given below:

$$h_l = K_w.V^2 / 2g \qquad \textbf{(5.5)}$$

where
h_l = head loss (m)
K_w = head loss co-efficient (from Fig. 5.8)
V = full bore velocity = Q/A (m/s)
g = acceleration due to gravity (9.81m/s^2)

If negative head losses at junctions are encountered when using charts such as the Missouri Charts, they should be ignored and the pit loss taken as zero. Where a downstream pipe from a straight through junction (but not a drop pit) is flowing part full at a depth of less than 70% of the pipe diameter, the pit loss may be ignored.

Hydraulic Grade Line Calculations

The hydraulic grade line for a stormwater pipe system can be determined by either of the two methods listed below:

i) Starting at the top of the system and working down to the known downstream water level.

ii) Starting at the known downstream level and working back upstream to the top of the system.

The 1987 AR&R recommends the use of the first of the two alternatives but adds that the calculations should be checked by starting at the downstream end of the system and working back upstream.

It is desirable to firstly draw a longitudinal section of the proposed drainage lines, preferably with an exaggerated vertical scale (the vertical scale is usually in the order of 5 times the horizontal scale). The proposed finished surface levels and any public utility services or other obstructions are plotted on this section. The trial pipe reaches may then be drawn if desired. These can be located initially by providing the minimum cover allowable, maintaining greater than the minimum pipe grade and ensuring that the pipeline is located clear of all services and obstructions. Alternatively, pipe reaches may be plotted on the section as the calculation for each pipe reach proceeds.

The trial pipe layout is then analysed by calculating and plotting the hydraulic grade line on the longitudinal section. A brief explanation of the general principles involved is given below.

For calculations commencing from upstream, firstly, determine the pit loss in the first pit in the reach. This head loss is subtracted from the maximum allowable water surface level at this pit (i.e. 150 mm below the grate level for an on-grade pit and pond level for a sag pit) to give the H.G.L. level at the downstream side of the pit. The head loss due to friction in the downstream pipe reach is then determined. This head loss is then subtracted from the H.G.L. level at the downstream side of the pit to give the H.G.L. at the upstream side of the next downstream pit. These levels are then plotted on the longitudinal section and connected by a straight line to give the H.G.L. for this pipe reach. The obvert of the pipeline in this reach must be located below the H.G.L. but not necessarily at the same grade.

The head loss for the next downstream pit is then calculated and subtracted from the previously calculated H.G.L. level on the upstream side of this pit to give the H.G.L. level on the downstream side of the pit. The calculations proceed in this manner until the hydraulic grade line for the entire system has been determined.

If a situation occurs where the H.G.L., when drawn from an upstream pit, is located above the maximum allowable water surface level at the next downstream pit then this maximum allowable water surface level should be adopted as the H.G.L. level at the upstream side of this pit. In this case, the H.G.L. should be drawn from this maximum level, upstream at the same slope as the H.G.L. originally calculated. If this line intersects the obvert of the pipe reach at any point, then the pie will flow part full upstream of this point. The partial flow depth and partial flow velocity should then be to ensure that the maximum allowable velocity is not exceeded.

If the slope of the H.G.L. determined for a downstream reach is very steep and results in an excessively deep pipeline, then a larger pipe size should be investigated. If the slope of the H.G.L. is very flat, then a smaller pipe size should be investigated.

The main requirement when working from upstream to downstream is that the H.G.L. level at the outlet of the system, determined by the calculations, must be at or above the tailwater level (i.e. the water surface level of the receiving waters or a suitable level selected from other criteria. If this requirement is not met, then the calculations will have to be revised using larger pipe sizes or increasing the depth of pipes where appropriate. If either of these changes does not satisfy this requirement, then the overall situation will have to be reviewed and the Engineer Investigations or Subdivision Engineer should be consulted.

When designing a system comprised of a main line and one or more side lines, the calculations are carried out for the main line first in the manner described above. The calculations then proceed for the side lines in the same manner. The tailwater level for the side line(s) is taken as the higher of the main line H.G.L. level in the junction pit, and the obvert level of the side line where it enters the main line.

The calculations for the check starting at the downstream end are simply the reverse of those described above.

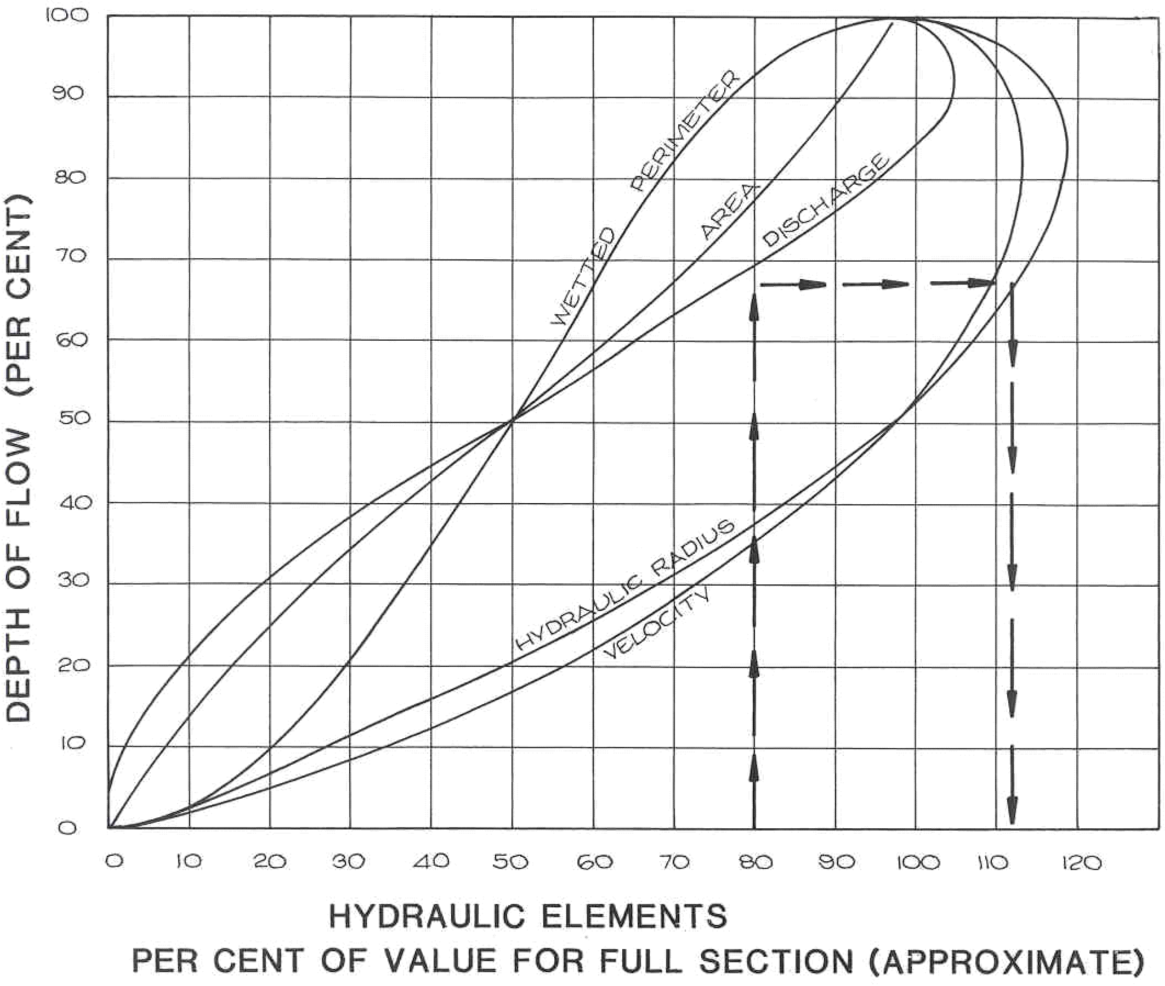
Pipe Cover Requirements

Pipe Cover and bedding are to be carried out in accordance with the requirements of AS 3725 'Loads on Buried Concrete Pipes'. The Concrete Pipe Association of Australia (CPAA) on its web site, *www.concpipe.asn.au* has available computer software to determine the correct concrete pipe for all depths and soil conditions. For Fibre Reinforced Pipes (FRC), James Hardy FRC Pipes has computer software on its web site – *www.jameshardyfrcpipes.com.au*.

Council will accept designs based on other installation programs/charts provided by CPAA and James Hardy, etc that comply with the requirements of AS 3725.

Council will allow the use of pervious concrete pipes for special applications. These pipes must conform to Australian Standard AS 4058 – 1992, Precast Concrete Pipes.

FIGURE 5.4 - VALUES OF HYDRAULIC ELEMENTS OF CIRCULAR SECTION FOR VARIOUS DEPTHS OF FLOW



<u>EXAMPLE</u> : FOR D = 450 R.C.P. , GRADE 9% , NOT PLOWING UNDER PRESSURE WITH A FLOW OF 0.776 m^3/s. FROM MANNINGS EQUATION $Q_o = 0.970\ m^3/s$, $\therefore V_o = 5.9\ m/s$, $\therefore Q/Q_o = 0.80 \Longrightarrow$ FROM FIG. V/V_o 1.125, $\therefore V$ 6.6 m/s.

VALUES OF G HYDRAULIC ELEMENTS OF CIRCULAR SECTION FOR VARIOUS DEPTHS OF FLOW .

FIGURE 5.5- HYDRAULIC GRADIENTS - FOR REINFORCED CONCRETE PIPES K = 0.60mm

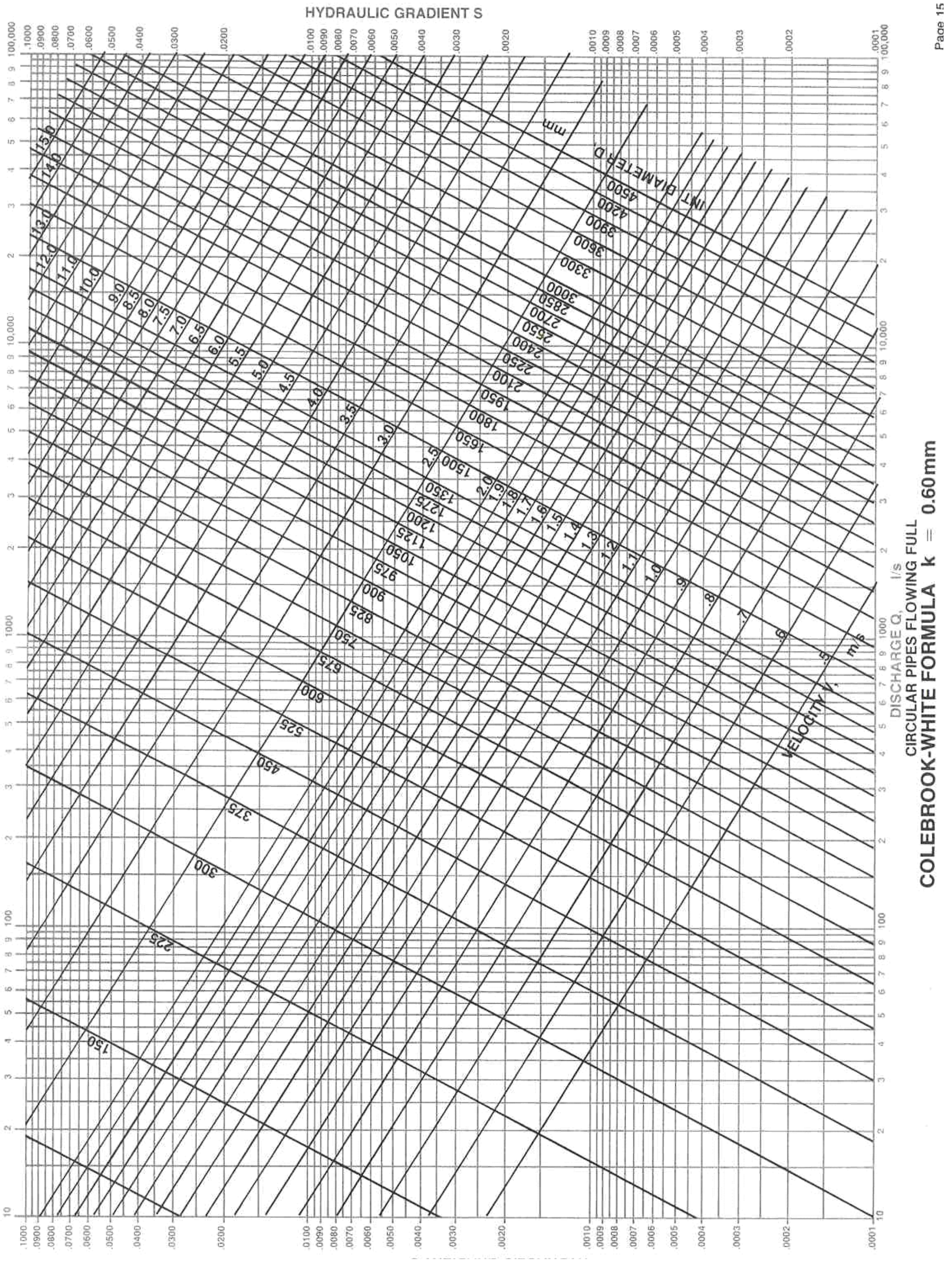


FIGURE 5.6 - HYDRAULIC GRADIENTS - FOR FRC PIPES K=0.06mm

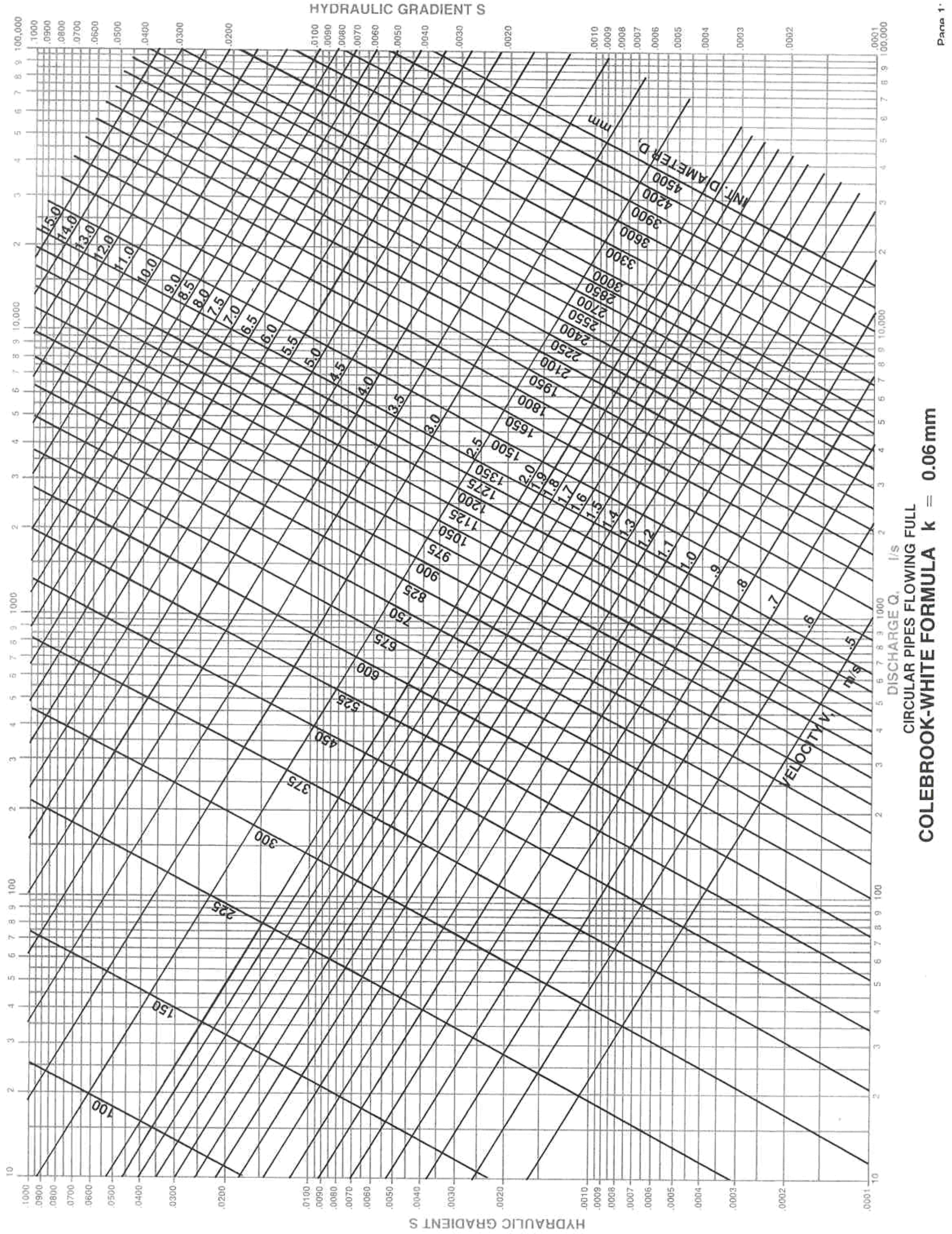


FIGURE 5.7 - PREFERRED PIT LAYOUT

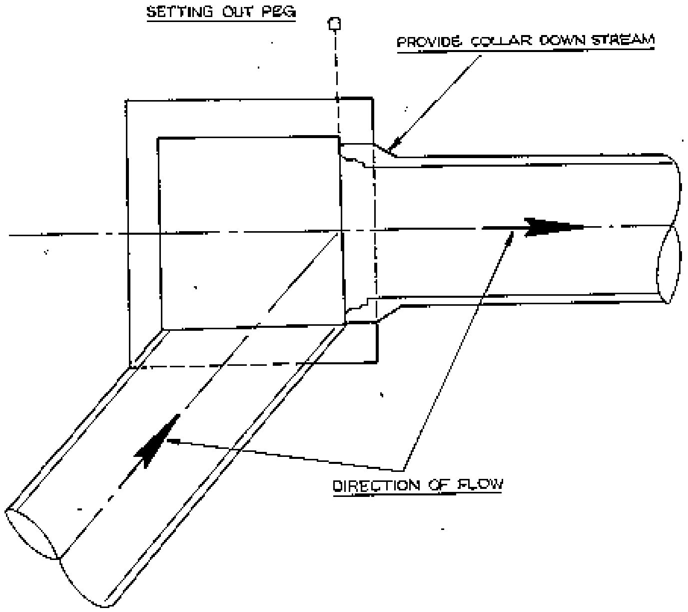


FIGURE 5.8 - APPROXIMATE VALUE FOR CO-EFFICIENT Kw - PIPES CONCURRENT OR AT RIGHT ANGLES

Figure (a) represents a general, simple junction pit layout with upstream, lateral and grating inflows, Q_u, Q_l and Q_g respectively. By assigning values to these parameters all possible simple pit configurations can be described. Figure (b) is an elevation section through the pit taken along the alignment of its discharge pipe, diameter Do. The K_w values listed are based on findings of Sangster et al (1958) known as 'Missouri Charts', de Groot and Boyd (1983), Black and Piggott (1983).

INLET / JUNCTION PITS WITH GUTTER FLOWS

CODE	**DESCRIPTION**	$Q_u \approx$	$Q_l \approx$	$Q_g \approx$	$K_w =$
I-1	Inlet pit with single pipe outflow	-	-	Q_o	4.0
	Inlet on through pipeline				
I-2A	$Q_u \approx Q_g$	$Q_o / 2$	-	$Q_o / 2$	2.0
I-2B	$Q_u \approx Q_o$	Q_o	-	some	0.5
	Inlet on through pipe with				
I-3A	lateral(s)				
I-3B	$Q_u >> Q_l$	Q_o	some	some	0.5
I-3C	$Q_u > Q_l$	$Q_o / 2$	some	$Q_o / 2$	1.5
I-3D	$Q_u \approx Q_l$	$Q_o / 2$	$Q_o / 2$	some	1.5
I-3E	$Q_u << Q_l$	some	Q_o	some	2.0
	$Q_u < Q_l$	some	$Q_o / 2$	$Q_o / 2$	2.5
	Inlet on 'L' pipe junction				
I-4	i.e. $Q_u = 0$	-	Q_o	some	2.5
	Inlet on 'T' pipe junction i.e. $Q_u = 0$				
I-5A	opposed laterals	-	Q_o	some	3.0
I-5B	offset laterals	-	Q_o	some	2.5

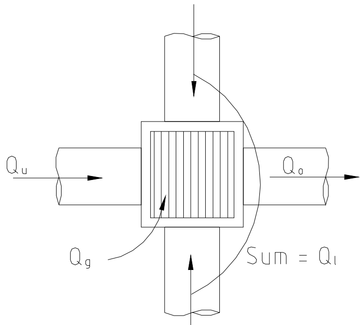


Figure (a)

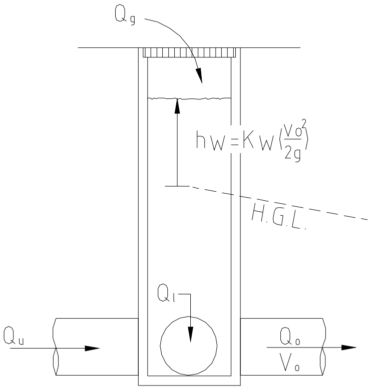


Figure (b)

JUNCTION PITS WITHOUT GUTTER FLOWS

CODE	**DESCRIPTION**	$Q_u \approx$	$Q_l \approx$	$Q_g \approx$	$K_w =$
J-1	Junction pit on through pipeline, i.e. $Q_u = Q_o$	Q_o	-	Q_o	0.2
	Junction pit on through pipe with lateral(s)				
J-2A	$Q_u >> Q_l$	Q_o	some	-	0.5
J-2B	$Q_u \approx Q_l$	$Q_o / 2$	$Q_o / 2$	-	1.0
J-2C	$Q_u << Q_l$	some	Q_o	-	2.0
J-3	Junction pit on 'L' pipe junction i.e. $Q_u = 0$	-	Q_o	-	2.0
	Junction pit on 'T' pipe junction i.e. $Q_u = 0$				
J-3A	opposed laterals	-	Q_o	-	2.5
J-3B	offset laterals	-	Q_o	-	2.0

DROP JUNCTION PITS

It is often necessary in steep terrain or when an existing service (water main, electricity cable, etc) must be avoided to construct junction pit entry and exit pipes at significantly different levels. Unpublished research by Black and Piggot (QIT) and Logan City Council (1983) suggests the following for the pit water level headloss coefficient K_w:

$\theta < 45^o$ situations
rectangular pits, $K_w = 2.0$
circular pits, $K_w = 1.5$

$\theta > 45^o$ situations
rectangular pits, $K_w = 2.5$
circular pits, $K_w = 2.0$

Use of these values for K_w is restricted to installations in which both pipe obverts (entry and exit) are submerged under design flow conditions AND there is no gutter flow. It is considered unlikely that gutter flow, if present, will affect the listed values of K_w, but this is presently unresearched.

Some designers prefer to break vertical alignment and introduce a short length of steeply sloping pipe (slope, say, 1 vertical to 4 horizontal), if necessary, in preference to using a drop pit. They argue that the headloss thus introduced, although unknown, must be less that that occurring at a drop pit. Designers following this practice are entitled to use slightly reduced values for K_w.

MULTI-PIPE JUNCTION PITS

The bulk of practical situations for which a pit headloss values are required can be found from Figure 5.8 and the above. Cases not covered are those where flows enter pits from two or more pipes which are not concurrent with and / or not at 90 degrees to their respective discharge pipes. The multitude of pipe / pit geometries met in practice and the range of flows which need to be tested to produce generalised tables make the full research of this topic a mammoth if not impossible task.

The following suggestions are offered to designers who face this problem:

(i) in situations where the risk of property inundation is highly sensitive to uncertainty in head loss estimates, values of K_w should be obtained from hydraulic models of pit / pipe installations tested under design conditions (see Bates et al 1984), and,
(ii) in all other situations use $K_w = 3.0$, with or without gutter flow.

SOURCE: ARRB SR 34, 1986

5.4 DRAINAGE CALCULATION SHEETS

Stormwater Runoff Calculation Sheet given as Figure 4.8 makes provision for some hydraulic calculations to be carried out in conjunction with the hydrologic calculations. The preliminary pit layout is checked by determining the width and depth of flow in the gutters in columns 15 to 20. The required inlet sizes are determined in columns 21 to 25 and the pipe sizes determined in columns 26 to 31. Column 32 provides space for any remarks.

A detailed description of the entries to the Stormwater Runoff Calculations Sheet is included as Table 5.5.

The hydraulic grade line calculations are carried out on the Stormwater Drainage Hydraulic Grade Line Calculations sheet given as Figure 5.9. This sheet provides for the calculation of hydraulic grade line levels in columns 1 to 16 and the determination of pipe invert levels and grades in columns 17 to 24.

A detailed description of the entries to the Stormwater Drainage Hydraulic Grade Line Calculations sheet is included as Table 5.6.

The hydraulic grade line check calculations are carried out in columns 20 to 33 of the combined Major System Check Sheet/Hydraulic Check Sheet given as Figure 4.9.

A detailed description of the entries to the combined Major System Check Sheet/Hydraulic Check Sheet is included as Table 5.7.

FIGURE 5.9 – HYDRAULIC GRADE LINE CALCULATIONS SHEET

HORNSBY SHIRE COUNCIL
Works Division

STORMWATER DRAINAGE
HYDRAULIC GRADE LINE CALCULATIONS
STARING AT UPSTREAM END

Basin: ....
Sub Area: ....
File No.: ....
Plan No.: ....

																U/S INVERT LEVELS				D/S INVERT LEVELS				
PIPE SECTION	LENGTH - L	FLOW	DIAMETER	VELOCITY - V	$\frac{V^2}{2g}$	U/S PIT SURFACE LEVEL	MAX. U/S PIT WATER SURFACE LEVEL	PIT LOSS COEFFICIENT - K	K - $\frac{V^2}{2g}$	H.G.L. LEVEL AT U/S PIT	HYDRAULIC GRADIENT - So	PIPE FRICTION LOSS - SoL	H.G.L. LEVEL AT D/S PIT	D/S PIT SURFACE LEVEL	MAX.D/S PIT WATER SURFACE LEVEL	HYDRAULIC	COVER	UPSTREAM PIPE	ADOPTED	HYDRAULIC	COVER	ADOPTED	PIPE GRADE	REMARKS
	m	m^3/sec	mm	m/sec	m	m	m		m	m	m/m	m	m	m	m	m	m	m	m	m	m	m	%	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

RECURRENCE INTERVAL: 1 in .... YEARS | ROUGHNESS K_S............ | DATE: 11 September, 1998 | PLAN NO. 448.37 | 6/87

TABLE 5.5 - DESCRIPTION OF ENTRIES TO STORMWATER RUNOFF CALCULATION SHEET

(Refer to Figure 4.8)

Column 1:	The sub-catchment number as per Section 4.6.
Column 2:	Surface type to be chosen from list at the bottom of the sheet to suit the particular situation.
Column 3:	Length of path of longest time of overland flow.
Column 4:	Slope of overland flow path from contours and scaled distances.
Column 5:	Overland flow time as per Section 4.3.
Column 6:	Length of gutter flow equal to the distance from the point where overland flow reaches the gutter to the pit.
Column 7:	Slope of gutter over length determined in (6)
Column 8:	Gutter flow time from Figure 4.2.
Column 9:	Sub area time of concentration being the sum of (5) and (8). Minimum time to be used is 5 minutes.
Column 10:	Rainfall intensity determined from Table 4.5. using the time determined in (9).
Column 11:	Co-efficient of runoff as per Section 4.5.
Column 12:	Area of sub-catchment scaled from catchment plan.
Column 13:	Equivalent impervious area being (11) x (12).
Column 14:	Sub area discharge being (13) x (10) / 360.
Column 15:	Bypass flows from upstream as per columns 24 and 25.
Column 16:	Total gutter flow being (14) + (15).
Column 17:	Road crossfall at pit obtained from design plans.
Column 18:	Longitudinal grade of gutter at pit obtained from design plans.
Column 19:	Width of gutter flow from Table 5.2, (not to exceed 2.5 metres for normal road profiles) using total gutter flow from (16).
Column 20:	Depth of gutter flow from Table 5.2 using total gutter flow from (16).
Column 21:	Inlet pit number from trial drainage layout as per Section 4.6.
Column 22:	Inlet pit type from list at bottom of sheet.
Column 23:	Inflow to pit determined from Table 5.1 and Table 5.2
Column 24:	Bypass flow from the pit being the excess of gutter flow over inflow, calculated as (16) - (23).
Column 25:	Pit number of downstream pit to which bypass from (24) flows.

Column 26: The critical time of concentration is the longest time of the sub area time of concentration and any the times of concentration of any contributing upstream sub-catchments, as per Section 4.7. This time should include any significant upstream pipe flow time.

Column 27: Rainfall intensity for the critical time of concentration from Table 4.5.

Column 28: Total equivalent impervious area being the sum of the sub area equivalent impervious area and the equivalent impervious areas of all contributing upstream sub-catchments.

Column 29: Outflow from pit being (27) x (28) / 360.

Column 30: Grade as shown on trial layout or as determined from minimum cover or public utility controls.

Column 31: Trial pipe diameter chosen to suit flow (29) and grade (30).

Column 32: Remarks on any unusual features of the design, or cross references to notes or other design sheets.

TABLE 5.6 - DESCRIPTION OF ENTRIES TO STORMWATER DRAINAGE HYDRAULIC GRADE LINE CALCULATIONS SHEET

(Refer to Figure 5.9)

Column 1:	The pipe reach name as per Section 4.6.
Column 2:	The length of the pipe reach.
Column 3:	Design flowrate derived from hydrologic calculations.
Column 4:	Trial pipe diameter. This may be changed if calculations indicate that head losses are too high and the pipe is too deep, or where there is interference with other services.
Column 5:	The full bore velocity obtained by dividing the flowrate in (3) by the area of the pipe with the diameter in (4).
Column 6:	$V^2/2_g$ calculated using V from (5).
Column 7:	Upstream pit surface level - grate level for a DGGP. or top of headwall, etc.
Column 8:	Allowable water surface level in the upstream pit. For the first pit in a line, it will be the surface level (7) minus a freeboard of 0.15m. For other pits, it will be the lower of this value and the levels set in Column 14 during calculations for the pipe reach immediately upstream.
Column 9:	A pit loss co-efficient (as determined from Figure 5.9) appropriate to the pit geometry, pipe sizes and relative flowrates.
Column 10:	A pit head loss calculated as (6) x (9).
Column 11:	Assumed H.G.L. level for flows leaving the pit calculated as (8) - (10).
Column 12:	Hydraulic gradient determined from Figure 5.6 for the given flowrate and pipe size.
Column 13:	Head loss due to pipe friction being (12) x (2). The H.G.L. will drop by this amount over the length of the reach.
Column 14:	The H.G.L. level at the downstream pit, being (11) - (13).
Column 15:	Surface level of downstream pit.
Column 16:	Allowable water surface level in the downstream pit found by subtracting 0.15m freeboard from (15). This is checked against the H.G.L. level calculated in (14). The lower of these should be adopted as the pit water surface level in Column 8 of subsequent calculations for the pipe reach downstream of this pit.
Column 17:	An upstream pit invert level based on hydraulic requirements, found by subtracting (4) from (11).
Column 18:	An upstream pit invert level obtained by subtracting (the required cover depth + pipe wall thickness + pipe diameter) from the surface level in (7).
Column 19:	An upstream pit invert level equal to the invert level of the lowest upstream pipe entering the pit, minus any allowance for slope across the pit.
Column 20:	The adopted upstream pit invert level being the lowest of (17), (18) and (19).
Column 21:	A downstream pit invert level based on hydraulic requirements, obtained by subtracting the diameter (4) from the lower of the levels in (14) and (16).

Column 22:	A downstream pit invert level obtained by subtracting (the required cover depth + pipe wall thickness + diameter) from the surface level in (15).
Column 23:	The adopted downstream pit invert level being the lower of (21) and (22).
Column 24:	Pipe grade calculated from adopted levels in (20) and (23) and reach length in (2).
Column 25:	Remarks on any unusual features of the design, or cross references to notes or other design sheets.

TABLE 5.7 - DESCRIPTION OF ENTRIES TO MAJOR SYSTEM CHECK/ HYDRAULIC CHECK SHEET

(Refer to Figure 4.9)

Column 1 to Column 14:	As per descriptions given in Table 5.5 for Stormwater Runoff Calculations Sheet.
Column 15:	Cumulative pit capacities for all upstream pits along the branch being considered. These will be approximate due to uncertainty regarding pit capacity during major events.
Column 16:	Capacity of the downstream pipe, assuming that major flow conditions apply and flows are surcharged beyond the levels used in minor system design.
Column 17:	Overflow rate, being (14) minus the lesser of (15) and (16).
Column 18:	Check on capacity of road which must carry overflows, using Figure 4.7.
Column 19:	Remarks on unusual features of the design or cross references to notes or other design sheets.
Column 20 to Column 33:	As per descriptions given in the relevant columns.

5.5 CULVERT DESIGN

Culverts should be designed using a procedure such as that described in the publication "Pipe and culvert Hydraulics Manual - Rocla Concrete Pipes Limited", or “Hydraulics of Precast Concrete Conduits – Pipes And Box Culverts Hydraulic Design Manual”. – Concrete Pipe Association of Australasia. The value of Manning's "n" chosen for concrete pipes should be 0.012 and for FRC pipes 0.011.

5.6 OPEN CHANNELS

1. Generally, open channels will only be permitted where they form part of the trunk drainage system and shall be designed to have smooth transitions with adequate access provisions for maintenance and cleaning. Where Council permits the use of an open channel to convey flows from a development site to the receiving water body, such a channel shall comply with the requirements of this Specification.

2. Design of open channels shall be in accordance with Volume 1, Chapter 14, of AR&R. Open channels will be designed to contain the major system flow less any flow that is contained in the minor system, with an appropriate allowance for blockage of the minor system.

3. Friction losses in open channels shall be determined using Manning’s "n" values given below:-

Manning’s "n" Roughness Co-efficients for open channels shall generally be derived from information in Chapter 14 of AR&R. Manning’s "n" values applicable to specific channel types are given below:-

Concrete Pipes or Box Sections	0.011
Concrete (trowel finish)	0.014
Concrete (formed without finishing)	0.016
Sprayed Concrete (gunite)	0.018
Bitumen Seal	0.018
Bricks or pavers	0.015
Pitchers or dressed stone on mortar	0.016
Rubble Masonry or Random stone in mortar	0.028
Rock Lining or Rip-Rap	0.028
Corrugated Metal	0.027
Earth (clear)	0.022
Earth (with weeds and gravel)	0.028
Rock Cut	0.038
Short Grass	0.033
Long Grass	0.043

4. Where the product of average Velocity and average flow Depth for the design flow rate is greater than 0.4m^2/s, the design will be required to specifically provide for the safety of persons who may enter the channel in accordance with Volume 1, Chapter 14, of AR&R.

5. Maximum side slopes on grassed lined open channels shall be 1 in 4, with a preference given to 1 in 6 side slopes, channel inverts shall generally have minimum cross slopes of 1 in 20.

6. Low flow provisions in open channels will require low flow / base flows to be conveyed by a natural system, consisting of riffles, rock pools, fall drop structures and aquatic vegetation to filter pollutants, conserve bio diversity and create habitat.

7. Transition in channel slopes is to be designed to avoid or accommodate any hydraulic jumps due to the nature of the transition.

5.7 MINOR SYSTEM CRITERIA

1. The acceptable gutter flow widths in the Q20 storm event is 2.5 metres maximum. Wider flow widths may be approved on roads with flat grades.

2. Minimum conduit sizes shall be as follows:

Pipes	-	375mm diameter. All pipes are to rubber ring jointed reinforced concrete or fibre reinforced concrete.
Box culverts	-	600mm wide x 300mm high. All culverts are to be constructed from precast reinforced concrete.

3. Minimum and maximum velocity of flow in stormwater pipelines shall be 0.6m/sec and 6m/sec respectively.

5.8 MAJOR SYSTEM CRITERIA

1. Overland Flow Paths are to be designed to convey the 1 in 100 year Q100 storm flow. For calculation of the overland flow the following criteria is to be used:

- ***For pipe sizes up to and including 750mm nominal diameter the drainage system is to be assumed fully blocked.***
- ***For pipe sizes greater than 750mm nominal diameter the drainage system is to be assumed 50% blocked.***

These criteria are to be used in conjunction with Minor system pit inlet blockages shown in Table 5.8. They are intended to approximate Council's experience of the operation of the system in major storms.
Overland flow paths are not to be obstructed by structures or landscaping. Fencing across flow paths must have hinged panels or grills to a minimum height of 0.5 metres for the full width of the flow path for the 100 year ARI storm.
The design of the overland flow path must consider the velocity x depth product detailed in section 3 below.

2. Surcharging of drainage systems which would provide for water depth above the top of kerb will not be permitted except:

a) Surcharging of the drainage system for storm frequencies greater than Q20 probability may be permitted across the road centreline where the road pavement is below the natural surface of the adjoining private properties
b) Flow across footpaths will only be permitted in situations specifically approved by Council, where this will not cause flooding of private properties.

3. The velocity x depth product of flow across the footpath and within the road reserve shall be such that safety of children and vehicles is considered. The maximum allowable depth of water is 0.2 metres and the maximum velocity x depth product of 0.4m^2/s is permitted. Where the safety of only vehicles can be affected, a maximum velocity x depth product of 0.6m^2/s is permitted. In open channels the above velocity x depth product criteria will be followed where possible or the design shall address the requirements for safety in relation to children by providing safe egress points from the channel or other appropriate methods.

4. Freeboard requirements for floor levels and levee bank levels from flood levels in roadways, stormwater surcharge paths and open channels are given below:

In Roadways:-

(a) A minimum freeboard of 0.5m shall be provided between the 100 year flood level and habitable floor levels on structures and 0.3m to garages and entrances to underground car parks. A higher freeboard may be required in certain circumstances.

(b) Where overtopping of kerbs and flow through properties may occur a 100mm freeboard shall be provided between the ponding level of water in the road and the high point in the footpath. Driveway construction in these instances needs to consider this requirement. Any deviation from this requirement must be approved by Council.

In Stormwater Flow Paths:-
(c A minimum freeboard of 0.5m shall be provided between the 100 year flood level and habitable floor levels on structures and 0.3m to garages and entrances to underground car parks.

In Open Channels:-
(d) A minimum freeboard of 0.5m shall be provided between the 100 year flood level and habitable floor levels on structures and 0.3m to garages and entrances to underground car parks.

5.9 MAJOR STRUCTURES

1. All major structures in urban areas, including bridges and culverts, shall be designed for the 100 year ARI storm event without afflux. Some afflux and upstream inundation may be permitted in certain rural and urban areas provided the increased upstream flooding is minimal and does not inundate private property.

2. A minimum clearance of 0.5m between the 100 year ARI flood level and the underside of any major structure superstructure is required to allow for passage of debris without blockage.

3. Certified structural design shall be required on bridges and other major culvert structures and may be required on some specialised structures. Structural design shall be carried out in accordance with the Specification for STRUCTURES BRIDGE DESIGN.

4. Culverts (either pipe or box section) shall be designed in accordance with this specification, with due regard being given to inlet and exit losses, inlet and outlet control and scour protection. See section D5.5.

5.10 RETARDING BASINS

Council may require retarding basins to be constructed as part of its overall stormwater management strategy.

1. For each ARI a range of storm events shall be run to determine the peak flood level and discharge from the retarding basin. Storm patterns shall be those given in Volume 1, Chapter 11 of AR&R. Sensitivity to storm pattern should be checked by reversing these storm patterns.

2. The critical storm duration with the retarding basin is likely to be longer than without the basin. A graph showing the range of peak flood levels in the basin and peak discharges from the basin shall be provided for the storms examined.

3. Flood Routing should be modelled by methods outlined in AR&R.

4. The high level outlet to any retarding basin shall have capacity to contain a minimum of the 100 year ARI flood event. Additional spillway capacity may be required due to the hazard category of the structure. The hazard category should be determined by reference to ANCOLD (Australian National Committee On Large Dams).

5. The spillway design shall generally be in accordance with the requirements for Open Channel Design in this Specification.

5. The spillway design shall generally be in accordance with the requirements for Open Channel Design in this Specification.

6. Wherever practical and certainly in areas known to be affected by high water tables and/or salinity of groundwater, retarding basins shall be designed to be water retentive so that surface drainage water does not leak to the subsurface, recharging groundwater.

7. Pipe systems shall contain the minor flow through the Retarding Basin wall. Outlet pipes shall be rubber ring jointed with lifting holes securely sealed. Pipe and culvert bedding shall be specified to minimise its permeability, and cut off walls and anti-seepage collars installed where appropriate.

8. The low flow pipe intake shall be protected to prevent blockages.

9. Freeboard - Minimum floor levels of dwelling shall be 0.5m above the 100 year ARI flood level in the basin.

10. Public Safety Issues - Basin design is to consider the following aspects relating to public safety.

- Side slopes are to be a maximum of 1 in 6 to allow easy egress. Side slopes of greater than 1 in 4 may require handrails to assist in egress.
- Water depths shall be, where possible, less than 1.2m in the 20 year ARI storm event. Where neither practical or economic greater depths may be acceptable. In that case the provision of safety refuge mounds should be considered.
- The depth indicators should be provided indicating maximum depth in the basin.
- Protection of the low flow intake pipe shall be undertaken to reduce hazards for people trapped in the basin.
- Signage of the spillway is necessary to indicate the additional hazard.
- Basins shall be designed so that no ponding of water occurs on to private property or roads.
- No planting of trees in basin walls is allowed.
- Basin spillways are to be located such that any flows do not impact on downstream property.
- Submission of design Drawings to the Dam Safety Committee is required where any of these guidelines are not met or Council specifically requires such submission.

5.11 STORMWATER DETENTION

1. Installation of Stormwater Detention is required on redevelopment sites within the Shire where under capacity drainage systems exist. A redevelopment site is defined as a site which used to have or was originally zoned to have a lower density development than is proposed.

2. Council's policy on OSD is being reviewed. The current OSD requirements for developments are that the Q20 post development outflow from the site is restricted to the Q5 predevelopment flow.

Note: Council may require additional storage for OSD systems for all storms up to Q100 in areas known to be subject to flood inundation.

OSD can be provided in an underground tank or as an above ground storage area. All systems require a positive covenant and a restriction as to use to ensure the system is not modified without Council consent.

Outlets to both systems is to be restricted to the PSD by means of a sharp edged stainless steel orifice plate fixed over the outlet pipe or a length of suitable diameter pipe embedded in the outlet wall. Orifice plates are to be fixed such that they cannot be removed.

To calculate the outflow rate, the following formula is to be used:-

$$Q = C_d.A_o(2gh)^{0.5} \qquad \textbf{(5.6)}$$

where

A_o = area of outlet

h = the maximum water depth in the storage area measured to the centre

of the outlet

C_d = discharge coefficient

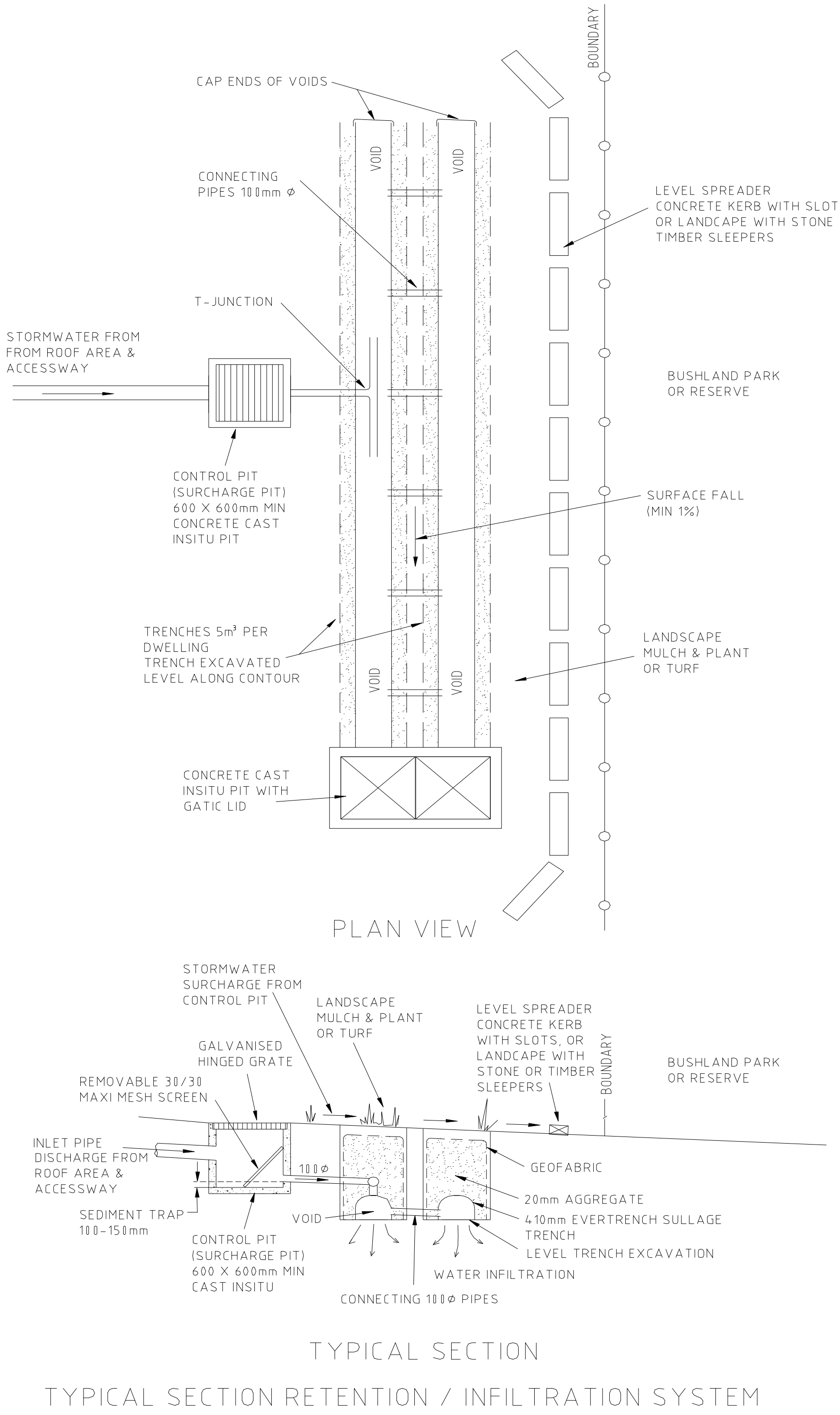
0.6 for orifice plate outlets and
0.8 for piped outlets

5.12 ONSITE RETENTION/INFILTRATION

1. On Site retention/infiltration is the temporary storage of stormwater on site and the permanent retention of silt, debris and pollutants. The system encourages infiltration to promote groundwater recharge, improves water quality and prevents erosion and weed spread to downstream lands.

2. On site retention is used for new developments in areas where there is no Council drainage system and stormwater discharges into bushland. The principals of this method of stormwater control rely on the ability of the existing soils to retain water after a stormwater event. The system is often used in conjunction with a simplified OSD system to reduce flow into bushland. Figure 5.10 below shows a typical system layout

FIGURE 5.10 – TYPICAL RETENTION/INFILTRATION SYSTEM



5.13 INTERALLOTMENT DRAINAGE

1.Interallotment Drainage shall be provided for every new allotment created that does not drain directly to the street frontage, Councils stormwater system or a natural watercourse.

2. Interallotment drainage shall be contained within an easement not less than 1.0m wide , and the easement shall be in favour of the upstream allotments.

3. Pipe Capacity - The interallotment drain shall be designed to accept concentrated drainage from buildings and paved areas on each allotment for flow rates having a design ARI the same as the "minor" street drainage system.

4. In lieu of more detailed analysis, the following pipe sizes may be assumed for interallotment drain:-

No. of dwellings	Pipe Diameter (mm)
1	90
2-3	150
4-6	225
>6	Full design required.

5. Pipes shall be designed to flow full at the design discharge without surcharging of inspection pits.

6. Interallotment drainage pits shall be located at all changes of direction. Pits shall be constructed of concrete, with 100mm thick walls and floor and have a minimum 600 x 600 internal dimensions. Pits shall be with a 100mm concrete lid finished flush with the surface of works. Depressed grated inlets are acceptable.

7. Pipes - Minimum Grade - The interallotment drainage shall have a minimum longitudinal gradient of 1.0% for pipes 150mm diameter or smaller and not less than 0.5% for larger pipes.

8. Interallotment Drainage Pipe Standards - The interallotment drainage shall be constructed from rubber ring jointed pipes of either fibre reinforced concrete drainage pipe, reinforced concrete pipe, or uPVC pipe which shall conform respectively to the requirements of AS 4139, AS 4058 and AS 1254. In public road and recreation reserves where vehicle loads may be encountered, reinforced concrete pipe or fibre reinforced concrete only, shall be used.

9. Interallotment Drainage Pipe - Relationship to Sewer Mains - Where interallotment drainage and sewer mains are laid adjacent to each other they are to be spaced 1.5 metres between pipe centrelines (where the pipe inverts are approximately equal).

10. Where there is a disparity in level between inverts the spacing is to be submitted for approval.

11. Where sewer mains are in close proximity to interallotment drainage lines they are to be shown on the interallotment drainage plan.

12. All interallotment drainage pits shall be cast in-situ concrete and benched for flow efficiency and self cleansing.

13. All pits constructed on driveways are to have a 0.9m lintel opening.

6 DETAILED DESIGN

6.1 PIPES

1. Pipes and materials shall be in accordance with the standards detailed in this specification.

2. Pipe bedding and cover requirements for reinforced and fibre reinforced concrete pipes shall be determined from the Concrete Pipe Association "Concrete Pipe Guide" or AS 3725. For uPVC pipes, the requirements shall be to AS 2032.

3. Pipe jointing shall be rubber ring only for reinforced concrete and fibre reinforced pipes. uPVC pipes are to be jointed in accordance with AS 1254.

4. Drainage lines in road reserves shall generally be located in front of the kerb line and parallel to the kerb. Drainage lines in easements shall generally be centrally located within easements.

5. Bulkheads shall be designed on drainage lines where the pipe gradient exceeds 10 per cent. The design details shall address the size, and position in the trench as well as spacing along the line.

6.2 PIT DESIGN

1. Pits shall be designed with benching to improve hydraulic efficiency and reduce water ponding. Typical pit designs and other pit design requirements are included in Part D of this Specification. Safety and safe access are important considerations in pit design. Step irons shall be detailed where pits are greater than 1.2 metres deep and grates shall be of “bicycle safe” design.

6.3 STORMWATER DISCHARGE

1. Scour protection at culvert or pipe system outlets shall be constructed in accordance with this specification unless outlet conditions dictate the use of more substantial energy dissipation arrangements.

2. Kerb and gutter shall be extended to drainage pit or natural point of outlet. Where outlet velocity is greater than 2.5m per second or where the kerb and gutter discharge causes scour, then protection shall be provided to prevent scour and dissipate the flow.

3. At points of discharge of gutters or stormwater drainage lines or at any concentration of stormwater from one or on to adjoining properties, either upstream or downstream, Council will require a Developer to enter into a Deed of Agreement with the adjoining owner(s) granting permission to the discharge of stormwater drainage and the creation of any necessary easements with the cost of the easement being met by the Developer.

4. Where the drainage is to discharge to an area under the control of another statutory authority eg, Public Works, the design requirements of that Statutory Authority are also to be met.

5. The minimum drainage easement width shall be 3.0m for drainage systems to be taken over by Council. For pipes greater than 900mm diameter the width of the easement is to be the nominal diameter of the pipe plus 2.5 metres. The overall width of the easement in Council's favour will be such as to contain the full width of overland flow or open channel flow in the major system design event.

6. Stormwater discharge shall be located so as to avoid recharging groundwater and creating or worsening salinity degradation of adjacent land. Stormwater discharge shall be located to avoid areas with high groundwater tables, groundwater discharge areas or salt affected land. The Designer shall

meet requirements of the appropriate land and water resources authority with regard to the salinity levels of discharge to natural watercourses.

7. Piped stormwater drainage discharging to recreation reserves is to be discharged in a Council approved outlet structure.

6.4 TRENCH SUBSOIL DRAINAGE

1. Subsoil Drainage shall be provided in pipe trenches as follows:

In cases where pipe trenches are backfilled with aggregate , a 3m length of subsoil drain shall be constructed in the bottom of the trench immediately upstream from each pit or headwall. The subsoil drain shall consist of 100mm diameter agricultural pipes with appropriate geotextile sock. The upstream end of the subsoil drain shall be sealed with cement mortar, and the downstream end shall discharge through the wall of the pit or headwall.

7 WATER QUALITY

7.1 GROSS POLLUTANT TRAPS (GPT) AND SEDIMENT TRAPS

General

Locating a GPT/sediment trap: Determine the best location(s) for GPT(s)/sediment trap(s) and its catchment size in conformance with ARQ(Australian Runoff Quality) clause 8.4 and the following:

- Complementary with the strategic catchment treatment objectives.
- Topography.
- Available space.
- Proximity to pollutant source areas.
- Outlet approach: Use a single device to treat a whole catchment (up to 200 ha or more).
- Distributed approach: Target smaller individual catchments with many traps.
- Site constraints: Including topography, soils and geology, groundwater, space, access, odour problems, visual impacts, safety concerns and vermin.

GPT/sediment trap performance and type

Design: Determine the performance for GPT and sediment traps in conformance with ARQ clause 8.5 including the following:

- Treatment objectives: Define the objectives for the project e.g. Gross pollutants: Remove litter and vegetation larger than 5 mm. Sediment: Remove particles larger than 0.125 mm. e.g. Remove 90% of all material greater than 0.125 mm.
- Operating design flows: Select the design flow in conformance with ARQ chapter 7 e.g. 3 month ARI.
- Flood capacity: Analyse hydraulics of the drainage system including the headloss of the GPT and diversion weir under flood conditions. Check the design of the bypass system for impacts on the local drainage system and consequences on flooding.
- Trapped pollutant storage: Assess the pollutants that are likely to be collected and determine the holding capacity with respect to the maintenance operations and frequency.
- Maintenance requirements: Design the GPT for maintainability and operability including the following considerations:
  - Ease of maintenance and operation.
  - Access to the treatment site.
  - Frequency of maintenance.
  - Disposal.

Assessment of GPT performance: Include in the maintenance program requirements for validating the GPT performance by field monitoring, physical laboratory models or computer simulation.

Selection of the GPT: Design the GPT with consideration of the following and the checklist available in ARQ Appendix 8A:

- Life cycle costing.
- Footprint and depth of the unit.
- Hydraulic impedance and requirements.
- Disposal costs.
- Occupational health and safety.

Hydrocarbon management: Where required, design and size water/oil separators or interception devices in conformance with ARQ clause 9.7.

7.2 CONSTRUCTED WETLANDS AND PONDS

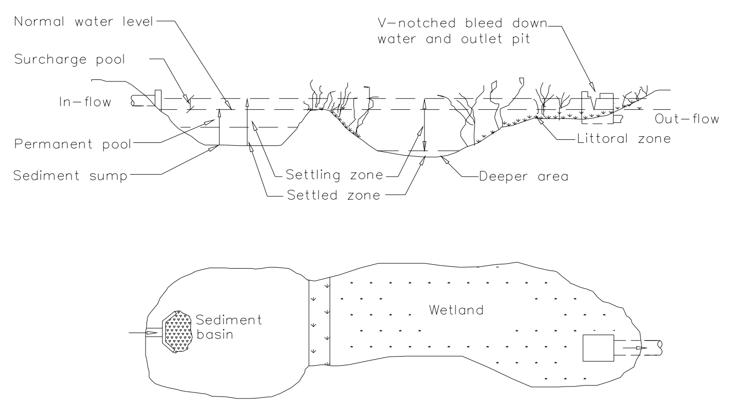
General

Assess the treatment process: Determine the pollutant requirements in conformance with ARQ clause 12.3 and the following:

- Sedimentation.
- Filtration.
- Adsorption.
- Biological uptake.
- Pollutant transformation.
- Pollutant storage.

System design: Design the system in conformance with ARQ clause 12.4 and 12.5 including the following:

- Hydrological effectiveness: Quantify the effects of the interaction between the following:
  - . Volume of the detention system.
  - . Hydraulic capacity of the outlet structure of the system.
  - . Variability of runoff inflow to the system.
- Hydraulic efficiency: Control the flow patterns for uniform distribution throughout the system to provide optimal treatment on the inflow.
- Notional detention time: Select the design detention period.
- Facilitate and optimise water quality treatment processes.
- Locate ponds and wetland systems.
- Select treatment device or treatment train.
- Select wetland vegetation, fish or fauna.



SEDIMENT BASIN/CONSTRUCTED WETLANDS

7.3 BUFFER STRIPS, VEGETATED SWALES AND BIORETENTION SYSTEMS

Buffer strips

Urban catchments: Design for grassed areas to direct runoff from adjoining impervious areas to the stormwater discharge location.

Design: Consider the following:

- Maximum slope: 5%.
- Maximum velocities: 0.4 m/s.
- Usage of flow spreaders.
- Vegetation density.
- Distribution/spread of stormwater over the buffer strip.
- Prevention of the formation of rills through properly designed entry conditions and vegetation.
- Design vegetation: Conform to ARQ clause 10.3.

Vegetated swales

Location: At any point of the flow including the following:

- Applied to the top of a catchment: Serve minor drainage requirements.
- Applied further downstream: Generally will require a parallel underground pipe network.

Geometry: Trapezoidal or parabolic shapes.

Side slopes: No steeper than 1V:3H.

Longitudinal slope: 1 – 4 %. If greater or less than 1 – 4 %, conform to the following:

- Slopes greater than 4%: Design for check dams.
- Slopes less than 1%: Design for under drains.

Maximum swale width: 2.5m.

Maximum flow velocity: Conform to the following:

- For 1 year ARI: 0.5 m/s.
- For 100 year ARI: 1.0 m/s.

Mannings ‘n’ value:

- For flow conditions where depth of flow is below the height of the vegetation: 0.15 to 0.3.
- For 100 year event: approximately 0.03.
- Design vegetation: Conform to ARQ clause 10.4.2.

Bioretention systems

Requirement: Design the bioretention system of 2 or 3 subsurface layers including:

- Base or drainage layer.
- Transition layer.
- Filtration layer.

Design vegetation: To complement the landscape of the area. Conform to ARQ clause 10.5.1.

7.4 INFILTRATION SYSTEMS

General

Requirement: Design infiltration and aquifer recharge systems: Submit calculations demonstrating the effectiveness of the infiltration device for successions of storms and hydrological effectiveness to ARQ clause 11.4.

System design: Conform to ARQ clause 11.3.4 for the following:

- Unsuitable soils: Test solis for permeability and assess for suitability.
- Clearance distances to building footings and boundaries: Conform to ARQ clause 11.3.1 with regard to the soil classification.
- Rock and shale: Test for permeability and assess for suitability.
- Shallow soil cover over rock: Test for permeability and assess geology for weathered or fractured rock.

- Steep terrain: Check soil depth on a downslope and assess suitability.
- Watertable interaction with infiltration systems: Check watertable stability and salinity for suitability and the presence of any aquifers that may interact.
- Watertable effected by upstream infiltration devices: Assess geology for any likely upstream infiltration devices that may limit retention.
- Aquifer recharge/retrieval annual balance: Assess for continual equilibrium of local potentiometric levels.
- Water quality inflows to infiltration devices: Provide treatment is required for all water running directly into soakaways in conformance with ARQ clause 11.2.3.

Flood control: Design on-site storage for flood control to ARQ clause 11.6.

Constructed wetlands and ponds: Design hydrological effectiveness and location of wetlands or ponds to ARQ chapter 12.

8 DOCUMENTATION

8.1 GENERAL

Authority approvals

Conditions: Document the approval conditions established by the appropriate authority which form the basis of the design.

Drawing requirements

Requirement: Provide drawings and/or computer output defining the works and assumed operating and maintenance procedures.

Calculations

Design: Provide a design report incorporating the criteria, computer studies, calculations and references supporting the design.

8.2 DRAWINGS

Catchment area plans

Catchment area drawings: Provide drawings showing the following.

- For any variation: Submit for approval.
- Scale 1:500, 1:1000, 1:5000 or 1:20000 as appropriate.
- Contour interval: 1 – 2 m (closer if the area is very flat).
- Grade direction for kerb and gutter.
- General layout of the drainage system with pit locations.
- Catchment limits.
- Any other information necessary for the design of the drainage system.

Drainage system layout

Drainage system layout drawings: Provide drawings showing the following:

- For any variation: Submit for approval.
- Scale 1:500.
- Drainage pipeline location.
- Drainage pit location, number and centreline chainage.
- Size of opening.
- Drainage easements.
- Reserves and natural water courses.
- Location of buffer strips, vegetated swales and bioretention systems.
- Location and details of infiltration systems.
- Any other information necessary for the design and construction of the drainage system.
- If appropriate, combine with the road layout plan.

Longitudinal section

Drainage system longitudinal sections: Provide drawings showing the following:

- For any variation: Submit for approval.
- Horizontal scale: 1:500.
- Vertical scale: 1:50.
- Pipe size, class and type.
- Pipe support type to AS/NZS 3725 or AS/NZS 2032.
- Pipeline and road chainages.
- Pipeline grade.
- Hydraulic grade line.
- Any other information necessary for the design and construction of the drainage system.

Open channels

Open channel cross sections: Provide drawings showing the following:

- For any variation: Submit for approval.
- Scale: 1:100.
- The direction of the view of cross sections, normally downstream.
- Reduced levels to Australian Height Datum (AHD).
- Provide a data input file for the design flow rates.

Other

Detailed drawings: Provide details including standard and non-standard pits and structures, pit benching, open channel designs and transitions to scales appropriate to the type and complexity of the detail being shown.

Easements for subdivision: Submit witnessed letters by the landowners in agreement of any increased flood levels on their property or other adverse effects to their property. Prior to issue of the subdivision certificate, create any required easements.

Submit hydrology and hydraulic summary sheets: To the *Handbook*.

Computer data files and output: Submit final hydrological and hydraulic computer data files.

Landscape plans and planting plans: For inclusion of buffer strips, vegetated swales and bioretention systems.

8.3 WORK-AS-EXECUTED DRAWINGS

Work-as-Executed Drawings shall be submitted to Council upon completion of the drainage construction and prior to the issue of the subdivision certificate. The detailed Drawings may form the basis of this information, however, any changes must be noted on these Drawings.

9 EASEMENTS AND AGREEMENTS

9.1 EASEMENTS WHICH BENEFIT COUNCIL.

The minimum drainage easement width shall be 3.0m for drainage systems to be taken over by Council. For pipes greater than 900mm diameter the width of the easement is to be the nominal diameter of the pipe plus 2.5 metres. The overall width of the easement in Council's favour will be such as to contain the full width of overland flow or open channel flow in the major system design event.

Maintenance: Maintenance and minor improvements of these systems will be undertaken as part of the routine maintenance of Council's assets. Drainage facilities within these systems need to be confined within the easements.

Construction: Generally Council will not undertake construction of pipelines in unpiped drainage easements. Council recognises that natural channels have environmental benefit and their preservation is an important part of the management of the total catchment. Where the flow in an easement is increased due to roadworks, drainage improvement works or an upstream development an assessment must be made of the most appropriate treatment for the easement to minimise the likelihood of damage to private property. All costs associated with the design and construction of any necessary works will be borne by Council in respect of works carried out by Council and by developers in respect of works required in connection with new development proposals. A developer's responsibility for such works may, where required by the Council, be satisfied by payment of a contribution for the cost of drainage works pursuant to Section 94 of the Environmental Planning & Assessment Act or otherwise.

9.2 INTERALLOTMENTS EASEMENTS.

These easements only benefit private properties.

Maintenance and Construction: Council will not be involved in investigation, design, construction or maintenance of these systems.

In some areas there are no interallotment easements between properties. Any drainage works in such areas required to carry stormwater from private properties only are a matter solely for the owners involved. Where redevelopment occurs in such areas developers may be required to provide interallotment easements for future drainage of upstream properties.

9.3 NATURAL WATERCOURSES.

Maintenance: In urban areas, maintaining obstruction free flow of water will be undertaken as part of Council's routine maintenance activities. However, Council will not accept responsibility for the alignment of a natural watercourse, nor engage in any manner whatsoever the realignment of a natural watercourse.

Construction: Generally Council will not undertake construction of pipelines in natural watercourses. Council recognises that natural channels have environmental benefit and their preservation is an important part of the management of the total catchment. Where the flow in a watercourse is increased due to roadworks, drainage improvement works, or an upstream development, an assessment must be made of the most appropriate treatment for the watercourse to minimise the likelihood of damage to private property and degradation of the watercourse. All costs associated with the design and construction of any necessary works will be borne by Council in respect of works carried out by Council or by developers in respect of works required in connection with new development proposals. Where work is carried out in a natural watercourse an easement in favour of Council over the watercourse, will be obtained at Council's expense, or the developers' expense, as appropriate.

9.4 REQUIREMENTS FOR A DRAINAGE EASEMENT.

1. Council has registered at the Land Titles office memorandum 5341305 that sets out requirements for a drainage easement in favour of Council. A copy of this memorandum is attached in the Annexure and the wording must be used for all Drainage Easements created in favour of Council.

2. Evidence of any deed of agreement necessary to be entered into as part of the creation of a drainage system will need to be submitted prior to any approval of the engineering drawings. Easements will need to be created prior to the issue of the subdivision certificate.

10 ANNEXURE

10.1 ANNEXURE A – TERMS OF DRAINAGE EASEMENT

Council has set out Memorandum 5341305 registered at the Land and Property Information NSW office, the terms which Council requires to be incorporated in most drainage easements to be vested in it.

Where a drainage easement is to be vested in Council by a transfer Granting Easement or by a Section 88B Instrument registered with a plan of subdivision, attention should be given to the following points:

a) On the Plan and in the Transfer or the Instrument the easement should be referred to as “drainage easement _._m wide”. The expression “easement to drain water” should NOT be used.

b) In the Transfer or in Part 1 of the Instrument the Authority benefited should be described as “The Council of the Shire of Hornsby”

c) In the Transfer or in Part 2 of the Instrument the terms of the easement may be set out in the following words:-

> “Drainage easement in the terms as set out in memorandum 5341305 filed with Land and Property Information NSW.

The terms set out in the above Memorandum will not be appropriate if, in addition to the Council, specified lots are indicated in Part 1 of the Schedule to a Section 88B Instrument or a Transfer as being benefited by the easement.

10.2 ANNEXURE B – MEMORANDUM 5341305

TERMS OF DRAINAGE EASEMENT 'B'

Full and free right for the Authority in whose favour this easement is created and every person authorised by it from time to time and at all times to drain water (whether rain, storm, spring soakage or seepage water or the like) in any quantities together with any soil or other materials which may be dissolved or suspended therein across and through the easement site through pipes and/or culverts, together with the right to use, for the purpose of the easement, any pipes or line of pipes and or culverts already located within the easement site.

AND THE RIGHT for the purposes of the easement to do within the easement site any one or more of the following, namely:

1. lay or construct pipes, box culverts and/or other drainage works beneath the surface of the easement site;
2. treat any part or parts of the easement site and/or carry out work thereon for the purpose of protecting the easement site and land adjacent thereto against erosion;
3. construct pits for the purpose of gaining access to the pipes and/or culverts within the easement site for the purpose of undertaking maintenance works as and when necessary;
4. construct access ways and pits for the purpose of allowing the ingress of stormwater from the ground surface and/or from stormwater lines serving improvements located on the lot burdened;
5. remove, relocate and/or replace any drainage works or any part thereof now or at any time hereafter within the easement site;
6. inspect, cleanse, repair, maintain, and/or renew any or all of the drainage works or facilities within the easement site.

AND THE RIGHT for the Authority in whose favour this easement is created and every person authorised by it with any tools, implements, machinery or vehicles required by it or them in order to carry out any of the aforesaid work to enter upon the easement site and to remain there for any reasonable time and for the purpose of gaining access to the easement site to pass and repass over that part of any lot burdened as is not within the easement site.

In exercising the rights conferred on it hereunder, the said Authority shall take reasonable steps to ensure that as little disturbance as possible is caused to the lot burdened and shall at its own cost restore the lot burdened as near as practicable to its condition existing immediately prior to any such disturbance having been occasioned.

For the purpose of ensuring the better enjoyment by the said Authority of the rights hereby granted, no improvement shall be constructed and no other work carried out within the easement site without the consent, in writing, of such Authority and, notwithstanding any such consent or anything elsewhere herein contained, the Authority shall not be liable for any damaged which may be cause to any such improvement or work constructed or carried out within the easement site after the date of this transfer as a result of the exercise by the Authority of the rights hereby granted to it.

The owner for the time being of the lot burdened shall be entitled to connect stormwater pipes serving the lot burdened, including improvement thereon, into any pipe or culvert within the easement site provided that such connection is made at a point and in a manner approved by the said authority.