DEVELOPMENT DESIGN SPECIFICATION

D5

STORMWATER DRAINAGE DESIGN

Amendment Record for this Specification Part

This Specification is Council's edition of the AUS-SPEC generic specification part and includes Council's primary amendments.

Details are provided below outlining the clauses amended from the Council edition of this AUS-SPEC Specification Part. The clause numbering and context of each clause are preserved. New clauses are added towards the rear of the specification part as special requirements clauses. Project specific additional script is shown in the specification as italic font.

The amendment code indicated below is 'A' for additional script 'M' for modification to script and 'O' for omission of script. An additional code 'P' is included when the amendment is project specific.

Amendment Sequence No.	Key Topic addressed in amendment	Clause No.	Amendment Code	Author Initials	Amendment Date
1	IPWEA Mid North Coast Working Party Review,.	D05	A,O,M	HC	Jan 2001

DEVELOPMENT DESIGN SPECIFICATION D5
STORMWATER DRAINAGE DESIGN

GENERAL

D5.01 SCOPE

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

D5.02 OBJECTIVES

1. The objectives of stormwater drainage design are as follows:

   (a) To ensure that inundation of private and public property occurs only on limited occasions and that, in such events, surface flow routes convey stormwater below the prescribed velocity/depth limits.

   (b) To provide convenience and safety for pedestrians and traffic in frequent stormwater flows by controlling those flows within prescribed limits.

   (c) Retain within each catchment as much incident rainfall and runoff as is possible and appropriate for the planned use and the characteristics of the catchment.

   (d) To control and treat the flow of stormwater to achieve acceptable standards prior to discharge to receiving waters.

2. In pursuit of these objectives, the following principles shall apply: ***Design Principles***

   (a) New Developments are to provide a stormwater drainage system in accordance with the "major/minor" system concept set out in Chapter 14 of Australian Rainfall & Runoff, 1999; that is, the "major" system shall provide safe, well-defined overland flow paths for rare and extreme storm runoff events while the "minor" system shall be capable of carrying and controlling flows from frequent runoff events.

   (b) Redevelopment - Where the proposed development replaces an existing development, the on-site drainage system is to be designed in such a way that the estimated peak flow rate from the site for the design average recurrence interval (ARI) of the receiving minor system is no greater than that which would be expected from the existing development.

D5.03 REFERENCE AND SOURCE DOCUMENTS

Current versions of all documents shall be used.

(a) Council Specifications

C220	-	Stormwater Drainage - General
C221	-	Pipe Drainage
C222	-	Precast Box Culverts
C223	-	Drainage Structures
C224	-	Open Drains including Kerb & Gutter
	-	Council Stormwater Management Plan
D7	-	Erosion & Stormwater Management Design Specification.

(b) Australian Standards

AS 1254 - Unplasticised PVC (uPVC) pipes and fittings for stormwater or surface water applications.
AS 2032 - Code of practice for installation of uPVC pipe systems.
AS 3725 - Loads on buried concrete pipes.
AS 4058 - Precast concrete pipes.
AS 4139 - Fibre reinforced concrete pipes and fittings.
AS 3500 - Part 3 National Plumbing & Drainage Code – Stormwater Drainage

(c) State Authorities

RTA, NSW - Model Analysis to determine Hydraulic Capacities of Kerb Inlets and Gully Pit Gratings, 1979.
NSW Dept Housing Dept of Housing Road Manual.
NSW Govt - Floodplain Development Manual 2001.

(d) Other

Argue, John - Stormwater drainage design in small urban catchments: a handbook for Australian practice. Australian Road Research Board Special Report 34

Australian National Conference On Large Dams, Leederville WA.
- ANCOLD 1986, Guidelines on Design Floods for Dams.

AUSTROADS - Bridge Design Code.

Chow, Ven Te - Open Channel Hydraulics, 1959.

Concrete Pipe Association of Australia
- Concrete Pipe Guide, charts for the selection of concrete pipes to suit varying conditions.

Hare CM. - Magnitude of Hydraulic Losses at Junctions in Piped Drainage Systems. Transactions, Inst. of Eng. Aust., Feb. 1983.

Henderson, FM. Open Channel Flow, 1966.

Inst. of Eng. - Australian Rainfall and Runoff - A guide to flood estimation. Sept 1999.

Queensland Urban Drainage Manual, Volumes 1 & 2, 1993.

Sangster, WM., Wood, HW., Smerdon, ET., and Bossy, HG.
- Pressure Changes at Storm Drain Junction, Engineering Series, Bulletin No. 41, Eng. Experiment Station, Univ. of Missouri 1958.

HYDROLOGY

D5.04 DESIGN RAINFALL DATA

I-F-D Relationships

1. Design Intensity-Frequency-Duration (IFD) Rainfall – IFD relationships shall be derived in accordance with Book 2, Volume 1 of ARR 1998, for the particular catchment under consideration.

2. The nine basic parameters read from Maps 1-9 in Volume 2 of ARR 1987 shall be

shown in the calculations submitted to Council, except where the Bureau of Meteorology provides a polynomial relationship for the catchment.

3. Design IFD rainfalls are provided for specific locations at the end of this chapter in D5.26.

Average Recurrence Intervals

4. Design Average Recurrence Interval (ARI) - For design under the "major/minor" concept, the design ARIs to be used are given below.

5. Recurrence intervals for major/minor events depend on the zoning of the land being serviced by the drainage system. The system design ARIs are detailed below:-

- 100 years for the “major” system in all developments.
- 20 years for trunk drainage "minor" systems
- 10 years for commercial/industrial area "minor" systems
- 5 years for residential area "minor" systems
- 5 years for rural residential area "minor" systems
- 1 year for parks and recreation area "minor" systems.

6. In addition, where a development is designed in such a way that the major system flows involve surcharge across private property, then the underground system (both pipes and inlets) shall be designed to permit flows into and contain flows having an ARI of 100 years from the upstream catchment which would otherwise flow across the property. A surcharge path shall be defined for systems even where 100 year ARI flows can be maintained within the system. Easements are to be provided in private property over pipe systems and surcharge paths.

Detention Basin

7. Where development increases the peak flow rate a detention basin is to be constructed to limit the post development flows to be less than or equal to the pre development flows for all storm events up to and including the 1 in 100 year storm event. Alternatively the down stream drainage system is to be upgraded to accommodate the increase in the peak flow rate.

D5.05 CATCHMENT AREA

Catchment Definition

1. The catchment area of any point is defined by the limits from where surface runoff will make its way, either by natural or man made paths, to this point. Consideration shall be given to likely changes to individual catchment areas due to the full development of the catchment.

2. Where no detailed survey of the catchment is available, 1:4000 orthophoto maps, or GIS data approved by Council, is to be used to determine the catchments and to measure areas. Catchment boundaries and characteristics are to be confirmed by field survey.

3. Catchment area land use shall be based on current available zoning information or proposed future zonings, where applicable.

D5.06 RATIONAL METHOD

1. Rational Method calculations to determine peak flows shall be carried out in accordance with Book 8, AR&R and the requirements of this Specification.

Qualified Person

2. All calculations shall be carried out by a qualified person experienced in hydrologic and hydraulic design.

Runoff Co-efficients

3. Co-efficients of Run-off shall be calculated as per Book 8, Section 1.5 of AR&R and full details of co-efficients utilised shall be provided. Full development of the catchment is to be assumed.

4. Details of percentage impervious for specific locations and for individual zonings are

given below. These can be used in lieu of more detailed calculations.

Open space	10%
Low density residential	50%
Medium & high density residential	75%
Industrial	95%
Commercial	100%
Other	as calculated.

Times of Concentration

5. Times of Concentration - The time of concentration of a catchment is defined as the time required for storm runoff to flow from the most remote point on the catchment to the outlet of the catchment. Partial area effects are to be checked.

6. Where the flow path is through areas having different flow characteristics or includes property and roadway, then the flow time of each portion of the flow path shall be calculated separately.

7. The maximum time of concentration in an urban area shall be 20 minutes unless sufficient evidence is provided to justify a greater time. The minimum time of concentration used shall be 5 minutes.

8. Flow paths to pits shall be representative of the fully developed catchment considering such things as fencing and the likely locations of buildings and shall be shown for each collection pit on the catchment area plan. Consideration shall be given to likely changes to individual flow paths due to the full development of the catchment.

Overland Flow Retardance

9. Surface roughness co-efficients "n*" shall generally be derived from information in Book 8 of AR&R. Values applicable to specific zoning types and overland flow path types are given below:

Flow across Parks	0.35
Flow across Rural Residential land	0.30
Flow across low density Residential	0.21
Flow across medium density Residential	0.11
Flow across Industrial	0.06
Flow across Commercial	0.04
Flow across Paved Areas	0.01
Flow across Asphalt Roads	0.02
Flow across Gravel Areas	0.02

D5.07 OTHER HYDROLOGICAL MODELS

Alternative Models

1. Other hydrological models may be used as long as the requirements of AR&R 1999 are met, summaries of calculations are provided and details are given of all program input and output. See D5.24 for sample.

2. Where computer analysis programs are used, copies of the final data files shall be provided on submission of the design to Council and with the final drawings after approval by Council.

HYDRAULICS

D5.08 HYDRAULIC GRADE LINE

Qualified Person

1. Hydraulic calculations shall generally be carried out in accordance with Australian Rainfall and Runoff and shall be undertaken by a qualified person experienced in hydrologic and hydraulic design. The calculations shall substantiate the hydraulic grade line adopted for design of the system and shown on the drawings. Summaries of calculations are added to the plan and details of all calculations are given including listings of all programme input and output.

Calculations

2. The "major" system shall provide safe, well-defined overland flow paths for rare and extreme storm runoff events while the "minor" system shall be capable of carrying and controlling flows from frequent runoff events.

3. Downstream water surface level requirements are given below:- ***Downstream Control***

(a) Known hydraulic grade line level from downstream calculations including pit losses at the starting pit in the design event.

(b) Where the downstream starting point is a pit and the hydraulic grade line is unknown, a level of 0.15m below the invert of the pit inlet in the downstream pit is to be adopted.

(c) Where the outlet is an open channel and the design storm is the minor event the top of the outlet pipe shall be the downstream control.

(d) Where the outlet is an open channel and the design storm is the major event, the downstream control shall be the 1% probability flood level.

(e) Where tidal, the greater of high water mark and pipe culvert shall be used.

4. The water surface in drainage pits shall be limited to 0.150m, below the gutter invert for inlet pits and 0.150m below the underside of the lid for junction pits. ***Water Surface Limits***

D5.09 MINOR SYSTEM CRITERIA

1. The acceptable gutter flow widths in the 20% ARI event is 2.5 metres maximum. Gutter flow around kerb returns shall be limited to 20 l/s. ***Gutter Flow Widths***

2. Minimum conduit sizes are given below: ***Conduit Sizes***

- The minimum pipe size shall be 375mm diameter.
- The minimum box culvert size shall be 600mm wide x 300mm high.

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

D5.10 PITS

1. Inlet Pits shall be spaced so that the gutter flow width is limited in accordance with this specification and so that the inlet efficiency is not affected by adjacent inlet openings or kerb variations and upstream of carriageway narrowing. Preference shall be given to the location of drainage pits at the upstream side of allotments. Pits are to be located clear of kerb returns and kerb marks. Pits are to be located to limit flow across intersections. ***Spacing***

2. Other pits shall be provided:

- To enable access for maintenance.
- At changes in direction, grade, level or class of pipe.
- At junctions.

Maximum Spacing

3. The maximum recommended spacing of pits where flow widths are not critical are given below:

	Pipe Size (mm)	Spacing (m)
Generally	less than 1200	80
	1200 or larger	120
In tidal influence	all	80

Inlet Capacity

4. Maximum kerb inlet opening lengths to side entry pits are to be a preferred maximum of 3.0m, with an absolute maximum of 5.0m where the grade is 10% or more, and an absolute maximum of 4.0m where the grade is less than 10%. The minimum kerb inlet opening length to side entry pits is 1.8m.

5. Information on pit capacities is available in the following sources:-

- Roads and Traffic Authority's "Model analysis to determine Hydraulic Capacities of Kerb Inlets and Gully Pit Gratings", with due allowance to inlet bypass due to grade, for grade inlet pits, and recognised orifice or weir formulae for sag inlet pits.
- NSW Department of Housing Road Manual – Pit capture charts.
- Pit relationships given in Book 8 of AR&R 1998.

Allowance for Inlet Blockage in Minor System Analysis

6. Pit capture rates shall include the following capture allowances for blockage for the major system:-

Condition	Inlet Type	Percentage of Theoretical Capture Allowed
Sag	Side entry	80%
Sag	Grated	50%
Sag	Combination	Side inlet capacity only. Grate assumed completely blocked
Sag	"Letterbox"	50%
Continuous Grade	Side entry	80%
Continuous Grade	Grated	50%
Continuous Grade	Combination	90%

7. Pits shall be designed with benching to improve hydraulic efficiency and reduce water ponding. Typical pit designs and other pit design requirements are included as standard drawings. Safety and safe access are important considerations in pit design. Non standard pits are to be fully detailed in the construction drawings.

8. Bends are generally not to be used. Specific Council approval regarding their use is

required prior to detailed design.

D5.11 HYDRAULIC LOSSES

Pit Losses

1. The pressure change co-efficient "Ke" shall be determined from Missouri Charts or Hare equations. Common loss co-efficients may be found in AR & R.

2. Pipeline systems are to be streamlined where possible to reduce head losses at pits.

3. Reserved

4. Reserved

5. Reserved

6. Requirements for private pipes entering Council's system are given below:-

   (a) All pipe inlets, including roof and subsoil pipes, shall where possible, enter the main pipe system at junction pits. These shall be finished flush with and be grouted into the pit wall.

   (b) Connection to existing pipelines using fabricated slope junctions shall be accepted. Connections are to be to the top of the pipe in accordance with the standard drawing.

Pipe Junction Losses

7. Construction of a junction without a structure should be avoided where possible. Permission to do this is required by Council prior to detailed design.

Contraction/ Expansion Losses

8. Transitions to smaller downstream conduits is not permitted without approval of Council prior to detailed design.

Pipe Friction Losses

9. Drainage pipe systems shall be designed as an overall system, with due regard to the upstream and downstream system and not as individual pipe lengths. Drainage pipeline systems shall generally be designed as gravity systems flowing full at design discharge, but may be pressurised with the use of appropriate pits and joints. Pipe friction losses and pipe sizes in relation to discharge shall be determined using the Colebrook-White formula with the acceptable roughness co-efficients being 0.6mm for concrete pipes and 0.06mm for FRC pipes. Details of any streamlining claimed in the design calculation must be fully detailed on the construction drawings.

D5.12 MAJOR SYSTEM CRITERIA

Surcharging

1. Surcharging of drainage systems which would provide for water depth above the top of kerb will not be permitted except as defined below. Surcharging of drainage system for storm frequencies greater than 5% ARI probability may be permitted across the road centreline where the road pavement is below the natural surface of the adjoining private property. Flow across footpaths will only be permitted in situations specifically approved by Council, where this will not cause flooding of private property.

Velocity/ Depth Criteria

2. 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 and surcharge flow paths 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. Designs must be in accordance with the Floodplain Development Manual (figure G1).

Freeboard

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

Generally:-

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

In Surcharge Paths:-

(c) A minimum freeboard of 0.5 shall be provided between the 100 year flood level and floor levels on structures and entrances to underground car parks.

Freeboard calculations for drainage in new subdivisions shall assume raft slab construction on lots adjoining surcharge paths.

In Open Channels:-

(d) A minimum freeboard of 0.5m shall be provided between the 100 year flood level and floor levels on structures and entrances to underground car parks.

Roadway Capacities

4. Flow capacities of roads should be calculated using Technical Note 4 in Book 8 of AR&R.

Roadway Capacities

5. Pit capture rates to be determined in accordance with clause 1.5.4 Book 8 AR&R.

D5.13 OPEN CHANNELS

Safety

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 generally in accordance with Book 8, Volume 1 of AR&R, and shall be designed with safety requirements as set out in Section 14.10.4 of AR&R as a primary criterion. 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, as given in D5.10.6.

3. Friction losses in open channels shall be determined using Mannings "n" values given below:- ***Channel Roughness***

Mannings "n" Roughness Co-efficients for open channels shall generally be derived from information in Chapter 14 of AR&R. Mannings "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.

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

6. Low flow provisions in open channels (man-made or altered channels) will require low flows to be contained within a pipe system or concrete lined channel section at the invert of the main channel. Subsurface drainage shall be provided in grass lined channels to prevent waterlogging of the channel bed. The width of the concrete lined channel section shall be the width of the drain invert or at least sufficiently wide enough to accommodate the full width of a tractor. ***Low Flows***

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

D5.14 MAJOR STRUCTURES

1. All major structures shall be designed for the 100 year ARI storm event without afflux in urban areas unless otherwise approved by Council. 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. ***Afflux***

2. A minimum clearance of 0.3m 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. ***Freeboard***

3. All bridges shall be designed for 1% probability flood intensity without afflux in urban areas. ***Bridges***

4. 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 AUSTROADS Bridge Design Code.

5. All culverts shall be designed to ensure that roads are not overtopped in the 1% ARI ***Culverts***

flow.

6. Culverts (either pipe or box section) shall be designed using established design techniques in AR&R. Design charts issued by the Concrete Pipe Association of Australia (1983) may be used with due regard to inlet and exit losses, inlet and outlet control and scour protection.

D5.15 RETARDING BASINS

Critical Storm Duration

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

AR&R Volume II. 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.

Routing

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

High Level Outlet

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 (1986).

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

Low Flow Provision

6. 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 seepage collars installed where appropriate.

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

Freeboard at Dwellings

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

Safety Issues

9. 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.
- 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 and spillway.
- The basin and spillway are to have appropriate hazard signage.
- Protection of the low flow intake pipe shall be undertaken to reduce hazards for people trapped in the basin.
- Basins shall be designed so that no ponding of water occurs on to private property or roads.

- No planting of trees within 2.5m of basin walls is permitted.
- No basin spillway is to be located directly upstream of urban areas.
- Submission of design plans to the Dam Safety Committee is required where any of these guidelines are not met or Council specifically requires such submission.

10. Minimum basin slope shall be 0.5%.

11. Retarding basins may be used to supplement stormwater pollution control facilities (See D7 Erosion Control and Stormwater Management.)

12. Access for maintenance vehicles shall be provided.

D5.16 ON-SITE STORMWATER DETENTION

1. Installation of On-site Stormwater Detention may be required on redevelopment sites within the Council area 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. ***Re-development***

D5.17 INTERALLOTMENT DRAINAGE

1. Interallotment Drainage shall be provided for every lot which does not drain directly to its frontage street or a natural watercourse within the lot.

Where excessive overland flow is anticipated from upstream property (eg downstream of parks or undrained lots) appropriate drainage and easements shall be provided.

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

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. Provision is to be made for overland flow from upstream property.

4. In lieu of more detailed analysis, the following areas of impervious surface are assumed to be contributing runoff to the interallotment drain:- ***Impervious Area***

Development Type	% of Lot Area
• Residential (2a) (low density)	50
• Residential (2b) (medium density)	75
• Industrial	95
• Commercial	100

5. Pipes shall be designed to flow full at the design discharge without surcharging of inspection pits minimum pipe size shall be 150mm diameter.

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 fitted with a 100mm concrete lid finished flush with the surface of works. Depressed grated inlets are acceptable (see standard drawings). ***Pits***

7. Pipes - Minimum Grade - The interallotment drainage shall have a minimum longitudinal gradient of 0.5% . ***Grade***

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, pipes of appropriate loading capacity. ***Pipe Type***

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 a minimum of 0.5 metres between pipes ***Sewer***

10. Reserved

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

D5.18 PIPES

1. Pipes and Material Standards – Reinforced concrete pipes shall conform to AS 4058-1992. Fibre reinforced cement pipes shall conform to AS 4139-1993. uPVC pipes shall conform to AS 1254-91 (use of uPVC pipes shall be restricted to interallotment drainage).

2. Pipe Bedding and Cover - 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. ***Bedding***

3. Pipe Jointing shall be rubber ring jointed, where high water table level and unstable ground is encountered, and in accordance with manufacturer’s instruction manuals for the individual pipe material.

4. Pipe Location - Drainage lines in road reserves shall generally be located behind the kerb line and parallel to the kerb. Drainage lines in easements shall generally be centrally located within easements.

5. Curved pipes can be utilised where the natural surface is flat and losses through pits and lines are to be kept to an absolute minimum. Rubber ring jointed pipes are to be used and the maximum deflection at each joint is not to exceed the manufactures specifications. ***Curved Pipes***

6. Concrete bulkheads to councils standard drawing are to be constructed when the grade of pipes exceed 10%. The spacing of bulkheads to be determined by the following formula 30/g where g = gradient of pipe.

7. Alternatives to pipes shall be considered on merit.

8. The use of Fibre reinforced cement (FRC) pipes will not be considered within road reserves, below the seasonal high water table and where the pipe size exceeds 600 mm diameter. ***FRC Pipes***

D5.19 RESERVED

D5.20 STORMWATER DISCHARGE

1. Scour protection at stormwater system outlets shall include energy dissipation measures incorporating gabion mattresses or suitable alternatives. ***Scour***

2. 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 the subdivider to enter into a Deed of Agreement with the adjoining owner(s) granting permission to the discharge of stormwater drainage and the ***Easements***

creation of any necessary easements with the cost of the easement being met by the developer.

3. 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.

4. The minimum drainage easement width shall be 3.0m for drainage systems to be taken over by Council. 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.

Council Control

System Type		Easement Width (rounded up to nearest 0.5m)
Drainage	Single pipe	3.0m (minimum)
	Multiple pipes	Overall outside width of pipe group +2m
	Box culverts	Overall width of box + 2m
	Open channels	Width including free board + 2m (generally restricted to drainage reserves
	Surcharge paths	Width including free board + 2m
	Interallotments Drainage	2.0m (minimum)

5. Discharge to Recreation Reserves - Piped stormwater drainage discharging to recreation reserves is to be taken to a natural water course and discharged in an approved outlet structure or alternatively taken to the nearest trunk stormwater line.

D5.21 MISCELLANEOUS

1. Subsoil Drainage shall be provided at the bottom of pipe trenches upstream of pits for a minimum depth of 3 metres. Construction to be in accordance with design specification D4.

2. In cases where pipe trenches are backfilled with sand or other pervious material, 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, butt jointed, with joints wrapped with hessian or slotted PVC pipe.

Subsoil Drain at Pis

3. 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.

4. Termination of Kerb and Gutter and Associated Scour Protection - 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 is likely to cause scour, then protection shall be provided to prevent scour and dissipate the flow.

Kerb & Gutter Termination

DOCUMENTATION

D5.22 PLANS

1. Catchment Area Plans shall be drawn at appropriate scales normally 1:1000, 1:4000 or 1:25000, unless alternative scales are specifically approved by Council and shall show contours, direction of grading of kerb and gutter, general layout of the drainage system with pit locations, catchment limits and any other information necessary for the design of the drainage system. Refer section D1.06 for plan set list.

Scales for Drawings

2. The Drainage System shall be shown on the road layout plan and shall be drawn at

a scale of 1:500 and shall show drainage pipeline location, drainage pit location and number and road centreline chainage, size of opening and any other information necessary for the design and construction of the drainage system. The plan shall also show all drainage easements, reserves and natural water courses.

3. The plan shall also show all drainage easements, reserves and natural water courses. The plan may be combined with the road layout plan.

4. The Drainage System Longitudinal Section shall be drawn at a scale of 1:500 horizontally and 1:100 vertically and shall show pipe size, class, jointing and type, pipeline and road chainages, pipeline grade, hydraulic grade line and any other information necessary for the design and construction of the drainage system.

Open Channels

5. Open Channel Cross Sections shall be drawn at a scale of 1:100 natural and shall show the direction in which the cross sections should be viewed

6. Special Details including non-standard pits, pit benching, open channel designs and transitions shall be provided on the design drawings at scales appropriate to the type and complexity of the detail being shown.

Work-as-Executed Plans

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

D5.23 EASEMENTS AND AGREEMENTS

1. Evidence of any Deed of Agreement necessary to be entered into as part of the drainage system will need to be submitted prior to any approval of the engineering plans. Easements will need to be created prior to approval of the linen plan of subdivision.

2. Where an agreement is reached with an adjacent landowner to increase flood levels on his property or otherwise adversely affect his property, a letter signed by all the landowners outlining what they have agreed to and witnessed by an independent person shall be submitted prior to any approval of the engineering plans.

D5.24 SUMMARY SHEETS

Hydrology

1. A copy of a Hydrological Summary Sheet providing the minimum information is set out below.

HYDROLOGICAL DESIGN SHEET

PIT	LAND USE	FLOW LENGTH	SLOPE	"n"	TIME	TIME	INTENSITY	CODE	COEFF	AREA	C.A	SUM AREA	Q	BY PASS	TOTAL FLOW	GUTTER SLOPE	FLOW WIDTH	PIT TYPE	LINTEL	INFLOW	BY FLOW	BY PIT	KINEMATIC MIN TIME 5 MAX TIME 20 COFFS REMARKS
		m	%		min	min	mm/h			ha	ha	ha	L/s	L/s	L/s	%	m		m	L/s	L/s		
11	2					5 ADP	186 5Yr	-1	.855	.023	.020	.02	10		10		9999	5		10		11	
12	2					5 ADP	186 5Yr	-1	.855	.024	.021	.021	11		11		9999	5		11		12	
6	2					5 ADP	186 5Yr	-1	.855	.020	.017	.017	9		9		9999	5		9		6	
7	2					5 ADP	186 5Yr	-1	.855	.036	.031	.031	16		16		9999	5		16		7	
8	2					5 ADP	186 5Yr	-1	.855	.041	.035	.035	18		18		9999	5		18		8	
9	2					5 ADP	186 5Yr	-1	.855	.031	.027	.027	14		14		9999	5		14		9	
10	2					5 ADP	186 5Yr	-1	.855	.022	.019	.019	10		10		9999	5		10		10	
1	1 2 2	40 65	2 .5		.725 2.152	5	186 5Yr	-.330 -1	.721 .855	.040 .060	.029 .051	.08	41		41	.5	1.971 .06PH	3 SAG	1.82	41		1	
2	1 2	85	5	.2	13.379	13.4	128 5Yr	-.330 -1	.721 .855	.225 .065	.162 .056	.218	78		78	6	1.688	3	3.64	78		3	
2A						5	186 5Yr										9999	5		ADP			
3	1 2	90	5	.2	13.945	13.9	126 5Yr	-.330 -1	.721 .855	.250 .025	.180 .021	.202	71		71	.6	1.989 .07PH	3 SAG	2.73	71		3	
4	1 2	90	5	.2	13.945	13.9	126 5Yr	-.330 -1	.721 .855	.145 .010	.105 .009	.113	40		40	.5	2.071	3	2.73	40		3	
5	1 2	75	5	.2	12.222	12.2	133 5Yr	-.330 -1	.721 .855	.080 .020	.058 .017	.075	28		28	1	1.588	3	1.82	28		4	
5A						5	186 5Yr										9999	5		ADP			
5B						5	186 5Yr										9999	5		ADP			

2. A copy of a Hydraulic Summary Sheet providing the minimum information is set out in below. ***Hydraulics***

HYDRAULIC DESIGN SHEET

PIT	TIME	INTENSITY	AREAS	FLOW	LENGTH	DIAMETER	GRADE	H.G.L. GRADE	VEL Q/A	K	HEAD LOSS	VEL CAP	PIPE VEL	PIPE CAP	PIPE TIME	C.W.= .0006 MAX TIME 20 COFFS REMARKS
	min	mm/hr	ha	L/s	m	mm	%	%	m/s		m	m/s	m/s	L/s	min	
LINE 4 11-12	5	186 5Yr	.02	10	14	150	1.286	.337	.576	5	.085	1.154	1.02	20	.23	
12-5B	5.2	183 5Yr	.04	20	47	225	1.266	.162	.516	1.5	.02	1.485	1.18	59	.66	
LINE 3 6-7	5	186 5Yr	.017	9	13	150	2.5	.256	.501	5	.064	1.608	1.23	28	.18	
7-8	5.2	184 5Yr	.048	25	41	225	1	.229	.616	1.5	.029	1.32	1.15	52	.59	
8-9	5.8	177 5Yr	.083	41	49	225	1.01	.626	1.03	1.5	.081	1.327	1.35	53	.6	
9-10	6.4	171 5Yr	.109	52	19	225	1	1.012	1.313	1.5	.132	1.32	1.42	52	.22	
10-5B	6.6	169 5Yr	.128	60	26	225	1	1.352	1.52	1.5	.177	1.32	1.32	52	.33	
LINE 1 1-3	5	186 5Yr	.08	41	7	381	1	.042	.364	5	.034	1.843	1.22	210	.1	
LINE 2 2-2A	13.4	128 5Yr	.218	78	12	381	10.542	.143	.682	5	.119	5.983	3.46	682	.06	
2A-3	13.4	128 5Yr	.218	78	9	381	1	.142	.68	.6	.014	1.843	1.49	210	.1	
3-4	13.9	126 5Yr	.5	175	28	534	1	.123	.782	1.5	.047	2.276	1.8	510	.26	
4-5	14.2	125 5Yr	.613	213	31	534	1	.181	.951	.5	.023	2.276	1.92	510	.27	
5-5A	14.5	124 5Yr	.688	237	11	534	1	.222	1.058	.7	.04	2.276	1.98	510	.09	
5A-5B	14.6	123 5Yr	.688	236	39	534	3.949	.221	1.055	.6	.034	4.523	3.18	1013	.2	
5B-HW	14.8	123 5Yr	.856	292	24	534	1.5	.337	1.306	1	.087	2.788	2.44	624	.16	

D5.25 COMPUTER PROGRAM FILES AND PROGRAM OUTPUT

1. Computer program output may be provided as long as summary sheets for Hydrological and Hydraulic calculations in accordance with this Specification are provided with plans submitted for checking and with final drawings.

2. Copies of final computer data files, for both hydrological and hydraulic models shall be provided for Council's data base of flooding and drainage information in formats previously agreed with Council.

D5.26 RESERVED

D5.27 RESERVED

D5.28 RESERVED

ANNEXURE A

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DEVELOPMENT DESIGN SPECIFICATION

ANNEXURE A
INTENSITY FREQUENCY DURATION TABLES

D5

STORMWATER DRAINAGE DESIGN

IFD ANALYSIS BASED ON AUSTRALIAN RAINFALL & RUNOFF (1987)

Site name: Crescent Head

Site latitude = 31.02 degrees S
longitude = 152.97 degrees E
skewness = .03

2-year ARI, 1 hour intensity = 41.80 mm/hr
12 hour intensity = 9.40 mm/hr
72 hour intensity = 2.90 mm/hr

50-year ARI, 1 hour intensity = 90.56 mm/hr
12 hour intensity = 18.00 mm/hr
72 hour intensity = 5.86 mm/hr

IFD Table for Various ARIs and Durations

Duration	1 yr	2 yr	5 yr	10 yr	20 yr	50 yr	100 yr	200 yr	500 yr
5 min	104.07	133.51	171.18	193.13	222.26	260.47	289.64	319.27	359.40
6 min	97.49	125.19	160.93	181.81	209.46	245.78	273.54	301.76	340.00
10 min	79.68	102.61	132.96	150.84	174.38	205.42	229.22	253.47	286.43
12 min	73.63	94.94	123.39	140.21	162.32	191.51	213.91	236.77	267.86
15 min	66.53	85.90	112.10	127.65	148.03	174.99	195.72	216.89	245.73
18 min	61.00	78.86	103.27	117.80	136.81	162.00	181.39	201.23	228.27
20 min	57.93	74.95	98.34	112.30	130.54	154.73	173.37	192.44	218.47
24 min	52.85	68.46	90.15	103.14	120.08	142.59	159.96	177.75	202.05
30 min	47.03	61.03	80.73	92.59	108.02	128.55	144.42	160.71	183.00
45 min	37.67	49.03	65.43	75.39	88.29	105.52	118.90	132.65	151.53
1.0 hr	31.96	41.71	56.02	64.76	76.05	91.19	102.97	115.11	131.80
1.5 hr	25.29	32.90	43.84	50.47	59.06	70.53	79.43	88.57	101.12
2.0 hr	21.35	27.71	36.71	42.13	49.17	58.56	65.82	73.27	83.46
3.0 hr	16.76	21.70	28.50	32.57	37.87	44.92	50.35	55.90	63.49
4.5 hr	13.15	16.97	22.10	25.14	29.14	34.41	38.46	42.60	48.23
6.0 hr	11.07	14.25	18.46	20.93	24.19	28.49	31.78	35.14	39.70
9.0 hr	8.69	11.16	14.33	16.18	18.63	21.85	24.31	26.81	30.20
12.0 hr	7.33	9.38	11.98	13.48	15.49	18.11	20.11	22.13	24.88
18.0 hr	5.70	7.31	9.37	10.58	12.17	14.27	15.87	17.49	19.69
24.0 hr	4.75	6.11	7.86	8.88	10.24	12.02	13.38	14.77	16.65
30.0 hr	4.12	5.30	6.84	7.74	8.93	10.50	11.70	12.92	14.58
36.0 hr	3.66	4.70	6.08	6.90	7.97	9.37	10.45	11.55	13.05
48.0 hr	3.01	3.88	5.03	5.71	6.61	7.79	8.70	9.63	10.89
72.0 hr	2.24	2.89	3.78	4.30	4.99	5.90	6.60	7.31	8.28

IFD Polynomial: ln I = a + b*ln(D) + c*ln(D)**2 + d*ln(D)**3 + e*ln(D)**4 + f*ln(D)**5 + g*ln(D)**6
where duration D is in hrs and average intensity I is in mm/hr

ARI	a	b	c	d	e	f	g	Max % error
1	3.4655682	-.5738260	-.0211766	.0082185	-.0006420	-.0002958	.0000291	.20
2	3.7295377	-.5735306	-.0263928	.0080863	-.0001000	-.0002893	.0000136	.14
5	4.0187087	-.5727129	-.0406267	.0077279	.0013779	-.0002718	-.0000286	.70
10	4.1607041	-.5722826	-.0481160	.0075393	.0021555	-.0002626	-.0000508	1.01
20	4.3188620	-.5719259	-.0543246	.0073829	.0028001	-.0002550	-.0000692	1.27
50	4.4975108	-.5715231	-.0613375	.0072063	.0035283	-.0002463	-.0000900	1.56
100	4.6170414	-.5712535	-.0660297	.0070881	.0040155	-.0002406	-.0001039	1.75
200	4.7267258	-.5710061	-.0703354	.0069797	.0044625	-.0002353	-.0001167	1.93
500	4.8600287	-.5707055	-.0755682	.0068479	.0050059	-.0002288	-.0001322	2.15

Overland Flow Travel Time Aid
Table of t*I**0.4 where t = time in min and I = intensity in mm/h

Duration	1 yr	2 yr	5 yr	10 yr	20 yr	50 yr	100 yr	200 yr	500 yr
5 min	32.05	35.42	39.14	41.08	43.46	46.31	48.33	50.26	52.70
6 min	37.47	41.41	45.77	48.05	50.84	54.19	56.56	58.82	61.68
7 min	42.72	47.22	52.22	54.84	58.04	61.88	64.60	67.19	70.48
8 min	47.82	52.86	58.51	61.47	65.08	69.41	72.47	75.39	79.11
9 min	52.78	58.37	64.65	67.95	71.96	76.78	80.19	83.44	87.58
10 min	57.62	63.74	70.66	74.29	78.71	84.02	87.77	91.35	95.91
12 min	67.00	74.16	82.33	86.64	91.85	98.12	102.55	106.79	112.18
14 min	76.02	84.19	93.60	98.57	104.57	111.78	116.88	121.77	127.98
16 min	84.74	93.89	104.52	110.14	116.91	125.05	130.82	136.34	143.37
18 min	93.20	103.30	115.14	121.40	128.92	137.98	144.40	150.54	158.37
20 min	101.43	112.47	125.48	132.38	140.64	150.60	157.65	164.41	173.02
22 min	109.46	121.42	135.58	143.10	152.09	162.93	170.60	177.97	187.35
24 min	117.31	130.16	145.46	153.59	163.29	174.99	183.29	191.24	201.38
26 min	125.00	138.73	155.13	163.86	174.27	186.82	195.72	204.26	215.14
28 min	132.55	147.13	164.63	173.95	185.04	198.42	207.92	217.02	228.63
30 min	139.95	155.38	173.95	183.85	195.62	209.82	219.89	229.56	241.89
40 min	175.31	194.76	218.41	231.05	246.03	264.12	276.96	289.29	305.01

IFD ANALYSIS BASED ON AUSTRALIAN RAINFALL & RUNOFF (1987)

Site name: Hat Head

Site latitude = 31.07 degrees S
longitude = 153.05 degrees E
skewness = .03

2-year ARI, 1 hour intensity = 42.80 mm/hr
12 hour intensity = 9.00 mm/hr
72 hour intensity = 2.40 mm/hr

50-year ARI, 1 hour intensity = 86.00 mm/hr
12 hour intensity = 16.80 mm/hr
72 hour intensity = 5.70 mm/hr

IFD Table for Various ARIs and Durations

Duration	1 yr	2 yr	5 yr	10 yr	20 yr	50 yr	100 yr	200 yr	500 yr
5 min	107.13	136.37	171.26	191.12	217.95	252.82	279.21	305.84	341.66
6 min	100.39	127.89	160.93	179.78	205.20	238.26	263.31	288.60	322.63
10 min	82.14	104.88	132.79	148.83	170.33	198.38	219.68	241.23	270.29
12 min	75.94	97.05	123.17	138.22	158.36	184.66	204.65	224.90	252.21
15 min	68.65	87.83	111.83	125.70	144.21	168.41	186.83	205.51	230.73
18 min	62.97	80.65	102.96	115.89	133.11	155.65	172.83	190.26	213.82
20 min	59.82	76.66	98.01	110.41	126.91	148.52	165.00	181.72	204.35
24 min	54.59	70.03	89.80	101.31	116.58	136.63	151.93	167.47	188.52
30 min	48.61	62.45	80.36	90.83	104.69	122.90	136.83	150.99	170.19
45 min	38.98	50.20	65.04	73.78	85.29	100.46	112.10	123.95	140.07
1.0 hr	33.11	42.71	55.62	63.26	73.29	86.55	96.73	107.13	121.28
1.5 hr	25.89	33.34	43.20	49.02	56.67	66.76	74.50	82.38	93.10
2.0 hr	21.66	27.86	35.98	40.75	47.04	55.32	61.66	68.11	76.87
3.0 hr	16.81	21.58	27.72	31.31	36.07	42.31	47.09	51.94	58.51
4.5 hr	13.02	16.69	21.33	24.03	27.62	32.33	35.91	39.55	44.48
6.0 hr	10.87	13.91	17.72	19.92	22.86	26.71	29.64	32.61	36.62
9.0 hr	8.43	10.77	13.65	15.31	17.53	20.43	22.63	24.86	27.87
12.0 hr	7.04	8.98	11.35	12.70	14.52	16.90	18.70	20.52	22.97
18.0 hr	5.28	6.78	8.75	9.90	11.43	13.43	14.97	16.53	18.65
24.0 hr	4.29	5.54	7.26	8.28	9.62	11.39	12.76	14.15	16.06
30.0 hr	3.64	4.72	6.26	7.19	8.39	10.00	11.24	12.52	14.27
36.0 hr	3.17	4.13	5.54	6.39	7.49	8.97	10.12	11.30	12.92
48.0 hr	2.54	3.33	4.53	5.27	6.22	7.51	8.52	9.56	11.00
72.0 hr	1.81	2.39	3.34	3.94	4.70	5.74	6.57	7.43	8.62

IFD Polynomial: ln I = a + b*ln(D) + c*ln(D)**2 + d*ln(D)**3 + e*ln(D)**4 + f*ln(D)**5 + g*ln(D)**6
where duration D is in hrs and average intensity I is in mm/hr

ARI	a	b	c	d	e	f	g	Max % error
1	3.4937434	-.5897430	-.0271452	.0106305	-.0010661	-.0006788	.0001005	.94
2	3.7474941	-.5883769	-.0317285	.0100839	-.0004123	-.0006043	.0000712	.74
5	4.0087228	-.5846664	-.0441721	.0085848	.0013691	-.0003996	-.0000087	.99
10	4.1360159	-.5827141	-.0507195	.0077960	.0023064	-.0002919	-.0000508	1.13
20	4.2819861	-.5810956	-.0561472	.0071422	.0030834	-.0002026	-.0000857	1.26
50	4.4468680	-.5792675	-.0622781	.0064036	.0039611	-.0001017	-.0001251	1.39
100	4.5571874	-.5780443	-.0663802	.0059094	.0045483	-.0000342	-.0001514	1.49
200	4.6584194	-.5769219	-.0701444	.0054559	.0050872	.0000277	-.0001756	1.57
500	4.7814498	-.5755578	-.0747190	.0049048	.0057421	.0001030	-.0002050	1.68

Overland Flow Travel Time Aid
Table of t*I**0.4 where t = time in min and I = intensity in mm/h

Duration	1 yr	2 yr	5 yr	10 yr	20 yr	50 yr	100 yr	200 yr	500 yr
5 min	32.45	35.74	39.15	40.91	43.12	45.76	47.61	49.38	51.61
6 min	37.88	41.74	45.76	47.83	50.43	53.54	55.72	57.81	60.44
7 min	43.17	47.58	52.19	54.57	57.55	61.12	63.62	66.01	69.04
8 min	48.33	53.27	58.46	61.15	64.51	68.52	71.34	74.03	77.44
9 min	53.37	58.83	64.60	67.58	71.31	75.76	78.90	81.89	85.67
10 min	58.29	64.27	70.61	73.89	77.98	82.86	86.31	89.59	93.75
12 min	67.83	74.81	82.27	86.14	90.95	96.70	100.74	104.61	109.50
14 min	77.01	84.97	93.54	97.98	103.49	110.08	114.73	119.16	124.78
16 min	85.89	94.80	104.45	109.47	115.66	123.09	128.32	133.31	139.65
18 min	94.50	104.34	115.05	120.63	127.51	135.75	141.55	147.10	154.14
20 min	102.88	113.62	125.38	131.51	139.05	148.10	154.47	160.56	168.29
22 min	111.04	122.66	135.45	142.13	150.33	160.16	167.10	173.72	182.13
24 min	119.01	131.50	145.31	152.52	161.37	171.97	179.46	186.61	195.69
26 min	126.81	140.15	154.95	162.70	172.18	183.55	191.57	199.24	208.98
28 min	134.46	148.63	164.41	172.68	182.78	194.90	203.45	211.63	222.02
30 min	141.96	156.94	173.70	182.47	193.19	206.05	215.12	223.80	234.83
40 min	177.67	196.56	217.91	229.13	242.76	259.14	270.71	281.78	295.84

IFD ANALYSIS BASED ON AUSTRALIAN RAINFALL & RUNOFF (1987)

Site name: Kempsey

Site latitude = 31.08 degrees S
longitude = 152.42 degrees E
skewness = .05

2-year ARI, 1 hour intensity = 41.90 mm/hr
12 hour intensity = 9.90 mm/hr
72 hour intensity = 3.00 mm/hr

50-year ARI, 1 hour intensity = 88.75 mm/hr
12 hour intensity = 20.50 mm/hr
72 hour intensity = 6.25 mm/hr

IFD Table for Various ARIs and Durations

Duration	1 yr	2 yr	5 yr	10 yr	20 yr	50 yr	100 yr	200 yr	500 yr
5 min	104.40	133.39	169.88	191.12	219.50	256.76	285.22	314.16	353.39
6 min	97.81	125.09	159.71	179.91	206.85	242.26	269.34	296.89	334.27
10 min	79.98	102.57	131.96	149.25	172.18	202.43	225.63	249.30	281.49
12 min	73.93	94.91	122.47	138.74	160.26	188.69	210.53	232.83	263.19
15 min	66.81	85.89	111.26	126.30	146.14	172.40	192.60	213.25	241.40
18 min	61.27	78.86	102.50	116.55	135.06	159.59	178.48	197.82	224.21
20 min	58.19	74.95	97.61	111.11	128.86	152.41	170.57	189.16	214.56
24 min	53.09	68.47	89.48	102.04	118.53	140.44	157.35	174.69	198.40
30 min	47.26	61.05	80.14	91.60	106.61	126.59	142.05	157.91	179.64
45 min	37.87	49.07	64.96	74.58	87.12	103.89	116.90	130.29	148.69
1.0 hr	32.15	41.75	55.61	64.06	75.04	89.76	101.21	113.02	129.28
1.5 hr	25.58	33.20	44.15	50.82	59.49	71.11	80.14	89.45	102.26
2.0 hr	21.67	28.12	37.36	42.98	50.29	60.07	67.68	75.52	86.30
3.0 hr	17.11	22.19	29.44	33.84	39.57	47.23	53.19	59.32	67.75
4.5 hr	13.50	17.50	23.17	26.62	31.10	37.10	41.75	46.54	53.13
6.0 hr	11.41	14.78	19.56	22.45	26.22	31.26	35.17	39.19	44.72
9.0 hr	9.01	11.67	15.41	17.68	20.63	24.58	27.64	30.78	35.10
12.0 hr	7.62	9.87	13.02	14.92	17.41	20.73	23.30	25.94	29.57
18.0 hr	5.91	7.65	10.11	11.59	13.52	16.10	18.10	20.16	22.99
24.0 hr	4.93	6.38	8.42	9.66	11.28	13.43	15.10	16.82	19.18
30.0 hr	4.26	5.52	7.30	8.37	9.77	11.64	13.08	14.58	16.62
36.0 hr	3.78	4.90	6.47	7.42	8.66	10.32	11.61	12.93	14.75
48.0 hr	3.11	4.02	5.32	6.10	7.12	8.49	9.55	10.64	12.14
72.0 hr	2.31	2.99	3.95	4.54	5.30	6.32	7.11	7.92	9.04

IFD Polynomial: ln I = a + b*ln(D) + c*ln(D)**2 + d*ln(D)**3 + e*ln(D)**4 + f*ln(D)**5 + g*ln(D)**6
where duration D is in hrs and average intensity I is in mm/hr

ARI	a	b	c	d	e	f	g	Max % error
1	3.4726982	-.5667104	-.0162162	.0085184	-.0012402	-.0003451	.0000534	.35
2	3.7325709	-.5636923	-.0188688	.0085522	-.0010106	-.0003640	.0000505	.37
5	4.0152904	-.5553742	-.0261988	.0086450	-.0003760	-.0004161	.0000423	.41
10	4.1546853	-.5509790	-.0300719	.0086940	-.0000407	-.0004436	.0000380	.52
20	4.3110989	-.5473257	-.0332911	.0087348	.0002380	-.0004665	.0000344	.70
50	4.4882228	-.5431889	-.0369366	.0087809	.0005536	-.0004923	.0000304	.90
100	4.6069955	-.5404148	-.0393810	.0088119	.0007652	-.0005097	.0000276	1.03
200	4.7161686	-.5378650	-.0416280	.0088403	.0009598	-.0005257	.0000251	1.15
500	4.8490861	-.5347606	-.0443636	.0088749	.0011966	-.0005451	.0000221	1.30

Overland Flow Travel Time Aid
Table of t*I**0.4 where t = time in min and I = intensity in mm/h

Duration	1 yr	2 yr	5 yr	10 yr	20 yr	50 yr	100 yr	200 yr	500 yr
5 min	32.09	35.40	39.01	40.90	43.23	46.04	48.02	49.92	52.33
6 min	37.52	41.40	45.64	47.85	50.60	53.89	56.22	58.44	61.28
7 min	42.78	47.21	52.08	54.63	57.77	61.55	64.23	66.78	70.04
8 min	47.89	52.86	58.35	61.24	64.78	69.05	72.06	74.95	78.63
9 min	52.86	58.37	64.48	67.70	71.64	76.39	79.75	82.96	87.05
10 min	57.72	63.75	70.48	74.02	78.36	83.59	87.28	90.82	95.33
12 min	67.11	74.16	82.11	86.31	91.43	97.59	101.96	106.14	111.47
14 min	76.15	84.19	93.33	98.17	104.05	111.14	116.17	120.98	127.12
16 min	84.88	93.88	104.20	109.67	116.30	124.30	129.96	135.40	142.33
18 min	93.35	103.29	114.76	120.85	128.22	137.10	143.40	149.45	157.15
20 min	101.60	112.45	125.05	131.75	139.83	149.59	156.51	163.15	171.62
22 min	109.64	121.39	135.10	142.39	151.18	161.80	169.33	176.56	185.78
24 min	117.51	130.13	144.93	152.81	162.30	173.75	181.88	189.69	199.64
26 min	125.22	138.69	154.57	163.02	173.19	185.47	194.19	202.56	213.25
28 min	132.77	147.10	164.02	173.05	183.88	196.98	206.27	215.21	226.60
30 min	140.20	155.35	173.31	182.90	194.39	208.28	218.15	227.63	239.74
40 min	175.66	194.78	217.70	229.96	244.61	262.33	274.93	287.04	302.51

IFD ANALYSIS BASED ON AUSTRALIAN RAINFALL & RUNOFF (1987)

Site name: South West Rocks

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Site latitude  =  31.00 degrees S
     longitude = 153.00 degrees E
     skewness  =    .03

 2-year ARI, 1 hour intensity  =  42.80 mm/hr
            12 hour intensity =   9.00 mm/hr
            72 hour intensity =   2.50 mm/hr

50-year ARI, 1 hour intensity  =  85.00 mm/hr
            12 hour intensity =  17.00 mm/hr
            72 hour intensity =   6.00 mm/hr
```

IFD Table for Various ARIs and Durations

Duration	1 yr	2 yr	5 yr	10 yr	20 yr	50 yr	100 yr	200 yr	500 yr
5 min	107.26	136.44	170.84	190.31	216.70	250.91	276.75	302.79	337.74
6 min	100.52	127.96	160.51	178.99	203.98	236.40	260.91	285.61	318.80
10 min	82.25	104.93	132.40	148.09	169.19	196.65	217.45	238.46	266.74
12 min	76.04	97.09	122.79	137.51	157.26	182.99	202.50	222.22	248.77
15 min	68.75	87.87	111.46	125.01	143.15	166.81	184.77	202.94	227.44
18 min	63.07	80.69	102.60	115.23	132.09	154.11	170.85	187.80	210.66
20 min	59.91	76.69	97.66	109.77	125.92	147.02	163.06	179.32	201.26
24 min	54.68	70.06	89.46	100.69	115.64	135.19	150.08	165.17	185.56
30 min	48.69	62.47	80.04	90.25	103.79	121.55	135.08	148.82	167.39
45 min	39.05	50.22	64.75	73.26	84.49	99.26	110.54	122.02	137.57
1.0 hr	33.17	42.73	55.36	62.79	72.57	85.45	95.31	105.36	118.99
1.5 hr	25.92	33.35	43.07	48.76	56.28	66.16	73.72	81.41	91.83
2.0 hr	21.68	27.87	35.91	40.61	46.81	54.97	61.20	67.54	76.12
3.0 hr	16.81	21.58	27.71	31.28	36.01	42.21	46.95	51.75	58.26
4.5 hr	13.02	16.69	21.36	24.07	27.66	32.38	35.97	39.61	44.53
6.0 hr	10.86	13.91	17.76	19.99	22.95	26.83	29.78	32.77	36.81
9.0 hr	8.42	10.77	13.70	15.39	17.65	20.60	22.84	25.11	28.17
12.0 hr	7.03	8.99	11.40	12.80	14.66	17.08	18.93	20.79	23.31
18.0 hr	5.31	6.84	8.87	10.06	11.63	13.70	15.28	16.89	19.08
24.0 hr	4.34	5.63	7.40	8.46	9.85	11.68	13.10	14.55	16.52
30.0 hr	3.70	4.82	6.42	7.38	8.64	10.30	11.60	12.93	14.75
36.0 hr	3.24	4.24	5.70	6.59	7.74	9.28	10.48	11.71	13.41
48.0 hr	2.61	3.43	4.69	5.47	6.47	7.82	8.88	9.97	11.49
72.0 hr	1.88	2.49	3.49	4.13	4.94	6.04	6.91	7.82	9.09

IFD Polynomial: ln I = a + b*ln(D) + c*ln(D)**2 + d*ln(D)**3 + e*ln(D)**4 + f*ln(D)**5 + g*ln(D)**6

where duration D is in hrs and average intensity I is in mm/hr

ARI	a	b	c	d	e	f	g	Max % error
1	3.4959742	-.5897137	-.0291022	.0099888	-.0006162	-.0005787	.0000725	.71
2	3.7485118	-.5878086	-.0330689	.0094557	-.0000264	-.0005057	.0000453	.64
5	4.0053320	-.5826649	-.0438067	.0079951	.0015776	-.0003054	-.0000292	.86
10	4.1301214	-.5799613	-.0494506	.0072275	.0024207	-.0002000	-.0000683	.97
20	4.2739209	-.5777215	-.0541262	.0065915	.0031191	-.0001128	-.0001007	1.06
50	4.4362477	-.5751932	-.0594042	.0058737	.0039075	-.0000143	-.0001373	1.17
100	4.5447973	-.5735025	-.0629337	.0053936	.0044347	.0000516	-.0001618	1.24
200	4.6443627	-.5719517	-.0661710	.0049533	.0049183	.0001120	-.0001842	1.31
500	4.7653133	-.5700678	-.0701037	.0044184	.0055057	.0001854	-.0002115	1.39

Overland Flow Travel Time Aid

Table of t*I**0.4 where t = time in min and I = intensity in mm/h

Duration	1 yr	2 yr	5 yr	10 yr	20 yr	50 yr	100 yr	200 yr	500 yr
5 min	32.46	35.75	39.11	40.83	43.01	45.61	47.43	49.17	51.36
6 min	37.91	41.75	45.72	47.76	50.32	53.38	55.53	57.58	60.17
7 min	43.20	47.59	52.15	54.49	57.43	60.94	63.41	65.76	68.73
8 min	48.36	53.29	58.41	61.05	64.36	68.31	71.09	73.74	77.08
9 min	53.40	58.85	64.54	67.47	71.14	75.53	78.61	81.54	85.26
10 min	58.32	64.28	70.53	73.75	77.78	82.59	85.98	89.20	93.28
12 min	67.86	74.82	82.17	85.96	90.69	96.35	100.32	104.11	108.91
14 min	77.05	84.98	93.40	97.76	103.18	109.66	114.21	118.56	124.06
16 min	85.93	94.80	104.29	109.20	115.29	122.58	127.71	132.60	138.80
18 min	94.54	104.34	114.86	120.32	127.08	135.16	140.85	146.28	153.16
20 min	102.92	113.61	125.16	131.16	138.57	147.44	153.68	159.64	167.19
22 min	111.09	122.66	135.22	141.75	149.80	159.43	166.22	172.70	180.91
24 min	119.07	131.50	145.05	152.10	160.78	171.17	178.50	185.49	194.35
26 min	126.88	140.15	154.68	162.25	171.54	182.68	190.53	198.03	207.53
28 min	134.53	148.64	164.12	172.20	182.10	193.98	202.34	210.33	220.47
30 min	142.05	156.96	173.39	181.96	192.47	205.07	213.94	222.42	233.18
40 min	177.81	196.60	217.55	228.51	241.88	257.92	269.23	280.05	293.77