ACT Government

STORMWATER

MUNICIPAL INFRASTRUCTURE STANDARDS 08

Transport Canberra andCity Services

SEPTEMBER 2021

Publication Number:	MIS 08 Edition 1 Revision 1	
Date of Effect:	SEPTEMBER 2021	
Supersedes:	Municipal Infrastructure Standard 08 Edition 1 Revision 0	
Endorsed By:	Steve Hare	A/Deputy Senior Director, Infrastructure Planning
Approved By:	Shelly Fraser	A/Executive Branch Manager, Roads ACT

Document Information

Document	Key Information
Document Title	MIS 08 Stormwater
Next review date	
Key words	
AUS-SPEC Base Document	0074 Stormwater drainage (design)

Revision Register

Edition/ Revision Number	Clause Number	Description of Revision	Authorised By	Date
1/0				
1/1	N/A	Acknowledgement of Country added		
	1.1.2.2	Relevant ACT legislation added		
	1.1.2.3	ACT Practice Guidelines for WSUD added		
	1.1.2.5	MITS 06 added		
	1.1.3.1	AS 1289, AS 2648, AS 2700, AS 2845, AS 3972, AS 3996, AS 4239, AS 5100, AS/NZS 5667 added		
	1.1.5.1	Abbreviations not used in document removed, PMF, TSS, TP, TN and TWL added		
	1.2.6	Use of Aboriginal plants added		
	3.2.2.1	Table 8-8 cross reference corrected		

Edition/ Revision Number	Clause Number	Description of Revision	Authorised By	Date
	3.2.2.2	Table 8-9 cross reference corrected		
	4.3.5	Standard drawing reference removed		
	4.4.1	Table 8-17 cross reference corrected		
	4.7.4	Reference to floodway advisory standard drawing updated		
	9.3.1.2	Table 8-27 cross reference corrected		
	9.4.1	Cross reference to standard sump types corrected		
	10.6.1	Cross reference to scour protection		
	10.7	Use of Aboriginal plants added		
	13.2.4	Use of Aboriginal plants added		
	13.2.6	References to Figures 8-16 and 8-17 corrected. References to all subsequent figures updated.		
	13.8	Reference to Aboriginal plants, as applicable, added		
	14.6.1	Standard drawing reference corrected to ACTSD 0855		
	15.4.2	Cross reference corrected		
	15.9.1	Cross reference corrected		
	15.10.1	Use of Aboriginal plants encouraged		
	16.7.2	Cross references corrected		
	17.1.1	Consider Aboriginal cultural significance added		
	F2	Removed reference to Figure 1		
	F5.1	Link to Dam Safety Code updated		

ACKNOWLEDGEMENT OF COUNTRY

Transport Canberra and City Services (TCCS) acknowledge that Aboriginal people are the Traditional Owners of Australia. We acknowledge and pay respect to the Ngunnawal peoples as the custodians of the land and waters that we live and thrive on today here in the ACT.

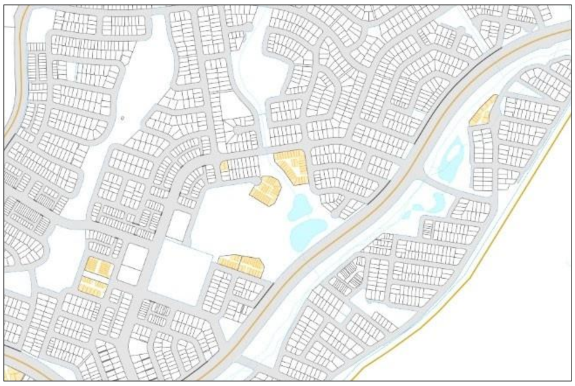
TCCS acknowledges that Canberra's cultural and natural heritage was maintained by the Ngunnawal people for many generations before colonial settlement on Australian soil. Aboriginal people's management of the land preserved the natural balance of local plants and animals. This knowledge of the environment in which we live is critical to the protection and restoration of our land today.

It is our responsibility to preserve and encourage Ngunnawal, Aboriginal and Torres Strait Islander cultural integrity. When using this document, consider opportunities to incorporate Ngunnawal, Aboriginal and Torres Strait Islander culture into stormwater works and designs.

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION



1 STORMWATER

1.1 General

1.1.1 Responsibilities

1.1.1.1 Objectives

Design objectives: Provide stormwater drainage systems design and documentation to meet the followingobjectives:

- Contribute to a sustainable urban environment;
- Provide safety for the public;
- Minimise the impacts of flooding on life and property;
- Stabilise the landform and control erosion;
- Enhance the urban environment by providing assets of social, environmental and economic value;
- Protect and maximise the value of aquatic and terrestrial ecosystems within the stormwater system;
- Enhance water security by minimising the need for irrigation with potable water; and
- Encourage community involvement and connection with country.

Principles: These objectives are based on the following set of holistic inter-related principles for effectivestormwater environment management within a catchment and it's receiving waters:

- Site specific: understanding that the importance of specific requirements varies within and betweencatchments and compromises between them may be needed at any particular site to achieve a balanced outcome.
- Integrated catchment management: applying a holistic approach to a catchment's services and how these can most optimally be provided (e.g. treatment trains).
- Hydrological: emulate the natural hydrological characteristics of a catchment, including wet and dry weather flows. This includes a holistic approach to floodplain management and land use within floodplain areas.
- Whole of life: considering the full life cycle of assets from safety in design to construction to ongoingmaintenance to renewal.
- Water quality: minimising the amount of pollution entering receiving waters and removing an appropriate amount of any residual pollution by implementing water quality control measures.
- Water sensitive urban design: connecting the needs of people living in an urban setting with the needs of the environment through the design of an interrelated stormwater system.
- Disconnection: minimising runoff at or near its source, by directing runoff from impervious surfaces topervious areas to reduce the quantity and improve the quality of runoff.
- Stormwater harvesting: capture and re-use of stormwater as an alternative source of water to conserve potable water.
- Vegetation: maximising viable natural habitat for fauna via indigenous riparian, floodplain, and foreshore vegetation.

Compliance: The stormwater objectives are seen as being achieved when:

> The planning, design and construction of new facilities is adequate to service new and futuredevelopments consistent with the requirements of both TCCS and the EPSDD;
> There is compatibility with existing facilities, operational methods, and maintenance techniques; and
> The facilities provide adequate environmental, community, and asset protection consistent with theaccepted design and construction requirements set out in this document and with developments in technology as approved from time to time.

1.1.1.2 Requirements

Requirements: The requirements for stormwater infrastructure in the ACT are set in the documents listedin **Cross references.** Some of the requirements to be met include:

> No increase in peak outflows due to a development for the 20% and 1% AEP storm events;
> A reduction in the quantity of pollutants discharged from development sites and to receiving waters;and
> Leases to be protected from stormwater runoff from public land up to the 1% AEP event.

Runoff control requirements for flows within developments and discharges to a receiving watercourse are summarised in **Table 8- 1 Flow control criteria.**

Table 8- 1 Flow control criteria

Category	Minimum Standard
Redevelopment	Peak flow ≤ pre-redevelopment peak flow for minor andmajor system design AEP of existing development
New Development	Peak flow ≤ pre-development peak flow for minor and majorsystem design AEP of new development Surface flow criteria limits as specified in **Table 8-19 Surfaceflow criteria for roads**
Stormwater System Augmentation	No inundation of leases from overland flows up to and including the major system design AEP

Refer to **Design flow** for minor and major system design AEPs.

1.1.1.3 Precedence

Where any document (except legislation or the Territory Plan) issued in conjunction with this Design Standard includes technical requirements that conflict with this Design Standard, the requirements of this Design Standard shall take precedence.

1.1.2 Cross references

1.1.2.1 Commonwealth legislation

Australian Capital Territory (Planning and Land Management Act)

Environment Protection and Biodiversity Conservation Act

1.1.2.2 ACT legislation

Environmental Protection Act

Lakes Act

Territory Plan

Water Resources Act

Work Health and Safety Act

Planning and Development Act

Utilities Act (Dam Safety Code)

Utilities (Non- drinking Water Supply Code) Determination

1.1.2.3 ACT Government strategic documents

ACT Environmental Flow Guidelines, Environment ACT

ACT Practice Guidelines for Water Sensitive Urban Design

ACT Water Strategy 2014-44: Striking the Balance

AP2 - A new climate change strategy and action plan for the ACT

Sustainable Water Action Management Project – Strategy and Action Plan, Environment ACT

Water Resources Management Plan, Environment ACT

1.1.2.4 Design Standards

General: The following Design Standards are related to this standard:

MIS 01	Street Planning and Design
MIS 04	Subsurface Drainage
MIS 06	Verges
MIS 07	Driveways
MIS 09	Bridges and Related Structures
MIS 10	Guardrails, fences and barriers
MIS 15	Urban Edges Management Zone
MIS 25	Plant Species for Urban Landscape Projects

Water Supply and Sewerage Standards (Icon Water):

WSA-02	Gravity Sewerage Code of Australia (WSAA)
WSA-03	Water Supply Code of Australia (WSAA)
STD-SPE-G-011	Supplement to WSA-02 2014 (Icon Water)
STD-SPE-G-012	Supplement to WSA-03 2011 (Icon Water)
STD-SPE-M-006	Requirements for property service connections and water meters

1.1.2.5 Specifications

General: The following Specifications are related to this standard:

MITS 03 Underground services

MITS 06 Concrete kerbs, footpaths and minor works

1.1.2.6 TCCS Reference Documents

Reference document 4 Protection of public landscape assets

Reference document 6 Design Acceptance submissions

Reference document 7 Operational acceptance submissions

Reference document 8 WAE quality records

Reference document 9 Final acceptance submissions

1.1.3 Referenced documents

The following documents are incorporated into this Design Standard by

reference:*TCCS Products previously considered for use list*

1.1.3.1 Australian Standards

AS/NZS 1254	PVC pipes and fittings for storm and surface water applications.
AS 1289:	Methods of testing soils for engineering purposes
AS 1289.4.2.1	Soil chemical tests - Determination of the sulfate content of a natural soil and thesulfate content of the groundwater - Normal method
AS 1289.4.3.1	Soil chemical tests - Determination of the pH value of a soil - Electrometric method
AS 1289.4.4.1	Soil chemical tests - Determination of the electrical resistivity of a soil - Method for sands and granular materials
AS 1289.5.4.1	Soil compaction and density tests - Compaction control test - Dry density ratio, moisture variation and moisture ratio
AS 1345	Identification Of The Contents Of Pipes, Conduits And Ducts
AS 1926.1	Swimming pool safety - safety barriers for swimming pools
AS/NZS 2032	Installation of PVC pipe systems
AS 2200	Design charts for water supply and sewerage
AS/NZS 2566	Buried flexible pipelines
AS/NZS 2566.1	Structural design
AS/NZS 2566.2	Installation
AS 2648	Underground Marking Tape - Non-detectable tape
AS 2700	Colour Standards for General Purposes
AS 2845.2	Water Supply - Backflow Preventions Devices - Registered Air Gaps And Registered Break Tanks
AS/NZS 3500	Plumbing and drainage
AS/NZS 3500.3	Stormwater drainage

AS/NZS 3725	Design for installation of buried concrete pipes
AS 3972	General purpose and blended cements
AS 3996	Access Covers And Grates
AS/NZS 4058	Precast concrete pipes (pressure and non-pressure)
AS 4139	Fibre reinforced concrete pipes and fittings
AS 4239	Information Technology - Telecommunications And Information Exchange Between Systems
AS/NZS 5065	Polyethylene and polypropylene pipes for drainage and sewerage applications
AS 5100	Bridge design
AS 5334	Climate change adaptation for settlements and infrastructure – A risk based approach
AS/NZS 5667.1	Water quality - Sampling Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples
AS/NZS 5667.6	Water quality - Sampling Guidance on sampling of rivers and streams

1.1.3.2 Other publications

Austroads

AGRD	Ausroads Guide to Road Design
AGRD05	Part 5: Drainage – General and Hydrology Considerations
AP-R232	Guidelines for treatment of stormwater runoff from the road infrastructure
AP-23	Waterway design – A guide to the hydraulic design of bridges, culverts, and floodways

Engineers Australia

ARR 2016: Australian Rainfall and Runoff – A Guide to Flood Estimation

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

ANCOLD

Guidelines on the Consequence Categories for Dams

Guidelines on Risk Assessment

Guidelines on Dam Safety Management

Guidelines on Selection of Acceptable Flood Capacity for Dams

Guidelines on Retarding Basins

1.1.4 Standards

Standard: Conform to the following except where this standard advises

otherwise:Rainfall and runoff: Refer to latest edition of *ARR*; and

Water sensitive urban design: Refer to *ARQ* and *WaterWays: Water Sensitive Urban Design General Code*.

Overview: **Figure 8- 1 Overview of relationship between the Territory Plan and TCCS Municipal documentation** illustrates the relationship between the various policy instruments and resourcesgoverning development in the ACT and the role of this Design Standard in informing the process.

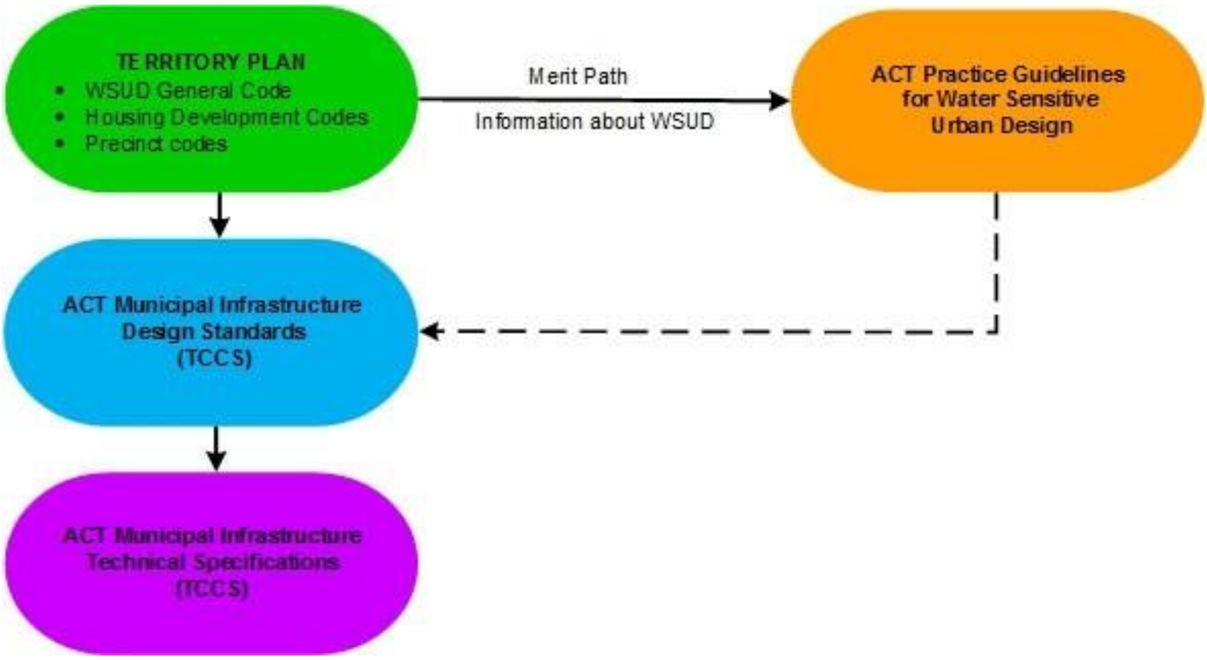


Figure 8- 1 Overview of relationship between the Territory Plan and TCCS Municipal documentation

1.1.5 Interpretations

1.1.5.1 Abbreviations

General: For the purposes of this Design Standard, the abbreviations given below shall apply:

AEP: Annual Exceedance Probability

AFC: Acceptable Flood Capacity for retarding basin and water retaining structure secondary outlets determined from a Consequence Category assessment.

ANCOLD: Australian National Committee on Large Dams

ARI: Average Recurrence Interval

ARBM: Australian Representative Basins Model

ARR: Australian Rainfall and Runoff

ARQ: Australian Runoff Quality

BOD: Biochemical oxygen demand

BoM: Bureau of Meteorology

DOL: Dissolved oxygen

EC: Electrical conductivity

EDD: Extended Detention Depth

EPSDD: Environment, Planning and Sustainable Development Directorate

FCR: Fine crushed rock

FD: Functional description

EY: Exceedances per Year

GPT: Gross Pollutant Trap

IFD: Intensity-Frequency-Duration

ILSAX: ILLUDAS-SA with eXtras (ILLUDAS-SA: ILLinois Urban Drainage Area Simulator-South Africa)

HGL: Hydraulic Grade Line

KIS: Type KI Sump

MIS: Municipal Infrastructure Standards (TCCS)

MUSIC: Model for Urban Stormwater Improvement Conceptualisation

NWL: Normal Water Level

O&M: Operation and maintenance

OSD: On-site Detention

P&ID: Process and instrumentation diagram

PFD: Process flow diagram

PMF: Probable Maximum Flood

RAFTS: Runoff Analysis and Flow Training Simulation

TCCS: Transport Canberra and City Services, ACT Government, and its successors

TED: Top of extended detention

TN: Total nitrogen

TP: Total phosphorous

TSS: Total suspended solids

TWL: Tail water level

USTM: Unified Stormwater Treatment Model (MUSIC)

WAE: Work-as-executed

WBNM: Watershed Bounded Network Model

WCFACT: Relative lag lime for runoff from impervious and pervious surfaces

(WBNM) WQCP: Water quality control pond

WSUD: Water Sensitive Urban Design

1.1.5.2 Definitions

General: For the purposes of this section, the definitions given below apply. Please note there are additional definitions and commentary included in **Appendix F** relevant Floodplain planning and design:

Annual Exceedance Probability (AEP): The probability of a flood occurrence of a given magnitude occurring in any year, expressed as a percentage.

Average Recurrence Interval (ARI): A long-term statistical estimate of the average period in yearsbetween flood occurrences of a given magnitude.

Catchment: A topographically defined area such that all outflow is directed to a single point.

Catchment area: The catchment area of any point is defined by the limits from where surface runoff will make its way, either by natural or manmade paths, to this point.

Composite waterway: A waterway with more than one surface material lining e.g. a floodway with grassed sides and a concrete low-flow invert.

Consequence Category assessment: An assessment of the risk to life, property and the environmentresulting from a dam failure.

Culvert: Refer to *MIS 09 Bridges and Related Structures.*

Detention: Detaining water and releasing it at a controlled rate.

Dual drainage: The major/minor approach to street drainage.

Exceedances per Year (EY): The average number of occurrences equalling or exceeding a given value inone year.

Floodplain: The land area covered by a flood up to the probable maximum flood. This definition is consistent with national definitions and for Canberra this would include all waterbodies, floodways and asignificant proportion of urban areas including leased land (residential, commercial, industrial etc).

Freeboard: The height of a portion of a structure or other construction, measured to the underside of thesuperstructure above a given level of water.

Gross Pollutant Trap (GPT): A primary treatment device designed to capture gross pollutants such as: sediment, litter and organic matter.

Major system: The network of planned and unplanned drainage routes which provides safe, well-definedoverland flow paths for rare and extreme storm runoff events. It includes roads, natural channels, streams, culverts, community retention/detention basins and other facilities.

Minor system: The gutter and pipe network capable of carrying and controlling flows from frequent runoff events. It includes kerb and channels, inlet structures, open drains and underground pipes and on-site detention facilities. Redevelopment site: A site which had (or was originally zoned to have) a lower density development than is proposed.

Retardation: See Detention

Retention: Retaining water without release except through evaporation, infiltration, reuse, or emergencybypass.

Stormwater: Water from precipitation commencing when it becomes runoff and ending when it is turnedinto another use.

Stormwater management plan: Plan to manage the stormwater quantity and quality within a catchmentand 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 streamor main drain draining a catchment.

Time of concentration: The time for storm runoff to flow from the most remote point on the catchmentto the catchment outlet or to the inlet of a drainage asset within the catchment.

Treatment train: The sequencing of WSUD treatment devices within a catchment.

Trunk drains: Large capacity channels or conduits which carry runoff from local street drainage systems toreceiving waters. For example, natural or artificial channels, transitions and hydraulic structures, culverts and road crossings, ponds and lakes, and detention or retention storages.

Water retaining asset: An element of the stormwater system which holds water either temporarily orpermanently. Examples include lakes, ponds, dams, infiltration basins, retarding basins, wetlands and tanks.

Waterway: An element of infrastructure intended for overland water conveyance. Examples include:constructed and natural channels, floodways, swales and cut off drains.

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, watersupply, wastewater, stormwater and groundwater management, urban design and environmental protection.

1.2 Pre-design planning

1.2.1 Consultation

1.2.1.1 TCCS and other Authorities

Requirement: Consult with TCCS and other relevant Authorities during the preparation of design. In addition to the requirements of this Design Standard, identify the specific design requirements of these authorities.

1.2.1.2 Utilities services plans

Existing site conditions: Obtain plans from all relevant utilities and other organisations whose services, trees, important ecological habitats or other assets exist within the area of the proposed development. Plot this information on the relevant drawings including the plan and cross-sectional views. As a minimum, designs should refer to 'Dial-before-you-dig' information that is readily available in most areas.

Responsibility: Confirm service plans accuracy with onsite inspection and also potholing if deemed necessary. Protect existing assets to the satisfaction of asset owners.

Proposed new services: Detail any new services proposed or relocated as part of the proposed works.

1.2.2 Site specific planning

General: Refer to **Appendix F** for additional guidance for site specific planning requirements, such as access and egress.

Site assessment: Assess the existing physical and natural attributes of the site including the following:

> Area, slope and shape of the catchment area;
> Available space;
> Proximity to pollutant source areas;
> Receiving environment;
> Evidence of previous flooding;
> Soils and geology;
> Erosion;
> Vegetation affecting run-off and/or loss factors;
> Existing infrastructure at risk of inundation;
> Existing drainage infrastructure location and capacity;
> Sensitive inhabited locations to be protected;
> Services and transport works to be protected;
> Groundwater; and
> Access.

Constraints: Design for site-specific constraints including heritage and environmental.

Documentation: Document the site specifics and constraints that may affect the design with respect to the Territory Plan and related documents.

1.2.3 Conceptualise

Continuous: Continuous designated overland flow paths shall be provided from the top of the catchmentthrough the entire urban area to ensure a clear major drainage network.

Complementary: Concepts should be complementary with the strategic stormwater objectives such as theland use set out in the Territory Plan, Master plans, or Structure plans.

Pervious land: As a key design driver, concepts should be integrally linked with the degree of perviousland both in the vicinity of stormwater elements and throughout the catchment.

Element assessment: Evaluate all the structural and non-structural elements (such as those listed in laterchapters) that may go into a design that perform the prevention, collection, treatment, conveyance, storage and re-use functions of a water management scheme to arrive at the optimum solution to meet the strategic stormwater objectives.

Distribution: Evaluate the life cycle costs and benefits of different distribution approaches such as:

> Outlet approach: Use a single element to treat a whole catchment; or
> Distributed approach: Target smaller individual catchments with many elements.

Dedicated reserves: Floodways in drainage reserves should be provided in preference to floodways alongroads wherever possible.

Retardation: Attenuation of peak flows by the provision of dry retarding basins or the incorporation of flood storage within water retaining assets should be provided as an integral part of the major drainagesystem in new development areas to:

> Provide a more economic system by reducing downstream flow rates and waterway reserve widths,or
> Meet a specific planning requirement such as that downstream flow rates not exceed pre-development values for both the minor and major system design AEP.

Multi-purpose: Elements should be selected to gain maximum land use benefit by designing them toaccommodate other complementary functions such as recreation, access, and habitat.

1.2.4 Design

Elements: Design stormwater infrastructure elements in accordance with their relevant chapters in thisdesign standard.

WSUD: Plan and design WSUD elements at an allotment and regional scale using WSUD practices in accordance with the *Waterways: WSUD General Code* and *ACT Practice Guidelines for Water Sensitive Urban Design* including the following:

> Minimisation of runoff at or near its source, by directing runoff from impervious surfaces to perviousareas to reduce the quantity and improve the quality of runoff;
> OSD where appropriate and necessary;
> Capture and use of stormwater as an alternative source of water to conserve potable water;
> Use of vegetation for filtering purposes; and
> Water-efficient landscaping.

1.2.5 Subdivisions

Subdivisions: Plan and design with due consideration of the objectives and requirements for stormwater management outlined in **Responsibilities**.

Flow concentration: Avoid the concentration and discharge of runoff from upstream blocks to adjacentdownstream blocks.

1.2.1.3 Easements

Collaboration: Plan the stormwater system layout to avoid clashes with other services.

1.2.6 Ecology and landscaping

Ngunnawal / Aboriginal cultural integrity: Incorporate Ngunnawal and Aboriginal culture through utilising traditional plants where applicable in stormwater designs.

Vegetation: Design the vegetation for stormwater infrastructure elements in line with their relevantchapters in this standard.

Water quality: Vegetation for stormwater infrastructure should maximise water quality benefits. *MIS 25Plant Species for Urban Landscape Projects* provides example species according to their inundation conditions.

Aesthetics: The stormwater drainage system shall be designed to enhance the appearance of the area andto maximise its use by the community while still considering maintenance (Refer to **Maintenance**).

Clearance: In General, no vegetation other than grass shall be planted within a waterway, water retainingor retarding basin embankment, a dam spillway or within 3 m of a stormwater pipeline or structure.
Vigorous rooting tree species (e.g. poplar, willow, or elm) shall not be planted within 10 m of astormwater pipeline.

Exception: Tree planting within 3 m of a stormwater pipeline or structure shall be permitted in narrowstreet verges where a clearance of 3 m cannot be achieved.

Exception: In some instances, tree and shrub planting within a waterway may be desirable to reduce velocities and therefore should be considered as an integral part of the stormwater system. The area of such waterways shall be increased to allow for tree and shrub planting. This exception does not apply towater retaining and retarding basin embankments or dam spillways.

Floodplains: No trees other than those with clean boles, strong crown structure, and no propensity forroot suckering may be planted in the floodplain.

1.2.7 Maintenance

1.2.1.4 General

Avoid: Where possible stormwater infrastructure should be designed to minimise the requirement formaintenance.

Life-cycle cost: Whole of life-cycle cost should be considered in the design process by reducing maintenance requirements. Where applicable, the lifecycle cost shall be determined in accordance withthe latest edition of *Best Practice Cost Estimation Standard for Publicly Funded Road and Rail Construction, Department of Infrastructure and Transport.*

Access: Where maintenance is required, access shall be provided to the asset.

Safe environment: Where maintenance is required, a safe working environment shall be provided in accordance with *ACT Government OH&S legislation.*

Mowing: Maintenance free 'thicket' zones used for hydraulic reasons shall have a minimum 3 m clearance from lease boundaries to provide access for mowing

Specific Requirements: Refer to TCCS for specific maintenance requirements for situations not covered by this document.

1.2.1.5 Operation and Maintenance Plan

Requirement: An Operation and Maintenance Plan shall be prepared for the following stormwater assets that require regular routine maintenance for their effective operation:

> Retarding basins;
> Wetlands;
> Ponds;
> Bioretention basins;
> Bioretention swales;
> Gross pollutant traps; and
> Stormwater harvesting schemes.

Document: Operational and maintenance provisions must be finalised and documented during detailed design. The designer shall prepare a comprehensive Operation and Maintenance Plan which includes the following items for the facility:

> Description of the works;

- The system type
- System location and what it serves
- What the system depends upon in order to function
- Design data, basic design parameters, basic assumptions made during design
- Expected service life
- Planned water quality efficiency
- Method of control and operational constraints

> List of equipment used;

- Manufacturer’s literature
- Spare part information

> Commissioning information;

- Test Results
- Test Certificates
- Warranty certificates

> Operational requirements;

- A recommended strategy for operation and control of system
- An outline of the general operating mode of the system
- Standard operating and emergency operating procedures, and sequences for any system start-up, running and shut-down procedures, under both normal and emergency conditions
- Work Health and Safety information for operation of the facility

> Maintenance requirements;

- The isolation and return to service of system, plant and equipment
- Adjustments, calibration and testing to system
- Work Health and Safety information for maintenance
- The nature of deterioration and checks for defects
- Special tools, test equipment and ancillary services
- Maintenance schedule including;
    - Inspections
    - Examinations
    - Tests
    - Adjustments
    - Calibration
    - Lubrication
    - Periodic overhaul.

Approval: The Operation and Maintenance Plan must be submitted to TCCS for approval.

1.2.8 Safety

1.2.1.6 General

Public safety: Adequate provision for public safety shall be included in the design of all stormwater infrastructure. Safety requirements for specific assets are provided in their relevant section of this standard.

Velocity/depth criteria: Stormwater infrastructure shall consider the safety of children and vehicles by limiting the velocity x depth product of flow in the major design storm event. The limit must be set in reference to the likelihood of exposure of the public to the flow in accordance with **Table 8- 2 Velocity x depth limits for major design storm event.**

Barriers: Asset locations, arrangement, planting and fencing at a minimum must be considered to preventand to discourage the public from being exposed to high-hazard areas during storms or in the periods between them. Refer to *MIS 10 Guardrails, fences and barriers.*

1.2.1.7 Safety in Design

Requirement: Implement safety in design processes in accordance with the *ACT Government Work Healthand Safety Act.*

Table 8- 2 Velocity x depth limits for major design storm event

Location	Likelihood of exposure to pedestrians	Maximum VxD (m^2/s)
Roads, footpaths, public open space	Regular or likely exposure	0.4
Waterways, major traffic routes	Irregular exposure	0.6
Drop structures, dam spillways	Rare or unlikely exposure or barriers to prevent access provided	No limit (signage required)

Note: V is the average velocity for the flow cross-sectional area

CONVEYANCE SYSTEMS

2 DESIGN FLOW

Design flow: Determine the design flow for each element of the stormwater system. Design flows are designated for each asset type in the relevant section of this standard.

Design concept: Refer to the major/minor drainage concept as defined in *ARR 2016 Book 9.*

2.1 Major design storm event

Design AEP: The major design storm shall be the 1% AEP event. Major stormwater infrastructure, except for water retaining and retarding basin embankments and secondary spillways, shall be sized for the full major design storm flow.

2.2 Minor design storm event

Design AEP: Design all minor infrastructure on the basis that the cost/benefit of providing a certain standard of flood protection varies with the type of development. The minor drainage system design AEP shall be selected in accordance with **Table 8-3 Minor system design AEP**

Table 8-3 Minor system design AEP

Type of Development	AEP
Parliamentary Area (bounded by Lake Burley Griffin, Flynn Drive, State Circle (including Capital Hill), Brisbane Avenue & Bowen Park)	5%
Town centres (e.g. Civic, Woden, Belconnen, Gungahlin and Tuggeranong)	5%
Group and neighbourhood shopping centres (e.g. Pearce, Mawson, Torrens, Kippax and Kingston)	10%
Industrial areas (e.g. Fyshwick, Mitchell and Hume)	10%
Service trades areas (e.g. Belconnen and Phillip)	10%
Urban neighbourhood development i.e. residential areas (except in designated preserved environment areas)	20%

2.3 Other design events

Footpaths: The level of footpaths and cycleways shall be above the 0.5 EY flood level.

Retarding basins and water retaining structures: The design AEP for embankments and spillways shall be determined from a Consequence Category assessment of failure of the structure in accordance with *ANCOLD guidelines*. This is termed the AFC for the structure and will normally require embankment dam break analyses to be undertaken for both a 'flood initiated' and a 'sunny day' failure.

Excess flows: Consideration shall be given to the effect of flows in excess of the design capacity of the asset. This should be done by considering the risk profile of the downstream area. TCCS shall be advised if, in the opinion of the Designer, such flows will cause significant additional risk.

3 HYDROLOGY

3.1 General

3.1.1 General

General: Refer to **Appendix F** for additional guidance for Hydrological considerations, such as climatechanges and sensitivity analysis.

3.1.2 Terminology

Design events: Design events should typically be expressed in terms of AEP. Additionally, AEP is to beexpressed using percentage probability.

Frequent events: Design events more frequent than 50% AEP should be expressed in terms of

EY.Extreme events: Design events less frequent than 0.05% AEP should be expressed as 1 in X

AEP.

3.1.3 Rainfall data

IFD data: The design event rainfall depths from the latest BoM rainfall IFD Data System shall be used forthe estimation of design flows in all urban areas of Canberra.

Temporal patterns: The storm burst temporal patterns from the ARR Data Hub shall be used for theestimation of design flows in all urban areas of Canberra.

Documentation: The table of design rainfall depths from the latest BoM Rainfall IFD Data System used forthe design shall be included in documentation provided.

Interpolation: Design rainfall durations between those normally provided by the latest BoM Rainfall IFD Data System shall be interpolated using the BoM interpolation procedure and included in documentationprovided.

Conversion: The design rainfall intensities shall be determined from the design rainfall depths.

Source: For water balance modelling and other non-event based assessments, relevant long-term rainfalldata for the site should be used where possible. If site data is not available, BoM rainfall data for the Canberra Airport station for the period 1968 to 1977 may be used.

3.1.4 Climate change

General: Refer to **Appendix F** for additional guidance for Climate Change.

Consider: Future climate change effects must be considered as part of the drainage network.

Hydrology: Design rainfall intensities/depths shall be increased by 20% to account for the potential futureeffects of climate change.

3.1.5 Catchment area

Extent: Determine the extent of the catchment area from current topographical mapping, aerial photographs or field survey.

Site inspection: Verify catchment boundaries by site inspection.

Reference: Catchments should be defined to *AGRD05-13 clause 6.5 Catchments*.

Land uses: The proportion of land uses in the catchment should be estimated. At a minimum these should include:

> Leases;
> Road Reserves; and
> Open spaces / unleased land.

Record: A catchment area plan and proportion of land use types should be included in documentation provided.

Design variations: Consider potential changes to individual catchment areas due to the full development of the catchment.

Catchment area land use: Establish catchment area land use on current available zoning information or proposed future zonings, where applicable.

3.1.6 Impervious area

2.1.1.1 Leases

Impervious area: For hydrology purposes, single residential lease impervious area shall be estimated based on the maximum permissible building plot ratio for the development type plus 10% of the total lease area to allow for driveways, carports, surface paving etc.

Impervious area: For all other development types, the total impervious area values should be determined from site plans or aerial photography. Where this is not possible, the values provided in **Table 8-4 Composite impervious area guidelines** may be adopted.

Table 8-4 Composite impervious area guidelines

Type of Development	Design Impervious Area (%)
Single Residential	**35-60**
Multi-Units	**70**
Commercial and Service Trades	**70**
Group and Neighbourhood Shopping Centres	**80**
Town Centres	**90**
Industrial	**90**

2.1.1.2 Roads

Impervious area: Road area and formal off street car parks (not including pervious verges) should be considered 100% impervious.

2.1.1.3 Open spaces

Impervious area: Open space areas should be considered 0% impervious.

2.1.1.4 Composite areas

Composite areas: For larger-scale modelling of urban catchments, sub-catchments are typically composite areas that include leases, road reserves and open space areas. In these cases the impervious area shall be determined from the proportion of each land use.

3.2 Rainfall-runoff models

Hydrology standard: Generally to the latest version of *ARR.*

Accepted models: The hydrological models listed in this standard will be permitted by TCCS.

Flow estimation: The *ARR 2016* Ensemble of Storm Patterns method is the preferred method for theestimation of design flows.

Documentation: Full details of the hydrological method or model to be used including all assumptionsmade, recommended parameter values, and tabulated flow comparisons for major and minor design storm events shall be included in documentation provided.

Approval: To obtain approval for new methods, the Designer must demonstrate, to the satisfaction of TCCS, that a particular method or model is appropriate for ACT conditions as set out in the *ACT Practice Guidelines for Water Sensitive Urban Design.* One of the following procedures shall be used to calibrate the method or model and determine appropriate assumptions and parameter values for the estimation ofmajor and minor system design flows:

> Calibration to the flood frequency curves for the catchment considered;
> Calibration to the current flood frequency rating curves for the Giralang, Mawson, and Curtincatchments; or
> Comparison with one of the rainfall/runoff models described herein.

3.2.1 xprafts

2.1.1.5 Rainfall loss rates

Approach: For xprafts, the use of the ARBM loss model should be used in preference to theinitial/continuing loss model.

Loss parameters: Values to be adopted for the ARBM loss model are given in the **Table 8- 7 xprafts ARBM parameters**

Loss parameters: Values to be adopted for the initial/continuing loss model are given in **Table 8- 5 xprafts initial/continuing loss parameters**

2.1.1.6 Surface runoff routing

Surface Runoff Routing Parameters: The values given in **Table 8- 5 xprafts initial/continuing loss parameters** shall be adopted.

Table 8- 5 xprafts initial/continuing loss parameters

Parameter	Initial Loss (mm)	Continuing Loss (mm)
Impervious surfaces	1.0	0
Pervious surfaces	13.0	3.5

Table 8- 6 xprafts surface runoff routing parameters

Parameter	Value
Impervious surface roughness	0.015
Pervious surface roughness	0.040
Non-linearity coefficient (default)	-0.285

Table 8- 7 xprafts ARBM parameters

Parameter	Adopted Values	Initial Values
Storage Capacities		
Impervious (IMP)	0.5	0.0
Interception (ISC)	1.0	0.0
Depression (DSC)	1.0	0.0
Upper soil (USC)	25.00	20.00
Lower soil (LSC)	50.00	40.00
Infiltration		
Dry soil sorptivity (SO)	3.00	
Hydraulic conductivity (K0)	0.33	
Lower soil drainage factor (LDF)	0.05	
Groundwater recession;		
constant rate (KG)	0.94	
variable rate (GN)	1.00	
Evapo-Transpiration		
Proportion of rainfall intercepted by vegetation (IAR)	0.70	
Max potential evapo-transpiration;		
upper soil (UH)	10.00	
lower soil (LH)	10.00	
Proportion of evapo-transpiration from upper soil zone (ER)	0.70	
Ratio of potential evaporation to A class pan (ECOR)	0.90	

3.2.2 DRAINS (ILSAX)

2.1.1.7 Parameters

Loss parameters: For DRAINS (ILSAX), the parameter values in **Table 8- 8 DRAINS (ILSAX) parameters** shallbe adopted.

Table 8- 8 DRAINS (ILSAX) parameters

Parameter	Value
Impervious (paved) depression storage (mm)	1.0
Pervious (grassed) depression storage (mm)	5.0
Soil type	3.0
Antecedent Moisture Condition (AMC)	3.2

3.2.2.2 Time of concentration

Discretise: The time of concentration shall be determined for each sub-catchment.

Minimum: The minimum time of concentration to be considered shall be 5 minutes.

Method: The method of calculating time of concentration shall be selected based on the size and type of catchment.

General equation: Time of concentration shall be computed as the summation of travel times within eachflow path as follows:

$$t_C = t_{t1} + t_{t2} + t_{tm}$$

where,

t_c = time of concentration (minutes)

t_t= travel time of segment (minutes)

m = number of flow segments

Overland flow: In urban areas, the overland flow travel time component (t_0) of the total surface flow time (t_c) shall be estimated using the following equations:

$$t_0 = \frac{107nL^{0.333}}{5^{0.2}} \quad \text{for L} \leq 200 \text{ m}$$

$$t_0 = \frac{0.058L}{A^{0.1}5^{0.2}} \quad \text{for L} > 200 \text{ m}$$

where,

t_0 = overland shallow flow travel time (minutes)

n = Horton's roughness value for the surface (refer Table 8-9)

L = flow path length (m)

S = average vectored slope of surface (%)

A = catchment area (ha)

Concentrated flow: The travel time of concentrated flow segments in channels or pipes shall use an equation appropriate for the situation (e.g. Manning's for waterways).

Table 8- 9 Horton's roughness values

Surface type	'n' value
Paved surface	0.015
Bare soil surface	0.028
Poorly grassed surface	0.035
Average grassed surface	0.045
Densely grassed surface	0.06

3.2.3 RORB

2.1.1.8 Rainfall loss rates

Loss parameters: For RORB models, the rainfall loss parameters in **Table 8- 10 RORB pervious area rainfall loss parameters** shall be adopted for pervious areas.

Table 8- 10 RORB pervious area rainfall loss parameters

Parameter	Value
Initial loss (mm)	10
Runoff coefficient (%)	45

2.1.1.9 Surface runoff routing

Parameters: For RORB models, the runoff routing parameters in **Table 8- 11 RORB runoff routing parameters** shall be adopted.

Table 8- 11 RORB runoff routing parameters

Parameter	Value
m (adopt default)	0.8
kc (adopt default equation)	$2.2\ A^{0.5}$

A = catchment area (km^2)

3.2.4 WBNM

2.1.1.10 Rainfall loss rates

Approach: For WBNM, the initial/continuing loss model shall be used for both urban and rural catchmentsin preference to the initial/proportional loss model.

Loss parameters: The loss parameters shall be as recommended in **Table 8-12 WBNM rainfall loss values**.

Table 8- 12 WBNM rainfall loss values

Catchment	Initial Loss (mm)	AEP 50%	 20%	 10%	 5%	 ≤2%
		Continuing Loss (mm)				
Rural	**0**	**3.6**	**3.3**	**2.8**	**1.7**	**1.0**
Urban (30% urbanized)	**0**	**2.5**	**2.3**	**1.9**	**1.2**	**0.7**

2.1.1.11 Surface runoff routing

C parameters: The values of parameter C in **Table 8- 13 WBNM parameter C values** are recommended foruse with the initial/continuing loss model for modelling ungauged catchments.

Table 8- 13 WBNM parameter C values

No. of Sub-catchments	Parameter C
1	1.14
≥4	0.09

WCFACT parameters: For non-linear channel routing, the recommended values for the watercoursefactor, WCFACT, are given in **Table 8- 14 WBNM WCFACT values**.

Table 8- 14 WBNM WCFACT values

Watercourse Type	WCFACT
Natural channel	0.6
Gravel bed with rip-rap	0.4
Excavated earth	0.3
Concrete lined	0.2

4 WATERWAYS

4.1 General

4.1.1 General

General: Refer to **Appendix F** for additional guidance for Floodways.

4.1.2 Classification

Type: Waterways are overland flow conveyance systems that are the major components of the major drainage system. The types of waterways covered by this design standard are:

> Major waterways;

- Floodways: Constructed waterways to be provided wherever the estimated minor system design AEP flow exceeds the flow capacity of a twin 1200 mm pipeline.
- Natural waterways: Existing waterways generally in the form of steep-banked streams whichhave erodible banks and bottoms, or mild channels which are reasonably stabilised.
- Cut-off drains: Constructed waterways to protect development from runoff from urban edgezones such as hills, ridges and buffers.

> Minor waterways;

- Swales and Roadways: Utilised for training overland flows to a major waterway.

4.1.3 Design capacity

Requirement: Major and minor waterways shall be designed to safely convey the major storm event.

4.2 Location

Land use: Waterways shall be wholly located outside leased areas within designated drainage reserves. Ifcircumstances arise where this arrangement cannot be provided, prior agreement by both the Planning Authority and TCCS shall be obtained.

Development plans: Waterway reservations shall be clearly defined on all development plans to ensurethat future development does not encroach upon land inundated by flows up to and including the 1% AEP.

Discharge: Waterways shall discharge into a legal point of discharge with consideration for the capacity ofthe downstream asset to contain the flow without breaching its requirements.

Natural path: Diversion of waterways away from their natural paths will be permitted only in exceptionalcircumstances and only with the approval of TCCS.

4.2.1 Roadway reserves

Parking: Waterways are not permitted in urban street verges where on-street parking is provided.

Location: In new roadways, the edge of a waterway should generally be located adjacent to the road shoulder. In existing roadways, this alignment may be varied depending on the alignment and depth of existing underground services within the road verge. The Designer should consult TCCS for appropriate alignments in existing areas.

Location: Waterways may also be located within road median strips, provided the median is of sufficient width to contain the asset plus a 1.0 m berm on either side. The waterway should be centrally located within the median.

4.3 Design parameters

4.3.1 Longitudinal grades

2.1.1.12 Minimum grades

Minimum grade: Where possible waterways shall have a minimum grade of 0.5%. If this is impractical,minimum grades as low as 0.2% will be allowed if siltation has been considered in the design.

2.1.1.13 Maximum grades

Maximum grade: Longitudinal grades shall be chosen to minimise erosion with reference to the channel material such that the major design storm event average flow velocity will not exceed the limits shown in **Table 8- 15 Maximum flow velocities for major design storm event.**

Table 8- 15 Maximum flow velocities for major design storm event

Material	Maximum Flow Velocity*(m/s)
Loose mulch, sand, bare earth	0.5
Grass (dryland mix, unlisted grass mix)	1.0
Gravel, decomposed granite	1.0
Grass (couch, reinforced turf)	2.0
Low flow inverts (concrete)	4.0
Drop structures	Refer to **Underpasses**

* Average value for the full cross sectional area

4.3.2 Cross-section

Shape: Waterways shall be trapezoidal shaped where possible (refer **Figure 8- 2 Typical waterway cross section**). 'Vee' shaped cross-sections will also be accepted.

Batter slopes: Where possible batter side slopes should not exceed 1(V):6(H). However, TCCS may consider steeper side slopes up to a maximum of 1(V):4(H) if required.

Steep slopes: In exceptional circumstances, where slopes steeper than 1(V):4(H) cannot be avoided, a maintenance free slope should be provided with increased planting density and specially chosen plants. Particular care should be given to the plant and topsoil conditions of these slopes during establishment.

Base slopes: All slopes shall be adequate to ensure drainage without localised ponding occurring. The waterway base side slopes shall not be less than 1(V):50(H).

Preliminary sizing: A base width for a floodway may initially be estimated using the sizing charts provided in **APPENDIX B FLOODWAY PRELIMINARY SIZING CHARTS** for the floodway cross section shown in **Figure 8- 2 Typical waterway cross section** and Manning's n roughness values of 0.035 and 0.05 respectively.

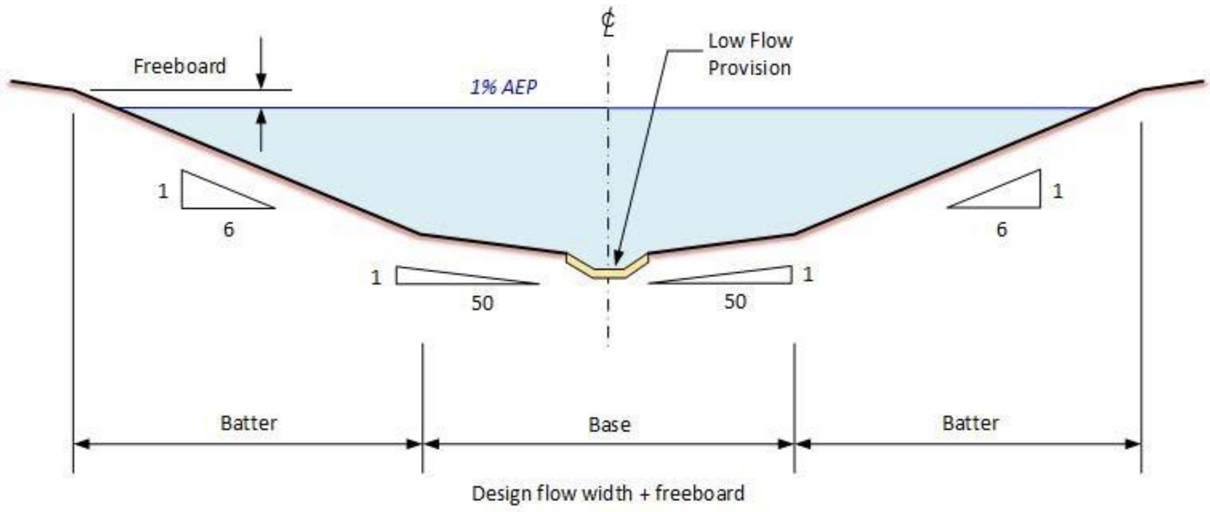


Figure 8- 2 Typical waterway cross section

4.3.3 Terracing & floodplains

General: Refer to **Appendix F** for interim floodplain planning and design.

Terracing: A terrace/floodplain may be introduced to a waterway to enable use of the terrace/floodplainfor other purposes such as recreation where flood protection less than the major design storm event is satisfactory.

Frequency of inundation: A terrace/floodplain shall not convey flow until the minor design event flow isexceeded (refer **Figure 8- 3 Typical waterway terracing**)

Base side slope: The minimum side slope for the base of the terracing shall be 1(V):50(H).

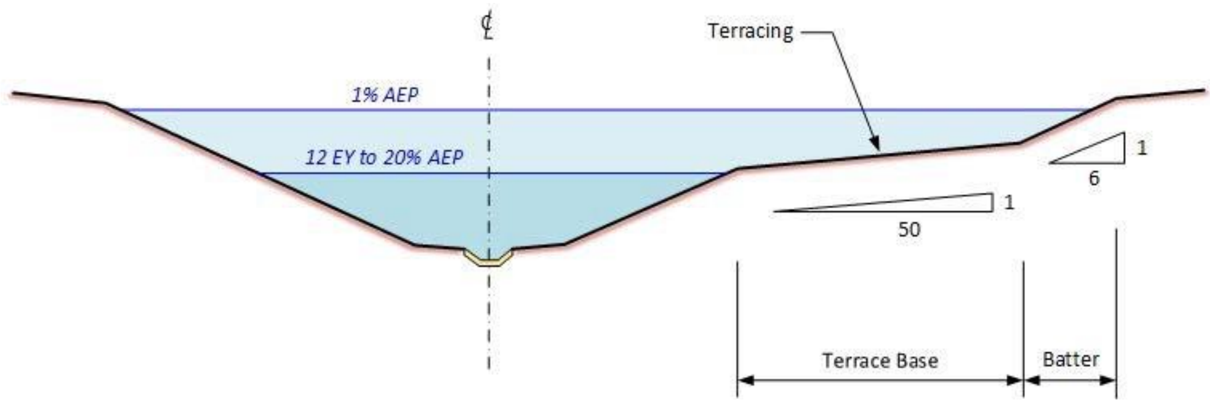


Figure 8- 3 Typical waterway terracing

4.3.4 Freeboard

General: Refer to **APPENDIX F** INTERIM FLOODPLAIN PLANNING AND DESIGN GUIDELINE for additional guidance for Freeboard.

Freeboard: Waterways must have a minimum freeboard based on their depth of flow and the major storm design flood level as set in **Table 8- 16 Minimum freeboard in waterways above the major storm design flood level.**

Table 8- 16 Minimum freeboard in waterways above the major storm design flood level

Design surface level	Minimum Freeboard (m)
Top of batter for a waterway with design flow depth < 0.3 m	0.1
Top of batter for a waterway with design flow depth 0.3-0.6 m	0.2
Top of batter for a waterway with design flow depth > 0.6 m	0.3
Bridges and culverts	Refer to **Bridges and Culverts**

4.3.5 Low flow provision

Requirement: Floodways should be provided with a low flow invert system when the catchment containsurban land use. Consult TCCS for advice on the requirement for a low flow invert system.

Capacity: Low flow inverts shall be designed for a minimum 12 EY flow capacity.

Preliminary sizing: The size of a low flow invert may initially be estimated using the sizing charts providedin **APPENDIX B** FLOODWAYPRELIMINARYSIZINGCHARTS.

Interface: Careful consideration shall be given to minimising the possibility of scour at the interface between the invert edge and the grassed surface of the floodway. It may be necessary to provide atransition zone using a stabilisation system such as reinforced grass.

Branch pipes: Attention shall also be given to making the transition of branch pipelines as smooth aspracticable to minimise turbulence and potential scour. Stabilisation may also be required on the downstream side of branch pipeline transitions.

Subsoil: A subsoil drainage system shall be provided for the invert. This may take the form of a standard subsoil pipe or geofabric wrapped aggregate.

Material: Inverts shall be constructed of reinforced concrete, mortared stone, revetment mattresses orother approved materials.

4.4 Waterway lining material

Material: Low maintenance grass is the preferred waterway lining material, however, alternative liningmaterials shall be considered to suit the situation and the selection shall be justified in documentation.

4.4.1 Roughness coefficients

Manning's roughness: Recommended Manning's roughness coefficient values for the design of waterwaysare provided in **Table 8- 17 Suggested values of Manning's roughness coefficient, n.** The Designer should use judgement in selecting a value to match the conditions of the waterway.

Sensitivity: The range of Manning's roughness values provided in **Table 8- 17** should be used to check the sensitivity of a waterway to varying roughness conditions throughout the design life of the waterway dueto vegetation type, season, and degree of maintenance. The potential effect on scour, siltation and flow depth shall be taken into account in the design.

Table 8- 17 Suggested values of Manning's roughness coefficient, n

Surface Cover	Suggested n values	
	Recommended	Range
Concrete, smooth formed	0.013	0.011 - 0.015
Bituminous concrete	0.015	0.012 - 0.018
Sprayed seal pavement	0.018	0.017 - 0.024
Shotcrete	0.020	0.016 - 0.025
Earth	0.022	0.018 - 0.030
Random stones in mortar or gravel	0.025	0.020 - 0.035
Short grass	0.035	0.025 - 0.035
Tall grass	0.040	0.030 - 0.050
Rock riprap	0.035	0.030 - 0.050
Scattered trees or brush	0.050	0.040 - 0.070
Rough cross-sections with boulders	0.060	0.030 - 0.100
Dense weeds or light brush	0.070	0.060 - 0.080

4.4.2 Composite waterways

Composite waterways: Estimation of an equivalent or composite Manning's roughness value in a waterway of varying roughness is required where there is a marked variation in the surface roughnessacross an individual cross-section. Examples of this situation include a waterway containing a concretelow flow invert, or a waterway containing a low level footpath, cycleway or access track.

Roughness estimation: The following equation may be used to estimate the overall roughness coefficientin engineered waterways of composite roughness:

$$n^* = \frac{\frac{A^{5/3}}{P^{2/3}}}{\sum_{i=1}^{m} \frac{A_i^{5/3}}{n_i P_i^{2/3}}}$$

where,

n^* = equivalent Manning's roughness coefficient for the whole cross-section

n_i = Manning's roughness coefficient for segment *i*

A = flow area of whole cross-section (m²)

A_i = flow area of segment *i* (m²)

P = wetted perimeter of whole cross-section (m)

P_i = wetted perimeter of segment *i* (m)

m = total number of segments

4.4.3 Natural waterways

General: The design standards for waterways can be utilised in gauging the adequacy of a natural waterway for future changes in runoff regime. However, natural waterways do not necessarily have to comply with every aspect of the design standard. An appreciation for the condition (e.g. erosion) of the waterway in the existing, future and pre- development scenarios should be applied in their design.

4.5 Cut-off drains

4.5.1 General

Requirement: Cut-off drains shall be provided to regulate surface runoff from public and unleased land such as urban edge zones adjacent to:

- Road reserves; and
- Lease boundaries where the total uphill catchment is greater than 0.5 hectares.

Location: Cut-off drains should be located such that the area between the drain and lease boundaries which will contribute surface runoff directly to leases is minimised as far as practicable.

Refer: Cut-off drains are part of the urban edge zone and shall be considered in the context of *MIS 15 Urban Edges Management Zone.* The management of the urban edge zone will generally incorporate a number of diverse functions other than protection of development from surface runoff. Designers should consider the total objectives of the edge zone and provide multi-functional facilities wherever possible.

Design flow: Cut-off drains shall be sized for the major storm event.

4.5.2 Primary outlets

Design flow capacity: Provision shall be made to discharge all flows from a cut-drain up to and including the major storm event.

Discharge points: Design flows shall normally be discharged to a designated overland flow path via and outlet pipe or a spillway chute. Discharge points shall be provided at intervals not exceeding 600 m.

Outlet pipes: Where outlet pipes are provided, care shall be taken in the design to ensure that the entire major storm flow from the cut-off drain can be transferred to the outlet pipe.

Screening: Inlet screening shall be provided to minimise the likelihood of blockage of the outlet pipe from large debris.

4.5.3 Relief spillways

Requirement: Relief spillways shall be provided to discharge flows in excess of the waterway capacity or in the event of blockage if the following conditions are met:

- Flow overtopping the waterway bank will enter and damage leasehold property; or
- The waterway runs parallel to contours.

Location: Relief spillways shall be provided at regular intervals with a maximum spacing of 600 m

Capacity: Relief spillways shall be designed to have a minimum capacity of the major design storm

event.

Discharge location: Where possible relief spillways shall discharge to designated overland flow paths. Where these are not available, the number of relief spillways shall be increased to avoid concentration ofdischarge and so minimise potential property damage. TCCS shall be advised of such instances, and the proposed spillway locations submitted for consideration prior to completing final designs.

Energy dissipation: Relief spillways shall be stabilised to prevent scour and provided with adequate energydissipation measures for supercritical flow.

4.5.4 Longitudinal grades

Refer: **Design capacity** for grading requirements.

4.5.5 Side slopes

Maximum: Maximum side slopes shall be:

- Slope in fill 1(V):2(H)
- Slope in cut: earth 1(V):2(H)
  rock 1(V):0.25(H)

4.5.6 Access tracks

Track requirement: An all-weather access track with a minimum width of 3.5 m shall be provided along the total length of the cut-off drain.

Cross fall: The access track shall be designed with the cross fall into the slope. The cross fall shall be within the following limits:

- 3% minimum
- 10% maximum

Scour protection: Adequate scour protection shall be provided for the track and access points. Forlongitudinal gradients exceeding 10%, the track should be surfaced with one of the following:

- Two coat seal;
- Reinforced concrete;
- Unit paving;
- Bitumen stabilised decomposed granite gravel; or
- Fine crushed concrete or rock.

Passing width: Where access tracks have insufficient width to allow maintenance vehicles to pass, pullover bays shall be provided at a maximum spacing of 100 m.

4.5.7 Access from urban areas

Access interval: Access from the urban road network via feeder roads, culs-de-sac, pedestrian ways, orfloodways shall be provided at intervals not exceeding 500 m.

Access points: Access points shall have a minimum width of 3.5 m to allow unconstrained access for maintenance vehicles. Structures should not be allowed to impinge on the access.

Unauthorised access: Provision shall be made to prevent access to the asset by unauthorised vehicles. Consult TCCS for requirements.

4.5.8 Access to higher areas

Requirement: Crossing points may be required to gain access to areas above a cut-off drain. The Designer shall refer to TCCS for the requirement and location of crossing points.

4.5.9 Minor drain

Consider: For small catchment areas, or in relatively flat terrain, it may be possible to utilise the access track as the waterway to provide 1% AEP flow capacity. Refer to **Figure 8- 4 Typical access track configurations.**

4.5.10 Major drain

Requirement: A separate waterway must be provided wherever the cross sectional area of a cambered track is insufficient to provide 1% AEP flow capacity. Refer **Figure 8- 4 Typical access track configurations.**

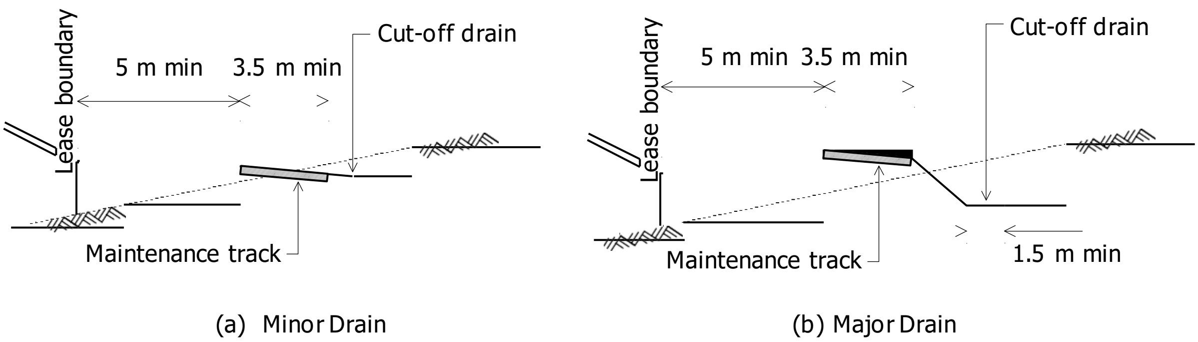


Figure 8- 4 Typical access track configurations

4.5.11 Maintenance

General: Cut-off drains shall be designed to allow for ease of maintenance, including ready access for maintenance machinery.

Design: Cut-off drains should be designed so that mechanical grass cutting equipment (ie. motor or tractor-mounted mowers) can be used to control grass and weed growth. Maintenance on the drain cross-section should be possible using conventional earthmoving equipment such as backhoes, front-end loaders, and trucks.

Exception: Where conditions do not permit ready access, cut-off drains shall be designed for minimum maintenance by providing such measures as concrete lining or stone-pitching of the drains.

4.6 Erosion and scour protection

Channel material: Waterway linings shall be chosen to provide erosion protection up to the major design storm event conditions as specified in **Table 8- 15 Maximum flow velocities for major design storm event.**

Local erosion: Erosion protection measures shall be considered at the following locations at a minimum inorder to protect against localised erosion:

- Transitions: Any changes in cross-section or changes in waterway lining material. Particular attention should be paid to the region immediately alongside low flow inverts.
- Bends: The outside bank of bends will be subject to higher flow velocities.
- Branch pipelines: Waterways usually have many small capacity branch pipeline connections. Flows from these branch pipelines will normally be of relatively high velocity and the angle of entry will cause turbulence in the waterway.
- Waterway tributaries: Other waterways entering the main waterway system may cause turbulence and erosion of the waterway bottom and opposing bank.
- Energy dissipator structures: Changes in the flow regime will usually occur immediately upstream and downstream of drop structures and energy dissipation basins.
- Culverts: Exit velocities from culvert crossings will normally be supercritical.
- Bridges and underpasses: Flow velocities around piers and abutments may be higher than the waterway limit.

Toe protection: Erosion protection facilities must have deep toe protection to prevent failure by undermining.

4.7 Waterway design elements

4.7.1 Vegetation

Limit: In general, no vegetation or trees are to be within a waterway other than grass.

Exception: In some instances, tree and shrub planting within the waterway may be desirable to reduce velocities and therefore should be considered as an integral part of the stormwater system. The area of such waterways shall be increased to allow for tree and shrub planting.

Selection: Select appropriate vegetation for the site from the *MIS 25 Plant species for urban landscape projects* according to the inundation condition at the plant's location.

Cover: Vegetated landscapes should be planted to achieve a minimum of 90% cover at the landscape practical completion date.

Topsoil: Topsoil should be well stabilised during establishment as topsoil erosion is one of the most common causes of poor vegetation growth.

Floodplains: No trees other than those with clean boles, strong crown structure, and no propensity for root suckering may be planted in the floodplain or waterway.

4.7.2 Crossings

Requirement: Crossing points may be required to gain access across a waterway. The Designer shall refer to TCCS for the requirement and location of crossing points.

2.1.1.14 High-level

Culvert crossing: To avoid the exposure of pedestrians to flood flows, a culvert or bridge crossing with a minimum capacity of the major design storm event is preferred. These should be designed to **BRIDGES AND CULVERTS.**

Material: The crossing point shall be provided with a hard surface.

Maintenance access: Where it is likely that maintenance vehicles such as grass slashing and mowing operations will use a crossing, it shall be designed for a 7 tonne wheel load in a W-7 configuration in accordance with the *AUSTROADS Bridge Code (AS 5100).*

2.1.1.15 At-grade

Limitation: A crossing may be designed at-grade only in special circumstances where the requirements for pedestrian exposure to flood water and egress are met.

Restrictions: Crossings shall follow the shape and grade of the waterway as far as practical to avoid flow restrictions and minimise changes to the flow regime.

Side slopes: At grade crossings will only be allowed where side slopes are not steeper than 1(V):6(H).

Low flow clearance: Crossings spanning low flow inverts shall have a minimum 200 mm clearance above the base of the invert to minimise the likelihood of blockage by litter and debris.

Material: The crossing point shall be provided with a hard surface to delineate the point as a crossing, provide scour protection, and prevent damage to the waterway by vehicles. A hardstand area shall be provided at the floodway invert on the downstream side of the crossing to prevent the likelihood of water ponding in the crossing due to grass build-up.

4.7.3 Maintenance

Minimise: Waterways shall be designed to minimise or avoid maintenance wherever possible, particularly where conditions do not permit ready access. This shall be achieved by the appropriate selection of design attributes (e.g. longitudinal grade) and materials (e.g. plant selection).

Type: Waterway assets shall be designed to receive only rubbish collection maintenance. If grass cutting or earth moving is required then this should be clearly defined in the operational procedure.

Access: Where maintenance is required waterways shall be designed to allow for ease of access by mechanical grass cutting and earth moving equipment.

4.7.4 Advisory signs

Signage: Floodway advisory signage should be placed on floodways where the velocity x depth limit set for a waterway set in **Table 8- 2 Velocity x depth limits for major design storm event** is exceeded.

Signage location: Floodway advisory signs (Refer *ACTSD-0856 Stormwater advisory signs – Sheet 2*) should be placed at points of congregation (eg. pathways leading to floodway low-level pedestrian crossings) and at intervals of approximately 500 metres or shorter if there is a line of sight issue between posts.

5 ROAD CONVEYANCE

5.1 General

5.1.1 Road and street network

General: Urban street drainage systems are required to operate in an effective and maintenance free manner. The following provisions shall apply:

> Gutters shall be provided for all kerbs where pavement areas drain to the kerb;
> Adequate pipe and pit inlet capacity shall be provided such that surface flows up to the minor system design AEP are drained from the surface;
> Close attention should be given to the placement and location of drainage inlets to minimise driveway conflicts and to adequately intercept surface water from steep longitudinal grades. This particularly applies where a steep side street intersects a cross street at a 'T' intersection;
> The design of driveways across the verge should take account of water flowing in the street. The verge and driveway profile must maintain a positive grade for sufficient distance behind the kerb to avoid road flows in excess of the minor drainage system capacity up to the major design storm flow from entering adjacent leases;
> The use of high inlet capacity pits should be avoided wherever possible and will only be permitted in non-residential areas;
> Grated inlet pits will not be permitted except in laneways with narrow verges where a type R or type QS pit would conflict with other services; and
> A dedicated overland flow path shall be provided at all road low points to ensure that overflows do not inundate downstream leases in flows up to and including the major design storm event.

5.2 Surface flow criteria

Consider: Surface flow criteria must be applied to minimise both nuisance and hazardous flooding conditions on roadways. The criteria comprises the following three basic limits, depending on the road lane configuration and the design storm AEP:

> A flow width limit;
> A ponding or flow depth limit; and
> A flow velocity x depth limit (for stability of pedestrians and vehicles).

Criteria: Surface flow criteria road drainage design are provided **Table 8- 19 Surface flow criteria for roads** and **Figure 8- 5 Allowable flow widths on roadways – minor design storm event** (Source: adapted from Queensland Road Drainage Design Manual, 2010).

5.2.1 Freeboard

Freeboard: Roadways must have a minimum freeboard as set in **Table 8- 18 Minimum freeboard in roads above the major storm flood event.**

Table 8- 18 Minimum freeboard in roads above the major storm flood event

Design surface level	Minimum Freeboard (m)
Top of road reserve (e.g. shoulders & driveways) if flow through properties may occur when kerbs are overtopped (e.g. road in fill)	0.1
Entrances to underground car parks	0.3

5.2.2 Embankments

Embankments: Where temporary ponding of water is likely to occur due to a roadway (or other) embankment these should consider the requirements of **RETARDING BASINS** for the safe design of retardingbasins.

5.2.3 Protection drains

Requirement: Roadways in cuttings and cut batters should be adequately protected from runoff originating beyond the limits of the road. This protection will generally take the form of cut-off drains ordished gutters.

Refer: **Cut-off drains** for requirements for cut-off drains.

Table 8- 19 Surface flow criteria for roads

Criteria	Design storm event classification	Surface Flow Limit
Two through lanes in the same direction	Minor	One full clear lane + minimum 2.5 m clear width in the other lane
One lane plus parking lane	Minor	One full lane clear
One lane	Minor	Minimum 3.0 m clear width in the lane
At medians	Minor	Minimum 2.5 m clear width in the traffic lane
At turn lanes	Minor	Minimum clear width of 3.0 m in the lane
At intersection kerb returns	Minor	Clear turning width of 3.0 m
All roads	Major	Total flow contained within road reserve.
Bridges	Major	Minimum 3.0 m clear width in the lane
For roads with kerb and adjacent leases	Major	Flood depth to be limited to 50 mm above top of kerb
For roads with no kerb and adjacent leases	Major	Flood extents not to encroach on adjacent leases
2% AEP Event – Major Traffic Routes	Other	One full lane clear Maximum 0.45 m flow width from gutter invert
1 EY Event – Pedestrian Crossings	Other	One full lane clear Maximum 0.45 m flow width from gutter invert

(Source: adapted from Queensland Road Drainage Design Manual,2010)

Notes:

1. Clear width criteria applies to each direction of traffic flow.
2. Flow affected area shall be taken as that where the flow depth is greater than 3 mm.
3. Lane includes acceleration or deceleration lanes > 60 km/h and any parking lane that has the potential in the future to become used as a through lane for full or part time.

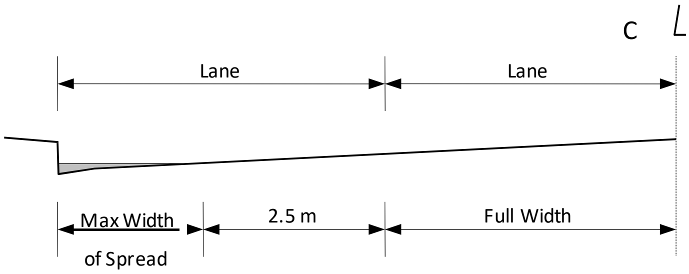
5.2.4 Underpasses

Free drainage: Pedestrian underpasses on roadways shall be provided with sufficient longitudinal grade to facilitate free drainage up to the major design storm event wherever possible.

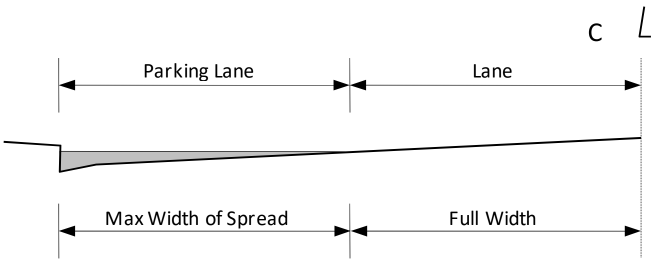
Trapped low point: Where a self-draining underpass is not possible, the underpass drainage system shall be designed for the 5% AEP storm event.

Grating: Public safety and blockage considerations preclude the use of grated sumps or grated strip drains in underpasses.

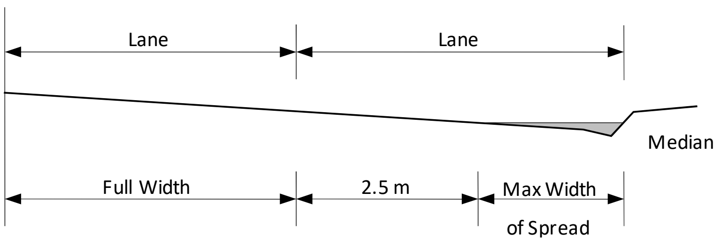
Signage: A floodway advisory sign shall be provided on each approach to the underpass (refer to **Advisory signs).**



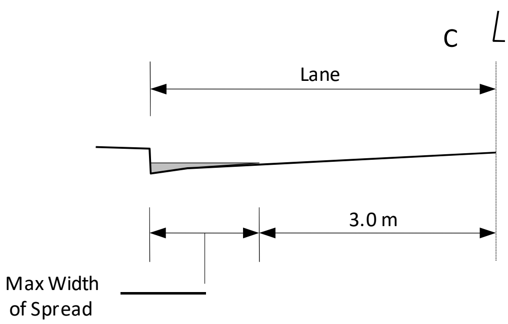
(a) Two Through Lanes in the Same Direction

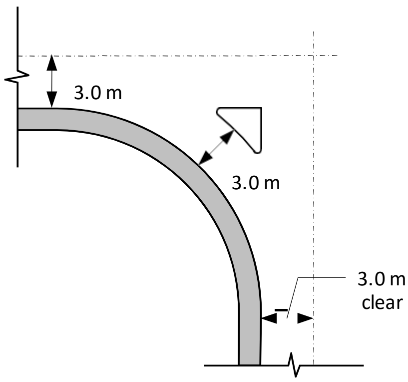


(b) One Lane + Parking Lane



(c) At Medians





(d) One Lane

(e) Turn Lanes and Intersection Kerb Returns

Figure 8-5 Allowable flow widths on roadways – minor design storm event (Source: adapted from Queensland Road Drainage Design Manual, 2010)

6 DROP STRUCTURES

Requirement: Drop structures should be provided to reduce waterway longitudinal grades such that 1%AEP average flow velocities meet the requirements of **Table 8- 15 Maximum flow velocities for major design storm event.**

Drowning out: Drop structures shall be designed to ensure that the structures do not 'drown out' underthe design flow plus freeboard.

6.1 Longitudinal design

Longitudinal grade: Longitudinal grades shall not exceed 1(V):1(H). Vertical faces will not be

permitted.Maximum: The maximum height of a drop structure shall be 1.8 m.

Fish passage: Where the structure occurs in a waterway populated with fish the requirements for fishpassage should be considered.

6.2 Materials

Materials: Drop structures shall be constructed of any of the following durable permanent materials (refer **Figure 8- 6 Typical drop structure section details** for drop structure typical section details):

- Reinforced concrete;
- Mortared stone;
- Rock riprap; or
- Revetment mattress.

Concrete: Concrete shall be a minimum of 25 MPa and be in accordance with *MITS 06 Concrete kerbs,footpaths and minor works.*

6.3 Scour protection

Requirement: A scour protection apron shall be provided at the upstream edge and downstream toe ofthe structure. The downstream apron length shall be sized as follows:

$$L = K(d + H)$$

where,

L = downstream apron length (m)

K = subsurface material;

= 1 for hard clay

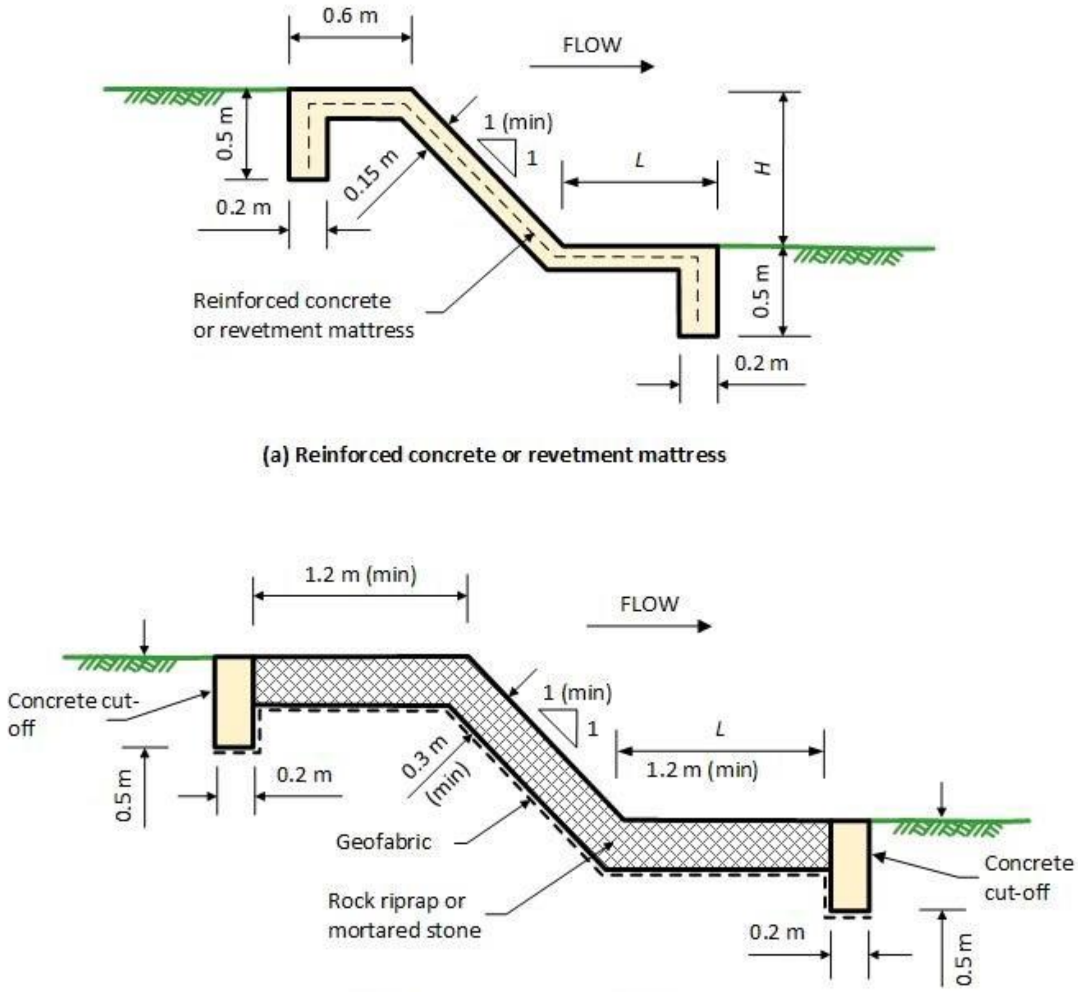
= 2 for fine gravel

= 2.5 for sandy loam

= 3.5 to 4.5 for sand

d = 1% AEP flow depth (m)

H = height of drop (m)



(a) Reinforced concrete or revetment mattress

(b) Rock riprap or mortared stone

Figure 8- 6 Typical drop structure section details

6.4 Safety

Velocity x depth: Velocity depth products listed in **Table 8- 2 Velocity x depth limits for major design storm event** recognise that these limits will be exceeded in localised areas such as drop structures. As a result, particular attention should be placed on limiting access to these areas such as by providing barriers.

7 PIPES

7.1 General

7.1.1 Hydraulic design

Hydraulic grade line (HGL): Perform calculations to latest edition of ARR. Record: Document and

provide hydraulic information to include the following:

> Detailed drawings of the HGL; and
> Listing of all program input and output.

Downstream control: Adopt the appropriate downstream water surface level requirements from the following options:

Known HGL level from downstream calculations including pit losses at the starting pit in the design event;

- If the downstream starting point is a pit and the HGL is unknown, then adopt a level of 0.15 m belowthe invert of the pit inlet in the downstream pit;
- If the outlet is an open channel and the design storm is minor, then the top of the outlet pipe is thedownstream control;
- If the outlet is a waterway, the design storm is major and downstream flood levels are not known,then the top of the bank of the waterway is the downstream control; or
- If the outlet is a waterway, the design storm is major and downstream flood levels are known, thenthe downstream control is the major storm flood level.

7.1.2 Size

Size: Minimum pipe diameters shall be in accordance with **Table 8- 20 Minimum pipe diameters.**

Maximum: Maximum diameter shall be 1200 mm. Larger pipes shall be referred to TCCS for approval.

Table 8- 20 Minimum pipe diameters

Pipe type	Diameter (mm)
Pipes generally	225
Any pipe draining a sump	300
Any pipe draining water from a surface subject to traffic loads	300
For a non self-draining underpass, the pipe shall be sized for5% AEP and shall not be less than	300
Culvert under roads	450

7.1.3 Materials

Preference: Reinforced concrete pipes, complying with *AS 4058*, are

preferred.Alternative: FRC pipes complying with *AS 4239.*

Alternative: HDPE solid wall pipes may be used where traffic loads are in accordance with the

Manufacturer's specifications. This material may not be used in commercial or industrial zoned

areas.

2.1.1.16 Loading

Class: Pipe class shall be selected to provide adequate strength to meet overburden, construction andtraffic loads.

Loading: Pipe loadings shall be determined in accordance with the relevant Australian Standard for the pipe material in question. In assessing pipe loadings, consideration shall be given to bedding type, relativetrench widths, uneven loading conditions, live loads, and construction loads.

Documentation: Where load limits apply, the location and load limitation shall be clearly shown on thedrawings.

7.2 Horizontal alignment

7.2.1 Roadway reserves

Road reserves: Stormwater pipelines should be located on the high side of road reserves to permitrelatively short service tie connections to adjacent properties.

Alignment: Acceptable alignments shall be in accordance with **Table 8- 21 Alignments within roadway reserves.**

Table 8- 21 Alignments within roadway reserves

Diameter (mm)	Alignment (m)
225 to 675	0.6 behind kerb line
750 to 1200	within median strip or roadway

Preference: Curved pipeline alignments are preferred on curved roadways. However, where there aresignificant advantages, e.g. cul-de-sac or narrow street verges, straight alignments may be permitted.

Consideration: In selecting pipeline locations, it is necessary to consider manhole and sump locations.

7.2.2 Leased land

Location: A stormwater pipe shall only be located within land to be leased where it is intended solely forthe purpose of providing drainage for the lease or adjacent leases. Such services should be located such that maintenance access can be readily achieved and restrictions imposed on the use of the land due to the presence of the service are minimised.

Approval: Stormwater pipes should not be constructed through land already leased. However, where suchworks cannot be avoided, the Designer shall refer the proposed design to TCCS for consideration.

Boundaries: Wherever stormwater pipes are required along shared lease boundaries, they should be located along the high side of the downhill lease. Stormwater pipelines are often constructed in parallel tosewers and as the sewerage system is usually deeper, pipes connecting to stormwater ties have fewer problems in crossing over the sewer.

Refer: Where a proposed development abuts undeveloped land which has the potential to be developed,the possibility of a shared service exists. Because it is undesirable to maintain unnecessary parallel services, the Designer shall refer any intended boundary service to TCCS for possible co-ordination of services.

Maintenance: Alignments shall be offset sufficient distance from building lines to allow working room forexcavation equipment.

Alignment: Acceptable centreline offset alignments from lease boundaries in residential, commercial, andindustrial areas shall be in accordance with **Table 8- 22 Alignments within leased land.**

Table 8- 22 Alignments within leased land

Diameter (mm)	Rear Boundary (m)	Side Boundary (m)
225 to 450	1.8	1.2
525 to 675	1.8	1.5

Minimum gap: Where electrical services are located on the same side of a lease boundary, the centreline of the stormwater pipeline shall be located 1.8 m from the lease boundary.

7.2.3 Unleased land

Location: The location of stormwater pipes within unleased public land such as open space shall be brought to the attention of TCCS for consideration. As a guide, unless directed otherwise, stormwater pipelines shall be located 5.2 m off the nearest lease boundary.

7.2.4 Curved pipelines

Reasoning: Curved stormwater pipelines may be utilised wherever there are significant advantages in their use. Ad hoc curving of pipelines to avoid obstacles such as trees, power poles, gas mains etc. is not permitted. Curved pipelines should be positioned to follow easily identifiable surface features, e.g. parallel to a kerb line.

Consistency: Curved pipelines shall have a constant radius.

Requirements: Curved pipelines are permitted provided they

are:

- In the horizontal plane only (no vertical curves); and
- In one direction only between successive structures (no reverse curves).

Construction: Curved pipelines shall be achieved as follows:

- Curves formed by using rubber ring or flush jointed pipes: the curve shall be achieved totally within the pipe joint system so that the rubber ring or external proprietary band remains effective. Because of different pipe joint performances, the maximum deflection angle shall be as recommended by the pipe manufacturer.
- Curves formed by using splayed pipes: splayed pipes may be used to construct a curved pipeline provided that the curve is totally formed by the splays.

Formation: Splayed pipes shall be either:

- Factory formed (preferred), or
- Field formed by cutting standard pipes with an approved cutting device.

Documentation: Design drawings shall show the following curve information:

- Centreline radius;
- Pipe type (normal or splayed);
- Effective length of individual pipes (if other than standard length);
- Type of jointing; and
- Tangent points.

Documentation: The Designer shall submit documentation to show that the above details are within the Pipe Manufacturer’s specifications.

7.3 Vertical alignment

7.3.1 General

2.1.1.17 Minimum depth

Minimum depth: Stormwater pipelines shall be deep enough to serve the whole of the adjacent block(s).

Minimum cover: Minimum cover over pipelines shall be 0.6 m from top of pipe to finished surface level. For pipelines under road pavements, the required cover shall be measured from top of pipe to pavementsubgrade level. Where this is not possible, a higher class pipe shall be used.

2.1.1.18 Maximum depth

Maximum depth: The maximum depth of stormwater pipelines to invert level shall be 6 m.

7.3.2 Grades

Definition: The longitudinal grade of a pipeline between drainage structures shall be calculated fromcentreline to centreline of such structures.

Minimum: Stormwater pipelines shall be designed and constructed to be self-cleansing, e.g. free from accumulation of silt. The desirable minimum grade for pipelines is 1.0%. An absolute minimum grade of0.5% may be acceptable where steeper grades are not practical. Such instances shall be brought to the attention of TCCS for consideration before finalising designs.

Maximum: Pipeline grades shall be chosen to limit the pipe full flow velocity to a value less than or equalto 6.0 m/s.

Scour stops: Pipelines laid on steep slopes shall be protected from failure due to wash-out of bedding. Where pipeline grades are greater than 7%, scour stops shall be provided at a maximum of 5 m intervals. Each block shall be 300mm wide (measured parallel to the pipe axis), extend into the solid trench sides and bottom by 150 mm and extend 75 mm above the crown of the pipe. A flexible joint shall be providedon both sides of the scour stop in accordance with *ACTSD-0831 Pipe connections.*

Vertical angles: Stormwater pipelines shall be constructed so that the bore of the pipe has no point wheredebris can lodge and cause reduction in capacity. The use of vertical angles will not be permitted.

7.4 Drainage easements

7.4.1 General

Width: A drainage easement shall be wide enough to contain the service and provide working space oneach side of the service for future maintenance activities.

Leases: Only pipelines up to and including 675 mm diameter may be located in easements within leased properties. Larger diameter pipelines shall be located outside leased properties in unleased open space or in separate drainage reserves.

Structures: In circumstances where stormwater pipelines are located in easements within leased properties only open space or the following structures can be constructed: light vehicle car parks (no trucks) or open sheds. In these situations the clearance between finished floor and the underside of the roof shall be greater than 3.5 m. Further the footing loadings should not impinge or bear on the pipe. The pipe installed should take the ultimate loadings proposed for future needs. The use of the easement as an internal access should be avoided.

Access: In some developments, direct maintenance access to a stormwater main within a block may be difficult or prevented entirely. In such cases, easements and inter-allotment pipelines shall not terminate at a dead end but shall be extended to a point where access may be gained from a road reserve or other unleased area with direct access. A manhole shall be located on both ends of the pipeline to facilitate access.

Minimum width: Minimum drainage easement widths shall be in accordance with **Table 8- 23 Minimum drainage easement widths.**

Table 8- 23 Minimum drainage easement widths

Diameter (mm)	Easement Width (m)	
	Single Easement	Common Easement
0 - 3.0 m deep		
225 to 450	2.5	3.5
525 to 675	3.0	3.5
3.0 - 6.0 m deep		
225 to 450	3.5	4.5
525 to 675	4.0	5.0

Note: Where other hydraulic services or electrical services are located within the same reserve, the required reserve width shall be increased to provide adequate clearance between services (refer to Table 8-24 Minimum clearances).

7.5 Connections and jointing

7.5.1 Connection to structures

Requirement: Where pipes are connected to rigid structures or are embedded in concrete, flexible joints shall be provided to minimise damage caused by differential settlement.

Standard drawing: Connections shall be constructed in accordance with *ACTSD-0831 Pipe Connections.*

7.5.2 Branch connections

Requirement: Pipeline junctions should occur within a sump, manhole, or special structure. Branchconnections may be permitted provided that adequate structural strength can be achieved at the junction.

Size: Allowable sizes of branch connections into pipelines of 375 mm to 1200 mm diameter are shown on *ACTSD-0801 Typical Pipe Junctions.*

Requirement: A manhole shall be constructed on the branch pipeline within 20 m of the branchconnection.

Entry angle: Entry angles for branches shall be between 45° and 90° to the main pipeline in horizontal direction only (refer to **Figure 8- 7 Permissible entry angles for branch connections**). Vertical entry will notbe permitted.

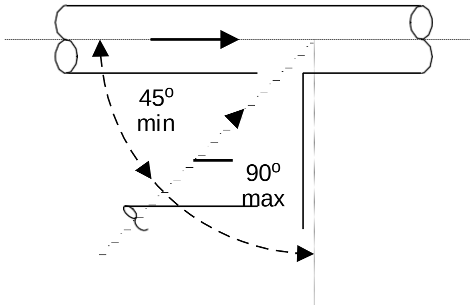


Figure 8- 7 Permissible entry angles for branch connections

7.5.3 Jointing

Requirement: Pipes need to be capable of resisting root intrusion, hydraulic pressure, soil loading, and preferably have some flexibility at joints.

Type: Pipe jointing shall be as follows:

> 100 mm to 375 mm diameter pipes shall be rubber ring jointed, except for 100 mm uPVC pipes whichshall be solvent welded;

> 450 mm diameter and larger pipes shall be rubber ring jointed, or flush jointed with an external proprietary band (e.g. Humes EB band, Rocla Sand or similar). However, pipes designed to operateunder hydraulic conditions that exceed 2.0 m head shall have rubber ring joints; and

> 450 mm to 675 mm diameter pipes located under roadways shall have rubber ring

joints.Documentation: Locations of various joint types shall be shown on the design

drawings.

Maximum head: The maximum allowable head for all pipes shall be in accordance with the appropriateAustralian Standard.

7.6 Dead end pipelines

Requirement: A dead end pipeline shall be constructed on a straight alignment and shall not be greaterthan 50 m in length.

Connection: Dead end pipelines shall drain directly to a manhole or sump. Connection of a dead end pipeline to another stormwater pipeline by a branch connection or slope junction will not be permitted.

7.7 Service ties

Requirement: Each new lease shall be individually serviced with a single service tie and riser from a stormwater pipeline to provide for drainage of buildings on the lease. However, on redevelopment andlarge multi-unit sites, if the provision of a single tie will not service the entire lease or is considered impractical, TCCS may permit additional service ties to be provided.

Exception: In some cases, such as blocks in a cul-de-sac or for 'preserved environmental areas', specific approval may be given for a direct connection to a stormwater pipeline to be waived and provision made for drainage to be connected to a road gutter or directed to an overland drainage path.

Standard drawing: Service ties and risers shall be provided in accordance with *ACTSD-0802 Typical service connections.*

Redevelopment: On redevelopment sites where existing blocks have been consolidated into a largersingle lease, all excess ties shall be disconnected at the main.

7.7.1 Depth

Requirement: The service tie shall be deep enough such that the lease drainage system can command thewhole lease at a grade not less than 0.5% with 400 mm minimum cover within the lease.

Minimum cover: The service tie shall have 600 mm minimum cover over lease drainage pipes at theservice tie connection.

Maximum cover: The service tie shall have 3.0 m maximum cover over lease drainage pipe at the servicetie connection.

7.7.2 Location

Preferred connection: Wherever practical, a service tie should be connected to a manhole or sump inpreference to a separate connection into a stormwater pipeline.

Connection to pipeline: A service tie connected to a stormwater pipeline shall be at right angles to thepipeline with the actual inlet made using a 45°slope junction.

Connection to structure: Where a service tie is connected to a manhole or sump, the horizontal connection angle shall be greater than or equal to 90° to the centreline of the downstream pipeline.

Lease boundary: Where the stormwater pipeline is located outside the lease, the service tie shallterminate 1 m inside the lease boundary.

Typical location: Service ties shall generally be located 3.5 m from the lowest corner of the block

(Refer **Figure 8- 8 Typical location for service tie**).

7.7.3 Size

Size: Service ties shall normally be 100 mm diameter rubber ring jointed pipes.

Refer: The size of service ties shall be calculated in accordance with the requirements of the *Building Codeof Australia* and *AS 3500* for the AEP of the minor stormwater drainage system as specified in **Minor design storm event.**

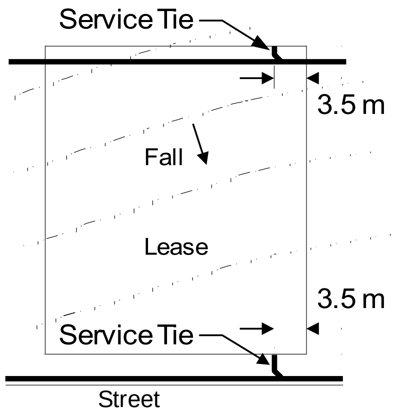


Figure 8- 8 Typical location for service tie

7.7.4 Grade

Grade: Service ties shall be constructed at a grade between 0.5% and 10.0% and terminate in a sealedpipe socket.

Approval: If required, service ties may be connected to the pipeline at a steeper grade by using a suitablebranch connection or 45° riser. Such cases shall be brought to the attention of TCCS for consideration.

7.7.5 Maximum length

Maximum length: The maximum length of a service tie shall be 20 m.

7.7.6 Connections

Connection method: Service tie connections into 225 mm to 375 mm diameter pipelines shall be made bymeans of a rubber ring jointed slope junction, or approved saddle slope junction, and 45° bend plus an appropriate length of pipe with the branch end sealed.

Connection method: Service tie connections into 450 mm to 600 mm diameter pipelines shall be made by means of an approved saddle slope junction. The tie piece shall be as short as possible and consist of a 45°angled socket piece epoxy jointed.

Standard drawing: Where the stormwater pipeline is 375 mm or larger, service ties may be connected asbranch connections as detailed on *ACTSD-0801 Typical Pipe Junctions.*

7.7.7 Marking

Marking type: Service tie locations shall be identified with a plastic tape. The tape shall be nominally 75mm wide and coloured 'blue' to *BS 4800 No.10C31* in accordance with the latest edition of *AS 2648.*

Marking method: The tape shall be secured to the end of the service tie and brought vertically to the surface and attached to a marker stake. The marker stake shall protrude at least 300 mm above the finished surface.

7.7.8 Clearance from other services

Disallowed methods: Under no circumstances shall stormwater pipelines be:

- Cranked to avoid other services or obstacles; or
- Located longitudinally directly above or below other underground services in the same trench.

Design method: Where a stormwater pipeline crosses or is constructed adjacent to an existing service, the design shall be based on the work-as-executed location and level of that service.

Documentation: The design documents shall direct the Contractor to verify the location and level of the existing service prior to constructing the stormwater pipeline in question.

Minimum clearance: Minimum clearances between stormwater pipelines and other underground services shall be in accordance with **Table 8- 24 Minimum clearances.**

Table 8- 24 Minimum clearances

Service	Clearance (mm)
Horizontal - All services	600
Vertical - Sewers	150
Vertical - Water mains	100
Vertical - Telecommunications	75
Vertical - High pressure gas	300
Vertical - Medium pressure gas ≥ 110 mm Ø	300
Vertical - Medium pressure gas ≤ 75 mm Ø	150
Vertical - High voltage electricity	300
Vertical - Low voltage electricity	75

8 BRIDGES AND CULVERTS

8.1 Bridges

Refer: Bridges shall be designed in accordance with *MIS 09 Bridges and related structures*.

Freeboard: The level of bridges should be above the major design storm event level with freeboard as set in *MIS 09 Bridges and related structures*.

8.2 Culverts

Refer: Culvert structural design shall be to *MIS 09 Bridges and related structures*.

Refer: Culvert design shall be to **PIPES**.

Use: Box culverts may be permitted as part of the stormwater system for road crossings or where availability of cover or minimal waterway depths make the use of pipes unsuitable.

Minimum size: Refer to **Table 8- 20 Minimum pipe diameters.**

Inlet protection: Culverts longer than 40 m must be provided with a sloped metal grate at the inlet for public safety purposes. Refer **Figure 8- 9 Typical culvert inlet protection grate** for a typical example.

Figure 8- 9 Typical culvert inlet protection grate

Documentation: The proposed use of box culverts in lieu of standard pipes shall be brought to the attention of TCCS for consideration prior to finalising designs.

Low flow: For multiple cell box culverts a means of concentrating low flows shall be provided.

Access: Access for maintenance shall be provided to the apron of all inlet and outlet headwalls.

9 SUMPS AND MANHOLES

9.1 General

Requirement: Stormwater sumps shall efficiently conduct storm flows from the surface to the underground pipe system.

Requirement: Manholes are required to gain access to the stormwater system for maintenance purposes or where pipes change direction or size.

Standard: Standard sizes and shapes should be used to achieve economy in construction and maintenance.

Disallowed methods: Deflector slabs on sump inlets will not be permitted.

9.2 Sump location

9.2.1 Location

Location: Kerb sumps for all roadways shall be located such that gutter flow widths do not exceed the surface flow limits specified in **Table 8- 19 Surface flow criteria for roads** and **Figure 8- 5 Allowable flow widths on roadways – minor design storm event** (Source: adapted from Queensland Road Drainage Design Manual, 2010).

Low points: All low points in road gutters shall be provided with sumps. When a low point occurs in an intersection kerb return, a type R sump should be placed at the low point. A type R sump shall be provided at one of the kerb return tangent points. Preferably, the type R sump should be positioned at the tangent point of the steepest street.

Disallowed location: The use of entry sumps within private leases is not acceptable where such sumps form part of the public stormwater system.

9.2.2 Spacing

Sump spacing: Maximum spacing of sumps shall be in accordance with **Table 8- 25 Maximum sump spacing.**

Table 8- 25 Maximum sump spacing

Diameter (mm)	Maximum Sump Spacing (m)
225 to 450	100
525 to 900	150
1050 to 1200	300

9.3 Manhole location

Location: Manholes should be located where maintenance personnel with machinery can have direct access at all times. Preference should be given to siting manholes in public land rather than in leased properties. Manholes shall be located:

> Where there is a high risk of blockage (e.g. At changes in direction, grade, pipe size);

> Where junction structures are required to combine flows efficiently; and

> At regular intervals for operation and maintenance access.

Preference: The order of preference for location of manholes in roadway reserves is:

> Roadside verges;
> Median strips; and
> Centreline of road pavements.

Road pavements: Where manholes are located in road pavements, the neck height shall be 100 mm minimum to allow for possible future adjustments.

Disallowed: manholes will not be permitted to be located within:

> Bicycle pathways; or
> Road pavements at intersections.

9.3.1 Spacing

Manhole spacing: The maximum spacing of manholes is dependent on whether entry along the pipeline is possible. For non-entry pipelines, the maximum spacing is dependent on the type of equipment available to maintenance crews.

2.1.1.19 Straight pipelines

Manhole spacing: Maximum spacing on straight pipelines shall be in accordance with **Table 8-26 Maximum manhole spacing on straight pipelines.**

Table 8-26 Maximum manhole spacing on straight pipelines

Diameter (mm)	Maximum Manhole Spacing (m)
225 to 450	100
525 to 900	150
1050 to 1200	300

2.1.1.20 Curved pipelines

Manhole spacing: Closer manhole spacing is required on curved alignments due to maintenance considerations.

Curves: A manhole shall be located on at least one curve tangent point.

Curve spacing: Maximum spacing along a curved pipeline, measured from the manhole at the tangent point, shall be in accordance with **Table 8-27 Maximum manhole spacing on curved pipelines.**

Table 8-27 Maximum manhole spacing on curved pipelines

Diameter (mm)	Maximum Manhole Spacing (m)
225 to 450	75
525 to 900	100
1050 to 1200	200

9.4 Design parameters

9.4.1 Maximum depth

Maximum depth: Sumps shall have a maximum depth to invert of 3.5 m (or less as provided in **Standard sump types**) and manholes shall have a maximum depth to invert of 6 m.

9.4.2 Materials

Sealing: Sumps and manholes shall be constructed so that they are structurally sound and do not permit ingress of water through the walls or joints. Sumps and manholes shall be resistant to erosion and corrosion. Where necessary, special corrosion resistant cement shall be utilised.

Material: Sumps and manholes shall be constructed from:

- In-situ concrete (Type C or Type D cement to *AS 2350* and *AS 3972*); or
- Precast concrete

9.4.3 Jointing

Connection: Pipe connections into the cone section of a manhole will not be permitted.

9.4.4 Freeboard

Limit: The water surface in drainage pits should be limited during the minor design storm event as follows:

- Inlet pits: To 150 mm below the gutter invert.
- Junction pits: To 150 mm below the underside of the lid.

9.4.5 Inlet capacity

Inlet capacity: Inlet capacities for on-grade and low point sumps on KG, MLBK, & MKG kerbs shall be obtained from **Appendix A** (includes multiple on-grade type R sumps on KG).

9.4.6 Blockage

Minor design storm event: Sump inlets shall be considered to have nil blockage when sizing pipe drainage systems.

Major design storm event: Sump inlets shall be considered to have a degree of blockage in accordance with **Table 8-28 Major design storm sump inlet blockage factors.** The blockage factors shall apply to all sumps in the drainage system.

9.4.7 Fall through

Energy loss: The fall through a sump or manhole on a pipeline not operating under a hydraulic head at maximum design flow shall be equal to or greater than the energy loss through the sump or manhole.

Minimum fall: A minimum fall of 50 mm shall be provided through a sump or manhole (refer **Figure 8-10 Minimum fall through pit)**. A 50 mm minimum fall shall also be provided for pipelines designed to operate under hydraulic head at maximum design flow.

Pipe grade: Irrespective of these requirements, the pipeline grade shall not be reduced through the sump or manhole.

Table 8- 28 Major design storm sump inlet blockage factors

Inlet Type	Blockage Factor
On grade - side entry, (no grate)	20%
On grade - side entry, (with grate)	10%
On grade – grate only	50%
Sag - side entry, (no grate)	20%
Sag - side entry, (with grate)	Nil
Sag – grate only	50%
Plantation sump, (single opening)	50%
Plantation sump, (double opening)	20%
Surcharge structure, (no grate)	10%
Surcharge structure, (with grate)	Nil

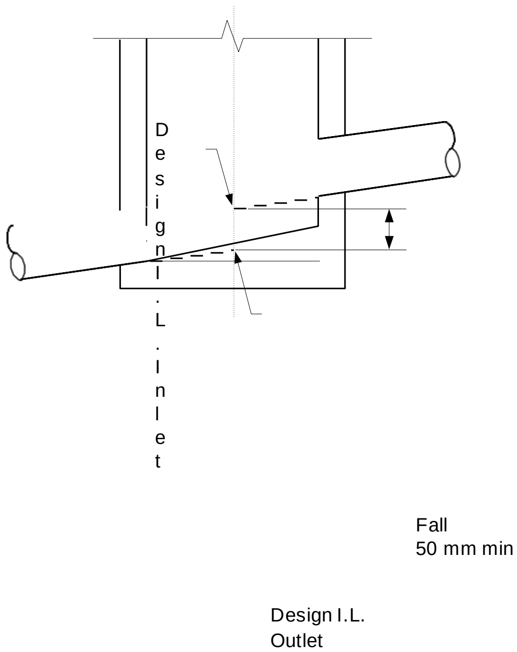


Figure 8- 10 Minimum fall through pit

9.4.8 Vertical drops

Free fall: Designs where the invert of an inlet pipe is located above the obvert of an outlet pipe should beavoided wherever possible. However, in cases where this is unavoidable, a free fall within the manhole shall be provided. Consult TCCS for requirements where vertical drops are deemed necessary.

Baseflow: Where a significant continuous baseflow is likely, consideration should be given to providing an external drop pipe. Such instances shall be brought to the attention of TCCS for consideration.

9.4.9 Benching

2.1.1.21 Sumps on new pipelines

Constant fall: The base of the sump shall be formed to provide a constant fall to the outlet and to stop theponding of water within the sump.

Minimum fall: The invert of the benching shall have a minimum fall of 50 mm towards the outlet (refer to **Figure 8- 10 Minimum fall through pit** for details).

Minimum slope: A minimum benching side slope of 1(V):50(H) shall be provided.

2.1.1.22 Sumps on existing pipelines

Bench height: The sump shall be benched to the full diameter (height) of the pipe for the full length of thesump. Refer to **Figure 8- 11 Benching for new sumps on existing pipelines** for details.

Minimum slope: The top of the benching shall be sloped at a minimum side slope of 1(V):10(H).

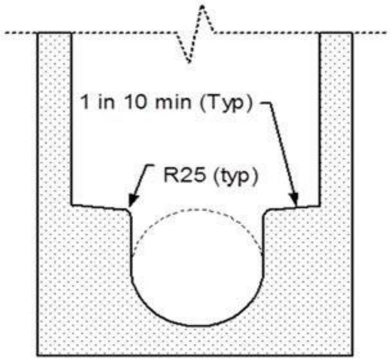


Figure 8- 11 Benching for new sumps on existing pipelines

9.5 Covers

9.5.1 Standard covers

Load: A sump or manhole cover not subject to traffic loads or hydraulic surcharge shall consist of astandard reinforced concrete seating ring and lid in accordance with *ACTSD-0830 Structures - Miscellaneous Details.*

9.5.2 Other access covers

Materials: Alternative material covers such as metal or decorate covers should be avoided where possibleto reduce maintenance cost (e.g. replacement) and complaints (e.g. sound).

Refer: A sump or manhole cover that will be subjected to either internal or external loadings shall be inaccordance with the latest edition of *AS 3996*.

Sump cover: The type of sump cover shall be selected according to the following criteria:

> Trafficable area (Class D);

> Non trafficable area (Class C); or

> Grated cover (Class D).

Cover selection: Access covers on surcharge structures (refer to *ACTSD-0829 Surcharge Structures*) shallbe bolted down with stainless steel bolts to secure the cover and the seating ring to the sump.

Cast iron cover: Cast iron covers shall be 'GATIC', or equal as approved in writing by TCCS.

9.5.3 Cover levels

Manhole locations: In locations where a cover at or above the surface could cause a hazard (e.g. in a golfcourse or a playing field), a cover level below the surface will be permitted providing that:

> There are no junctions or drops in the manhole;

> The change in direction is less than 30°;

> An unburied manhole is provided within 100 m;

> The precise location of the manhole is recorded on "work-as-executed" drawings; and

> A heavy duty sealed cover is set at 200 mm below finished grass level.

Level: Sump and manhole covers shall be set at the finished cover levels given in **Table 8- 29 Sump and manhole cover levels.**

Table 8- 29 Sump and manhole cover levels

Location	Cover Level
Paved Areas	Flush with finished surface
Footpaths and street verges	Flush with finished surface
Established plantations	Flush with finished surface
Elsewhere	100 mm above surface to allow for topsoiling and grassing (see note)

Steep slopes: Where finished surfaces are steeper than 1(V):10(H), the sump or manhole cover shall belevel. An adjacent flat area shall be provided with sufficient space on which to place a removed cover.

9.6 Standard sump types

9.6.1 Type R sump

Location: All kerbside sumps at low points and on-grade shall generally be type R sumps.

Maximum depth: This is a double sump suitable for pipe depths up to a maximum of 3.5 m.

Design: Refer to *ACTSD-0821 Type R and QS sumps.*

9.6.2 Type KI sump (KIS)

Location: This sump can be used where the use of R Sump is impractical or to avoid services or trees. Itmay also be used as an inlet sump that connects to the main on the other side of the road allowing thestormwater main to be installed without deflection or bends.

Maximum depth: This type of sump is suitable for pipe depths up to a maximum of 3.5 m. Its inlet widthvaries from 1.2 m to 3.6 m.

Approval: The use of the sump requires approval from TCCS.

Design: Refer to *ACTSD-0820 Type R & QS Sump Inlets.*

9.6.3 Type QS sump

Location: A QS sump may be used:

> At changes in direction where entry of water is not essential (i.e. side entry may be sealed);
> In tight radius kerb returns where the length of a type R sump is inappropriate; or
> As a plantation sump in locations not prone to blockage

Maximum depth: This is a single sump suitable for pipe depths up to a maximum

of 1.8 m.Design: Refer to *ACTSD-0821 Type R and QS sumps.*

9.6.4 Plantation sump

Location: This may be either a type QS or type R sump with a single or double-sided concrete apron.Plantation sumps shall be used in medians or grassed areas.

Design: Refer to *ACTSD-0825 Plantation and Grated Sumps in Open Space.*

9.6.5 Grated sump

Avoid: This type of sump blocks easily and should be avoided wherever possible. The use of grated sumpsfor roadway or underpass drainage is not permitted except in laneways with narrow verges where a type R or type QS sump would conflict with other services.

Conditions: Single and double-grated sumps may be used in paved pedestrian areas for pipe depths up to a maximum of 1.0 m, subject to the following conditions:

> The sump catchment area is minor;
> Grates conform to the requirements of *AS 3996*;

- In the event of blockage of the inlets, the resulting depth of flooding shall not exceed 50 mm and asafe passage for overflow shall be provided;
- Heavy duty grates are provided (light duty grates will not be permitted); and
- All grates are hinged and bolted.

Design: Refer to *ACTSD-0825 Plantation and Grated Sumps in Open Space*.

9.6.6 High inlet capacity

Location: Where high inlet capacity is required, the preferred solution is multiple type R sumps or KISsumps placed side by side.

Alternative: As an alternative to multiple type R sumps, special sumps may be designed and used.

Approval: The proposed sump arrangement for any location where high inlet capacity is required shall besubmitted to TCCS for consideration.

Resign: Refer to *ACTSD-0826 Multiple R Sumps* for details of multiple type R sumps.

9.6.7 Surcharge sump

Location: Surcharge sumps shall be provided where there are shallow points in the system to form anemergency overflow relief path in times of acute hydraulic overload or blockage of the pipe system.

Capacity: The surcharge capacity of the sump shall be at least twice the total inflow to the sump to allowfor partial blockage of the outlet during surcharge.

Design: Refer to *ACTSD-0829 Surcharge structures.*

9.7 Standard manhole types

Standard drawing: Manholes shall be constructed in accordance with *ACTSD-0827 1050 ND manholes* or *ACTSD-0828 Special chambered manholes* as required.

Maximum neck: The maximum length of the neck on standard manholes shall be 200 mm.

Step irons: Standard step irons located over the outlet pipe shall be provided.

9.7.1 1050 ND manhole

Location: A 1050 ND manhole shall be used for pipelines from 225 mm to 675 mm diameter as shown on *ACTSD-0827 1050 ND manholes*.

9.7.2 Special chambered manhole

Location: A special chambered manhole shall be provided for pipelines 750 mm diameter and larger inaccordance with *ACTSD-0828 Special chambered manholes*.

Alignment: It is preferable that straight-through flow be provided at these manholes by taking up anglesbetween pipelines with curved alignments.

Location: Special chambered manhole shall also be provided at the junction of two or more largediameter pipelines.

Review: Designs for these manholes shall be submitted to TCCS for consideration.

9.7.3 Deep manhole

Review: It is not envisaged that drainage systems will be constructed at a depth to invert greater than 6 m. However, should such an occasion arise, the matter shall be referred to TCCS for consideration.

10 RETARDING BASINS

10.1 General

10.1.1 Function

Requirements: Retarding basins may be provided as an integral part of the major drainage system in newdevelopment areas to either:

> Provide a more economic system by reducing downstream flow rates and waterway reserve widths,or

> Meet a specific planning requirement that downstream flow rates not exceed pre-developmentvalues for both the minor and major system design AEP.

Consider: It should be recognised that the provision of a retarding basin is only one method in a numberof techniques available to manage stormwater runoff and therefore should be tested against other drainage strategies to arrive at the optimum solution to meet either of the above objectives.

Integration: The provision of retarding basins in the drainage system should be planned and designed aspart of an overall catchment drainage strategy.

Multi-purpose use: To gain maximum land use benefit, retarding basins should be designed for multi- purpose use wherever possible. Recreational uses such as sporting fields and open space are consideredmost suitable. Sporting fields shall be provided with local drainage and a low flow by-pass for the minor drainage system.

10.2 Design criteria

Refer: The basin embankment and outlet designs shall conform to the requirements of the latest *ANCOLDguidelines.*

Basin sizing: The Designer shall test the performance of the basin using a range of 'design' storms or a long-term record of rainfall to determine the maximum storage requirements and the size of primary andsecondary outlets for the basin.

Inflows: A hydrograph estimation technique shall be used to estimate appropriate inflow hydrographs to the basin. Inflow hydrographs shall be routed through the basin using full reservoir routing calculations todetermine the basin characteristics and resultant outflow hydrographs.

Flood capacity: The consequences of a storm event exceeding the structure capacity must be considered in the design of a retarding basin. Accordingly, basins shall be designed to pass appropriate extreme stormevents safely as is the case for conventional permanent water storage dams.

Basins in series: Where there are a number of retarding basins in series in a catchment, the collective performance of the basins should be investigated. The effect of long duration outflows from an upper basin superimposing on flows through lower basins may require a revision of the operation of the basinsthroughout the catchment.

10.2.1 Flow control

General criteria: Refer to **Responsibilities** for general design flow control requirements.

Primary outlet: The primary outlet shall be sized to discharge all flows up to and including 1% AEP.

Secondary outlet: The secondary outlet shall be sized to discharge the full AFC AEP flow assuming that allprimary outlets are 100% blocked.

Maximum inundation period: The maximum inundation period during the critical duration 1% AEP designstorm shall be 72 hours to prevent long-term damage to grassed surfaces.

Flooding criteria: Retarding basins shall not cause floodwaters up to and including the 1% AEP event to inundate upstream roads or leases.

10.2.2 Consequence category assessment

Hazard rating: All retarding basins shall have a Consequence Category (hazard rating) assigned to them sothat the risk associated with a flood-initiated failure of the basin is understood and managed. A Consequence Category assessment shall be undertaken in accordance with the latest *ANCOLD* guidelines.

Certification: The Consequence Category assessment must be documented and certified by a suitablyqualified engineer and submitted to TCCS for approval.

10.2.3 Downstream development

Development extent: The extent of existing and future development in an urban catchment must beconsidered during design of a retarding basin as future extensive development within the catchmentcould significantly alter catchment inflow response at the basin.

Future development: Future development downstream of the basin could significantly increase theconsequences of failure presented by the basin. The flood capacity of a basin should therefore be designed to take into account possible future downstream development based on the expected population density.

10.3 Outlet design

10.3.1 Bypass flows

Low flows: Provision should be made in a retarding basin to bypass low flows through or around the basin. This is necessary to ensure that the basin floor, particularly if it is grassed, is not inundated by small storms or continually wetted by dry weather baseflow. The minimum amount of bypass flow shall be 12 EY (refer to **Low flow provision**).

Exception: In existing areas, it may be desirable to bypass a larger amount than the 12 EY flow if a chosensite has insufficient capacity to attenuate both the minor and major system design storms. However, the level of flow bypassed should not exceed the downstream minor system design AEP. It should also be noted that the larger the amount of flow bypassed, the more difficult it will be to reduce the post- development minor system design flow to the pre-development level.

10.3.2 Primary outlet

Configuration: To achieve the general design flow control requirements specified in

Responsibilities, theprimary outlet configuration will generally consist of a multi-outlet structure or several outlet structurescombined to provide multi-stage outlet control.

Hydraulic analysis: The outlet hydraulics for multi-outlet structures may be complicated and difficult to analyse. Care must be taken to ensure that the stage-discharge relationship adequately reflects the range of different flow regimes that the structure will operate under. In some cases, particularly if the consequences of failure of the structure are high, the stage-discharge characteristics may need to be verified by physical modelling.

Blockage: Primary outlets shall be designed to minimise the risk of blocking. The consequences of partial blockage of primary outlets must be investigated and, if found to be significant, shall be accounted for bythe provision of blockage resistant self-cleaning grates. Grates shall be aligned with the direction of flow and be no steeper than 1(V):3(H).

Anti-vortex device: Where a headwall or an open type structure is provided at the entrance to an outlet, an anti-vortex device should be considered to maximise hydraulic efficiency. The need for venting of theoutlet should also be investigated.

Protection: Outlets should preferably be concrete encased within a rock foundation or appropriately filtered in the natural earthen material under the basin. Sealing of an outlet within an embankment merits specific attention to prevent failure from piping under flood loadings.

10.3.3 Secondary outlet

Requirement: A secondary outlet to cater for storm events rarer than the 1% AEP event up to the AFCshall be provided. The most common outlet is a high-level weir crest and overflow spillway.

AFC assessment: The AFC for the secondary outlet shall be determined from a Consequence Categoryassessment of rare storm events up to and including the PMF. The assessment shall be carried out in accordance with the requirements of the latest *ANCOLD guidelines*.

Preferred location: The spillway should be located at or adjacent to one of the embankment abutments tolimit the possibility of embankment failure by scour.

10.4 Embankments

General: Embankments shall be designed and constructed as dams such that they will not breach under any flood conditions for all flows up to and including the AFC. They shall be designed using appropriate stability analysis and geotechnical design practices. In particular, appropriate foundation treatment and bonding of the embankment to the foundation must be specified. Suitable compaction levels, vegetation cover and stabilisation treatments should be specified for earthen embankments and protection provided to cater for cracking or dispersive soils.

Impervious core: Earthen embankments shall incorporate a centrally located impervious ‘core’ zone. Anupstream face impervious zone is not recommended due to potential cracking from wetting and drying.

Borrow areas: If the earth fill for any embankment is to be taken from borrow areas, these areas shouldbe kept as far away from the embankment as practicable. Should the borrow area penetrate any alluvial sand layers or lenses, the embankment’s cut-offs should be taken to at least 1 m below the estimated depth of such sand layers/lenses at the basin floor.

Surfacing: Embankments should be protected by a uniform, robust, grass cover that can be routinelymowed.

Conduits: The preferred location for conduits is through the basin abutments, to reduce the potential forembankment failure due to piping. If locating a conduit through or under embankments cannot be avoided, the conduit shall be provided with a concrete cut-off collar.

10.4.1 Freeboard

Minimum: 300 mm below the crest of the secondary outlet for the 1% AEP storm event.

Minimum: 300 mm below the embankment crest for the secondary outlet design AEP.

10.4.2 Grades

Embankment slopes: Retarding basin embankment slopes shall have a maximum batter of 1(V):6(H).Slopes up to 1(V):4(H) may be approved in special circumstances.

Basin floor: The floor of the basin shall be designed with a minimum fall of 1(V):50(H) to provide positivedrainage and minimise the likelihood of ponding.

10.5 Safety

Requirements: It is inevitable that people will have access to a retarding basin, especially if it is designed for multi-purpose usage incorporating active or passive recreation, or sporting facilities. A retarding basinmust be designed with public safety in mind both when the facility is in operation and also during periodsbetween storms when the facility is empty. Appropriate ways must be considered to prevent and to discourage the public from being exposed to high-hazard areas during these periods.

Considerations: The Designer must consider the following safety measures in the basin design:

- Provision of signs that clearly indicate the purpose and potential danger of a basin during storms. Signs should be located such that they are clearly visible at public access points and at entrances andexits to outlet structures;
- Gratings and trash racks at the inlet of a primary outlet structure. These should be inclined at an angleof 60° to the horizontal and placed a sufficient distance upstream of the inlet where the velocity through the rack is low. This should ensure that a person would not become held under the water against the grating or trash rack;
- Safety fencing on steep or vertical drops, such as headwalls and wingwalls, at the inlet and outlet to aprimary outlet structure to discourage public access. Safety fencing can also prevent a person inadvertently walking into or falling off these structures during periods when the basin is not in operation; and
- Screening of outlet structures with bunds or shrubs to reduce their attraction potential to playingchildren or curious adults during periods that the basin is not in operation.

10.6 Erosion protection

10.6.1 Primary outlet

Requirement: Consideration must be given to the need to protect the toe of the basin embankment andthe bed and banks of the downstream waterway from erosion by high velocity outlet discharges.

Operating heads: For operating heads less than 1.8 m, a scour protection apron sized in accordance withSection **Error! Reference source not found.** may only be required. For operating heads in excess of 1.8 m, an energy dissipating structureshould be provided.

10.6.2 Embankment and secondary outlet

Requirement: The surfaces of the embankment and secondary outlet (normally an overflow weir and spillway) must also be protected against damage by scour when subject to high velocities. The degree of protection required depends on the velocity of flow, v, to which the bank will be subjected. The following treatments are recommended as a guide:

> $v \leq 3$ m/s: a dense well-knit turf cover.
> 3 m/s < v < 7 m/s: a dense well-knit turf cover incorporating a turf reinforcement system.
> $v \geq 7$ m/s: hard surfacing with concrete, riprap or similar.

Stilling Basin: An open stilling basin may be required at the bottom of the spillway prior to discharge intothe downstream waterway. It may be possible, and more cost effective, to provide a single stilling basin for both the secondary and primary basin outlets.

10.7 Landscaping

Ngunnawal and Aboriginal cultural integrity: Ngunnawal and Torres Strait Islander culture should be showcased through the implementation of indigenous plants incorporated in the landscape design, as appropriate when considering the functional requirements of the basin.

Aesthetics: Retarding basins should be carefully incorporated into the urban setting in which they reside.This is not a hydrologic consideration, but it is a consideration the community will use to judge these facilities. Aesthetics of the finished facility is therefore extremely important.

Visual Amenity: Wherever possible, designs should incorporate naturally shaped basins with landscaped banks, footpaths, and selective planting of vegetation to help enrich the area and provide a focal point forsurrounding development. Sympathetic landscaping and the resulting improvement in local visual amenity will also encourage the public to accept retarding basins as an element of the urban natural environment and not as a target for vandalism.

Species selection and location: Select appropriate vegetation for the basin site from *MIS 25 Plant speciesfor urban landscape projects*. Refer to **Table 8- 30 Permitted vegetation locations** for permitted locationsfor types of vegetation.

Disallowed: Trees and shrubs shall not be planted on basin embankments as they may increase thedanger of embankment failure by ‘piping’ along the line of the roots.

10.8 Maintenance

Access: Retarding basins shall be provided with adequate access for maintenance machinery to mow theembankment and basin side slopes and remove silt or debris from the floor of the basin. Access for maintenance shall also be provided to the primary and secondary outlets.

10.8.1 Operation and maintenance plan

Requirement: Refer to **Maintenance** for details.

Approval: The operation and maintenance plan must be submitted to TCCS for approval

Table 8- 30 Permitted vegetation locations

Hazard Rating	Location	Acceptable Vegetation					
		Established trees (all)	New trees/ bushes	Existing bushes	Existing bushes (<2m)	Slashed grass (70 – 250mm)	Ground cover/ Non slashed grass types
High	Constructed embankment (top & both faces) including abutment region					✓	
	Minimum 3m clear of embankment toe (U/S & D/S)					✓	
	Slope areas in cut (non embankment areas)	✓	✓	✓	✓	✓	✓
	Floor of basin (min 3m clear of embankments/ spillway structures)					✓	✓
	Structures (min 3m clear of embankments/ spillway structures)	✓				✓	✓
Low	Constructed embankment (top & both faces) including abutment region	✓				✓	✓
	Minimum 3m clear of embankment toe (U/S & D/S)	✓				✓	✓
	Slope areas in cut (non embankment areas)	✓	✓	✓		✓	✓
	Floor of basin (min 3m clear of embankments/ spillway structures)	✓	✓	✓		✓	✓
	Structures (min 3m clear of embankments/ spillway structures)					✓	✓

WSUDSYSTEMS

11 DESIGN CRITERIA

Water quality standard: Refer to *ACT Waterways: WSUD General Code.*

Design load: The design loads for a catchment shall be determined using the methods listed in **Methods and models.**

Calibration: Where possible, calibration against actual data shall be undertaken.

Documentation: Each element of the stormwater system contributing to water treatment in the catchment shall have its design performance provided in terms of:

> Mean annual load reduction of TSS, TP and TN;
> Percentage reduction due to the element; and
> Contribution to total stormwater system treatment train for the catchment.

11.1 Pollutant reduction targets

Requirement: The water quality targets shown in **Table 8- 31 Pollutant reduction targets** shall apply to all urban development. The targets are total values to be achieved from a development / redevelopment site or from a regional catchment outlet. They may be achieved by a single treatment measure or by a number of measures in a treatment train.

Table 8- 31 Pollutant reduction targets

Pollutant	Development or redevelopment sites	Regional or catchment-wide
Reduction in gross pollutant export load	90%	90%
Reduction in average annual suspended solids (SS) export load	60%	85%
Reduction in average annual total phosphorus (TP) export load	45%	70%
Reduction in average annual total nitrogen (TN) export load	40%	60%

11.2 Flow control

Design requirements: If temporary flood storage is to be provided within a WSUD facility for the purpose of reducing peak flows downstream, refer to **Responsibilities** for general design flow control requirements.

11.3 Methods and models

Documentation: Full details of the water quality modelling methodology including all assumptions made, recommended parameter values, tabulated flow comparisons for major and minor system AEPs, and percentage reduction in annual pollutant loadings shall be included in documentation provided.

Performance: For the purposes of modelling, the water quality performance of an asset shall be the lesser of either its' long-term equilibrium performance or its' performance prior to agreed ongoing maintenance.

Approval: To obtain approval for new methods, the Designer must demonstrate, to the satisfaction of TCCS, that a particular water quality method or model is appropriate for ACT conditions as set out in the *ACT Practice Guidelines for Water Sensitive Urban Design*.

11.3.1 MUSIC

11.2.1.1 Hydrology

Hydrology: 6 minute pluviograph rainfall data from the Canberra Airport for the period 1968 to 1977 shall be used as the baseline for assessment purposes. Other baseline data may be used which is considered more reflective of the site if provided to and approved by TCCS and the planning authority. The *ACT Practice Guidelines for Water Sensitive Urban Design* provide further guidance on site reflective data.

Parameters: The standard parameters to be used in modelling water quality in MUSIC are listed in the Table 8- 32 MUSIC hydrology parameters.

11.2.1.2 Water quality

Parameters: The standard parameters to be used in modelling water quality in MUSIC are listed in **Table 8- 33 MUSIC water quality parameters.**

11.2.1.3 WSUD treatment devices

Guidelines: Advice on modelling WSUD treatment devices in MUSIC is provided in **Appendix E.**

Table 8- 32 MUSIC hydrology parameters

Parameter	Forest (Open Space), Urban and Agricultural
Impervious area properties	
Fraction impervious	Refer to **Impervious area**
Rainfall threshold (mm/day)	0
Pervious area properties	
Soil storage capacity (mm)	40
Initial storage (% of capacity)	20
Field capacity (mm)	25
Infiltration capacity coefficient - a	200
Infiltration capacity coefficient - b	1
Groundwater properties	
Initial depth (mm)	1
Daily recharge rate (%)	25
Daily baseflow rate (%)	1
Daily deep seepage rate (%)	15

Table 8- 33 MUSIC water quality parameters

Parameter	Forest (Open Space)	Agricultural	Urban
Estimation method	Mean	Mean	Mean
Standard deviations - std dev (log mg/L)	0	0	0
Serial correlation (R squared)	0	0	0
Total suspended solids			
Base flow concentration - mean (log mg/L)	0.9	1.40	1.10
Storm flow concentration - mean (log mg/L)	1.9	2.041	2.19
Total phosphorus			
Base flow concentration - mean (log mg/L)	-1.5	-0.88	-0.82
Storm flow concentration - mean (log mg/L)	-1.1	-0.662	-0.65
Total nitrogen			
Base flow concentration - mean (log mg/L)	-0.14	0.074	0.32
Storm flow concentration - mean (log mg/L)	-0.075	0.314	0.427

11.4 Extended detention

Minimum: The minimum EDD shall be 100 mm.

Maximum: The maximum EDD varies depending on the type of WSUD treatment device. The maximum depth specified shall also apply to a sediment forebay provided with the device.

Ponds and Wetlands: 500 mm

Bioretention basins: 300 mm

Exception: For bioretention tree pits, it is preferable that the EDD between the filter media surface and the surrounding landscape does not exceed 100 mm to reduce potential public health and safety risks.

12 INFILTRATION

Purpose: Wherever possible a vegetated pervious surface material should be used in overland flow pathsand contributing catchment areas in order to reduce the quantity and improve the quality of runoff whileavoiding the requirement for maintenance.

12.1 Vegetation

Species selection: Select appropriate vegetation for the site from *MIS 25 Plant species for urban landscapeprojects* according to the inundation condition at the plant's location.

12.2 Sub-surface drainage

Design: Sub-surface drainage systems (except for bioretention basins) shall conform to the requirementsof *MIS 04 Subsurface drainage.*

12.3 Buffer strips

Urban catchments: Runoff from impervious areas should be directed to flow across a vegetated perviousssurface prior to discharge to the stormwater drainage system wherever possible.

Design: Design buffer strips to include the following:

> Maximum slope of 10%;
> Maximum flow velocity in accordance with **Table 8- 15 Maximum flow velocities for major design storm event;**
> Usage of flow spreaders to evenly distribute stormwater over the buffer strip;
> The inlet should accept distributed overland flows;
> Prevention of the formation of rills through properly designed entry conditions and vegetation;
> Vegetation set down from the inlet area should be 75 mm below the inlet invert; and
> Vegetation should be dense and even.

Exfiltration: Buffer strips may be modelled with a soil exfiltration rate provided in **Table 8- 34 Representative soil exfiltration rates.**

Table 8- 34 Representative soil exfiltration rates

Soil Type	Median Particle Size(mm)	Saturated Hydraulic Conductivity (mm/hr)	Saturated Hydraulic Conductivity (m/s)
Gravel	2	36,000	1×10^{-2}
Coarse sand	1	3,600	1×10^{-3}
Sand	0.7	360	1×10^{-4}
Sandy loam	0.45	180	5×10^{-5}
Sandy clay	**0.01**	**36**	1×10^{-5}

12.4 Maintenance

Type: Infiltration assets shall be designed to require minimal cleaning maintenance aside from regularmowing and rubbish collection prior to replacement.

13 WETLANDS

13.1 General

13.1.1 Function

Purpose: Wetlands are permanent, predominantly shallow, water storages that function primarily to capture nutrients via emergent and submergent macrophytes. Wetlands should also include deeper open water zones to assist with the capture of coarse and fine sediments via sedimentation.

Components: The wetland design should incorporate the following main zones:

> Sediment forebay zone;
> Vegetated wetland (macrophyte) zone; and
> Inlet, intermediate and outlet pool zones.

13.1.2 Wetland configuration

Shape: Wetlands should be long relative to their width. The length to width ratio should be in the range from 3 to 5 to provide better distribution of flows across the wetland.

13.2 Sediment forebay zone

Requirement: A sediment forebay shall be provided at the upstream end of a wetland to capture coarse sediments prior to flows entering the main vegetated section of the wetland. A typical wetland sediment forebay zone is shown in **Figure 8- 12 Typical sediment forebay section (after Melbourne Water, 2016).**

Trash and litter: An upstream GPT or trash screen to intercept trash and litter must be provided on all sediment forebay inlets with a catchment area ≥ 8 ha. Refer to **GROSS POLLUTANT TRAPS** for design requirements for GPTs.

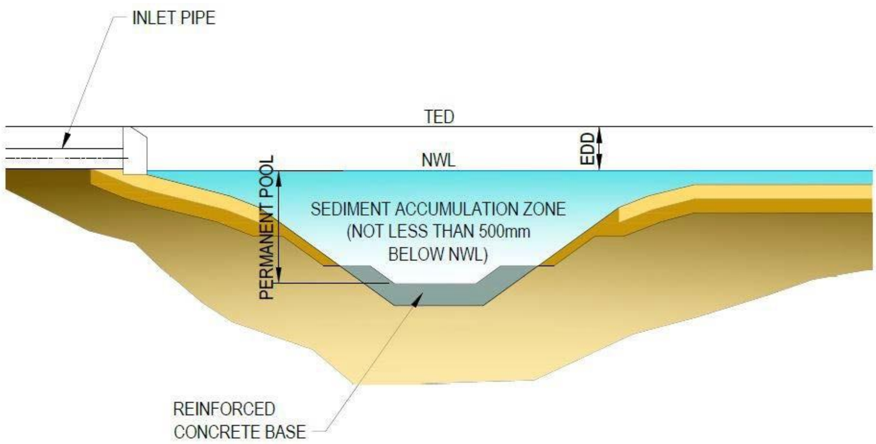


Figure 8- 12 Typical sediment forebay section (after Melbourne Water, 2016)

13.2.1 General design criteria

Preferred arrangement: The sediment forebay should be located online to the catchment being treated, but offline to the receiving waterway. It must provide for treatment of flows up to and including 4 EY andincorporate a high flow bypass to protect the vegetated wetland zone. A typical schematic showing this arrangement is shown **Figure 8- 13 Typical wetland schematic (outside of main waterway floodplain).**

Alternative arrangement: A wetland can be located within the floodplain of the receiving waterway asshown schematically in **Figure 8- 14 Typical wetland schematic (inside main waterway floodplain).**

However, bypass flows from the sediment forebay must not be adversely affected by water levels in thereceiving waterway up to and including 1% AEP. The wetland and sediment forebay must also be protected from inundation from the receiving waterway in flows up to and including 5% AEP.

Number of forebays: The number of sediment forebays in a wetland system should be reduced to the minimum possible, with a single forebay being desirable. Where there are multiple separate inlets to thewetland, a sediment forebay is not required at an inlet if:

- The contributing area of the inlet is less than 5% of the total wetland catchment area; or
- The incoming stormwater has already passed through a sediment treatment device.

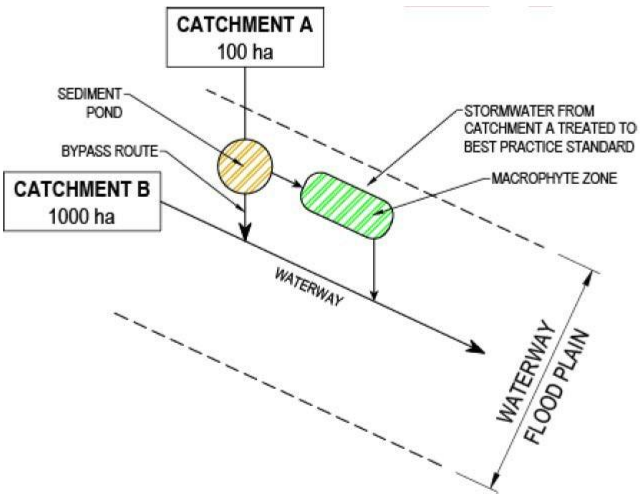


Figure 8- 13 Typical wetland schematic (outside of main waterway floodplain)

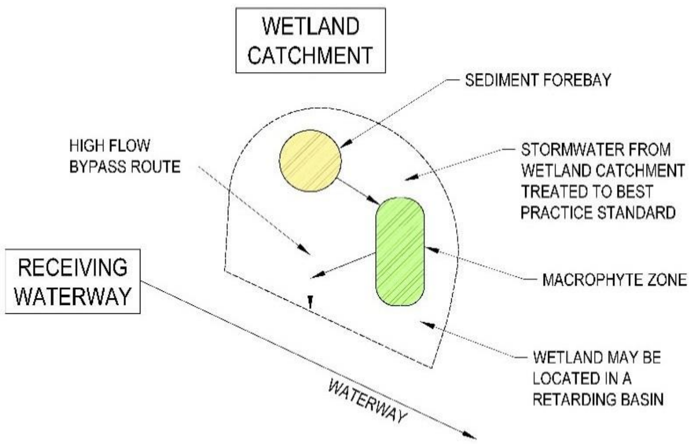


Figure 8-14 Typical wetland schematic (inside main waterway floodplain)

13.2.2 Performance requirements

Criteria: A sediment forebay shall be designed to:

- Capture 95% of coarse particles ≥ 125 µm diameter for the peak 4 EY flow;
- Provide adequate sediment storage volume to store five years sediment. The top of the sedimentaccumulation zone must not be higher than 500 mm below NWL; and
- Ensure the velocity through the sediment forebay during the peak 1% AEP event is ≤ 0.5 m/s. (The flow area must be assumed to be the extended detention depth multiplied by the narrowest width ofthe sediment forebay, at NWL, between the inlet and overflow outlet).

Size: Sediment forebays must be ≥ 120% of the size needed to meet the first dot point of the abovecriteria.

13.2.3 Sizing

Sizing method: The size of the sediment forebay is established using the following:

$$V_s = A_c.\ R.\ L_0.\ F_c \qquad \textit{(Equation 14-1)}$$

where:

V_s = volume of sediment storage required (m^3)

A_c = contributing catchment area (ha)

R = capture efficiency for particles ≥ 1 mm (assume 80%)

L_0 = sediment loading rate (m^3/ha/year)

F_c = desired cleanout frequency (years)

The area of the forebay is established by dividing the volume by the depth.

Efficiency: The sediment forebay area should be checked to ensure it captures particles ≥ 1 mm using thefollowing expression (modified version of Fair and Geyer (1954)):

$$R = 1 - \left[1 + \frac{1}{n}.\frac{V_{ts}}{Q/A}.\frac{d_e+d_p}{d_e+d^*}\right]^{-n} \qquad \textit{(Equation 14-2)}$$

where:

R = fraction of target sediment removed (80%)

V_{ts} = settling velocity of target sediment (m/s) (assume 0.1 m/s for 1 mm particle)

Q / A= applied flowrate divided by forebay surface area (m3/s/m2)

d_e = extended detention depth (m)

d_p = depth of permanent pool (m)

d^* = depth below permanent pool that is sufficient to retain the target sediment (m)(adopt the smaller of 1.0 m or d_p)

$$n = \frac{1}{1 - A}$$

where:

A = hydraulic efficiency based on the shape of the pond (refer **Figure 8-15 Hydraulic efficiency (A) of theoretical pond configurations (Persson et al, 1999)**)

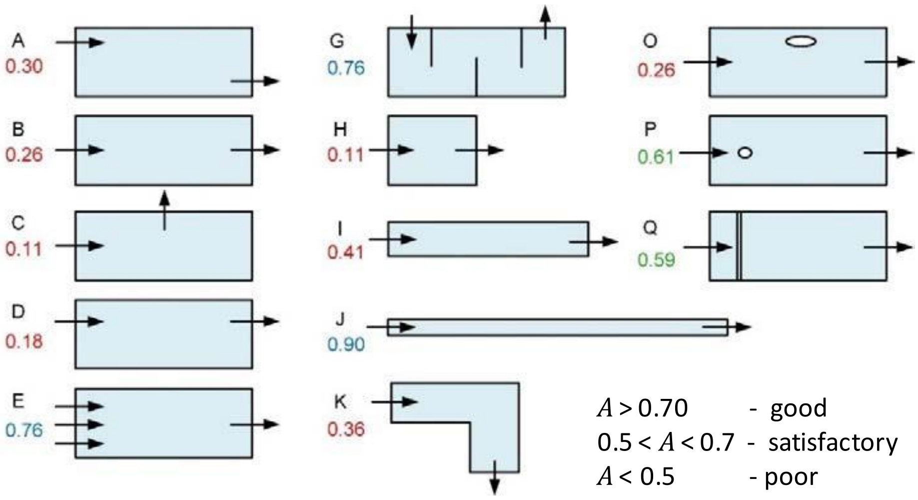


Figure 8-15 Hydraulic efficiency (A) of theoretical pond configurations (Persson et al, 1999)

Table 8-35 Parameters for theoretical pond configurations

Example Shape	CSTR Cells	Hydraulic Efficiency, λ
A	2	0.30
B	2	0.26
C	2	0.111
D	2	0.18
E	4	0.76
G	4	0.76
H	1	0.11
I	2	0.41
J	10	0.90
K	2	0.36
O	2	0.26
P	3	0.61
Q	2	0.59

13.2.4 Inlet design

Considerations: Flow velocities at inlets must be checked to ensure scour does not occur for both minorand major storm events. Erosion protection must be provided on all flow inlets to a wetland system. In most cases, flows will enter as 'concentrated flow' and as such, it is important to effectively slow and spread the inflows. Where inflows are from a piped system, the use of impact-type energy dissipation may be required to prevent scour of the pond embankment. In most cases this can be achieved by rock protection with several large rocks placed in the flow path to reduce velocities and spread flow.

Indigenous plants should also be taken into account in the design of the inlet in order to reintegrate and strengthen more Ngunnawal and Aboriginal culture in public space design.

Standard drawing: inlets shall be designed in accordance *with ACTSD-0844 Inlet Scour Protection Details.*

13.2.5 Base

Material: The sediment forebay base material must extend vertically up the batter by at least 300 mm andbe comprised of 150 mm thick steel reinforced concrete.

13.2.6 Connection to vegetated wetland zone

Preferred method: The preferred connection between the sediment forebay and the vegetated wetland zone is via a submerged earthen bund which acts as a weir as shown in **Figure 8- 16 Preferred connection to vegetated wetland zone (after Melbourne Water, 2016).** Thiswill create the look of a single water body instead of two separate zones.

Alternative method: Where the creation of a single wetland water body is not practical or desirable, a pit and transfer pipe is recommended as shown in **Figure 8- 17 Alternative connection to vegetated wetland zone (after Melbourne Water, 2016).** This allows the sediment forebay NWL to be higher than thevegetated wetland zone NWL if required. It also permits the sediment forebay to be pumped dry for maintenance purposes without affecting the water level in the vegetated wetland zone.

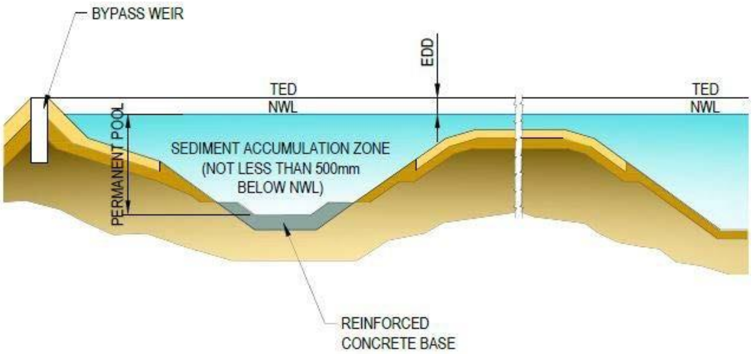


Figure 8- 16 Preferred connection to vegetated wetland zone (after Melbourne Water, 2016)

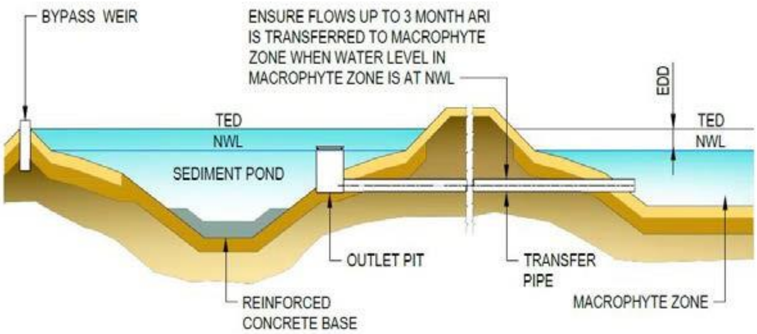


Figure 8-17 Alternative connection to vegetated wetland zone (after Melbourne Water, 2016)

Flow criteria: Regardless of type, the connection must be designed such that:

> All flows ≤ 4 EY are transferred into the macrophyte zone when the water level in the macrophytezone is at NWL;
> At least 60% of the peak 12 EY flow overflows from the sediment forebay to the high flow bypasssystem when the water level in the macrophyte zone is at TED; and
> The flow velocity through the macrophyte zone is ≤ 0.5 m/s during the peak 1% AEP event.

Design: The design of the sediment forebay outlet to the vegetated wetland zone must be undertaken inconjunction with the design of the high flow bypass system.

13.2.7 High flow bypass

Design: The high flow bypass system must be designed in conjunction with the design of the connection to the vegetated wetland zone and the vegetated wetland zone outlet. The bypass system must be sizedto convey the 'gap' flow between the peak wetland inflow and the vegetated wetland zone outflow during the 1% AEP design storm event.

Standard drawing: high flow bypass weirs shall be designed in accordance with *ACTSD-0843 SedimentForebay Typical High Flow Bypass Weir.*

13.2.8 Maintenance

Design: To enable appropriate maintenance of the sediment forebay zone, it is critical that the design of the wetland appropriately includes items that ensure maintenance activities can be completed safely andeasily.

Access ramp: To facilitate maintenance and ensure the proper operation of the sediment forebay, amaintenance access ramp into the base of the forebay must be provided. The access ramp must:

> Extend from the base of the forebay to at least 0.5 m above TED;
> Be at least 4 m wide;
> Be no steeper than 1(V):6(H);
> Be capable of supporting a 20 tonne excavator;
> Have a barrier to prevent unauthorised vehicle access (e.g. gate, bollard and/or fence); and
> Be constructed of either:

- reinforced concrete;
- 200 mm deep layer of cement treated crushed rock (6%), or

- 200 mm compacted FCR.

Exception: Where a maintenance access ramp is not feasible or practical, the forebay must be designed to be ‘edge cleaned’. ‘Edge cleaned’ forebays must:

> Have hardstand areas (e.g. Crushed rock covered in topsoil) within 7 m of the edge of the forebay forexcavation vehicles; and
> Be provided with a maintenance track around the perimeter of the forebay.

Access track: A maintenance access track must be provided to the sediment forebay maintenance accessramp or perimeter track to enable maintenance vehicles to safely access and exit the site. The maintenance access track must:

> Be at least 4 m wide;
> Be designed to take a 20 tonne vehicle;
> Be provided with a hardstand area adjacent to the sediment forebay maintenance access ramp with aminimum turning circle appropriate to the types of maintenance vehicles to be used to enable maintenance vehicles to safely reverse and exit the sediment loading area;
> At the road edge, have an industrial crossover and rolled kerb adjoining it; and
> Be constructed of either:

- 150 mm reinforced concrete;
- 200 mm 6% cement treated crushed rock; or
- 200 mm compacted FCR.

Dewatering area: Dedicated sediment dewatering areas must be provided that:

> Are accessible from the maintenance ramp;
> Free drain back to the sediment forebay;
> Have a length to width ratio no narrower than 10:1;
> Have a minimum area equal to 1.5 m^2 for each cubic metre of the sediment forebay capacity. Thearea shall be surfaced with 300 mm of compacted gravel;
> Be located above the peak 1% AEP water level and as close as possible to the sediment forebay;
> Be located at least 15 m from residential areas and public access areas (like pathways, roads, playgrounds, sports fields etc.);
> Consider potential odour and visual issues for local residents; and
> Be free from above ground obstructions (e.g. light poles) and be an area that TCCS has legal orapproved access to for the purpose of dewatering sediment.

13.3 Vegetated wetland zone

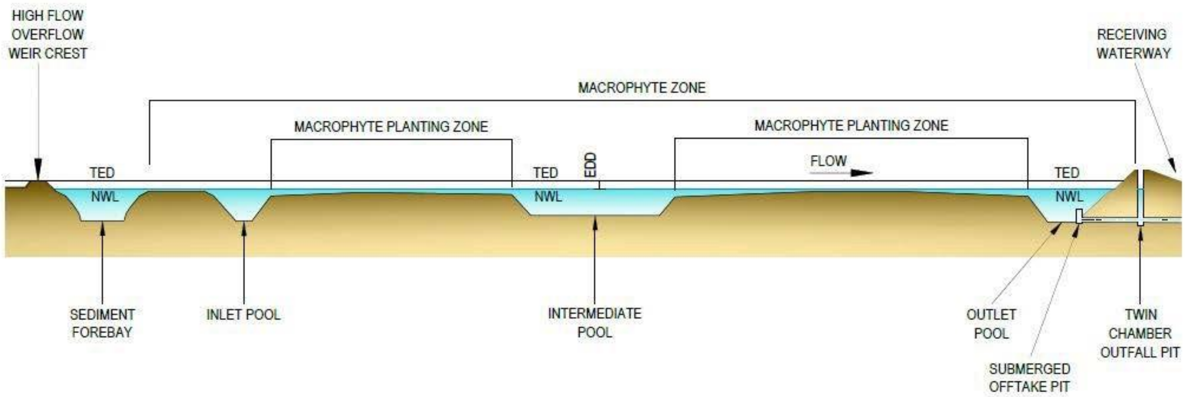


Figure 8- 18 Typical wetland long section (after Melbourne Water, 2016)

Components: The vegetated wetland zone incorporates bands of planting to treat stormwater runoff. A typical wetland section is shown in **Figure 8- 18 Typical wetland long section (after Melbourne Water, 2016).**

Design: The vegetated wetland zone should be designed such that:

> The wetland should be topsoiled to at least 200 mm depth throughout the entire vegetated wetland zone;

> The outlet of the vegetated wetland zone must be at the located at the opposite end of the zone to the inlets;

> The macrophyte planting zone must have a sequence and mix of submerged, shallow and deep marsh zones arranged in a banded manner perpendicular to the direction of flow; and

> Velocities in the vegetated wetland zone are:

- less than 0.5 m/s for the peak 1% AEP flow
- less than 0.05 m/s for the peak 4 EY flow

Residence time: The vegetated wetland zone must provide a 90th percentile residence time of 72 hours (assuming plug flow between inlet and outlet through the EDD and 50% of the permanent pool volume).Melbourne Water provides an online tool to calculate the 90th percentile residence time based on the following steps:

1. Create a six minute MUSIC model of the system. Ensure the wetland node has an accurate stage-discharge and stage-storage relationship. This will require the use of the "Custom Outflow and Storage Relationship" option in MUSIC.
2. Export a flux file from the wetland node.
3. Delete all columns except for "outflows" and "storage". Use a pivot table in Excel, or another data processing method, to determine the:
    a. Total inflow volume for each day
    b. Total outflow volume from the controlled outlet for each day (exclude overflows)
    c. Average storage volume for each day
4. Determine the average "plug flow volume" for each day in the time-series by subtracting 50% of the permanent pool volume from the average storage volume calculated from the flux file.
5. For each day in the time-series, count the minimum number of proceeding days until the cumulative outflow volume equals the previous day's plug flow volume. Use this method to create a daily time- series of residence times.
6. Modify the residence time time-series so that it only includes values corresponding to days where the inflow is > 0 (this avoids double counting of parcels of water at the front end of the wetland).
7. Determine the 10th percentile value of the daily residence times. If this is greater than 72 hours, the wetland provides an acceptable residence time.

13.4 Inlet, intermediate and outlet pools

Requirements: At the connection from the sedimentation zone to the vegetated wetland zone, an inlet pool is required. This pool enables flow to slow and spread across the width of the wetland. Intermediate pools can be included in larger wetlands to create transitions between marsh plantings and provide refuge to wetland fauna. The outlet pool enables the appropriate design of a submerged connection to a controlled outlet that minimises the risk of clogging. These pools must meet the following criteria:

- All inlets that drain more than 10% of the total catchment area to the vegetated wetland must be located within the first 20% of the vegetated wetland area (i.e. at the upstream end);
- Have a normal TWL that is at least 100 mm lower than the normal top water level in the sedimentation pond;
- The total open water pool area shall not be more than 20% of the total vegetated wetland area;
- The inlet and outlet pools should be no greater than 1.5 m deep;
- Intermediate pools should be no more than 1.2 m deep; and
- Provide for balance pipes to other permanent ponds in the vegetated wetland zone. Balance pipes must be placed between all open water zones (inlet, intermediate and outlet pools) to enable water levels to be drawn down for maintenance or water level management purposes.

Balance pipes: Balance pipes must:

- Be a minimum 225 mm diameter sewer class PVC;
- Have an invert level of the pipe at no more than 100 mm above the base of the connected pool and fitted with a truncated pit to minimise the risk of clogging (refer **Figure 8- 19 Balance pipe schematic (after Melbourne Water, 2016)**); and
- The connection from the macrophyte zone to the pit containing the controlled outlet must be submerged to minimise clogging from floating debris.

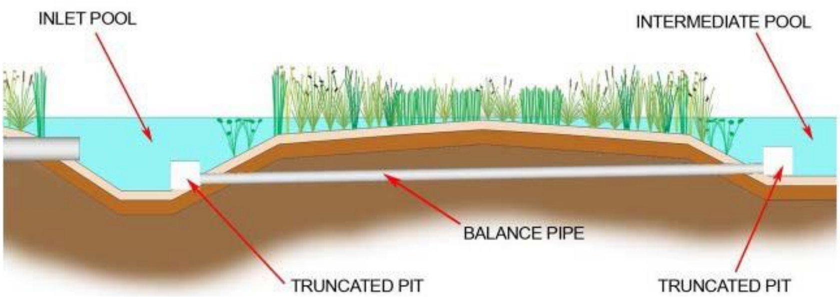


Figure 8- 19 Balance pipe schematic (after Melbourne Water, 2016)

13.5 Edge treatments

Requirements: The edge of wetlands (including sedimentation ponds) must be designed to conform to thefollowing to ensure the safety of the public:

> A minimum offset of 15 m must be provided from the edge of the water at NWL to any allotment orroad reserve (not including shared pathways). A safety design audit is required for any proposal thatdoes not achieve this condition;
> The edge of any deep open water should not be hidden or obscured by embankments or terrestrial planting unless measures are taken to preclude access. Public access to structures, the top of weirs, orifice pits and outlet structures must be restricted by appropriate safety fences and other barriers. Permanent fencing is required adjacent to potentially unsafe structures (i.e. deep water zones, steepdrops, top of weirs, outlet structures etc.);
> Wetlands with batters steeper than 1(V):4(H) between TED and 350 mm below NWL must have permanent fencing. Permanent fencing must be compliant with *AS 1926.1 Fencing for swimming pools*. Wetland batters with permanent fencing must make up no more than 10% of thewetland perimeter; and
> All wetland edges must have:

- Vegetated approach batters no steeper than 1(V):5(H), a 2.8 m wide vegetated safety bench at1(V):8(H) between NWL and 350 mm below NWL and a maximum 1(V):3(H) slope beyond
  350 mm below NWL (refer *ACTSD-0846 Typical Pond/Wetland Edge Details*); or
- Batters no steeper than 1(V):4(H) between TED and 350 mm below NWL with denseimpenetrable planting that is a minimum of 2.8 m wide and 1.2 m high.

13.5.1 Boardwalks

Macrophyte suppression: Measures must be provided to prevent the establishment and growth of emergent macrophytes, as shown in **Figure 8- 20 Typical examples of macrophyte growth through boardwalks**, in the vicinity of boardwalks wherever the depth of water is less than 1 m.

Bed treatments: The following bed treatments may be used:

> Rock riprap (graded to minimise voids, maximum 300 mm diameter);
> Coarse gravel (minimum 300 mm thick); or
> Fine meshed woven geofabric.

Treatment extent: The bed treatment shall extend from the waters edge to at least 1 m past the openwater side of the boardwalk.

Timber boardwalks: Approval for the use of timber boardwalks must be obtained from TCCS.

Figure 8- 20 Typical examples of macrophyte growth through boardwalks

13.6 Outlet design

13.6.1 Primary outlet

Requirements: Wetland systems have often used orifice riser or siphon type outlets to control the level and residence time of water entering the wetland. Experience has shown that these outlets are prone toblockage and are difficult to maintain. The outlet from the vegetated wetland zone to the downstream drainage system should consist of:

> A truncated submerged pit in the outlet pool, connecting to a controlled outlet pit. The invert level ofthe pit should be no more than 300 mm above the invert of the outlet pool; and
> A controlled outlet, consisting of a twin chamber outfall with an adjustable notch weir (either via anadjustable penstock or a manual pivot plate) configured to enable:

- The NWL to be drawn down by up to 150 mm during plant establishment and maintenance
- The NWL to be permanently adjusted up or down by 100 mm to respond to changes in wetland hydrology due to potential future climate conditions
- The stage/discharge rate to be adjusted if required to achieve suitable residence times and/orinundation patterns

Standard drawing: Primary outlet pits shall be designed in accordance *with ACTSD-0841 Twin ChamberOutlet Pit (EDD Control and Drawdown).*

Considerations: Design of the outlet structure must consider the following:

> The controlled outlet should be accessible from the land without entering the wetland system;
> The controlled outlet (e.g. weir plate) must be visible from the surface (e.g. through a grate); and
> Where possible, the controlled outlet should support gravity drawdown of the wetland system via aresilient sealed gate valve installed on the downstream side of the separator wall.

13.6.2 Secondary outlet

Contingency: a secondary emergency outlet should be provided with a flow capacity equal to the vegetated wetland zone outflow during the 1% AEP design storm event to ensure the wetland embankment is not overtopped should the primary outlet become fully blocked. The most common outletis a high-level weir crest and overflow spillway.

Standard drawing: inlets shall be designed in accordance *with ACTSD-0844 Inlet Scour Protection Details.*

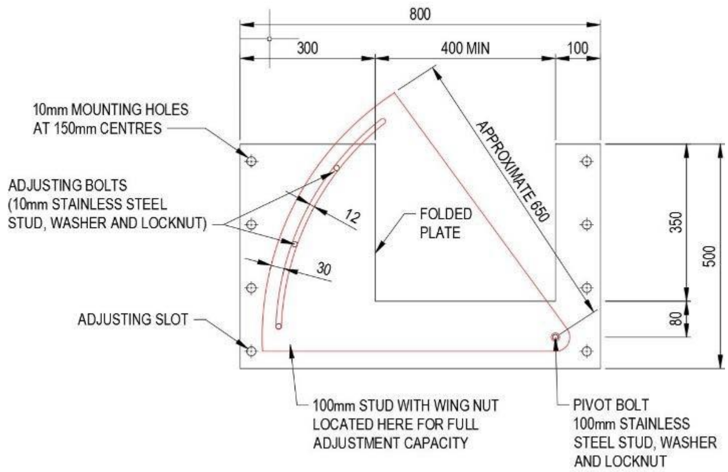


Figure 8- 21 Typical manual adjustable weir plate (Melbourne Water)

13.7 Embankments

Investigation and design: Full engineering investigation and design of wetland embankments will be required. Refer **Retarding basins, Embankments** for design requirements for embankments.

Vegetation: Refer to **Retarding basins, Landscaping** for permitted vegetation on wetland embankments.

13.8 Water plants

Species selection: Select appropriate vegetation (Ngunnawal and Aboriginal plants if applicable) for the wetland site from *MIS 25 Plant species for urban landscape projects* according to the inundation condition at the plant's location.

Requirements: Vegetation is key to the function of wetland systems. To ensure appropriate establishment and survival of wetland plants, the design must ensure:

> The vegetated wetland zone must contain a minimum 80% cover of emergent macrophytes calculated at NWL comprising of shallow and deep marsh zones;

> The macrophyte planting zone must have a sequence and mix of submerged, shallow and deep marsh zones arranged in a banded manner perpendicular to the direction of flow

(Figure 8- 22 Vegetated wetland section (after Melbourne Water, 2016));

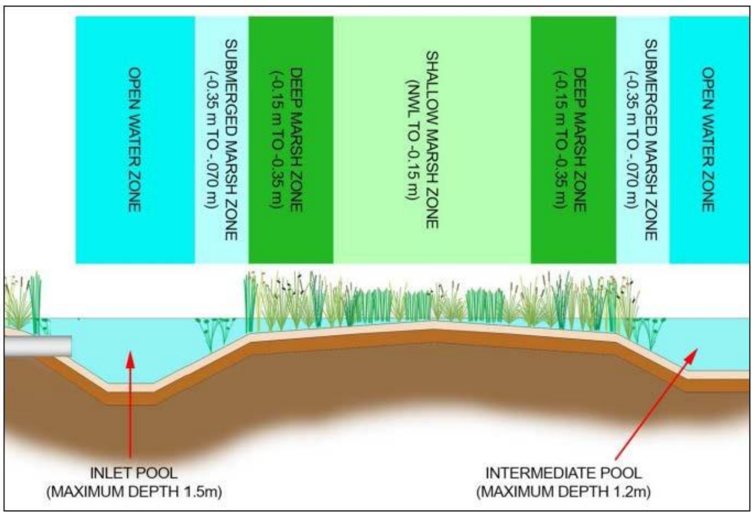


Figure 8- 22 Vegetated wetland section (after Melbourne Water, 2016)

- A minimum grade of 1(V):150(H) between marsh zones (longitudinally through the vegetated wetland zone) to enable the wetland to freely drain. Intermediate pools will generally be needed to transition between marsh zones;
- Ephemeral batters (NWL to 200 mm above NWL) of the macrophyte zone and sediment forebay must be densely planted with plants suited to intermittent wetting;
- The submerged marsh (350 to 700 mm below NWL) of the macrophyte zone must be densely planted;
- The shallow marsh (NWL to 150 mm below NWL) of the macrophyte zone and sediment forebay must be densely planted. A minimum of three species must be specified for the shallow marsh zone;
- The deep marsh (150 to 350 mm below NWL) of the macrophyte zone must be densely planted. 90% of the plants used in the deep marsh must be in accordance with the species and densities. A minimum of three species must be specified for the deep marsh zone; and
- The effective water depth (permanent pool depth plus EDD) must not exceed half of the average fullygrown plant height for shallow and deep marsh plantings for more than 20% of the time.

14 PONDS

14.1 General

14.1.1 Function

Purpose: Ponds are permanent water storages that function to capture coarse and fine sediments via sedimentation. They may also incorporate minor plantings around the periphery to absorb nutrients. Ponds may also have secondary functions by retaining stormwater for harvesting as a source of secondclass water supply for irrigation and/or providing temporary flood storage for attenuating peak flows.

Components: The pond design should incorporate the following main zones:

- Inlet zone;
- Macrophyte zone; and
- Open water zone.

14.1.2 Pond configuration

Shape: Ponds should be long relative to their width. The length to width ratio should be in the range from 3 to 5 to provide better distribution of flows across the pond.

14.1.3 Inlet zone

Requirement: An inlet zone shall be provided on all engineered waterways and pipelines discharging into a pond. This shall normally consist of an upstream GPT or trash rack to remove litter and debris, and a sediment forebay to remove coarse sediment particles. Refer to **Wetlands, Sediment forebay zone** for design requirements for sediment forebays and **Gross pollutant traps** for design requirements for GPTs.

Inlet structures: It is desirable that inlet structures be located as far from outlet structures as possible to maximise detention time and to ensure that the entire water body is utilised for pollution control.

Preference: From the point of view of in-pond processes, multiple inlets that disperse the total pollutant load around the upstream end of the pond are preferable to single inlets.

Disallowed: No water contact sports should occur in this zone.

14.1.4 Macrophyte zone

Purpose: Macrophytes (aquatic plants either emergent or submergent) enhance the pollutant removalpotential of ponds by filtering finer particles and taking up nutrients. They can also help to prevent scouring of the sediments during high flows and can reduce sediment mobilisation by wind-generated waves.

Configuration: The configuration and design of a pond should incorporate sufficient shallow areas to encourage the growth of beds of emergent and submergent aquatic macrophytes. As a general guide,between 10 and 30% of the total surface area of a pond should be set aside for macrophyte growth, particularly in the upper reaches.

Water depths: Depths shallower than 2.4 m are likely to be colonised by submergent macrophytes whiledepths shallower than 0.6 m are likely to be colonised by emergent macrophytes.

14.1.5 Open water zone

Requirement: A deeper area that allows time for fine particles to flocculate and settle, and allows sunlightto kill bacteria shall be provided.

Minimum water depth: Should be greater than 2.4 m to minimise the growth of rooted macrophytes.

Maximum water depth: Should not exceed 3.0 m because of the increased risk of temperaturestratification beyond this depth.

14.1.6 Flow velocities

Maximum velocity: The maximum average flow velocity in the macrophyte and open water zones ofponds shall not exceed 2 m/s in all storm events up to and including 1% AEP.

Design: For online ponds, an in-pond high flow bypass system should be considered to contain and directhigh flows to the pond outlet (refer **Figure 8- 23 Typical examples of in-pond high flow bypass systems**). Scour protection measures must be provided on pond batter slopes that would be adversely affected by such high flows.

Design: For offline ponds, flow velocities may be reduced by the provision of islands or groynes tolengthen the flow path through the pond.

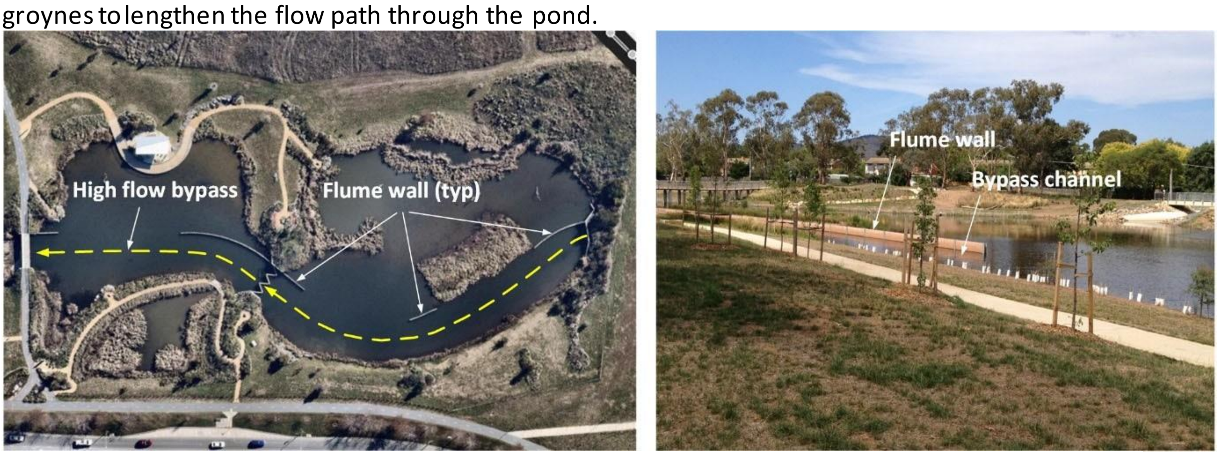


Figure 8- 23 Typical examples of in-pond high flow bypass systems

14.1.7 Islands

Consideration: Islands may be provided in ponds with wide inflow reaches to distribute flow evenly acrossthe reach and to prevent short circuiting. Islands will facilitate wind driven circulation and therefore should be aligned with respect to prevailing winds. Also, islands are especially beneficial as habitat since they protect birds from predators such as domestic cats and dogs.

14.1.8 Edge treatments

Requirements: Natural soft edges should be used wherever possible to encourage a variety of shorelineplants. The shore line edge is to be free draining to discourage isolated pockets of water (potential breading area for mosquitos). The edge should be capable of withstanding wave action erosion.

Materials: Hard edge treatments such as timber and stone walls should only be used where required foradjacent land uses, and where it is desirable to discourage emergent macrophytes.

Side slopes: An edge side slope of 1(V):15(H) should be provided in areas where it is desirable to establishaquatic macrophytes to trap pollutants, provide bank stability, and provide habitat. This gentle slope, freefrom sudden drops will not present a safety hazard to children wading.

Side slopes: Where it is desired to limit the extent of macrophyte growth, an edge side slope of 1(V):8(H) should be provided to a minimum depth of 1 m below NWL. A coarse gravel substrate may also be used toreduce macrophyte colonisation.

Standard drawing: Refer *ACTSD-0846 Typical Pond/Wetland Edge Details.*

14.2 Outlet design

14.2.1 Primary outlet

Design capacity: Pond primary outlets shall be designed for at least a 1% AEP flow capacity.

Preferred configuration: The primary outlet will normally take the form of an open pit structure and outletconduit. For smaller ponds, the outlet may be a weir crest and open spillway.

Flood protection: The outlet shall be designed to avoid floodwaters, up to and including 1% AEP, from inundating upstream roadways and leases. Flood protection requirements for other adjacent land usesshall also be considered where appropriate.

Dry weather baseflow: A low flow slot should be provided in the pit structure crest to concentrate dry weather baseflow and thereby prevent the entire crest of the structure being constantly wet.

Public safety: Pit structures must be provided with a grated domed cover or similar for public safety andto prevent unauthorised access to the primary outlet structure. The sizing of the outlet structure and cover must account for the loss of waterway area and associated head loss created by the cover. Refer **Figure 8-24 Typical primary outlet domed cover** for a typical example.

Figure 8- 24 Typical primary outlet domed cover

Maintenance access: Pit structures shall be provided with step irons and a locked access gate in the grated dome cover to allow maintenance access to the inside of the primary outlet. Consult with TCCS for lock requirements.

Location: The pit structure must be located within the pond permanent water storage area at least 6 m from the waters edge to discourage unauthorised access.

14.2.2 Secondary outlet

Design: The secondary spillway design shall be in accordance with the latest *ANCOLD* guidelines.

Preferred configuration: The secondary outlet will normally take the form of a high-level weir crest and open spillway.

Design capacity: A Consequence Category assessment in accordance with *ANCOLD* guidelines must be undertaken to determine the AFC AEP for the secondary outlet.

14.3 Embankments

Guidelines: The pond embankment design shall be in accordance with the latest *ANCOLD* guidelines.

Investigation and design: Full engineering investigation and design of pond embankments will be required. Refer **Retarding basins, Embankments** for design requirements for embankments.

Side slopes: Embankment slopes that require mowing should generally not exceed 1(V):6(H) although in some circumstances up to 1(V):4(H) may be accepted over small areas.

Vegetation: Refer to **Retarding basins, Landscaping** for permitted vegetation on pond embankments.

Access: Suitable access shall be provided to the pond embankment for maintenance machinery. Access ramps shall be at least 3.7 m wide (unobstructed) and have slopes no steeper than 1(V):6(H). Ramps steeper than 1(V):10(H) shall be constructed from concrete or other approved material.

Transitions: Transitions shall be provided at the crest and toe of ramps. Adequate space to manoeuvre machinery on and off the ramps shall also be provided.

14.4 Emergency drainage facility

Requirement: The pond design shall incorporate a drainage facility to enable at least 80% of the pond volume to be drained within 14 days.

Protection: Intakes to this facility must be screened to minimise the likelihood of blockage.

Careful consideration must also be given to the effect of sediment build-up around the outlet. Outlet valves must be located in a concrete pit accessible from the surface by authorised maintenance personnel.

Design: The drainage facility must be designed to be vandal resistant and secured to prevent unauthorised drawdown of the pond.

14.5 Water plants

Species selection: Select appropriate vegetation for the site from *MIS 25 Plant species for urban landscape projects* according to the inundation condition at the plant's location. Designers should also consider the site conditions, maintenance requirements and design intent when selecting species. The following criteria must be considered when selecting plants for a particular pond site:

- A plant must be unlikely to colonise outside the proposed area, or to colonise downstream of the pond;
- The maximum height of the plants must be consistent with maintaining desirable visual characteristics around the pond;
- The over-wintering form of a plant must not cause degradation of the aesthetics of the area; and
- Plants must not grow to a density that would provide habitats suitable for mosquito breeding.

14.6 Public safety

14.6.1 Advisory signs

Public safety: Water based recreation is generally inappropriate in small ponds and in the upstream parts of larger ponds (i.e. the inlet and macrophyte zones). Advisory signs shall be provided to warn of the danger of shallow water and advise where swimming and other recreational activities are not permitted.

Signage location: The signs shall be located at points where access to the pond edge is unobstructed and generally at intervals around the pond such that adjacent signs are visible from each other.

Sign details: The sign shall be 300 mm x 450 mm with red lettering on a white light reflective (refer *ACTSD-0855 Stormwater advisory signs*). The signs shall be erected back to back on a 75 mm grey galvanised steel pole and be located 1.5 m above the ground. The blades shall be oriented at right angles to the water.

14.6.2 Power line warning signs

Requirement: Where lakes or ponds which are likely to be used for boating are constructed such that power lines pass over either the water or the access to the water, appropriate warning signs must be erected to advise of the electrical hazard posed by the lines. Detail of type and location of signs are available from ActewAGL.

14.6.3 Boardwalks

Refer: **Wetlands, Edge treatments** for recommended treatments to prevent the establishment of macrophytes in the vicinity of boardwalks.

15 BIORETENTION SYSTEMS

15.1 General

15.1.1 Bioretention types

Asset types: The following types of bioretention systems are covered by this design standard:

> Tree pits (refer **Figure 8- 25 Typical tree pit (Melbourne Water, 2013)**);
> Bioretention swales (refer **Figure 8- 26 Typical bioretention swale (Tasmanian WSUD Manual, 2012)**); and
> Bioretention basins (refer **Figure 8-27 Typical bioretention basin (Melbourne Water, 2013)**)

Figure 8- 25 Typical tree pit (Melbourne Water, 2013)

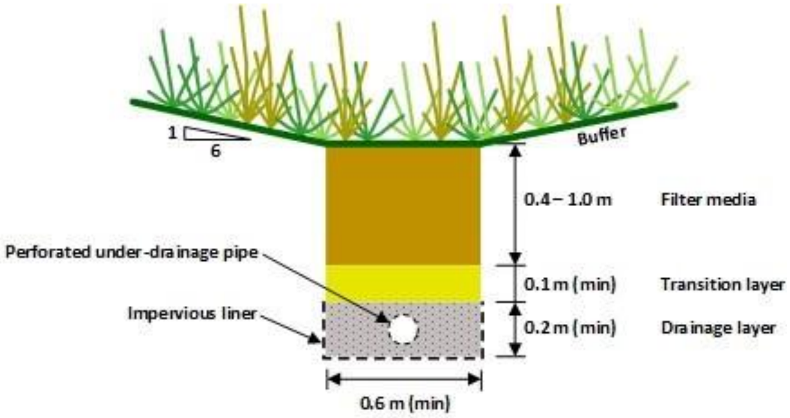


Figure 8- 26 Typical bioretention swale (Tasmanian WSUD Manual, 2012)

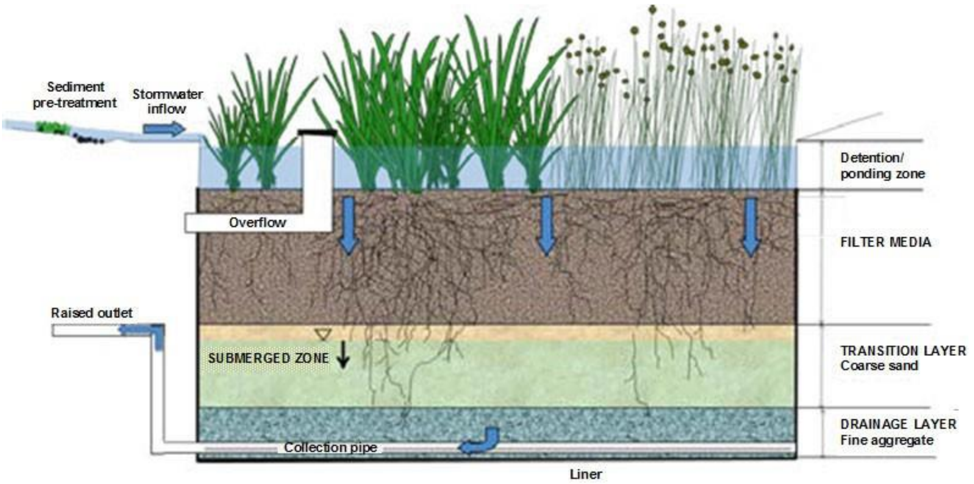


Figure 8- 27 Typical bioretention basin (Melbourne Water, 2013)

15.1.2 Size classification

Size classification: Bioretention systems have been classified by the following size ranges:

> Small systems (filter area ≤ 500 m^2); and
> Large systems (filter area > 500 m^2).

Refer: Large systems shall be split into a number of separate treatment cells (refer to **Cellular design for large systems).**

15.1.3 Service locations

Services check: As part of the initial assessment, the designer must check that there are no utility services(existing or proposed) located in the bioretention site. These include assets such as telecommunications, gas, power, stormwater, water and sewerage.

Requirement: The designer should liaise with the relevant service providers to ensure that:

> conflicts do not arise between the location of services and the bioretention system;
> access for maintenance to existing services is maintained; and
> bioretention will not result in water damage to existing services or structures.

15.1.4 Cellular design for large systems

Requirement: If the total plan area of the filter media exceeds 500 m^2, the bioretention system shall be split in separate self-contained cells as shown in **Figure 8- 28 Cellular bioretention basin (Blacktown City Council).** This, in combination with an appropriate flow spreader system, will facilitate a more even distribution on inflows across the filtration beds and thereby improve overall system performance.

Cell configuration: Each cell shall be designed as a separate self-contained unit with its own flow inlet, flow spreader system, filter media bed, under-drainage system and overflow pit. The underdrain systemof each cell should be connected to a collector drainage network to facilitate discharge to the downstream stormwater system.

2.1.1.23 Maximum cell size

Requirement: The maximum plan area of each cell's filtration media bed shall not exceed 500 m^2. Thelength of each cell shall not exceed 40 m and the width shall not exceed 15 m.

Figure 8- 28 Cellular bioretention basin (Blacktown City Council)

2.1.1.24 Cell grading

General: The longitudinal and lateral grading of the surface of each cell shall be horizontal.

Terracing: For steeper sites, cells should be terraced with provision for overflow from a higher cell to a lower cell via culverts under the access track between each cell. Care needs to be taken with the design ofthe flow spreader system to ensure that inflows are evenly distributed to all cells in the system.

Elevations: The maximum elevation difference between the surfaces of adjacent cells shall not exceed 0.5 m.

2.1.1.25 Edge batter slopes

Requirement: The batter slope around the perimeter of a cell should not exceed 1(V):4(H). Steeper slopesmay be allowed with appropriate low-maintenance landscaping.

2.1.1.26 Flow balancing

Requirement: Culverts may be placed under the access tracks between each cell to assist with flow balancing to ensure that inflows are evenly distributed across each cell in the system (refer **Figure 8- 28 Cellular bioretention basin (Blacktown City Council)**).

2.1.1.27 Maintenance access

Requirements: Each cell shall be configured such that an access track with a minimum width of 5 m is provided between each cell for maintenance. Limiting the width of each cell to 15 m will allow the arm ofan excavator with a 10 m reach to reach the middle of a cell from the access track on either side. This allows each cell to be maintained without machinery driving onto the cell and compacting the filtration media.

Double-sided access: The maximum width across a cell from the inside edge of the access tracks on eitherside shall not exceed 20 m.

Single-sided access: If an access track is provided on only one side of an outside cell, the width of the cellshall not exceed 7.5 m and the width from the far side of the cell to the edge of the access track shall notexceed 10 m.

Refer: **Figure 8- 29 Bioretention cell width limitations (after Water By Design)** for cell width limitations for ease of maintenance.

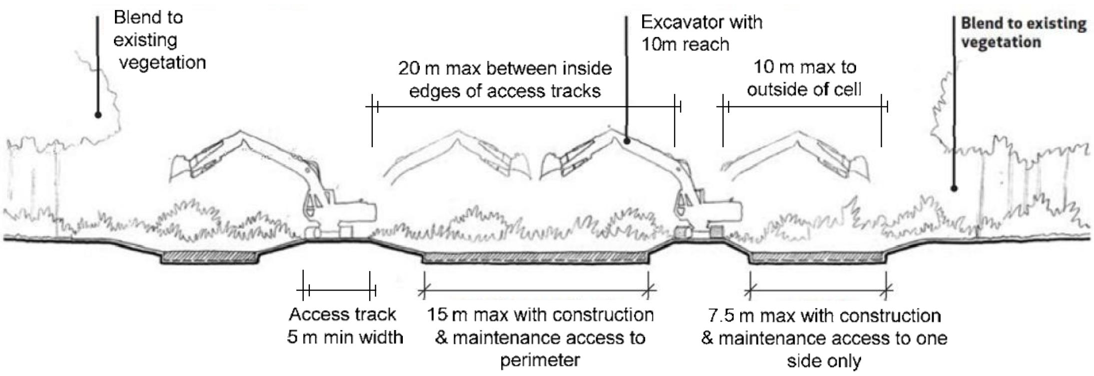


Figure 8- 29 Bioretention cell width limitations (after Water By Design)

15.2 Inflows

15.2.1 Design flows

Design flow requirements: Estimation of three design flows are required for bioretention systems:

> Minor system design flow (refer **Table 8- 3 Minor system design AEP**) to size theinflow system and overflow pit to allow minor floods to be safely conveyed and not increase any flooding risk compared to conventional stormwater systems;

> Major system design flow (1% AEP) to check that flow velocities in the bioretention system do not exceed the limits stated in **High flow bypass** which could potentially scour pollutants or damage vegetation; and

> Maximum infiltration rate through the filter media to allow for the underdrain to be sized, such that the under-drainage will allow the filter media to drain freely.

15.2.2 Minimum design flow

Criterion: The minimum design flow for treatment shall be 4 EY.

15.2.3 Design flow estimation

Method: A runoff routing model shall be used for the estimation of design flows for all bioretentionsystems.

Refer: **HYDROLOGY** for details of suitable hydrological design models and recommended model parameters.

15.3 Pre-treatment

15.3.1 GPT

Requirement: A GPT shall be provided upstream of all inlets to prevent litter and coarse sediment from entering the facility and clogging the filter media for on line bioretention systems. However, it is desirable to limit the number of GPTs on a bioretention facility. TCCS shall be consulted at the initial design stage for advice on rationalising the number of GPTs to be provided.

15.3.2 Sediment forebay

Location: For large bioretention systems, a sediment forebay should be provided upstream of the filtermedia area. The sediment forebay is in addition to the upstream GPT.

Refer: The performance requirements and sizing of sediment forebays shall be in accordance with **Wetlands, Sediment forebay zone.**

15.4 Flow inlets

Velocity limit: Flow velocities at inlets must be checked to ensure scour does not occur in the bioretentionsystem from inflows up to and including 1% AEP.

15.4.1 Inlet scour protection

Refer: **Wetlands, Sediment forebay zone** for details.

15.4.2 Kerb opening inlets

Sizing: The opening width must be large enough to ensure that road flow widths do not exceed the maximum allowable widths stated in **Table 8- 19 Surface flow criteria for roads.** The width of the opening in the kerb can be calculated by applying the broad crested weir equation (**Equation 16.5-3**) based on the kerb flow depth for the maximum allowable road flow width (refer **Figure 8- 30 Half road flow spread**).

Method: The opening width is estimated by applying the flow depth in the gutter invert (as *H*) and solvingfor *L* (kerb opening width).

$$L = \frac{Q_{des}}{C_w . H^{1.5}}$$

(*Equation* 16.5-*3)*

where:

L	=	kerb opening width (m)
Q_{des}	=	flow rate over weir (m^3/s)
C_w	=	weir coefficient (1.7 for broad-crested weir)
H	=	depth of water above the weir (m)

This method ensures the kerb opening does not result in an increase in the upstream gutter flow depth,which in turn ensures the streetscape system does not impact on the trafficability of the adjoining road pavement.

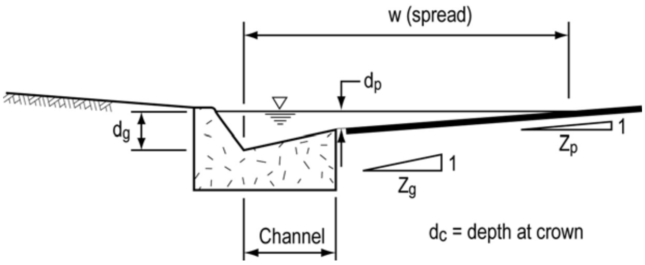


Figure 8- 30 Half road flow spread

15.4.3 Flow spreaders

Requirement: The provision of a flow spreader (especially in large bioretention systems) shall be providedto help distribute inflows over the whole filter area. Systems typically consist of a channel (preferably along the longest side of the filter media) with an impervious edge (broad-crested weir) at a constant level at or slightly above the top finished surface level of the filter media

Standard drawing: For details of flow spreaders, refer to *ACTSD-0845 Typical flow Splitters.*

15.4.4 High flow bypass

External bypass: An external high flow bypass system (typically a weir and overflow channel) shall be provided if flows greater than the bioretention design flow up to the 1% AEP would exceed the vegetationscour velocity limits stated in **High flow bypass**. The bypass system shall be sized for the 'gap' flow between the design flow and the 1% AEP. The bypass weir crest level must not be higherthan the top of the bioretention EDD.

Internal bypass: If flows greater than the 1 EY design flow do not exceed the vegetation scour velocitylimits stated in **High flow bypass**, such flows may be bypassed through the bioretention system via an overflow pit.

15.4.5 Vegetation scour velocity

Maximum velocities: The maximum permissible flow velocities over the filter media vegetation are:

- 0.5 m/s (design flow)
- 1.0 m/s (1% AEP flow)

15.4.6 Road flow limits

Requirement: The width of gutter flow at road entry points to bioretention systems (e.g. tree pits and bioretention swales) must comply with TCCS road flow requirements (refer **Table 8-19 Surface flow criteria for roads**) to ensure traffic is not adversely affected.

15.5 Public safety

15.5.1 Velocity depth product

Flow criteria: The following criteria must be met for all bioretention systems accessible by the public:

- velocity depth product (VxD) < 0.4 m^2/s; and
- depth of flow over vehicle crossings ≤ 0.3 m.

15.5.2 Tree pit covers

Requirements: In areas of high pedestrian traffic, such as at town and group centres, tree pits shall be provided with a surface cover. The cover may be a grating or solid cover with an opening of sufficient size to accommodate the expected trunk size of the tree when fully grown (refer **Figure 8-31 Example Tree Pit Cover (Melbourne Water)**). In all other areas with less pedestrian traffic, tree pits may be left uncovered.

Figure 8-31 Example Tree Pit Cover (Melbourne Water)

15.6 Biofiltration media

15.6.1 Filter media

Depth limits: The filter media depth shall be within the following limits:

> minimum 400 mm to support vegetation; and
> maximum 1000 mm.

General criteria: The primary bioretention filter media shall be permeable enough to allow runoff to filter through the media. The media shall meet the following general criteria:

> a loam/sand, or sand, or sand/gravel mix;
> clay content less than 3% (by mass);
> not susceptible to degradation or breakdown once incorporated in the works;
> hydraulic permeability of at least 100 mm/hour (i.e. silt/sand loam);
> free of stumps, roots, or other woody material over 25 mm in diameter; and
> free of brush or seeds from noxious plants.

Permeability: Filter media permeability for uniform clean sand can be estimated using the Hazen formula as follows:

$$k = c \cdot (d_{10})^2$$ *(Equation 16.12.2-1)*

where:

k = approximate filter media hydraulic conductivity (cm/s)

c = dimensionless constant ranging from 1.0 to 1.5 (assume 1.0)

d_{10} = particle size (mm) for which 10% by weight of particles are smaller

The calculated permeability should be reduced by a factor of 10 to account for likely reductions from roots and trapped particles.

Filter media: A planting soil shall be used as the primary filter media. The soil shall be permeable enough to allow runoff to filter through the media, while having characteristics suitable to promote and sustain a vegetation cover (e.g. a sand/loam mix – 35 to 60% sand content by mass).

Refer: Minimum requirements for filter media properties are provided in **Table 8- 36 Minimum filter media requirements**.

Table 8- 36 Minimum filter media requirements

	Property	Requirements
Essential Requirements	**Material**	A loamy sand, a washed well-graded sand or a sand/fine gravel mix
	Hydraulic conductivity	100 – 300 mm/hr. Determine using *ASTM F1815-11* method
	Clay & silt content	< 3% (w/w)
	Grading of particles	Smooth grading – all particle size classes should be represented across sieve sizes from the 0.05mm to the 3.4mm sieve (as per *ASTM F1632-03*)
	Nutrient content	Low nutrient content Total Nitrogen (TN) < 1000 mg/kg Available phosphate (Colwell) < 80 mg/kg
	Organic matter content	≤ 5% to support vegetation
	pH	5.5 – 7.5
	Electrical conductivity	< 1.2 dS/m
	Horticultural suitability	Assessment by horticulturalist – media must be capable of supporting healthy vegetation (refer once-off amelioration). Note that additional nutrients are delivered with incoming stormwater
Guidance	**Particle size distribution (PSD)**	Note that it is most critical for plant survival to ensure that the fine fractions are included (% w/w) Retained — Sieve size fraction Clay & silt: < 3% (< 0.05 mm) Very fine sand: 5-30% (0.05-0.15mm) Fine sand: 10-30% (0.15-0.25 mm) Medium sand: 40-60% (0.25-0.5 mm) Coarse sand: < 25% (0.5-1.0 mm) Very coarse sand: 0-10% (1.0-2.0mm) Fine gravel: < 3% (2.0-3.4 mm)
	Depth	400-600 mm or deeper
	Once-off nutrient amelioration	Added manually to top 100 mm once only to aid plant establishment Particularly important for engineered media
	Submerged zone	Strongly recommended, particularly if entirely engineered media is used, filter media has a relatively high hydraulic conductivity or a shallow depth

Note: PSD is used to provide guidance to achieve optimum hydraulic conductivity and water holding capacity for the filter media to support vegetation. Providing the hydraulic conductivity criteria are met, the particle size criteria do not need to be met with the exception for the criteria for clay and silt.

15.6.2 Transition layer

Criteria: The particle size difference between the filter media and the underlying drainage layer should be not more than one order of magnitude to avoid the filter media being washed through the voids of the drainage layer. Therefore, if fine gravels are used for the drainage layer (which will be at least two orders of magnitude coarser than the likely average particle size of the filter media), then a transition layer is required to prevent the filter media from washing into the under-drainage system.

Disallowed: Geofabric shall not be used as a separation layer between the filter media and drainage layersin lieu of a transition layer.

Minimum thickness: 100 mm.

Refer: Minimum requirements for transition layer properties are provided in **Table 8- 37 Minimum transition layer requirements.**

Table 8- 37 Minimum transition layer requirements

	Property	Requirements
Essential Requirements	**Material**	Clean well-graded sand e.g. A2 Filter sand
	Hydraulic conductivity	Must be higher than the hydraulic conductivity of the overlying filter media
	Fine particle content	< 2%
	Particle size distribution	Bridging criteria – the smallest 15% of sand particles must bridge with the largest 15% of filter media particles *(Water by Design, 2009) (VicRoads, 2004):* D15 (transition layer) ≤ 5 x D85 (filter media) where: D15 (transition layer) is the 15th percentile particle size in the transition layer material (i.e.,15% of the sand is smaller than D15 mm), and D85 (filter media) is the 85th percentile particle size in the filter media The best way to compare this is by plotting the particle size distributions for the two materials on the same soil grading graphs and extracting the relevant diameters *(Water by Design)* Bridging criteria: only in designs where transition layer is omitted (Water by Design, 2009; VicRoads, 2004): D15 (drainage layer) ≤ 5 x D85 (filter media) D15 (drainage layer) = 5 to 20 x D15 (filter media) D50 (drainage layer < 25 x D50 (filter media) D60 (drainage layer) < 20 x D10 (drainage layer)
Guidance	**Depth**	≥ 100 mm

15.6.3 Drainage layer

Criteria: A drainage layer shall be provided to convey treated flows from the base of the filter media layerinto the perforated under-drainage system. The composition of the drainage layer must be considered when selecting the under-drainage system. The size of the openings in the perforated pipes determine the minimum drainage layer particle size that will not be washed into the underdrain pipe system.

Preferred material: Sand is the preferred drainage layer media material. However, coarser material (e.g.fine gravel) shall be used if the opening sizes in the underdrain pipes are too large for the use of sand.

Minimum thickness: 200 mm.

Refer: Minimum requirements for drainage layer properties are provided in **Table 8- 38 Minimum drainage layer requirements.**

Table 8- 38 Minimum drainage layer requirements

	Property	Requirements
Essential Requirements	**Material**	Clean, fine aggregate - 2-7 mm washed screenings (not scoria)
	Hydraulic conductivity	Must be higher than the hydraulic conductivity of the overlying transition layer
	Particle size distribution	Bridging criteria: D15 (drainage layer) ≤ 5 x D85 (transition media) <u>where:</u> D15 (drainage layer) - 15th percentile particle size in the drainage layer material (i.e., 15% of the aggregate is smaller than D15 mm), and D85 (transition layer) - 85th percentile particle size in the transition layer material
	Underdrain Perforations	Perforations must be small enough relative to the drainage layer material Check: D85 (drainage layer) > diameter underdrain pipe perforation
Guidance	**Depth**	≥ 200 mm Minimum 50 mm cover over under-drainage pipe

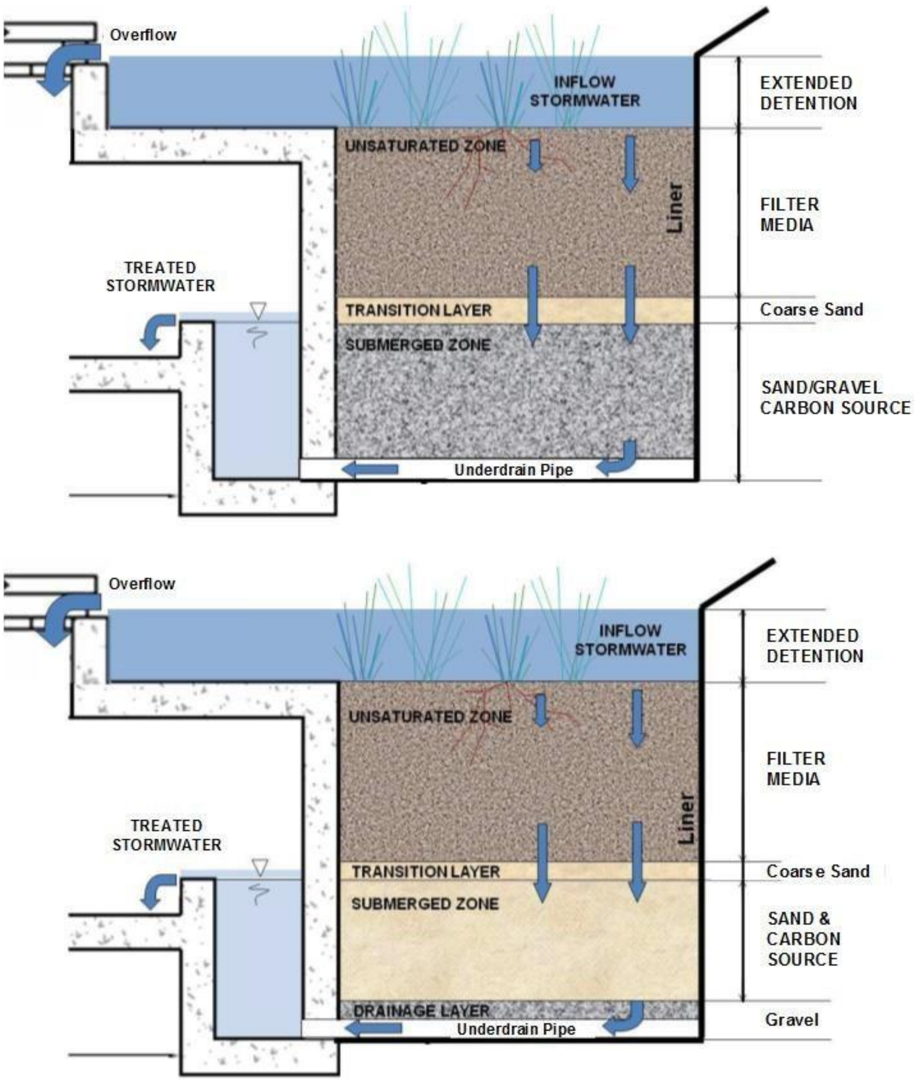


Figure 8- 32 Typical bioretention submerged zone (after FAWB, 2009)

15.6.4 Submerged zone

Criteria: A submerged zone shall be incorporated in the lower layers of the biofilter system. This zone shall be created by sealing the biofilter base and sides using an impermeable lining and providing a raised outlet. Refer to **Figure 8- 32 Typical bioretention submerged zone (after FAWB, 2009)** for typical submerged zones.

Minimum depth: 300 mm.

15.6.5 Impermeable liner

Requirements: The impermeable liner shall be polypropylene or polyethylene and cover the base and sides of the filter system up to at least the top of the filter media layer. All overlaps in the liner shall be welded to prevent water leakage.

15.7 Outflows

15.7.1 Under-drainage system

15.2.1.1 Flow Capacity

Requirement: The flow capacity of the under-drainage system must be greater than the maximum infiltration rate of the overlying filter media to ensure the filter media drains freely.

Infiltration rate: A maximum infiltration rate can be estimated by applying Darcy's equation:

$$Q_{max} = k.L.W_{base}.\frac{h_{max+d}}{d} \qquad \text{(Equation 16.14-1)}$$

where:

Q_{max} = maximum infiltration flow rate (m^3/s)

k = hydraulic conductivity of the filter media (m/s)

L = length of the bioretention zone (m)

W_{base} = base width of the ponded cross section above the filter media (m)

h_{max} = depth of pondage above the filter media (m)

d = depth of filter media (m)

Drainage outlet: The under-drainage system shall be connected to the municipal pipe stormwater network or free drain to a downstream open waterway.

15.2.1.2 Pipe Materials

Requirement: The under-drainage system shall consist of a perforated/slotted pipe or pipe network. The preferred pipe material is either slotted uPVC pipes or flexible perforated pipes (e.g. AG pipe). However, when selecting the type of pipe, the capacity of the pipe perforations must be greater than the maximum infiltration rate of the overlying filter media.

Disallowed: Under-drainage pipes must not be wrapped in geofabric or any other type of lining material.

15.7.2 Minimum pipe diameter

Minimum diameter: 100 mm.

15.7.3 Maximum spacing

Criteria: Under-drainage pipes shall be spaced such that the distance water needs to travel horizontally toward the perforated pipes through the drainage layer does not hinder drainage of the filter media. The maximum centre to centre spacing of the under-drainage pipes shall be as specified in **Table 8-39 Maximum pipe spacing.**

Table 8-39 Maximum pipe spacing

Bioretention Filter Area	Maximum Spacing
≤ 100 m^2	1.5 m
> 100 m^2	3.0 m

15.7.4 Minimum grade

Requirement: The perforated pipes shall have a minimum grade of 0.5% towards the overflow pit to ensure effective drainage. This is best achieved by grading the base of the bioretention system towards the pit and placing the perforated pipes (and the drainage layer) on this grade.

15.7.5 Pipe sizing

General: The flow capacity of the underdrains needs to be greater than the maximum infiltration rate to ensure free drainage of the filter media is not restricted by the hydraulic capacity of the pipes.

Sizing method: The required pipe size can be determined from Manning's equation (using a simplified assumption of pipe full flow but not under pressure). The Manning's 'n' roughness will be dependent on the type of pipe used. Recommended pipe roughness values are provided in **Table 8-40 Pipe Roughness Values.**

$$D = \left[\frac{4\,.Q.n}{\pi^2\,.\,S^{0.5}}\right]^{3/8}$$ *(Equation 16.14-2)*

Where:

D = pipe diameter (m)

Q = design flow rate (m^3/s)

n = Manning's roughness

S = pipe slope (m/m)

Table 8-40 Pipe Roughness Values

Pipe Material	*n*	*k* (mm)
Reinforced Concrete Pipe (RCP)	0.013	0.30
Fibre Reinforced Cement (FRC)	0.013	0.15
Unplasticised Polyvinyl Chloride(uPVC)	0.011	0.06

Glass Reinforced Pipe (GRP)	0.011	0.06

15.7.6 Pipe perforations

Criteria: The pipe perforations shall be sized such that sediment will not freely flow into the pipes from the drainage layer. This shall also be considered when specifying the drainage layer media.

Sizing: The number and size of perforations needs to be determined (typically from manufacturer's specifications) to estimate the flow rate into the pipes. A 50% blockage of the perforations shall be used.

Flow capacity: The flow capacity of the perforated pipe(s) is calculated using the orifice equation:

$$Q_{perf} = N_p.B.C_d.A\sqrt{2gH}$$

(*Equation 16.14-3)*

Where:

Q_{perf} = flow through perforations (m^3/s)

N_p = number of perforations

B = blockage factor (0.5)

C_d = orifice discharge coefficient (0.6)

A = perforation area (m^2)

g = acceleration due to gravity (9.81 m/s^2)

H = maximum depth of water above the pipe (m)

15.7.7 Inspection and maintenance riser

Criteria: Inspection and maintenance risers shall be provided by extending the underdrains vertically to the surface of the bioretention system to allow inspection and maintenance (backflushing of underdrains) when required. The vertical section of the underdrain inspection riser must be unperforated and capped to avoid short-circuiting of flows directly to the drain. Risers shall be located on the perimeter of the filter media bed so that they are readily accessible for inspection and maintenance purposes.

Standard drawing: Maintenance risers shall be designed in accordance with *ACTSD-0845 Bioretention Drainage Layer Details.*

15.7.8 Raised outlet

Requirement: The outlet(s) of the under-drainage system shall be raised to create a permanentsubmerged zone within the filter media system.

Standard drawing: Refer *ACTSD-0840 Bioretention Outlet Pit.*

15.8 Overflow pits

15.8.1 General

Criteria: An overflow system shall be provided to cater for flows in excess of the filtration capacity of thefilter media and extended detention storage. In bioretention basins, the overflow pit shall be designed with the pit crest raised above the level of the bioretention filter media, to establish the design EDD (i.e.maximum ponding depth).

Allowable head: The allowable head for discharge into the pit is the difference between the pit crest level and the maximum permissible water level. The design flow to be used to size the overflow pit will typically be the design flow for offline systems and the major system flow (1% AEP) for online systems.

15.8.2 Location

General: Overflow pits shall not be located within the bioretention filter media bed. They shall be keyedinto the surrounding batter slope with provision for ease of access for inspection and maintenance purposes.

15.8.3 Sizing

General: The size of the pit opening required to discharge flows up to the maximum allowable head shallbe checked under both free flow and drowned outlet conditions. The pit opening shall be the larger dimension determined from the two outflow conditions (refer ***Equations 16.14-4*** and ***16.14-5***).

Sizing of opening:

(1) For free flow outlet conditions (weir equation):

$$L = \frac{Q_{des}}{B.C_w.H^{1.5}}$$

(Equation 16.14-4)

Where:

L = perimeter length of pit opening (m)

Q_{des} = design flow over weir (pit) (m^3/s)

B = blockage factor (0.5)

C_w = weir discharge coefficient (1.7)

H = flow depth above the top of the pit opening (m)

Once the length of weir is calculated, a standard sized pit should be selected with a perimeter at least thesame length of the required weir length.

(2) For drowned outlet conditions (orifice equation):

$$A_0 = \frac{Q_{des}}{B.C_d.\sqrt{2gH}}$$

(Equation 16.14-5)

Where:

A_0 = area of pit opening or perforations in grate for a grated lid (m^2)

Q_{des} = design flow rate under drowned conditions (m^3/s)

B = blockage factor (assume 0.5)

C_d = orifice discharge coefficient (0.61)

g = acceleration due to gravity (9.81 m/s^2)

H = flow depth above the top of the pit opening (m)

15.8.4 Tree pits

Overflow pit crest level: Must be at least 100 mm belowthe invert of the street gutter (thereby settingthe maximum ponding depth).

15.9 Bioretention swales

15.9.1 Flow capacity

Requirement: Bioretention swales shall be sized to cater for the maximum 1% AEP flow from the contributing catchment plus freeboard (refer **Table 8-16** for freeboard requirements).

15.9.2 Maximum width and side slopes

Maximum width: The maximum width of a swale will normally be determined by the urban layout at the concept design stage (i.e. width of road reserve/verge and width of road/car park median). Where the swale width is not constrained by an urban layout (e.g. located within a large parkland area), the width ofthe swale should be selected based on consideration of;

- landscape objectives,
- maximum side slopes for ease of maintenance and public safety,
- hydraulic capacity required to convey the desired design flow, and
- treatment performance requirements.

Side slopes: The preferred maximum for swale side slopes is 1(V):6(H), however 1(V):4(H) may bepermitted in locations where space is limited such as in narrow street verges.

Driveway crossings: 'At-grade' driveway crossings are preferred for bioretention swales located instreetscape verges. The profile of the driveway will need sufficient transitions to allow for traffic movement across the crossing.

15.9.3 Maximum longitudinal grade

Criteria: The longitudinal grade of a swale shall be selected such that the average 1% AEP flow velocitydoes not exceed the limits specified in **Table 8- 15 Maximum flow velocities for major design storm event.**

15.9.4 Lateral inflows

Design: Distributed inflows to swales from road and car park pavements can be achieved by having a flush or castellated kerb as shown in **Figure 8- 33 Bioretention swale kerb treatments** to allow for even flows across the swale batter surface.

Figure 8- 33 Bioretention swale kerb treatments

15.9.5 Pavement edge treatment

Criteria: The top of the ground surface (before turf is placed) shall be approximately 150 mm below the road surface and the top of the vegetation must be set down a minimum of 75 mm (refer **Figure 8- 35 Bioretention swale vegetation edge set down**). This ensures that distributed inflows do not cause coarse sediments to accumulate on the any trafficable surface. **Figure 8- 34 Flush kerb without setdown, showing sediment accumulation on road** shows sediment accumulating on a street surface where the vegetation is the same level as the road.

15.9.6 Mowing strip

Requirement: In addition to the above requirements, the pavement edge along bioretention swales with mowable grassed batters shall be provided with a concrete mowing strip.

15.9.7 Castellated kerb

Requirement: Castellated kerb openings shall be not less than 1.0 m or greater than 1.5 m wide.

15.9.8 Pedestrian crossings

Criteria: At-grade pedestrian crossings shall be provided along median bioretention swales at intervals not exceeding 50 m. The crossings shall be a minimum 3 m wide.

Refer: *Building Code of Australia* for requirements for handrails.

Figure 8- 34 Flush kerb without setdown, showing sediment accumulation on road

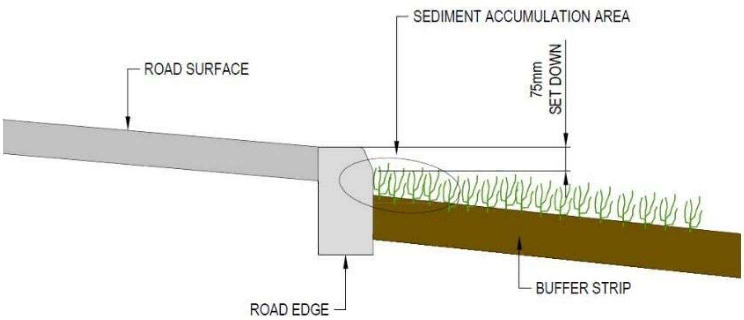


Figure 8- 35 Bioretention swale vegetation edge set down

15.10Vegetation

Criteria: Bioretention systems must be given an appropriate level of landscape design consideration to compliment the surrounding landscape character. The landscape design of bioretention basins must address stormwater quality objectives whilst also being sensitive to other important landscape objectivessuch as road visibility, public safety and community character and habitat.

Species selection: Select appropriate vegetation for the site from *MIS 25 Plant species for urban landscapeprojects* according to the inundation condition at the plant's location. Well-established uniform vegetation is crucial to the successful operation of bioretention systems. Species selection needs to consider both the aesthetic and functional requirements of the systems.

Design: Bioretention system vegetation can be either single or mixed species designs.

15.2.2 Plant species

Criterion: All bioretention system plants shall be selected from *MIS 25 Plant species for urban landscapeprojects. It is strongly encouraged to incorporate Ngunnawal and Aboriginal plants where applicable.*

15.10.1 Planting density

Requirements: Planting density generally varies depending on the species and the type of stock specified.Generally plants should be planted at high densities (6-8 plants/m^2) to ensure runoff does not establish preferential flow paths around the plants and erode the filter media surface. High density planting is alsorequired to ensure a uniform root zone in the filter media.

15.10.2 Plant characteristics

Requirements: In general, plant species must have the following features:

- plants need to be able to tolerate short periods of inundation punctuated by longer dry periods. These dry periods may be reasonably severe due to the free draining nature (relatively low water holding capacity) of bioretention filter media;
- plants can be either prostrate or erect. Prostrate species would typically be low mat-forming stoloniferous or rhizomatous plants. Erect species would typically be rhizomatous plants with simplevertical leaves;
- desirable species should have spreading rather than clumped growth forms;
- species should be perennial rather than annual; and
- species should have deep, fibrous root systems.

15.10.3 Trees

Disallowed: Trees shall not be planted in bioretention beds. Deciduous trees shall not be planted within 10 m of the perimeter of a bioretention bed.

15.11 Maintenance access

15.11.1 Street access

Maintenance: Provision shall be made in streetscape bioretention systems for maintenance vehicles to beable to park and access the facility from an off-road location to maintain trafficability and safety for road users.

15.11.2 Access ramps

Requirement: An all-weather ramp shall be provided to facilitate maintenance access to bioretentionbasins with a filter media bed area less than 500 m^2.

Design: Access ramps shall have a minimum width of 4 m and a maximum longitudinal grade of 1(V):6(H).

15.11.3 Operation and maintenance plan

Requirement: Refer to **Maintenance** for details.

Approval: The operation and maintenance plan must be submitted to TCCS for approval.

16 GROSS POLLUTANT TRAPS

16.1 Location

Location: GPTs shall be located either:

- within the pipe system with the structure below finished surface level, or
- within an engineered waterway with the structure at or below finished surface level.

Location: A GPT shall be provided prior to the inlet of any water retaining asset with permanent storage.

Location: A GPT shall be provided prior to a receiving waterway whenever the catchment area exceeds 8hectares.

16.2 GPT type

Considerations: 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;
- Occupational health and safety; and
- Ease of maintenance (e.g. special equipment required).

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

Definition: The most commonly used types of GPT in Canberra to date have been the 'Minor GPT' and the 'Major GPT' which consist of a concrete sediment basin with a fixed trash rack at the downstream end of the basin. However, numerous proprietary devices have been developed in recent years for trapping gross solids that may be suitable for use in Canberra. To help distinguish Minor and Major GPTs from the newer proprietary traps available, the former shall now be referred to as Minor and Major DUS GPTs. The term GPT shall refer to any device designed to trap gross solids.

Classification: Selection of suitable devices depends on many factors including catchment size, pollutant load, type of drainage system and cost. **Table 8- 41 General classification of GPTs** provides an overall classification of the types of GPT that may be permissible for use in Canberra, and the range of catchmentareas for which they are suitable.

Refer: Proposals for the use of GPT devices other than DUS GPTs shall be referred to TCCS for consideration. Only devices capable of being maintained with TCCS approved maintenance equipment willbe considered.

16.2.1 Proprietary devices

Proprietary devices: The GPT devices listed in the *TCCS Products previously considered for use list* areconsidered suitable for use in the ACT. The use of these devices shall be referred to TCCS for consideration and approval.

Sizing: Proprietary GPTs are to be sized in accordance with the manufacturer's recommendations.

Access: All GPTs are to be provided with access suitable for a 12 m Single Unit truck and hard standing required for maintenance to the satisfaction of TCCS.

Table 8- 41 General classification of GPTs

Group	Description and Function	Catchment Area Range	Purpose-built or Proprietary
Floating debris traps (booms)	Litter capture on permanent water bodies	> 200 ha	Proprietary
Trash racks & litter control devices	Hard or soft litter capture devices for pipelines and engineered waterways	2 – 400 ha	Purpose built
Sediment traps	Sediment removal only, on pipelines	> 200 ha	Purpose built
DUS GPTs	Sediment and litter capture for pipelines or engineered waterways	8 – 2000 ha	Purpose built
Proprietary devices	Range of devices, mainly for pipelines	2 – 40 ha	Proprietary

16.3 GPT performance

Design considerations: The following considerations shall be taken into account in selecting and designingGPTs and sediment traps:

> Treatment objectives: Define the treatment objectives for the project for the removal of grosspollutants and coarse sediment.

> Flood capacity: Analyse hydraulics of the drainage system including the head loss of the GPT and diversion weir under flood conditions. Check the design of the bypass system for impacts on the localdrainage system and consequences on flooding.

> Trapped pollutant storage: Assess the pollutants that are likely to be collected and determine theholding capacity with respect to the maintenance operations and frequency.

> Maintenance requirements: Design the GPT for maintainability and operability including the followingconsiderations:

- Ease of maintenance and operation;
- Access to the treatment site;
- Frequency of maintenance;
- Special equipment requirements; and
- Disposal of trapped materials.

Validation: Include in the maintenance program requirements for validating the GPT performance by fieldmonitoring, physical laboratory models or computer simulation.

16.3.1 Sizing criteria

2.1.1.28 DUS GPTs

Design: DUS GPTs shall be designed to retain trash and debris and retain a percentage of coarse sedimenttransported by dry weather base-flow and flow events up to and including 1 EY.

Sizing: DUS GPTs shall be sized in accordance with the methods outlined in **Gross pollutant traps, Minor DUS GPT**. The surface area of the sediment trap shall be sized to retain 70% of grain sizes greater than or equal to 0.04 mm. The trap volume shall be based on an average cleaning frequency of 2 per annum.

2.1.1.29 Proprietary GPTs

Design: The design efficiency of proprietary GPTs in trapping trash and debris and coarse sediment shallbe at least equal to the requirements for DUS GPTs.

Sizing: Approved proprietary traps shall be sized in accordance with the trap Manufacturer's specifications.

16.3.2 Maintenance

General: GPTs shall be designed to facilitate maintenance especially in respect of removal of silt and debris. Designs shall be based on cleaning operations being undertaken with conventional plant andequipment.

Davit arm base: A davit arm base plate shall be installed at a suitable location.

Dewatering: GPTs shall be designed to allow dewatering of supernatant water within the trap by gravitydrainage or pumping to a downstream waterway, upstream grassed area or WQCP.

Design: Dewatering facilities shall be:

- Designed for ease of maintenance;
- Screened to minimise the likelihood of pump or pipe blockage by sediment and debris; and
- Located such that maintenance equipment operating within the trap will not be obstructed.

16.4 Public safety

Requirements: Public safety shall be considered and the following minimum safeguards shall be provided:

- Hand rails at vertical drops where appropriate. Refer to *MIS 10 Guardrails, fences and barriers*; and
- Maximum side slopes adjacent to side walls shall be 1(V):6(H).

16.5 Major DUS GPT

Design: Major DUS GPTs shall incorporate the following specific features;

16.5.1 Trash rack

Requirements:

- Grill spacing shall be capable of retaining a 375 ml metal drink container;
- Trash racks shall be sized to operate effectively during flows up to and including the 1 EY;
- Trash racks shall be structurally stable when overtopped by flood events up to 1% AEP or when fullyblocked;
- Trash racks shall be able to withstand impact from a piece of debris weighing 500 kg and travelling at 3.0 m/s;
- Trash racks shall conform to *ACTSD-0874 GPT trash racks*; and
- Panel widths may be either 2.8 m or 4.8 m.

16.5.2 Sediment trap

Requirements:

> The minimum plan dimensions of the trap shall be 6 m x 12 m;
> The trap shall be dimensioned such that the length to width ratio is between 2 and 3 and the width is a multiple of 3.0 m or 5.0 m. The width shall be sized for a minimum of two trash rack panels;
> A base-flow bypass shall be provided around the sediment trap and trash rack to facilitate access for cleaning. The bypass shall operate under gravity and have a minimum capacity of 1.5 l/s per km^2 of catchment area;
> A sediment drying area with a minimum area equal to 1.5 m^2 for each cubic metre of trap volume shall be provided. The area shall be surfaced with 300 mm of compacted gravel or fine crushed concrete or rock;
> The sediment trap floor shall be graded to a low point to facilitate dewatering of the trap;
> The width of base-flow discharge over the trash rack weir wall and downstream apron shall be kept to a minimum, preferably confined within a single trash rack panel;
> The minimum level of the top of the trash rack side wall returns shall be the greater of the 1 EY flow level in the sediment trap when the trash rack is fully blocked or 300 mm above the top of the trash rack. The top of the return walls shall slope upward from the trash rack to finished ground level at a minimum slope of 1(V):10(H); and
> Side walls shall be keyed into original ground for a minimum depth of 300 mm.

16.5.3 Access

Requirements:

> Access shall be provided for cleaning by mechanical equipment such as front end loaders, back hoes, and tip trucks. The access shall be a separate all-weather track and ramp designed for a 7 tonne wheel load in a W-7 configuration in accordance with the *AUSTROADS Bridge Code*. Where possible, trucks should be able to drive within close proximity to where the loader is operating;
> The access track to the trap shall have a minimum clear width of 3.7 m and a maximum longitudinal grade of 1(V):6(H);
> The access ramp into the sediment trap shall have a minimum clear width of 6.0 m and a maximum longitudinal grade of 1(V):6(H). The 6.0 m clear width shall extend from the floor of the trap to the end of the side wall returns. Where the length of a trap is less than or equal to 15.0 m, the access ramp shall extend for the entire length of the trap;
> An access ramp and apron shall also be provided for the downstream side of the trash rack and shall have a minimum clear width of 4.0 m and a maximum longitudinal grade of 1(V):6(H); and
> Transitions shall be provided at the crest and toe of the ramps. Adequate space shall also be provided to allow vehicles to manoeuvre on and off the ramps.

16.6 Minor DUS GPT

Design: Minor DUS GPTs shall incorporate the following specific features.

16.6.1 Trash rack

Requirements:

> Grill spacing shall be capable of retaining a 375 ml metal drink container;
> Trash racks shall be sized to operate effectively during flows up to and including the 1 EY;
> Trash racks shall be structurally stable when overtopped by flows up to the total inlet design capacityor when fully blocked;
> Trash racks shall be able to withstand impact from a piece of debris weighing 250 kg and travelling at 2.0 m/s;
> Trash racks shall conform to *ACTSD-0874 GPT trash racks;*
> The standard panel width shall be 1.9 m; and
> Trash racks should not be placed directly in front of pipe outlet.

16.6.2 Sediment trap

Requirements:

> The width shall be 2.0 m;
> The allowable length shall be in multiples of 2.0 m within the following limits:

- minimum length: 4.0 m
- maximum length: 12.0 m

> The maximum depth of the GPT from the top of the concrete surround to the lowest level of thesediment pool base shall be 4.5 m;
> Pipe entries shall be either parallel or perpendicular to the major axis of the GPT. Angled pipe entrieswill not be permitted;
> For GPTs with a sediment trap volume greater than 5 m^3, a sediment drying area with a minimum area equal to 1.5 m^2 for each cubic metre of trap volume shall be provided. The area shall be surfacedwith 300 mm of compacted gravel;
> The width of baseflow discharge over the trash rack weir wall and downstream apron shall be kept toa minimum, preferably confined within a single trash rack panel; and
> The top of the structure shall be at least 150 mm above finished surface level to discourage vehiclesfrom being driven onto the structure.

16.6.3 Access

Requirements:

> Access shall be provided for cleaning by mechanical equipment such as front end loaders, back hoes,and tip trucks. The access shall be a separate all-weather track and ramp designed for a 7 tonne wheel load in a W-7 configuration in accordance with the *AUSTROADS Bridge Code*. Where possible, trucks should be able to drive within close proximity to where the loader is operating;

> The access track to the trap shall have a minimum clear width of 3.7 m and a maximum longitudinal grade of 1(V):6(H);

> Access shall be provided along the full length of at least two sides of the GPT as shown **Figure 8- 36 Access to Minor GPTs;** and

> A clear opening shall be provided for the full length of the sediment trap. Support beams across thetop of the trap will not be permitted as they restrict maintenance operations.

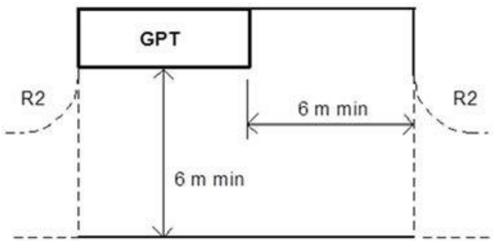


Figure 8- 36 Access to Minor GPTs

16.6.4 Covers

Design: Minor DUS GPT covers shall be fabricated using galvanised pressed steel mesh or similar. Recessed lifting lugs shall be provided at each corner to enable wire cables and/or hooks to be attached to enable lifting by maintenance equipment.

Openings: Covers shall be designed to be free spanning. GPTs shall have a clear unobstructed openingwhen all covers are removed.

Weight: The weight of the covers shall be governed by the following limitations:

> Minimum weight shall be 80 kg; and

> Maximum weight shall be 300 kg.

Bolts: Bolts for the covers shall be located such that they are accessible to maintenance personnel and notlocated with the bolthead under the cover.

16.6.5 Step irons

Location: Step irons shall be located on the shortest dimension of the GPT in such a manner that will not restrict the movement of a backhoe arm. Refer to **Figure 8- 37 Step irons in GPT.**

Access opening: A minimum 900 mm x 900 mm hinged access opening shall be provided in the GPT cover above the step irons to facilitate access into the GPT by maintenance personnel without the need to remove the larger cover. The access opening shall open away from the step irons.

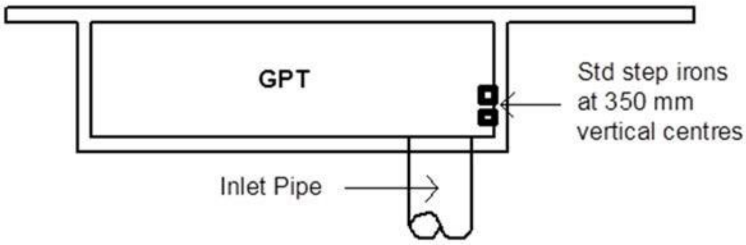


Figure 8- 37 Step irons in GPT

16.6.6 Davit arm base

Location: A davit arm base (refer **Figure 8- 36 Access to Minor GPTs**) shall be installed at a suitable location adjacent to the GPT opening such that:

> The function and maintenance of the GPT is not impeded; and
> The pulley of the davit arm can be positioned above the step irons.

Davit arm details: Consult TCCS for details of the davit arm used by maintenance personnel.

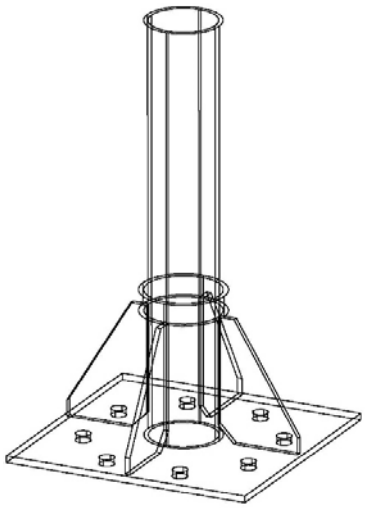


Figure 8- 38 Davit arm base detail

16.7 GPT design method

Design method: The method for sizing of major and minor DUS GPTs is based on correlations of predictedannual retention of sediment in a GPT and the expected average annual export of coarse sediment from Canberra catchments.

2.1.2 Notation and definitions

A Level difference between inlet base of invert andtrash rack (m)

M_{01} Annual sediment transportation (tonnes)

A_c Catchment area (m²)

A_t Minimum sediment trap area (m²) (%)

A_t^* Actual sediment trap area (m²) (%)

B Minimum clearance over trash rack (m)

D_s Depth of downstream sill (m)

D_t Total depth of sediment trap (m)

D_w Depth of sediment trap pool (m)

H_r Trash rack height (m)

H_r^* Adjusted trash rack height (m)

IL_{in} Inlet invert level (m)

Y_1 1 EY flow depth in inlet pipe or upstream floodway(m)

L_t Length of sediment trap (m)

N Number of trash rack panels

P_{01} Retention of grain sizes ≥ 0.01

P_{04} Retention of grain sizes ≥ 0.04

Q_{1EY} 1 EY flow rate (m³/s)

Q_p Total inlet pipe capacity (m³/s)

U Degree of urbanisation (%)

V_1 Nominal 1 EY flow velocity (m/s)

V_t Volume of sediment trap pool (m)

W_t Width of sediment trap (m)

L_r Length of trash rack panel (m)

16.7.1 Surface area of sediment trap

Requirements:

> Determine the catchment area (A_c) served by the GPT and the degree of urbanisation (U) for theultimate catchment development;

> Determine the type of GPT required from **Figure 8-57.**

> Determine the required area ratio A_t/A_c from **Figure 8-58** for P_{04} = 70% andthe degree of urbanisation (U);

> Determine the minimum trap area (A_t);

> Determine the trap length and width using:

- for a Major DUS GPT,
  W_t = integer multiple of 3.0 m or 5.0 m
  $L_t = 2W_t$ to $3W_t$
- for a Minor DUS GPT,
  W_t = 2.0 m
  L_t = integer multiple of 2.0 m
  (minimum 4.0 m, maximum 12.0 m)

> Determine the actual sediment trap area from:

- $A_t^* = L_t W_t \quad (A_t^* \geq A_t)$

16.7.2 Depth of sediment trap

Requirements:

- Determine the average annual sediment export of grains ≥ 0.01mm (M_{01}) from **Figure 8-59 Average annual export of sediments** ;
- Determine the average annual percentage retention of sediment ≥ 0.01 mm (P_{01}) from **Figure 8- 58 Average annual sediment retention against area ratio** for A_t/A_c;
- Determine the sediment trap pool volume below the trash racks using: V_t = 0.0065 P_{01} M_{01}
- This relationship is based on a sediment density of 2.65 tonnes/m³ and a sediment porosity of 0.42.

The required sediment trap pool volume is a function of the average required cleaning frequency. The following is based on an adopted average cleaning frequency of 2 times per year.

Determine the sediment trap pool depth below the trash racks using,

$$D_w = \frac{V_t}{A_t^*}$$

For a Minor DUS GPT, the total depth of the sediment trap (D_t) shall not exceed 4.5 m.

16.7.3 Trash rack

2.1.2.1 Number of panels

Criteria: Determine the number of trash rack panels (N) required based on the following centre to centre panel dimensions;

- 3.0 m or 5.0 m (Major DUS GPT)
- 2.0 m (Minor DUS GPT)

2.1.2.2 Height

Flow criteria: Generally, the trash rack height is based on the rack not being overtopped by a 1 EY flow when the rack is 50% blocked.

Application: The following is based on a standard trash rack with vertical 10 mm galvanised flat steel bars at 60 mm centres. A coefficient of 0.8 to account for contraction of flow through the trash rack has been assumed.

Sizing: Determine the trash rack height using:

$$H_r = 1.22 \left[\frac{Q_1}{L_r x N}\right]^{2/3}$$

For a Minor DUS GPT,

H_r = 0.3 m (Q_1 * 0.23 N)

H_r = 0.5 m 0.23 N * Q_1 * 0.50 N)

H_r = 0.7 m (Q_1 * 0.50 N)

Where a trash rack is easily accessible, the height shall be increased for public safety to,

$H_r^* = 1.2$ m

Determine the maximum trash rack sill level in relation to the 1 EY flow depth (Y_1) and the inlet invertlevel (IL_{in}) using:

For a Major DUS GPT,

$$A = H_r + \left[\frac{Q_1}{1.7W_t}\right]^{2/3} - Y_1$$

For a Minor DUS GPT,

$$A = H_r + \left[\frac{Q_1}{3.23N}\right]^{2/3} - Y_1$$

2.1.2.3 Clearance above trash rack

Application: This criterion only applies to a Minor DUS GPT and is based on the unobstructed clearancerequired to discharge the total inlet pipe capacity.

Sizing: Determine the minimum clearance over the trash rack using:

$$B = \left[\frac{Q_p}{3.23N}\right]^{2/3}$$

(B = 0.350 m min)

2.1.2.4 Submergence effects

Requirement: A step shall be incorporated at the trap outlet as shown in **Figure 8-39 Minor GPT dimensions** to reduce possible submergence effects at the trash rack which may in turn create adversebackwater effects in the inlet pipe or upstream waterway.

$D_S = 0.080$ m (minimum)

16.7.4 Flow velocity

Limitation: The flow velocity in the GPT should be minimised to inhibit the resuspension of deposited particles. The nominal velocity for a 1 EY flow should be less than or equal to 0.5 m/s. The required pooldepth below trash rack level should be checked against this criterion assuming the water level is at the top of the trash rack.

Calculation: Determine the nominal flow velocity using:

for a Major DUS GPT,

$$V_1 = \frac{Q_1}{(D_w + H_r)W_t} \leq 0.5$$

for a Minor DUS GPT,

$$V_1 = \frac{Q_1}{(D_w + H_r)L_t} \leq 0.5$$

Adjustment: Increase the dimensions of the sediment trap pool or increase the track rack height if theflow velocity is greater than 0.5 m/s.

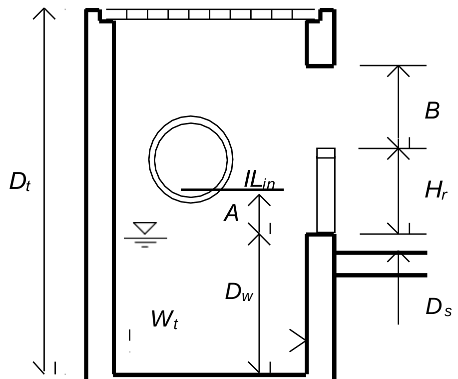


Figure 8-39 Minor GPT dimensions

17 STORMWATER HARVESTING

17.1 Pre-design planning

17.1.1 Site assessment

Site: Assess the existing physical and natural attributes of the site including:

> Ngunnawal and Aboriginal cultural significance;
> Area, slope and shape of the catchment from which it is proposed to harvest stormwater;
> Other assets such as water storages, wetlands and bio-retention systems that the stormwater harvesting scheme may be interrelated;
> Available space to construct water storages, primary and secondary water treatment systems and other infrastructure;
> Proximity to the potential water supply and demand (i.e. end use);
> Access for construction and long-term maintenance;
> Environment; and
> Land ownership.

Constraints: Design for site-specific constraints including heritage and environmental.

Documentation: Record the site specifics and constraints that may affect the design with respect to the *ACT Practice Guidelines for Water Sensitive Urban Design.*

17.1.2 Project objectives

Define: Identify the objectives of the project. Define the main driver, be it conservation of potable water, reduced stormwater flows and localised flooding, protecting the downstream environment. Or a combination of the above.

Specify: The project objectives will change the configuration of the stormwater harvesting scheme. There is a need to be clear about the objectives upfront and specify what they are.

Prioritise: If there are multiple objectives, it is ideal to have these prioritised.

17.1.3 Concept scheme

Complementary: Concepts should be complementary with the strategic stormwater objectives, such as land use set-out in the Territory Plan, Master Plans, or Infrastructure Plans. They should also compliment other WSUD assets that they interrelate.

Pervious Land: As a key driver, concepts should be integrally linked with the degree of pervious land both in the vicinity of the stormwater elements and throughout the catchment.

Element Assessment: Evaluate all the structural and non-structural elements (such as those listed in later sections) that may go into a design that perform the water collection, treatment, storage, conveyance and reuse function of the stormwater harvesting scheme to arrive at the optimal solution. This assessment will also describe the relationship to the other structural and non-structural elements that the scheme interrelates.

Multi-purpose: Elements should be selected to gain maximum land use benefit by designing them to accommodate other complementary functions, such as opportunity for recreation, improved access, habitat value, environmental enhancement and amenity.

17.1.4 Water supply

Define: Identify the water supply for the scheme, be it stormwater, borewater or wastewater. Calculatehow much water is available and how much water can be extracted. Stormwater base-flows shall be investigated and determined as part of the water supply calculations.

Determine: Estimate whether the supply is continuous throughout the year or variable. The flow ofwastewater is often continuous, but stormwater is the result of rainfall and is therefore variable.
Determine the catchment available, how reliable the supply of water is and the best point for extraction(i.e. the offtake). Appropriate hydraulic modelling and/or monitoring must be undertaken to accurately determine the flow characteristics.

Consider: A predicted impact of Climate Change is increased rainfall intensities or storminess coupled with a greater incidence of drought. This could affect catchment yield and water supply in the case of stormwater harvesting. The potential impacts of Climate Change for the useful life of the scheme (i.e. 25 to 50 years) must therefore be taken into consideration when sizing water storages. See *AS 5334* and *ARR* for guidance.

Note: ACT will typically get about 630 mm of rainfall in one year over an average 108 days of rain. How much stormwater can be captured depends on the offtake, water treatment functionality and flowrate, plus the water storage capacity. The smaller the water supply, the larger the storage required (and viceversa). So, the more water available, the smaller the storage capacity can be and the more viable the project. Stormwater drainage networks with base-flows are the best ones to harvest from.

Refer: The current most relevant Australian Standards, including amendments and supplements:

- *AS 5334 - Climate Change adaption for settlements and infrastructure - A risk based approach;*
- *Australian Rainfall & Runoff (ARR 2016) - A Guide to Flood Estimation;* and
- *Australian Runoff Quality (ARQ) - Guide to Water Sensitive Urban Design.*

17.1.5 Water usage

Define: Identify the water demand (i.e. end use), be it irrigation, environmental, amenity, toilet flushing,or industrial.

Determine: Estimate the water demand (i.e. end use). Determine if it is continuous or variable. Undertakedemand calculations on a daily time-step as a minimum.

Note: As an example, golf courses can use up to 1 ML of water for irrigation each night. While most sporting ovals use 20 kL to 50 kL overnight. Sydney Water suggest application rates of 0.25 kL/m^2/yr for alocal sporting ovals and 0.4-0.5 kL/m^2/yr for a premier sporting ovals. This may be highly variable depending on usage of the sporting oval and needs to be determined and recorded.

17.2 Design

17.2.1 Water balance

Requirement: A water balance to assess the viability of a proposed stormwater harvesting scheme shall be provided. It is necessary to include seasonal variations and base-flows where applicable. The water balance can be done using a number of different tools including MUSIC and common computer spreadsheets. The water balance shall take seasonal variations into consideration. The water balance shallhave a minimum time step of 1 day, but preferably less.

Output: A typical example of a MUSIC model water balance output is shown **Figure 8- 70 Typical MUSIC water balance output.**

Note: Supply and demand (i.e. end use) need to closely align. If the demand outstrips the supply, or thereis little demand for the supply, then the scheme may have a poor cost/benefit. Aim to meet 80% of demand. Schemes meeting less than 60% of demand will not be considered unless justified in writing and approved by the ACT Government representative(s). It is necessary to incorporate a potable water top-upto cater for those times when demand outstrips supply (e.g. if only 80% of demand is met then a potable water top-up is needed to meet the remaining 20%).

17.2.2 Initial water quality analysis

Define: Different water demands (i.e. end uses) will have different water quality requirements. The extentof water treatment needed obviously depends on the incoming quality and the required outgoing quality. Knowing the incoming quality will allow the sizing of equipment and the water storage/maintenance requirements of the water treatment system to be determined. The water quality required is dictated by the *Australian Guidelines for Water Recycling*. Note that the Australian Guidelines take a risk management approach, not one based on the scale or complexity of the stormwater harvesting scheme.

Determine: Characterise the quality of the proposed water supply.

Requirement: An initial water quality analysis shall accompany the Water Balance.

Consider: **Table 8- 42 Water quality requirements for potential end uses based on public risk** below adapted from the Interim NSW Guidelines for Management of Private Recycled Water Schemes sets-outthe water quality requirements for a range of potential end uses based on the risk of public exposure.

Refer: The current most relevant Australian Standards, including amendments and supplements:

- *AS/NZS 5667.1 - Water quality - Sampling Guidance on the design of sampling programs, samplingtechniques and the preservation and handling of samples*
- *AS/NZS 5667.6 - Water quality - Sampling Guidance on sampling of rivers and streams*
- *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2)Stormwater Harvesting and Reuse*

Table 8-42 Water quality requirements for potential end uses based on public risk

Potential End Use	Risk of public exposure	Parameter	Limit
End uses with a high level ofhuman contact, including: > Residential dual reticulation > Multi-unit dwellings, internal reuse and external irrigation > Agricultural irrigation – unprocessed foods (e.g. salad crops) > Urban irrigation with unrestricted access and application	High	E. coli	<1 cfu/100mL
	High	BOD	<10 mg/L
	High	SS	<10 mg/L
	High	pH	6.5-8.5
	High	Turbidity	<2 NTU (95th percentile)
	High	Turbidity	<5 NTU (maximum)
	High	Disinfection	Cl: 0.2-2.0 mg/L residual
	High	Disinfection	UV: TBA
	High	Disinfection	Ozone: TBA
	High	Coliphages	<1 pfu/100 mL
	High	Clostridia	<1 cfu/100 mL
End uses with a medium levelhuman contact, including: Urban irrigation with some restricted access and application; and Amenity	Medium	E. coli	<10 cfu/100mL
	Medium	BOD	<20 mg/L
	Medium	SS	<30 mg/L
	Medium	pH	6.5-8.5
	Medium	Turbidity	<5 NTU (95th percentile)
	Medium	Disinfection	Cl: 0.2-2.0 mg/L residual
	Medium	Disinfection	UV: TBA
	Medium	Disinfection	Ozone: TBA
End uses with a medium level human contact, including: > Urban irrigation with enhanced restricted access and application irrigation > Agricultural irrigation, processed foods	Low	E. coli	<1000 cfu/100mL
	Low	BOD	<20 mg/L
	Low	SS	<30 mg/L
	Low	pH	6.5-8.5
	Low	Disinfection(if used)	Cl: 0.2-2.0 mg/L residual
	Low	Disinfection(if used)	UV: TBA
	Low	Disinfection(if used)	Ozone: TBA

17.2.3 Water quality and treatment

Determine: Investigate the water quality requirements of the intended end use(s). The quality of the potential water supply and potential for public exposure will dictate what it can be used for, whether or not it requires pre-treatment and what this might entail. The level of pre-treatment can have a significantimpact on the cost to construct, operate and maintain the stormwater harvesting scheme. The water quality required for different uses is outlined in the *Australian Guidelines for Water Recycling*.

Consider: **Table 8- 43 Stormwater treatment criteria – public open-space irrigation** adapted from the Australian Guidelines for Water Recycling, sets-out the stormwater treatment criteria for public, open-space irrigation with no access control.

Table 8- 43 Stormwater treatment criteria – public open-space irrigation

Parameter	Stormwater treatment criteria (no public access control)
Disinfection	>1.5 log (96%) reduction of viruses and bacteria
Disinfection	>0.8 log (82%) reduction of protozoa parasites
Disinfection	E. coli < 10 colony forming units (CFU)/100mL (median)
Turbidity	<25 nephelometric turbidity units (NTU) (median)
Turbidity	100 NTU (95th percentile)
Turbidity	Provided the disinfection system is designed for such water quality and that during operation the disinfection system can maintain an effective dose by using up all the disinfectant demand and providing free disinfectant residual and/or provides adequate UV dose even in the presence of elevated turbidity and UV absorbing materials
Iron *	<9.6 mg/L (median)

* Total iron in urban stormwater is expected to be ferrous iron, because stormwater is normally well oxygenated.

Refer: *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2)Stormwater Harvesting and Reuse.*

17.2.4 Land ownership and asset management

Investigate: Find out who owns the land on which the stormwater harvesting scheme will be constructed.

Determine: Ascertain if land owners consent is required. Determine the ultimate asset owner, budget andcapacity to operate and maintain the scheme.

Note: Land ownership and asset management is especially important when there are multiple stakeholders, or schemes in private ownership or body corporate ownership. It is also important for non- ACT owned schemes to have some form of reporting or operational requirement, so a private owner can'tsimply turn the scheme off (which is not an uncommon occurrence).

17.2.5 Licensing

Determine: Investigate licensing requirements. A water access entitlement is required to make use of ACT water resources. In addition, a licence to take water and a waterway work license is needed to extract water specified by a water access entitlement.

A licence to take water from an ACT water resource is needed to irrigate crops, sporting ovals, parks and reserves. The licence states how much water can be taken and from where. A fee is payable for the license application. If the application is successful, there is an annual administration fee and charge based on water usage.

A utility is exempt from the requirement for a license to supply secondary water (i.e. non-drinking) under a customer contract, but must comply with the prescribed minimum requirements in *Utilities (Non- drinking Water Supply Code) Determination 2014.*

Consider: The ACT Government shall be consulted at the concept planning stage to determine the exact licensing requirements for the water harvesting scheme.

Requirement: If a license is required then an application must be made to the ACT Government.

Note: It is important to remain up-to-date on licensing requirements and changing legislation. Remember that if a scheme needs a license it can't operate without one.

17.2.6 Initial risk assessment

Determine: The *Australian Guidelines for Water Recycling* are based on a risk management approach. Investigate whether the stormwater harvesting scheme poses any public health and/or environmental risks. Determine if the scheme interrelates with any other (i.e. take base-flows from a scheme downstream). Submit the risk assessment to the ACT Government representative(s) for approval.

Requirement: A full Risk Assessment shall be done as part of the detail design, as well as a Safety in Design check. The *Australian Guidelines for Water Recycling* also address risk. Critical control points, describing procedures necessary to eliminate or reduce hazards identified in the risk assessment to an acceptable (i.e. critical) level must be identified early in the design process. Early determination of the expected water quality parameter log reduction values will make it easier to transition to a license where required.

A critical control point will have the following characteristics;

1. Ability to control hazards that present a significant risk to treated water quality and require elimination or reduction;
2. Have a parameter (surrogate) that can be measured in a timely manner for the hazardous event; and
3. Can be corrected in response to a deviation in the process.

Refer: **Table 8- 44 Recommended critical control points.**

Table 8-44 Recommended critical control points

Critical Control Point	Controls	Parameters
Media Filtration	operational monitoring – continuous on-line	turbidity
UV Disinfection	operational monitoring – continuous on-line	power intensity turbidity transmissivity
Chlorine Disinfection	operational monitoring – continuous on-line or daily	chlorine dose residual

Consider: The asset owner needs to understand and acknowledge that there is a small risk that any scheme could breakdown and either provide no water or poor quality water. This is easily outweighed bythe benefits of the project, but needs to be considered. “Don’t throw the baby out with the bath water”, but nothing happens without some degree of risk.

Refer: *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2)Stormwater Harvesting and Reuse.*

17.2.7 Geotechnical investigations

Geotechnics: Geotechnical advice is not mandatory. But, not knowing the ground conditions increases therisk of variations during construction. Advice must be sought from a suitably qualified and experienced Civil Engineer concerning the need for a geotechnical investigation.

Consider: Especially for sites having comparatively large water storages and infrastructure on land previously used for waste disposal, it is recommended to know if there is rock, groundwater or thepotential for contaminated material.

Refer: The current most relevant Australian Standards, including amendments and supplements:

> *AS 1289 - Methods of testing soils for engineering purposes;*
> *AS 1289.4.2.1 - Soil chemical tests - Determination of the sulfate content of a natural soil and thesulfate content of the groundwater - Normal method;*
> *AS 1289.4.3.1 - Soil chemical tests - Determination of the pH value of a soil - Electrometric method;*
> *AS 1289.4.4.1 - Soil chemical tests - Determination of electrical resistivity of a soil – Methods for sandsand granular materials; and*
> *AS 1289.5.4.1 - Soil compaction and density tests - Compaction control test - Dry density ratio, moisture variation and moisture ratio.*

17.2.8 Water quality analysis

Quality: The characteristics of the current water supply (commonly potable, but not always), proposed source and the "fit for purpose" water quality parameters for use, need to be determined to design an appropriate water treatment process.

Requirement: At a minimum the level of TSS, turbidity, and bacteria (normally coliforms) are necessary. There is no rule as to the number of samples needed for baseline data (studies), which are sometimes also referred to as pre-operational data (studies), but it must be sufficient to fully characterise the level of variability. The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000)* recommend that baseline data be gathered from at least three (3) to five (5) control or reference locations over a period of at least three (3) years wherever possible. This is not likely practical, so a minimum of five (5) wet weather samples and five (5) dry weather samples are required. Depending on the intended end use(s), it may also be necessary to analyse for colour, hardness, BOD, DO, pH, EC and potentially also nutrients.

Note: Water quality may vary over the course of a year or even a day, so long-term records are highly valuable. Also recognise that spikes in soluble pollutants within stormwater can be expected from time to time and the water treatment system should be able to detect these and act accordingly. In some cases a
% reduction is common, in others it is a concentration.

Refer: The current most relevant Australian Standards, including amendments and supplements;

- *AS/NZS 5667.1 - Water quality – Sampling Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples*
- *AS/NZS 5667.6 - Water quality – Sampling Guidance on sampling of rivers and streams*
- *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2) Stormwater Harvesting and Reuse*
- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000)*

17.2.9 Hydraulic modelling

Impact: A stormwater harvesting scheme could have an impact on the stormwater drainage network resulting in an increased risk of localised flooding (and/or environmental degradation).

Requirement: Undertake hydraulic modelling of the urban stormwater drainage network in accordance with ARR to accurately assess the flooding risk for the Major System storm event. The results shall be submitted to the TCCS for approval.

Consider: The network generally encompasses the public drainage network of pipes, culverts, open channels, pits and associated overland flow paths. Natural watercourses that predominantly convey urban stormwater should also be considered part of the network and need to be included in any hydraulic model.

Note: Most stormwater offtakes from the network utilise a weir to divert flow for water treatment and reuse. The hydraulic impact of the weir needs to be assessed to ensure that it does not cause or exacerbate upstream flooding.

17.3 Operation and maintenance manuals

17.3.1 Functional description

Prepare: A FD setting-out in general terms the objectives of the stormwater harvesting scheme, nature ofthe water supply as for source and potential yield and demand (i.e. end use).

Requirement: The FD shall include critical control points, describing procedures necessary to eliminate orreduce hazards identified in the risk assessment to an acceptable (i.e. critical) level. The FD will show:

1. Full description of the stormwater harvesting scheme including: offtake; stormwater treatmentsystem; and distribution network to the end use(s);
2. Start and stop conditions for all systems;
3. Control and alarm logic; and
4. Alarm list including: description; criticality; level of communication; and brief troubleshootingplan.

Note: The FD will accompany the Process Flow Diagram.

17.3.2 Manual/auto and remote monitoring/control requirements

Monitoring/Control: A stormwater harvesting scheme may be highly automated in operation requiring minimal routine operator input or it may be manual, needing appropriately qualified and experienced staff dedicated to meeting the operational requirements. The level of operator input required will naturally differ from one scheme to another. In general, the greater the degree of automation, the higherthe initial cost and complexity, but operating costs will be lower for the design life of the scheme. Aim forthe best solution "affordable", with a focus on Life Cycle Costs if possible.

Requirement: The level of operator input for the stormwater harvesting scheme will be specified by the ACT Government Representative(s) and incorporated into the Functional Description, Process Flow Diagram and Process and Instrumentation Diagram. The items listed below shall be included as required:

- Web-based remote access;
- Alarm notifications by SMS or email
- Automated reports (e.g. water flow, storage and quality);
- Remote access for fault resets;
- Manual/auto/off access to equipment;
- Different levels of access for the supervisors & operation and keep a clear actions record for eachuser;
- Alarm list and alarm history access;
- Trends (e.g. water flow, storage and quality);
- Equipment runtime; and
- Instrument operating range.

The requirement for Supervisory Control and Data Acquisition (SCADA) will be specified by the ACTGovernment Representative(s).

17.3.3 Draft operation and maintenance manual

Prepare: The asset owner must be provided with a comprehensive Operations and Maintenance (O&M)Manual.

Requirement: At a minimum, the O&M Manual shall include the headings listed below:

1. Overall explanation of the stormwater harvesting scheme and objectives;
2. General process description from stormwater offtake to end use(s);
3. Functional Description;
4. Process Flow Diagram;
5. Process and Instrumentation Diagram;
6. Physical location and means of access to all the components of the stormwater harvesting scheme;
7. Complete set of WAE drawings;
8. Equipment and Instrumentation List;
9. Operating instructions/standard operating conditions. This will encompass, but is not limited to the stormwater offtake, pumps, valves, sensors, meters (e.g. flow and turbidity), water treatment system (e.g. media filtration, backwash and disinfection), controls/automation, header tank, potable water top-up and treated water distribution network to the end use(s);
10. Routine monitoring requirements;
11. Expected maintenance schedule;
12. Troubleshooting; and
13. Appendices with manufacturers information.

Review: The O&M Manual will be reviewed in the Commissioning and Operation & Maintenance stages and updated accordingly.

Note: Other assets that may be interrelated to the stormwater harvesting scheme such as water storages, wetlands and bioretention systems will have separate O&M Manuals.

Table 8-45 Equipment to be used on ACT stormwater SCADA

Description	Supplier/Brand	Part Number	Comments
PLC	Allen-Bradley CompactLogix	1769-L30ER (CPU) + i/o modules as required	
24Vdc Power Supply	Allen Bradley 24Vdc 10A	1606-XLS240E	
24Vdc UPS	Allen Bradley	1606-XLS240-UPSD	
12Vdc Battery	Allen-Bradley 12V/20Ah	1606-XLSBATASSY2	
Cubicle	Zanardo 316 Stainless 800 x 600 c/w external padlock lock mechanism		
Network Switch	Stratix 5 RJ45 port Fast Ethernet, 24Vdc		
Radio-modem	Trio ER450	ER450-50A01EH0	
Coax Surge Arrester		IS-B50LN-C2	
Internal RCD Double GPO	Clipsal	2025 RCD series	

Table 8-46 Equipment to be used on ACT stormwater SCADA (remote sites)

Description	Supplier/Brand	Part Number	Comments
PLC	Allen-Bradley Micrologix 1400	1766-L32BXBA	
24Vdc Power Supply	Allen Bradley 24Vdc 5A	1606-XLS120E	
24Vdc UPS	Allen Bradley	1606-XLS240-UPSD	
12Vdc Battery	Allen-Bradley 12V/7Ah	1606-XLSBATASSY1	
Cubicle	Zanardo 316 Stainless 600 x 600 c/w rain hood and external lock mechanism		
Network Switch	Stratix 5 RJ45 port Fast Ethernet, 24Vdc		Has version with fibre ports, as required
Radio-modem	Trio ER450	ER450-50A01EH0	
Coax Surge Arrester		IS-B50LN-C2	
Internal RCD Double GPO	Clipsal	2025 RCD series	

17.3.4 Documentation Requirements

2.1.2.5 Process flow diagram

Prepare: A PFD shall accompany the FD. The PFD shows the interaction of major stormwater harvesting scheme components downstream of the offtake including: water storages; pumps; pipelines; components of the water treatment system; and the treated water distribution network to the end use(s).

The PFD broadly defines:

1. The sequence of all relevant processes represented schematically and specifies information considered desirable for analysis;
2. All processes that will change the physical or chemical characteristics of the water supply; and
3. The processes needed to treat stormwater to the specified quality.

The PFD will provide:

> The basis for system design;
> Scope of all processes;
> Equipment configuration; and
> Required utilities.

Requirement: Everything from the stormwater offtake to the end use(s) shall be shown on the PFD including the following:

1. Flow directions;
2. Process and utility lines in general;
3. Identification and numbering of equipment; and
4. Identification and general description of main instruments.

Refer: The current most relevant Australian Standards, including amendments and supplements.

2.1.2.6 Process and instrumentation diagram

Prepare: A P&ID shall be developed from the PFD. The P&ID is a detailed schematic diagram showing the interconnection of process equipment and the instrumentation used to control the process. It representsthe technical realisation of a process by means of graphical symbols for equipment and piping together with the process measurement and control functions. The P&ID allows a Process Engineer to quickly assess the functionality of the stormwater harvesting scheme and is the primary diagram used to lay-out and specify an installation. It is also the starting point for any future trouble shooting.

The P&ID generally includes:

> Instrumentation;
> mechanical equipment;
> valves;
> piping;
> water treatment control systems;
> flow directions; and
> inter-connections.

Requirement: The following design criteria shall be applied in preparation of the P&ID unless otherwisespecified:

1. Assembly piping of pumps;
2. Drains and vents;
3. Bypass lines;
4. Controls and instrumentation;
5. Line numbering;
6. Utility connections;
7. Unit battery limit installation; and
8. Sample connections.

The P&ID will present all information as required below during the detailed design phase:

> Symbols, legends, title boxes, equipment identification numbers and general notes;
> Equipment indication;
> Instrumentation;
> Piping; and
> General notes.

Refer: The current most relevant Australian Standards, including amendments and supplements.

2.1.2.7 Electrical drawings

Prepare: Electrical drawings showing the layout of the electrical network.

Requirement: Include the location of all electrical components including control panels.

Note: Having accurate electrical drawings provides a massive reduction in time and risk when future workneeds to be done on the network.

2.1.2.8 Mechanical drawings

Prepare: Mechanical drawings showing the location and layout of all mechanical components, such as pumps, filters, valves, etc.

Requirement: Include items requiring regular servicing or removal/replacement.

2.1.2.9 Civil and structural drawings

Prepare: Plans showing the details of structural and civil engineering work, including: steel framing; concrete slabs; retaining walls; embankments; excavation; shoring, trenching details, etc.

Note: During construction, it is common to make changes to minor civil elements and these can be captured in the WAE drawings.

2.1.2.10 Irrigation layout

Prepare: Plans showing the layout of the pipe network, irrigation pumps, sprinkler heads, and control panel.

Note: The irrigation layout should also show "where" the irrigation zones start and stop. This allows for future extension of the irrigation area if desired.

Refer:

- The current most relevant Australian Standards, including amendments and supplements; and
- *MIS 18 Irrigation.*

2.1.2.11 Irrigation equipment specification

Requirement: Provide a detailed specification of Irrigation heads, pumps and associated controls.

Refer:

- The current most relevant Australian Standards, including amendments and supplements; and
- *MIS 18 Irrigation.*

2.1.2.12 Electrical wiring diagram and standards

Requirement: Provide a detailed schematic wiring diagram of the electrical circuits showing all the devices, power and signal connections between them.

The electricity connection shall be confirmed by the Contractor who will provide shop drawings of the electrical switchboard and connections to pump control panels, pumps and other equipment.

Conduits and conduit fittings for all electrical cabling shall be category 'A' orange coloured heavy duty rigid UPVC with solvent welded joints. All conduits shall be of the sizes shown on the drawings.

Screened/shielded cables must be installed on submersible pumps.

House all cables to float switches and pumps in polyethylene pipe cable conduits.

Electrical junction pits shall be precast in polymer concrete with 'Electricity' impressed in the lid, or equivalent to the requirements of the local ACT Electricity Authority.

The control panel shall be housed in a secure cabinet on location. If outdoors, the cabinet shall be watertight and appropriately ventilated.

Refer:

- The current most relevant Australian Standards, including amendments and supplements;
- *ActewAGL service and installation requirements;* and
- *Australian Telecommunications Authority (AUSTEL) Standards.*

2.1.2.13 Site layout general arrangement

Prepare: A general arrangement plan of the stormwater harvesting scheme showing the location of majorelements, such as the stormwater offtake, water storages, pipelines, water treatment shed, header tank, potable water top-up and treated water distribution network to the end-use(s).

2.1.2.14 Piping plan

Prepare: A detailed plan showing the pipe network, including: length; diameter; type; valves; bends;pumps; and flow direction.

Piping and associated fittings shall be specified for the flow, head and specific requirements of the site.The type and materials used shall be suitable to the water quality. Pipes shall be affixed with the appropriate warnings indicating a secondary water (i.e. non-potable) supply.

- All pipes and valve box lids shall be identified by a purple colour complying with *AS 2700* being nodarker than P24 Jacaranda or P12 Purple and no lighter than P23 Lilac.
- All buried pipes shall have an identification tape complying with *AS 2648.1* marked with contrastingpurple lettering running longitudinally and fastened to the pipe at not more than 3 m intervals.
- Statement complying with *AS 1345* "Recycled or Reclaimed water – do not drink".

Refer:

- The current most relevant Australian Standards, including amendments and supplements; and
- *ACT Pumping and Irrigation Equipment Specifications 2015*.

17.4 Part selection

17.4.1 Stormwater harvesting pumps

Requirement: Pumps specified for the stormwater harvesting scheme shall be selected for the flow, headand specific requirements of the site. The type and materials used in the pump shall be suitable to the water quality.

Material: All pumps shall have corrosion resistant 304 (min) stainless steel shaft and casing.

Mounting: Pumps shall be firmly mounted (i.e. bolted) to a concrete plinth such that vibrations do not cause excessive noise and undue stress on piping. Where submersible pumps are specified they must bemounted on guiderails with appropriate lifting points.

Pump well: The pump well (i.e. wet well) will be constructed in concrete with a hinged galvanised steel access lid, which is lockable. The top of the pump well should ideally finish between 300 and 600 mm above the surrounding ground level. An appropriate valve (e.g. knife gate or similar) must be provided toisolate the pump well to facilitate ease in cleaning.

Float switch: All pump installations require an automatic low level float switch.

Offtake: Where a pump offtake is located in a stormwater drain, bioretention system, pond, wetland or other waterbody where gross pollutants, organic material or sediment may be found, the offtake shall belocated in a manner to minimise the risk of blocking and to facilitate ease in servicing. In the case of a pond, the offtake should not be from the water surface where floatable gross pollutants accumulate or the bottom where sediment could block the offtake. The offtake must be at an intermediate level abovethe sludge blanket (refer to **Figure 8- 40 Pump offtake configuration for a pond)**.

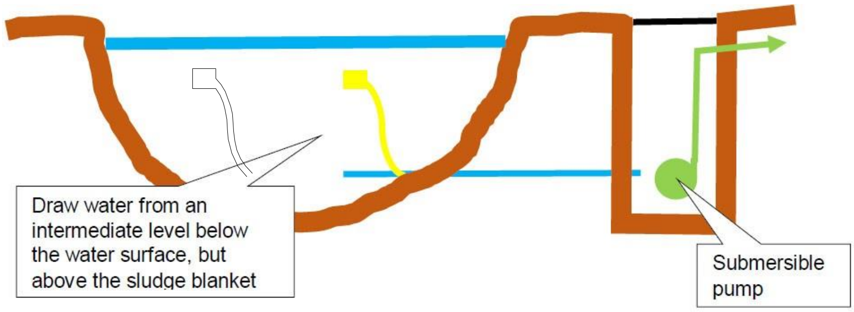


Figure 8- 40 Pump offtake configuration for a pond

Maintenance: Pumps shall be installed in a manner to facilitate ease in servicing and removal/replacement considering the location of interrelated assets such as water storages, wetlands andbioretention systems.

Manufacturer: The manufacturer of pumps shall be Grundfos, Lowara or an alternative approved by theACT Government representative(s). The make and model must be one that is in common use for the intended purpose with readily available parts and service.

Warranty: A minimum manufacturer's warranty of 12 months is required unless otherwise noted.

Consider: Where feasible, pumps should be above ground, centrifugal and multi-stage. If underground pump placement is unavoidable, consider ease of servicing and consult the ACT Government representative(s). The need for multiple pumps operating on duty/standby basis for critical applicationsshould also be considered.

17.4.2 Water flow meters

Requirement: Water flow meters shall be specified appropriately for the flow and pressure. They shall bemagnetic type with a 4-20 mA output and totaliser unless specified otherwise.

Installation: The water flow meters shall be installed as per the manufacturer guidelines.

Manufacturer: The manufacturer of water flow meters shall be Endress Hauser, ABB, Siemens or an alternative approved by the ACT Government representative(s). The make and model must be one that isin common use for the intended purpose with readily available parts and service.

Consider: Turbidity can affect the accuracy of a water flow meter, so water quality should be consideredand the manufacturer consulted when selecting a meter.

17.4.3 Water treatment

Requirement: Primary and secondary water treatment systems shall be provided appropriate to the quality of the harvested stormwater and intended end use(s). Additionally, if disinfection is required, itshall comply with the *Australian Guidelines for Water Recycling*. Advice must be sought from a suitably qualified and experienced professional concerning the most appropriate water treatment system.

Table 8- 47 Potential combinations of water treatment systems and controls

Option 1A: Municipal use with unrestricted access (e.g. open spaces, sports grounds, golf courses, and irrigation of non-food crops)			
Log reduction targets	V 1.3	P 0.8	B 1.3
Indicative treatment process	Filtration (if required) and disinfection		
Log reductions achievable by treatment	>1.5	>>4.0	>>4.0
On-site preventive measures	No specific measures		
Indicative exposure reduction (log reductions)	-		
Water quality criteria	Turbidity: < 25 NTU (median) < 100 NTU (95th percentile)		E. coli < 10/100 mL
Option 1B: Municipal use with restricted access and application			
Log reduction targets	V 1.3	P 0.8	B 1.3
Indicative treatment process	No treatment		
Log reductions achievable by treatment	0		
On-site preventive measures	Restrict public access during irrigation	Minimum 25-30 m buffer to nearest point of public access and spray drift control	
Indicative exposure reduction (log reductions)	2.0 (on-site)	2.0 (off-site)	
Water quality criteria	Not applicable		
Option 1C: Municipal use with drip irrigation			
Log reduction targets	V 1.3	P 0.8	B 1.3
Indicative treatment process	No treatment		
Log reductions achievable by treatment	0		
On-site preventive measures	Drip irrigation of plants		
Indicative exposure reduction (log reductions)	4.0		
Water quality criteria	Not applicable		
Option 2: Dual reticulation with indoor and outdoor use OR Irrigation of commercial food crops			
Log reduction targets	V 2.4	P 1.9	B 2.4
Indicative treatment process	Filtration (if required) and disinfection		
Log reductions achievable by treatment	>2.5	>>4.0	>>4.0
On-site preventive measures	Strengthened cross-connection controls required including ongoing education of householders and plumbers (for dual reticulation)		
Indicative exposure reduction (log reductions)	-		
Water quality criteria	Turbidity: < 25 NTU (maximum) < 100 NTU (95th percentile), < 2 NTU (target)		E. coli < 1/100 mL

NTU = nephelometric turbidity units; UV = ultraviolet

V = virus, represented by adenovirus type 41 for UV, which is more resistant and better characterised than rotavirus

P = protozoa, represented by Cryptosporidium spp. Oocysts

B = bacteria, represented by E. coli, which is more resistant and better characterised than Campylobacter

Indicative UV doses given are based on US EPA (2006) and refer to validated doses taking into consideration RED bias and other factors.

Consider: **Table 8- 47 Potential combinations of water treatment systems and controls** and **Table 8- 48 Indicative log reductions of reference pathogens after treatment** adapted from the *Australian Guidelines for Water Recycling*, set out the potential combinations of water treatment systems and indicative log reductions of reference pathogens after treatment. Special consideration should be given to controlling the risk of cross-connections where dual reticulation systems are used.

Primary treatment: At a minimum primary water treatment on the supply (e.g. stormwater drainage network, water storage, wetland or bioretention system) shall consist of a high performance vortex type offline GPT with a self-cleaning screen. The GPT will be specified appropriate to the catchment size, land use, pollutant load, hydraulics and site (Refer **Gross Pollutant Traps**).

Secondary treatment: At a minimum secondary water treatment shall consist of media filtration. The media shall consist of sand, zeolite, activated carbon or other materials appropriate for the required treatment of the incoming stormwater quality. Media filters shall be backwashed on a pressure/timer basis a minimum of once each week. The backwash may be classified as a trade waste and must not be discharged to the public drainage network. Innovative solutions for the treatment of backwash such as bioretention and/or a GPT may enable discharge to the public drainage network. The acceptance of any such proposal is subject to the approval of the ACT Government representative(s).

Table 8- 48 Indicative log reductions of reference pathogens after treatment

Treatment	Viruses (including rotavirus virions)	Protozoa (including *Cryptosporidium oocysts*)	Bacterial pathogens (including *Campylobacter* cells)
Dual-media filtration with coagulation	0.5-3.0	1.5-2.5	0-1.0
Membrane filtration	2.5 > 6.0	>6.0	3.5 > 6.0
Reverse osmosis	>6.0	>6.0	>6.0
Chlorination	1.0-3.0	0-0.5	2.0-6.0
Ozonation	3.0-6.0	no data available	2.0-6.0
Ultraviolet light	>1.0 adenovirus	>3.0	2.0 > 4.0
Ultraviolet light	>3.0 enterovirus, rotavirus	>3.0	*Campylobacter* 3.0-4.0

Source: *Australian Guidelines for Water Recycling:* Phase 1 guidelines

Media filters shall be:

1. Clearly labelled with manufacturer, model, local supplier, flow rate, filter area and pressure rating;
2. Designed to bear the pressure of the application and a minimum of 10 bar;
3. Capable of withstanding normal and continuous use without deterioration;
4. Built of corrosion-resistant components;
5. Equipped with all necessary gauges and instrumentation;
6. Mounted level on a concrete foundation; and
7. Linked to an alarm warning of failure.

Disinfection: The risk assessment for the stormwater harvesting scheme will determine the need fordisinfection prior to reuse to comply with the *Australian Guidelines for Water Recycling*.

The disinfection process shall be:

1. Rate adjustable;
2. Designed with backflow prevention;
3. Designed to prevent hydraulic short-circuiting; and
4. Linked to an alarm warning of failure.

Where specified, Ultra Violet (UV) disinfection systems shall be pre-validated based on US EPA Guidelines.The minimum dosage shall comply with the *Australian Guidelines for Water Recycling* and a minimum of 30 mJ/m^2. The lamps must be equipped with auto cleaning. The system shall be positioned to allow the lamps to be easily withdrawn for routine servicing.

UV disinfection shall have:

1. Maximum, minimum and average flowrates clearly identified plus any special surge conditions thatmay be experienced;
2. The required reduction equivalent dose and validation methodology;
3. Water quality criteria, including: influent temperature; turbidity; total hardness; pH; iron; UVtransmittance; and spectral absorbance; and
4. Alarms for lamp or ballast failure, low UV intensity, high temperature, low or high flow and wiperfailure.

Where chlorine is specified for disinfection, the dosage shall be sufficient to achieve the required log reduction in pathogen levels as specified in the *Australian Guidelines for Water Recycling* (generally, 0.5to 2 mg/L at the discharge point). Sufficient water storage capacity shall be provided and the level monitored, accordingly.

Turbidity meter: Turbidity must be metered at the inlet and outlet of the filter(s), so that the performancecan be monitored. At a minimum a turbidity meter shall be placed upstream of the disinfection system.

UV sensor: Where UV disinfection is provided, a UV intensity sensor connected to the SCADA system isrequired. UV function must be reported with alarms for faults and low performance. UV lamp run-overshould also be monitored.

Check valves: One-way valves are required either side of the media filter(s) or additionally where specifiedby the Process Engineer.

Isolation valves: Manually operated isolation valves are required upstream and downstream of the secondary water treatment system and individual components as required by on-going operation andmaintenance of the scheme.

Isolation valves are needed at the:

- Suction and discharge lines of a pump;
- Inlet and outlet of a storage tank; and
- Upstream and downstream of a media filter.

Butterfly and wedge gate are common types of isolation valves. The decision what to use is dependent oncost, pipe material, diameter and operating pressure. For example, a butterfly valve is often seen as a costeffective choice for a pump suction line, but the design of the valve affects flow behaviour and can have a detrimental impact on pump performance. For this application a wedge gate valve is often a better choicebecause it offers little resistance to flow.

Sampling: Manual water quality sampling points are required upstream and downstream of thecomponents of the secondary water treatment system or additionally where specified.

Maintenance: Water treatment systems shall be installed in a manner to facilitate ease in servicing and removal/replacement considering the location of interrelated assets such as water storages, wetlands andbioretention systems.

Guarantee: The water treatment system shall be guaranteed to meet the performance requirements stated in the specification for an identified period.

Warranty: A minimum manufacturer's warranty of 12 months is be provided unless otherwise noted.

Refer:

> The current most relevant Australian Standards, including amendments and supplements; and
> *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2)Stormwater Harvesting and Reuse.*

17.4.4 Header tank

Storage: Provision of a header tank(s) to store treated water is a common requirement to meet the demand (i.e. end use) be it irrigation, environmental, amenity, toilet flushing, or industrial.

Requirement: Unless otherwise directed by the ACT Government representative(s) a suitably sized headertank(s) with a separate pump connection to the end use shall be provided.

Construction: Header tanks shall be constructed in concrete and preferably below ground considering thelocation of interrelated assets such as water storages, wetlands, bioretention systems and public spaces. The top of the tank will ideally finish between 300 and 600 mm above surrounding ground level. The topsshould all be level in multiple tank installations.

Access: The header tank shall have a minimum of two (2) lockable access lids. The first will be above the inflow assembly and the other lid over the pump suction line with access to any sensor installations provided. The lids will be Class B or as dictated by the land use, be it subject to pedestrian or vehicular traffic. A ladder under one of the two lids will provide safe access down to the base of the tank. The tank will be fit with an overflow connected to a suitable discharge.

Multiple header tanks: For multiple installations, one header tank shall provide primary storage with a balance pipe between each successive tank. The balance pipe shall have a minimum 1.5% grade with a flanged sluice valve connection at base level.

Water level: A water level control system with a hydrostatic pressure transducer and multichannel controller with data logging capability shall be provided. An external solenoid valve will control flow into the header tank. The protocols regarding fill sequence shall be confirmed by a Process Engineer when more than one water supply inflow is to be used.

Stilling pipe: The treated water inflow and potable water top-up shall discharge into a stilling pipe within the header tank. Stilling pipes shall be a minimum 300 mm in diameter and securely fixed internally to thetank or lid. The stilling pipe will incorporate slots or holes to minimise air and wave action from the discharge of water.

Potable water top-up: The potable water top-up will be controlled automatically by an adjustable float switch. When the water level in the header tank drops to 30 to 40% of storage capacity, the float switch will open and potable water will flow into the tank. When the water level in the header tank reaches 50 to60% of storage capacity, the float switch will close and flow of potable water stop. The operation of the float switch will be optimised during commissioning and validation and will be affected by the:

> Flow of potable water from the supply network;
> Suction head of the end use (i.e. characteristics of the irrigation pump); and

> Water demand of the end use(s).

Backflow prevention: The potable water top-up shall have an unobstructed air gap through free atmosphere between the lowest opening of the stilling pipe and the spill level in the header tank to provide backflow prevention (refer to **Figure 8-41 Header tank air gap**). The spill level is the greatest height that water will reach when the overflow is operating at the maximum rate. Note that the spill levelwill vary depending on the hydraulic design of the overflow and must be determined. **Table 8-49 Minimum required air gap**, adapted from *AS 2845.2*, sets out the minimum required air gap.

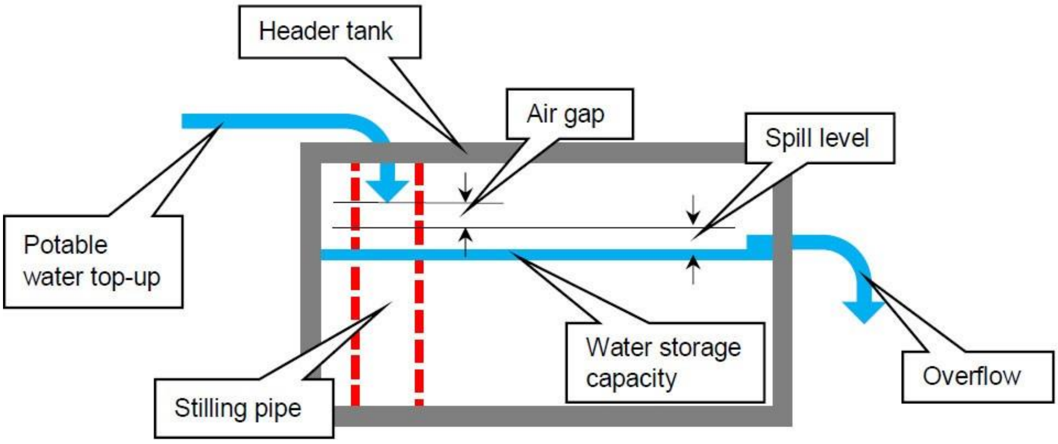


Figure 8-41 Header tank air gap

Pump sump: The sump in the base of the header tank for the suction line of the pump serving the end use (e.g. irrigation) shall be a minimum 2.5 m x 2.5 m x 1.0 m deep. A raised hob or lip shall be provided around the border of the sump to lessen the quantity of silt entering the sump. The pump sump shall be located on the opposite side of the tank as the treated water inflow. The pump suction line shall be fitted with a foot valve.

Table 8-49 Minimum required air gap

Internal diameter of the potable water top-up (mm)	Minimum required air gap (mm)	
	not affected by near wall	affected by near wall
<9	20	25
9<12	25	40
12<20	40	55
20<25	50	75
>25	2 x internal diameter	3 x internal diameter

Visual: To minimise the visual impact of the header tank(s), the surrounding ground surface shall be merged with the adjoining landform. Where feasible screening vegetation should be planted. Consult theACT Government representative(s) concerning species and landscape design.

Maintenance: Apply paint or other approved finish to all exposed surfaces of the header tank. All externalexposed pipework shall also be protected with a painted vandal proof shroud securely fixed to the headertank.

Refer: The current most relevant Australian Standards, including amendments and supplements.

17.4.5 Equipment and instrumentation list

Requirement: A comprehensive list of equipment and instrumentation shall be provided including:

- Equipment description;
- Location;
- Type;
- Size;
- Tag number;
- Manufacturer;
- Model;
- Fluid;
- Local supplier;
- Procurement Date or Installation date (if possible);
- Cost (if applicable);
- Condition up-to-date; and
- Importance.

List update: The list of equipment and instrumentation must be updated on the WAE drawings at projectcompletion and included in the O&M Manual.

Warranty: A minimum manufacturer's warranty of 12 months is be provided unless specified otherwise byTCCS.

APPENDICES

APPENDIX A SUMP INLET CAPACITIES AND GUTTER FLOW WIDTHS

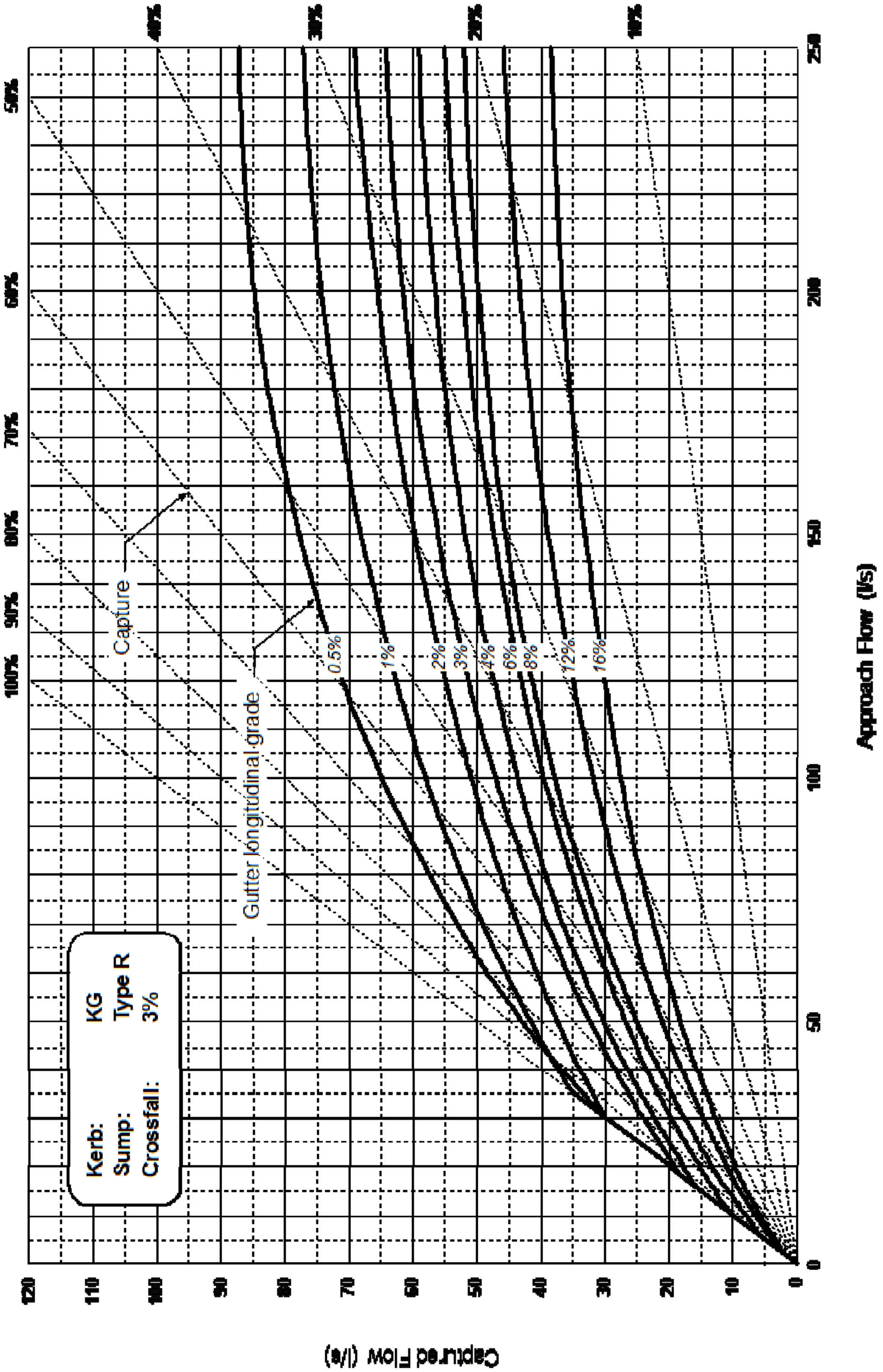


Figure 8- 42 On-grade Type R sump inlet capacities

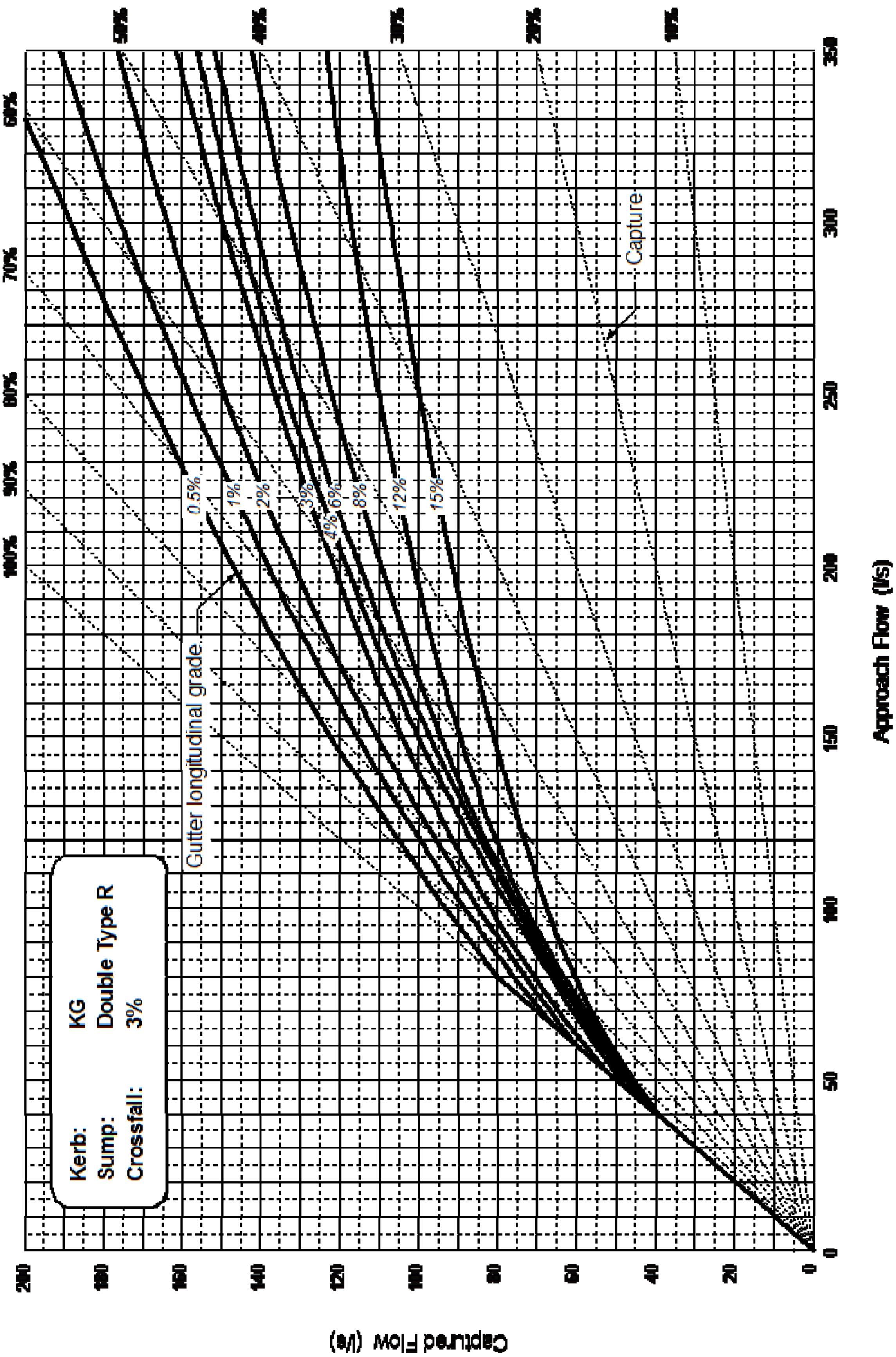


Figure 8- 43 On-grade Double Type R sump inlet capacities

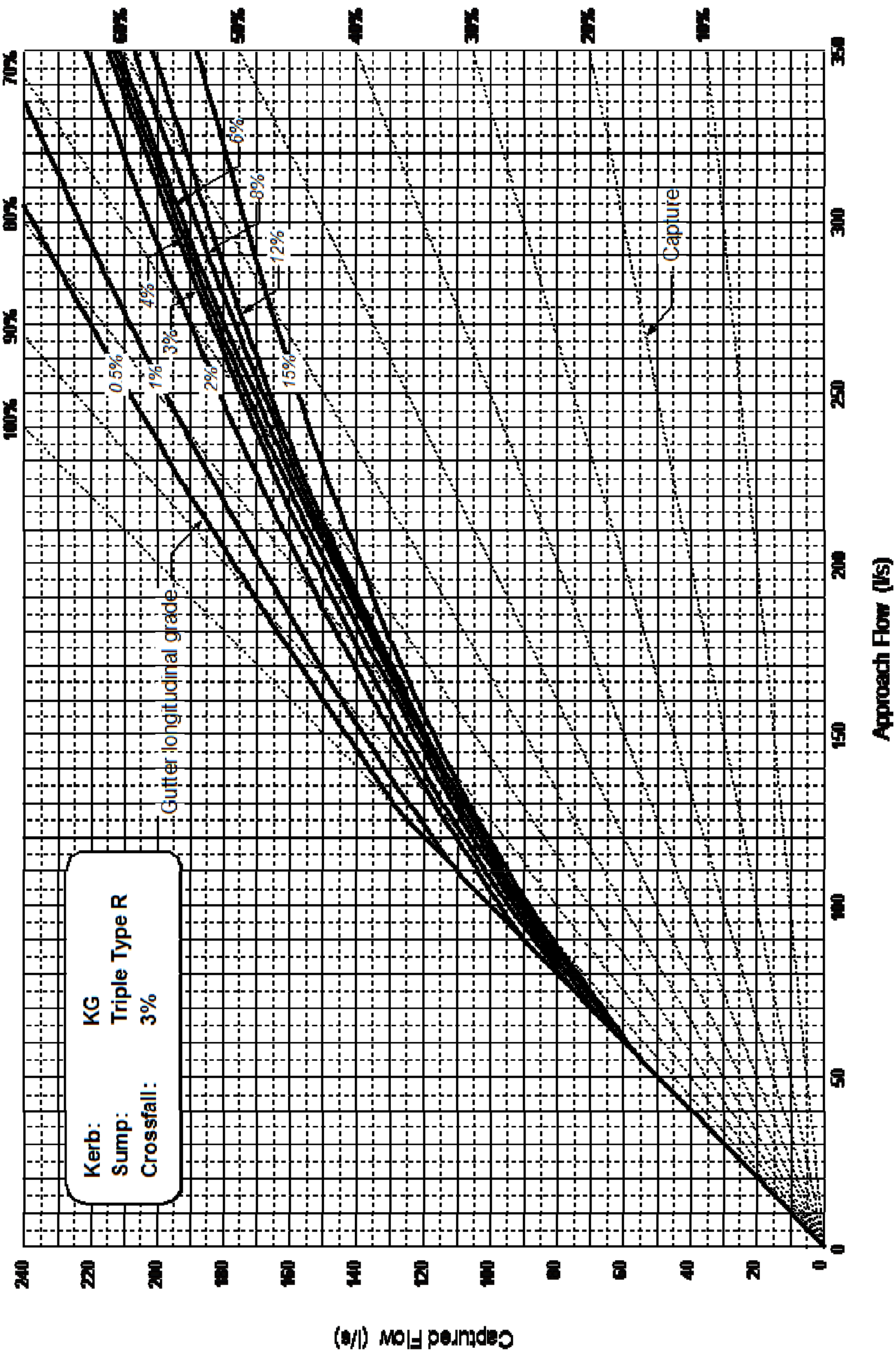


Figure 8- 44 On-grade Triple Type R sump inlet capacities

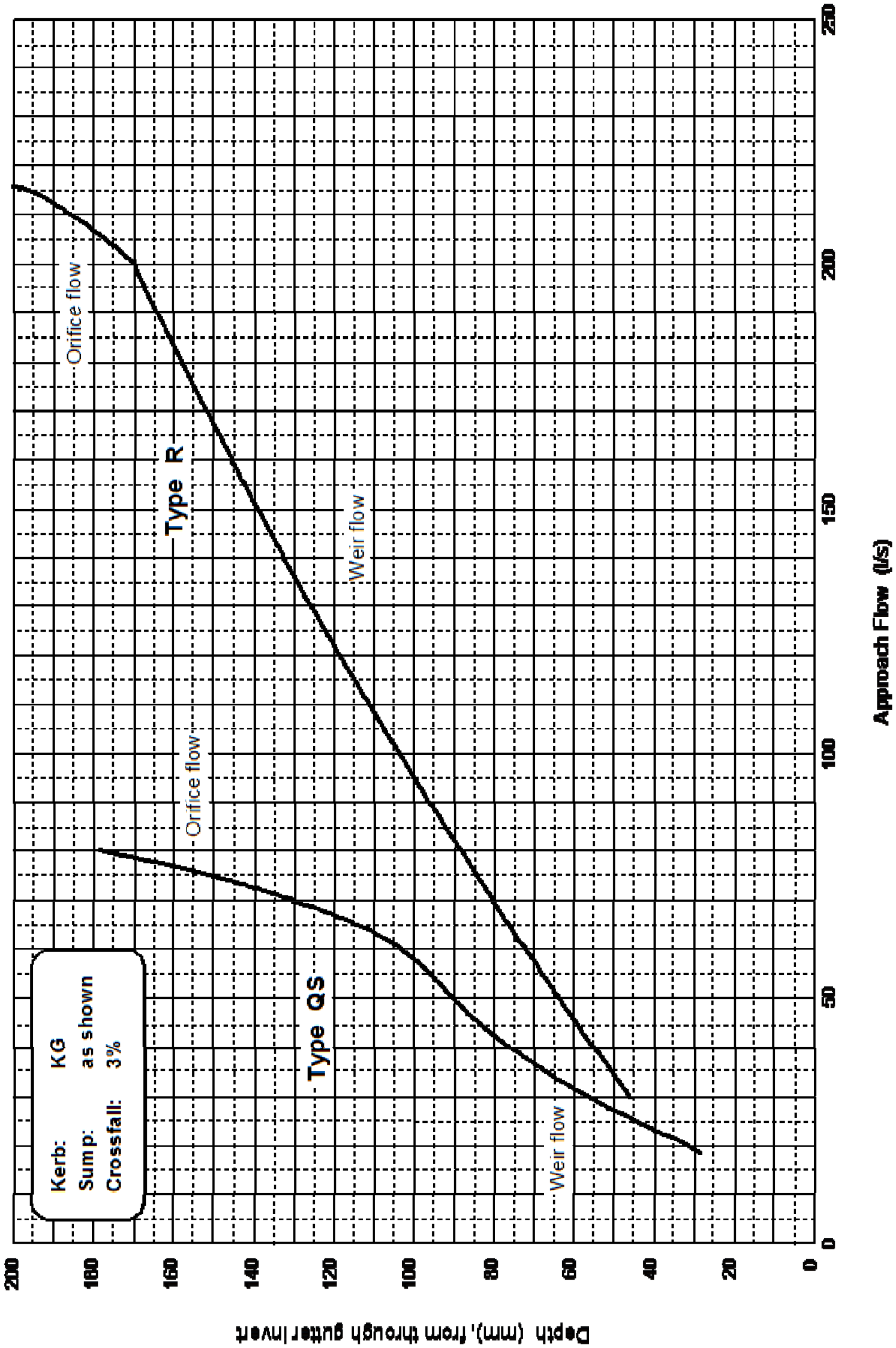


Figure 8-45 Low point sump inlet capacities

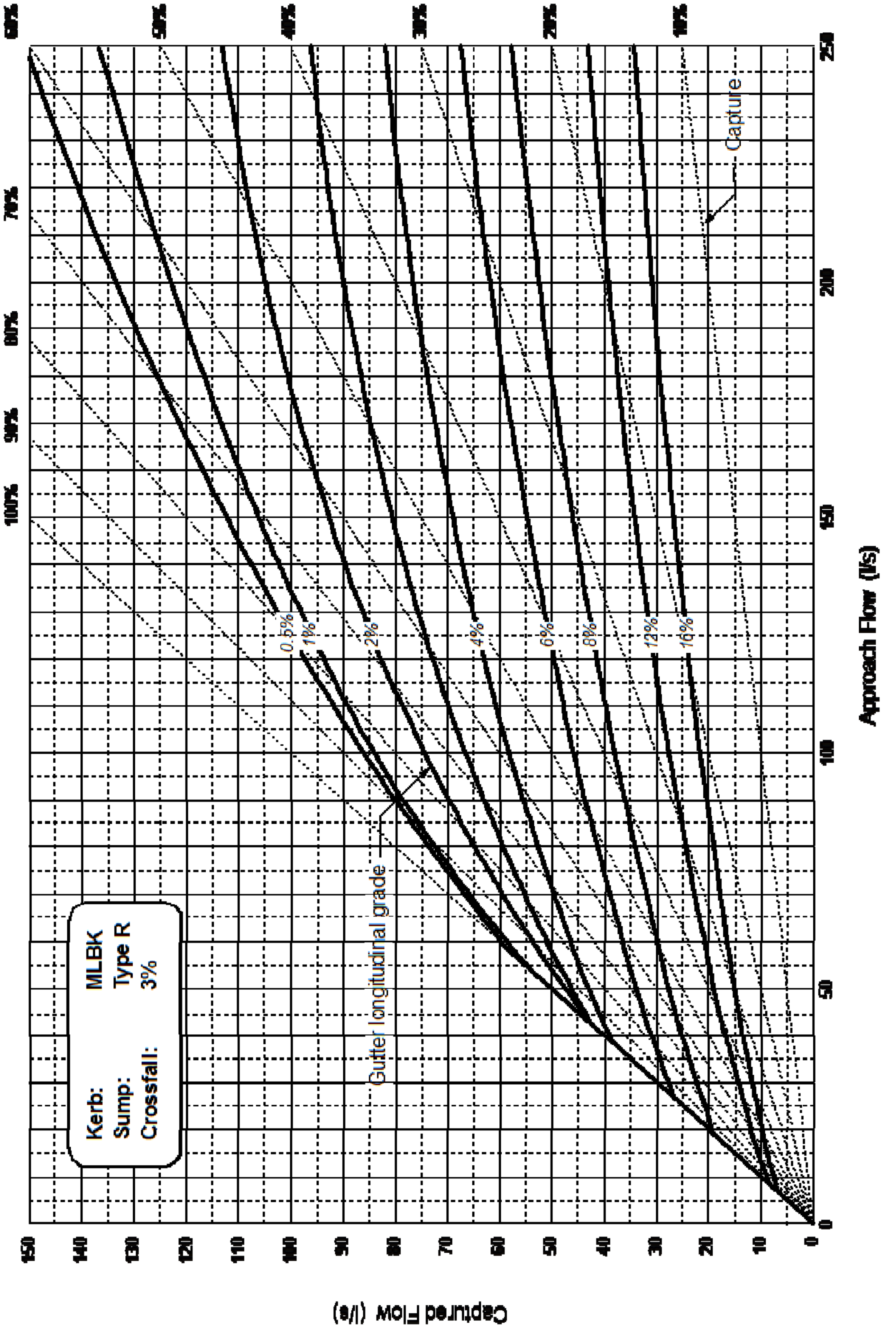


Figure 8- 46 On-grade Type R sump inlet capacities (MLBK)

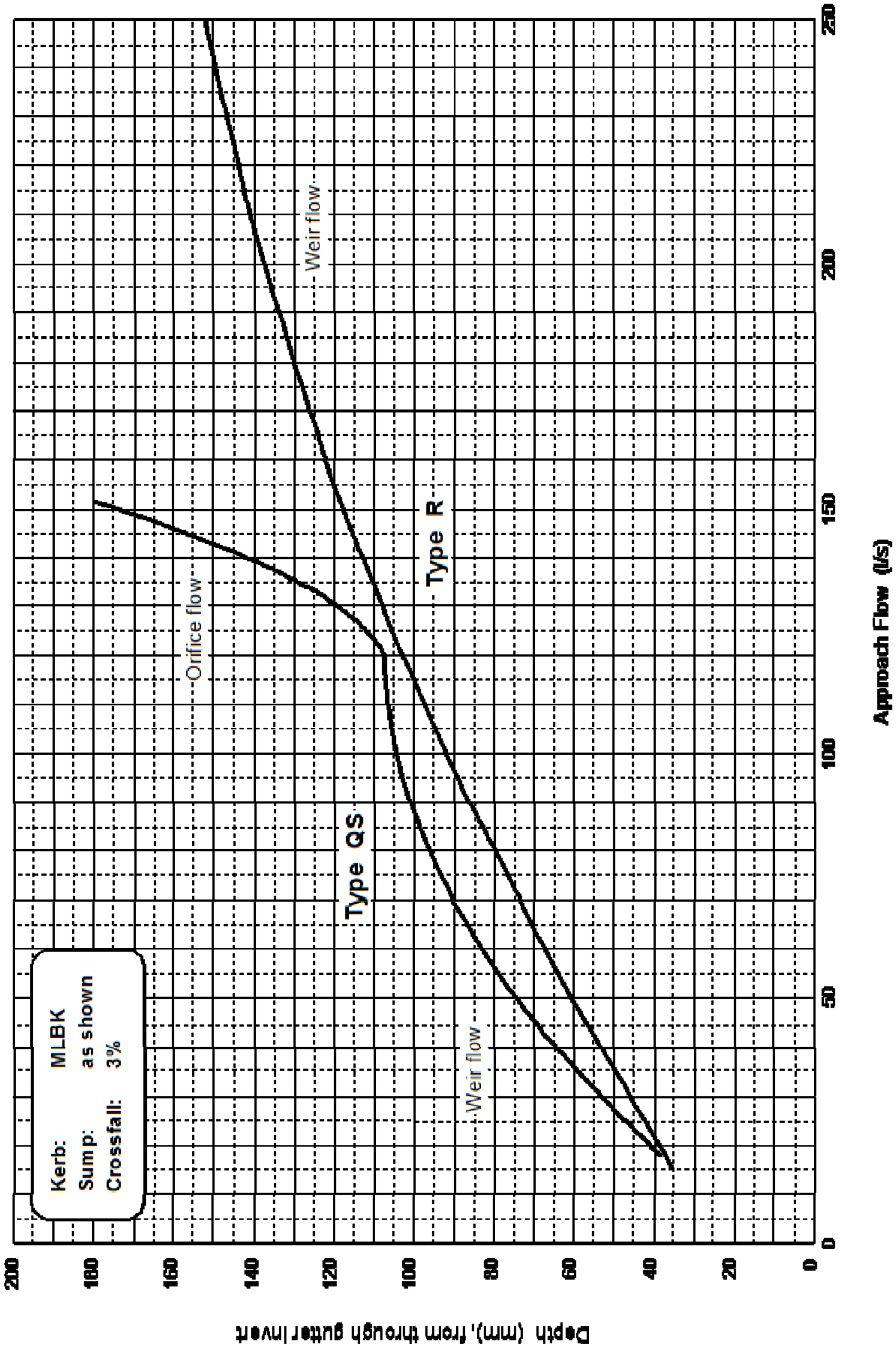


Figure 8- 47 Low point sump inlet capacities (MLBK)

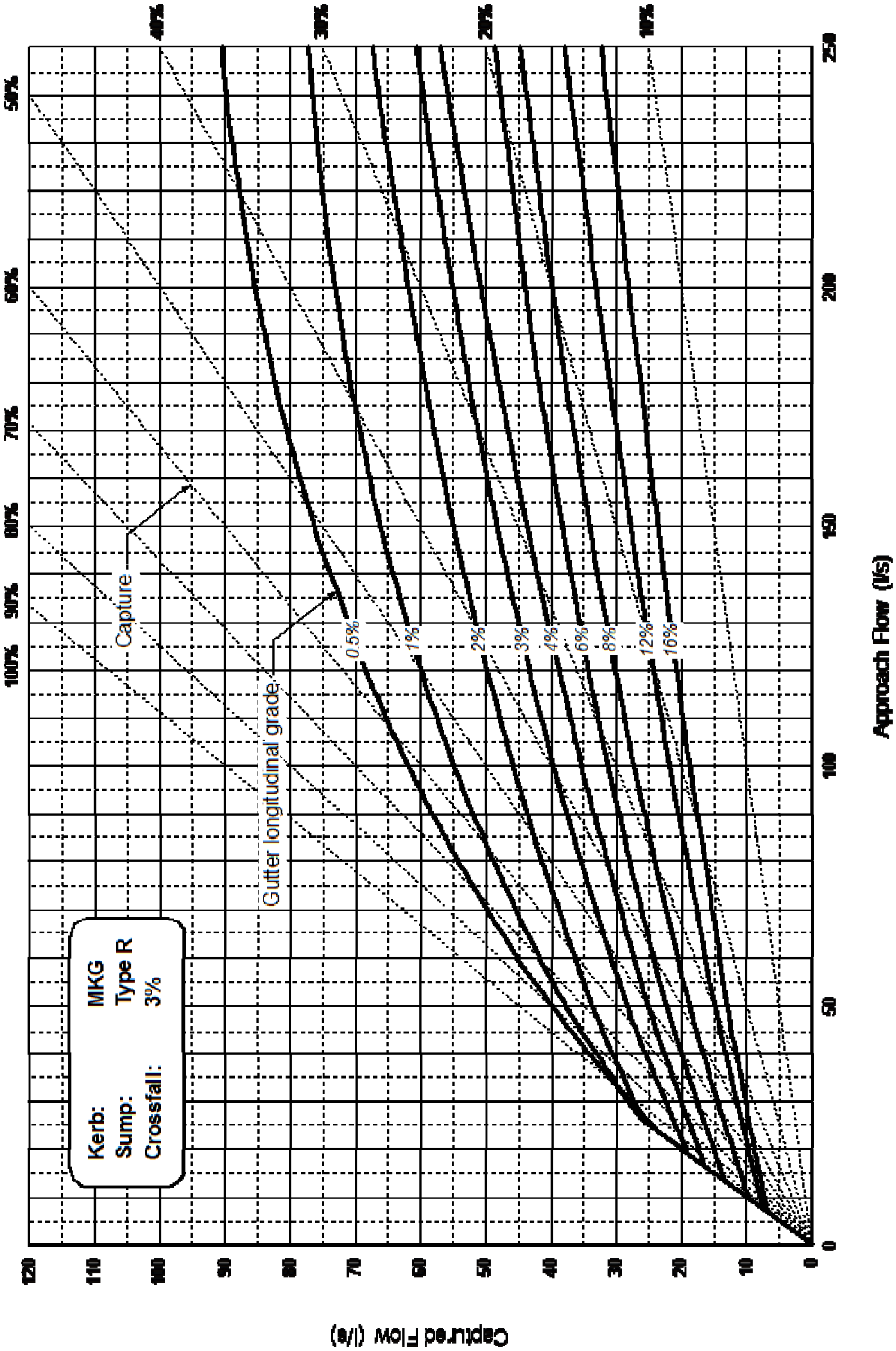


Figure 8- 48 On-grade Type R sump inlet capacities (MKG)

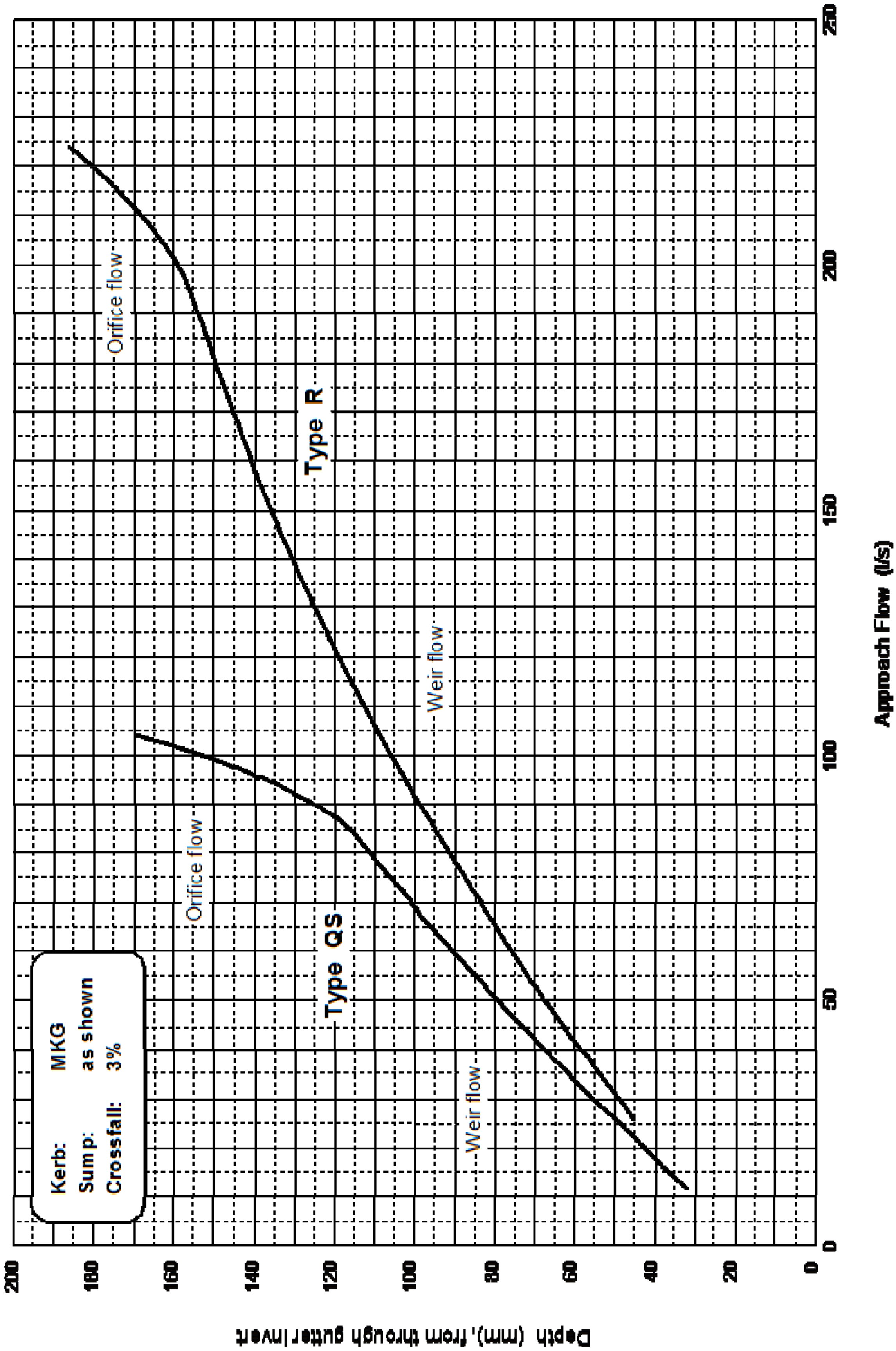


Figure 8- 49 Low point sump inlet capacities (MKG)

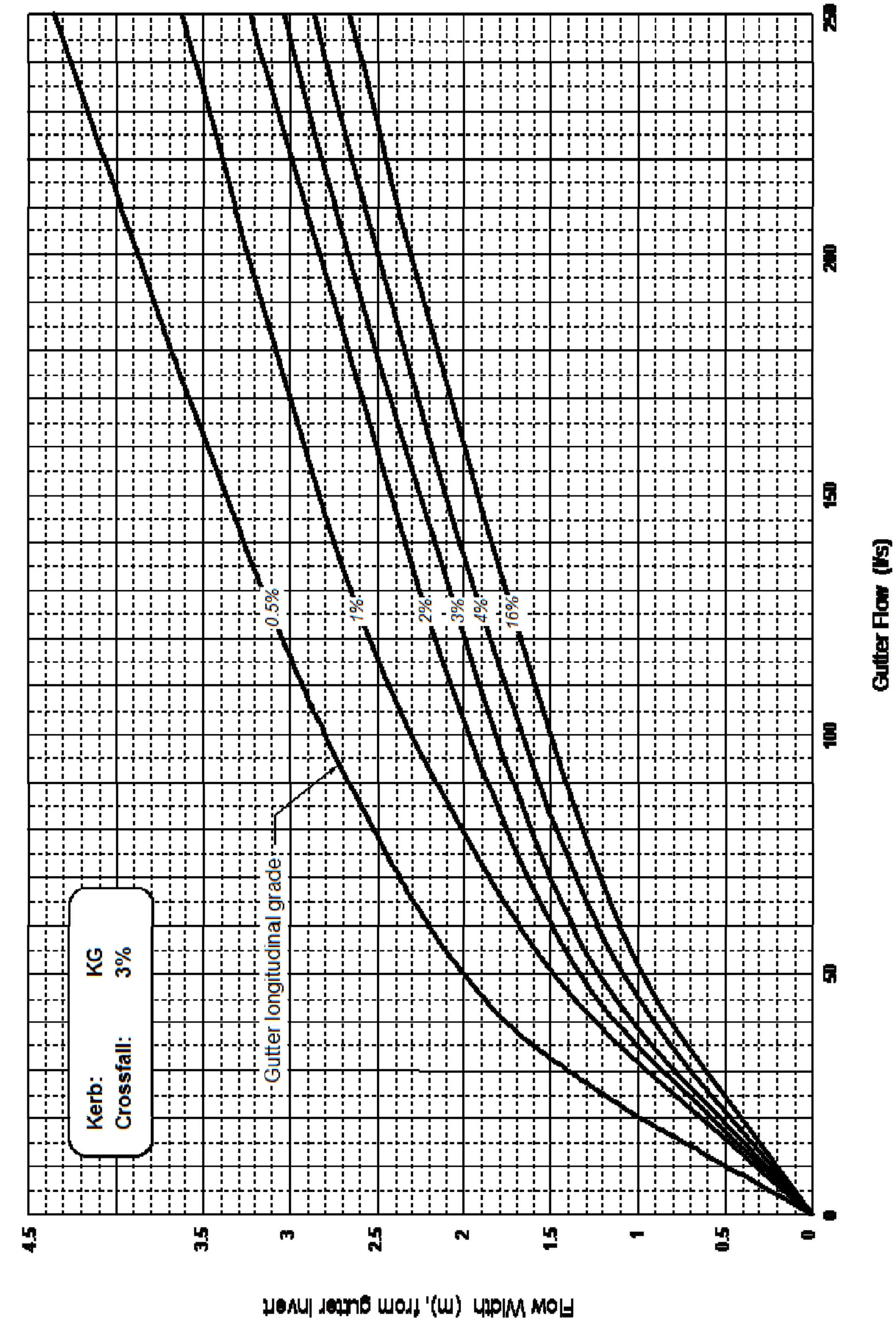


Figure 8- 50 KG gutter flow widths

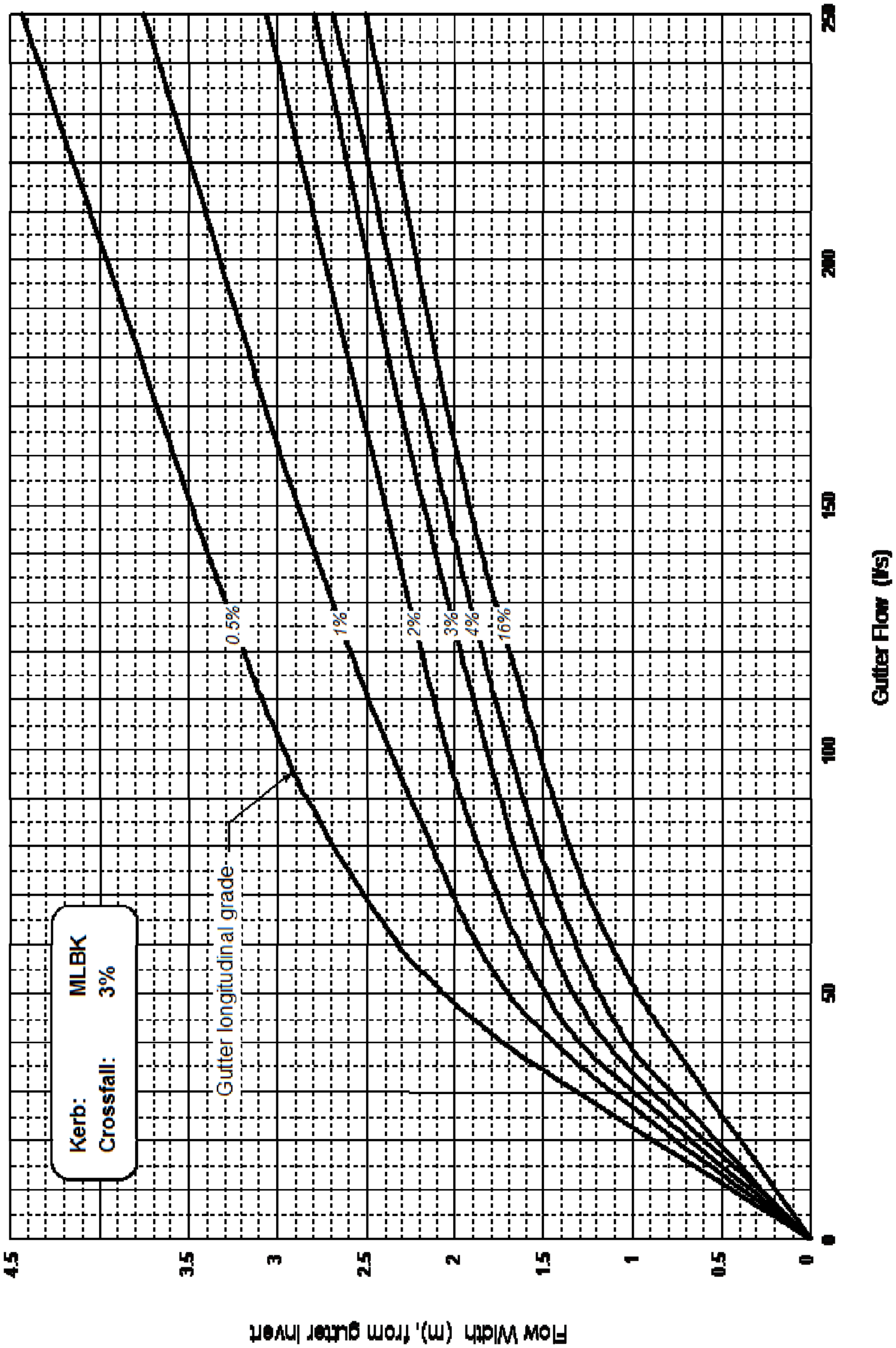


Figure 8- 51 MLBK gutter flow widths

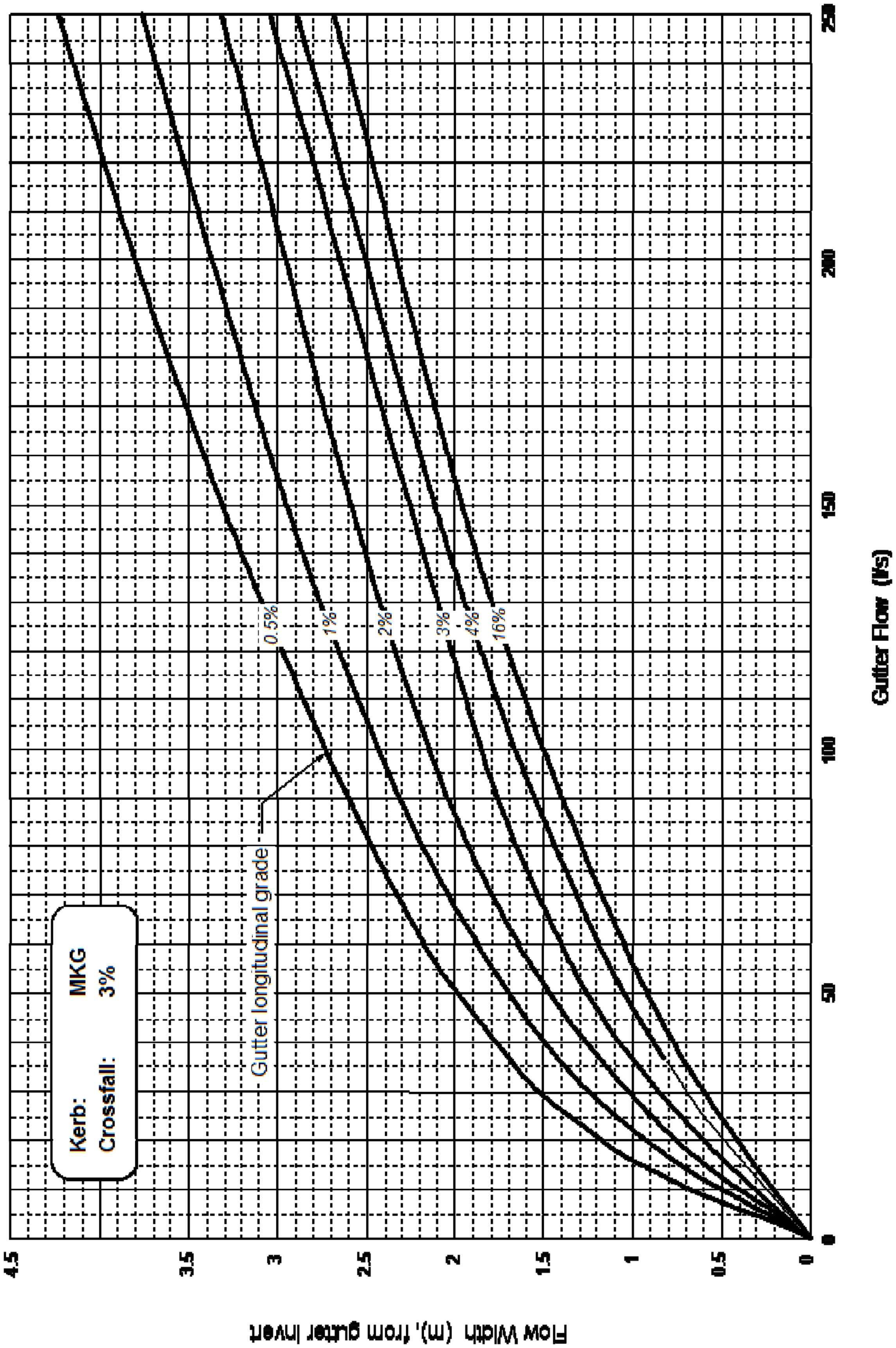


Figure 8- 52 MKG gutter flow widths

APPENDIX B FLOODWAY PRELIMINARY SIZING CHARTS

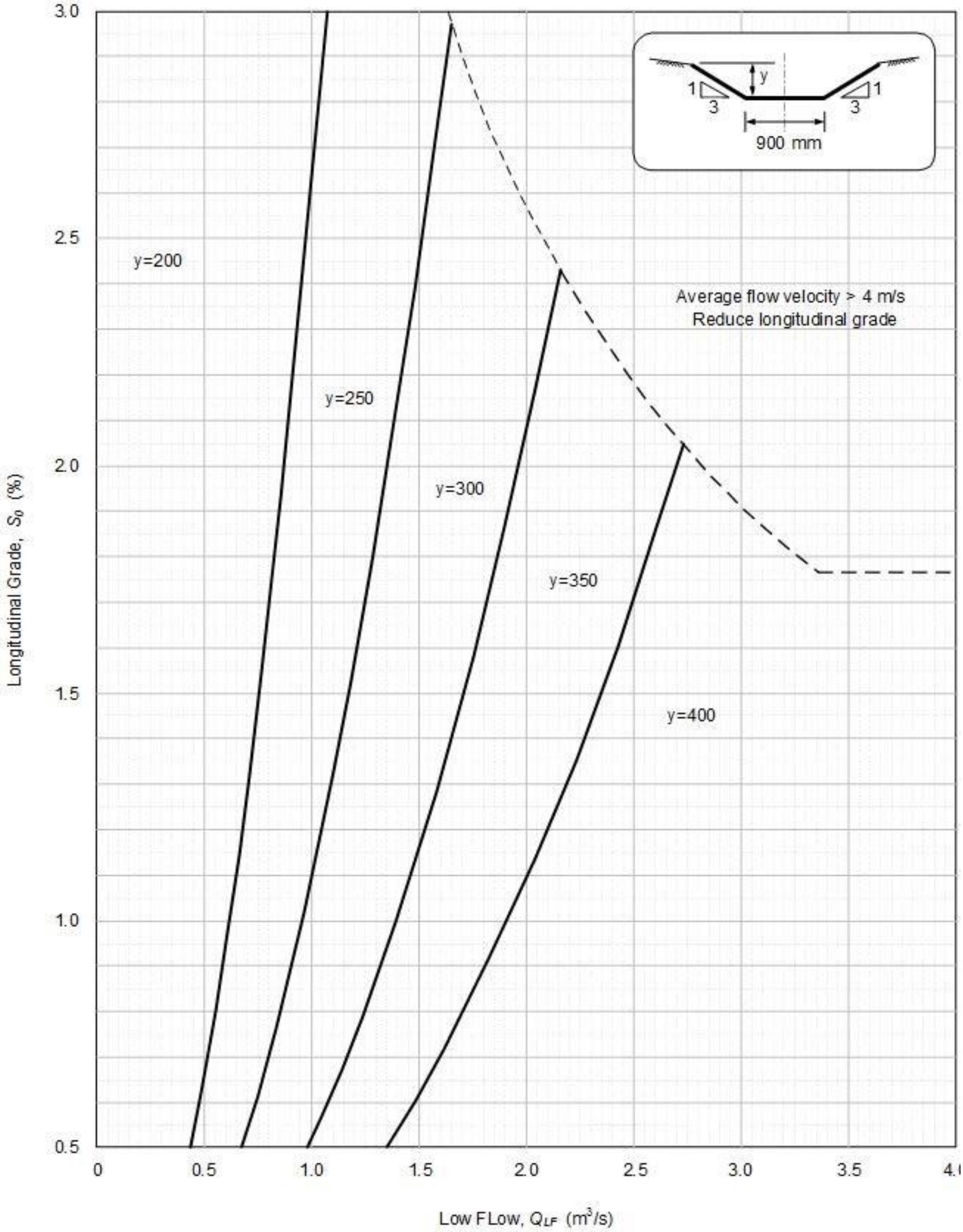


Figure 8- 53 Low flow invert – Type 1 – preliminary sizing chart

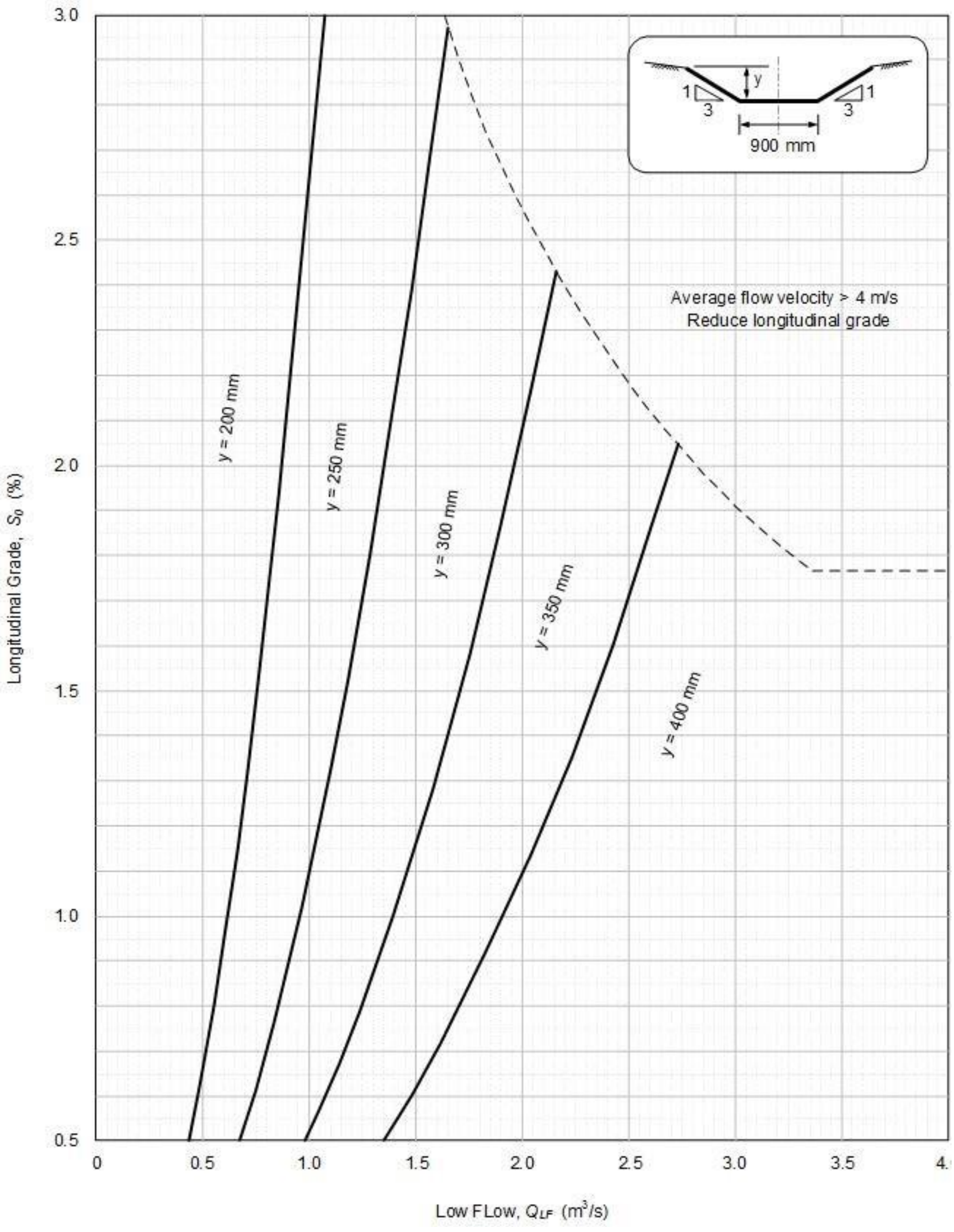


Figure 8- 54 Low flow invert – Type 2 – preliminary sizing chart

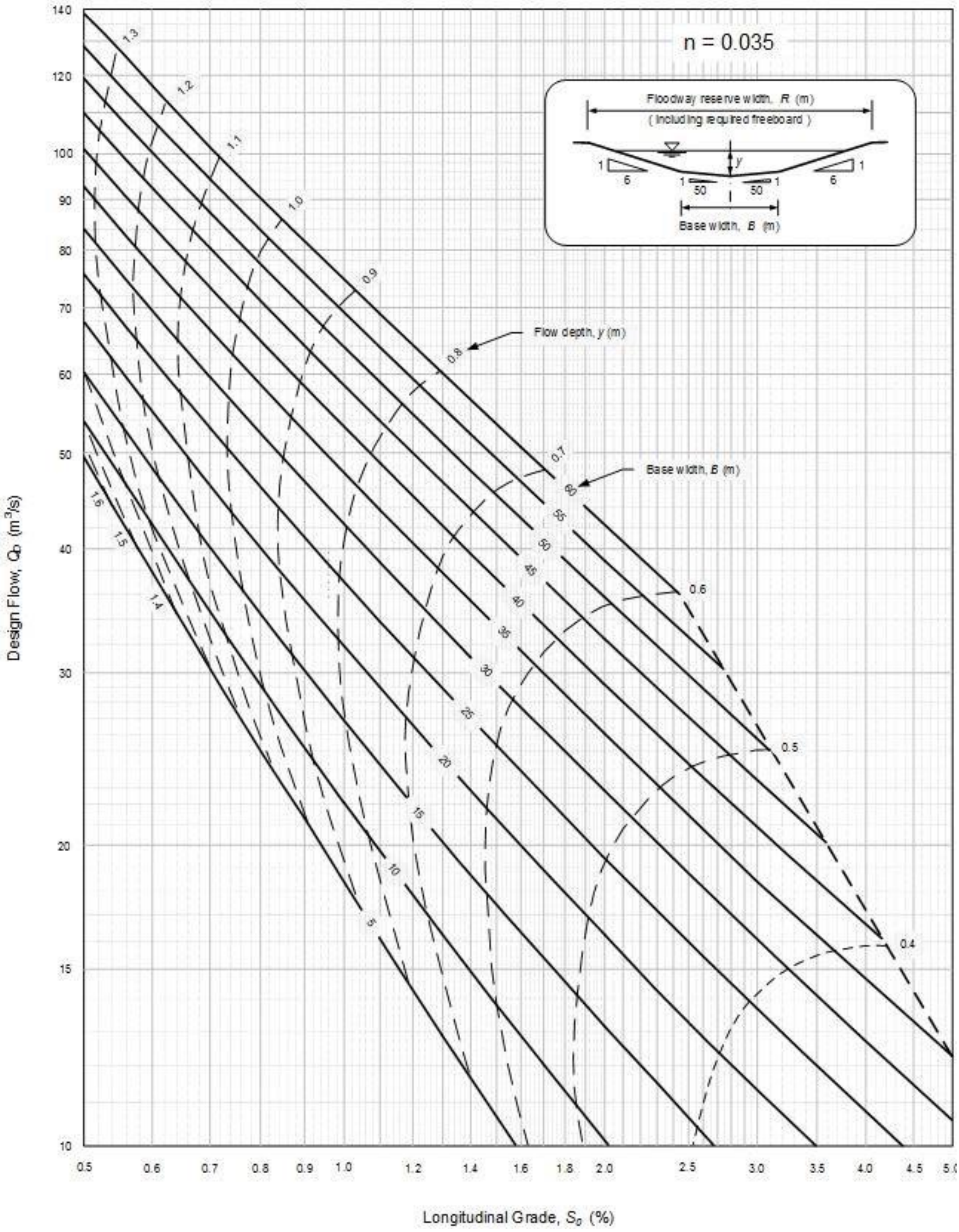


Figure 8- 55 Floodway base width preliminary sizing chart (n-0.035)

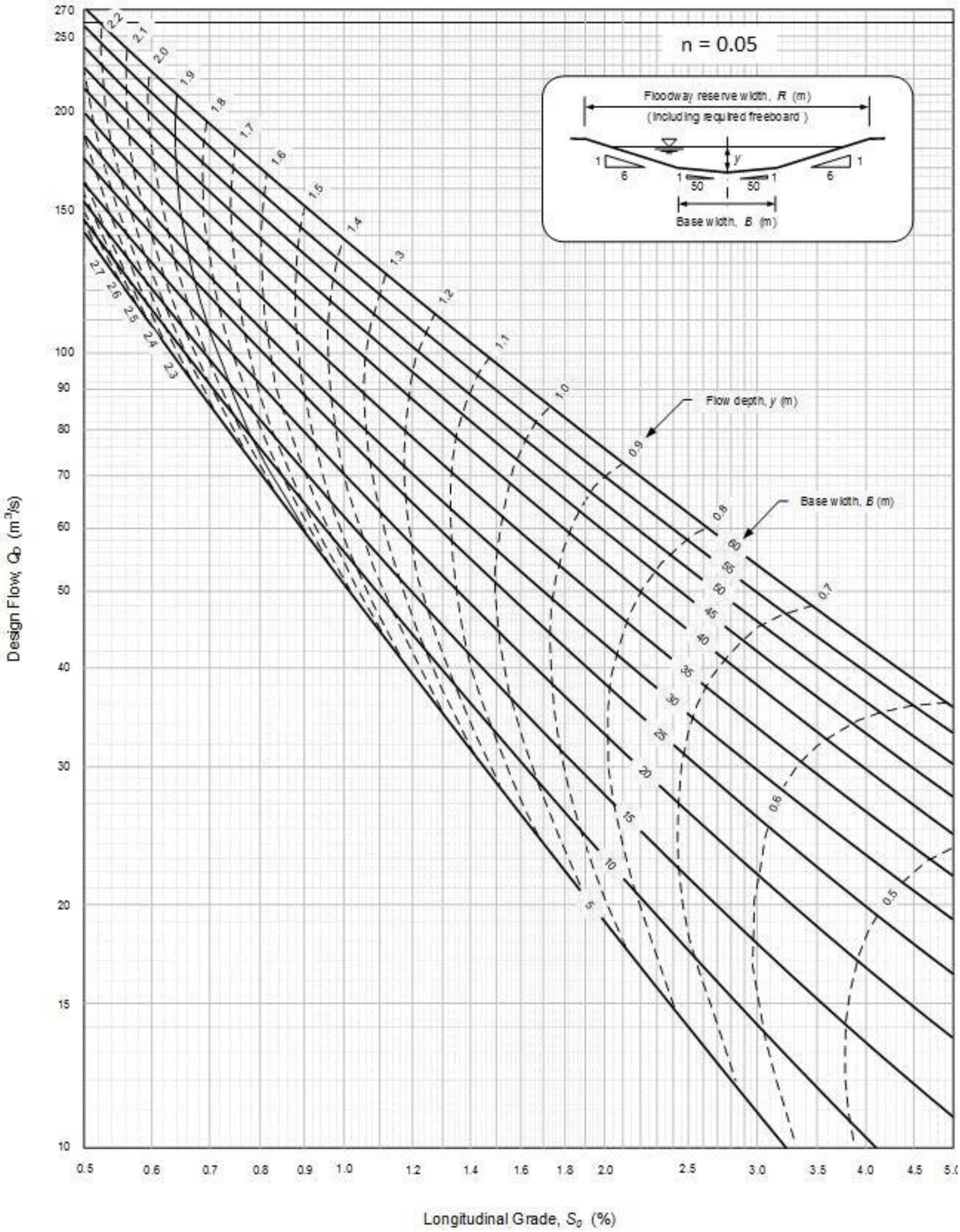


Figure 8- 56 Floodway base width preliminary sizing chart (n-0.05)

APPENDIX C GPT SIZING CHARTS

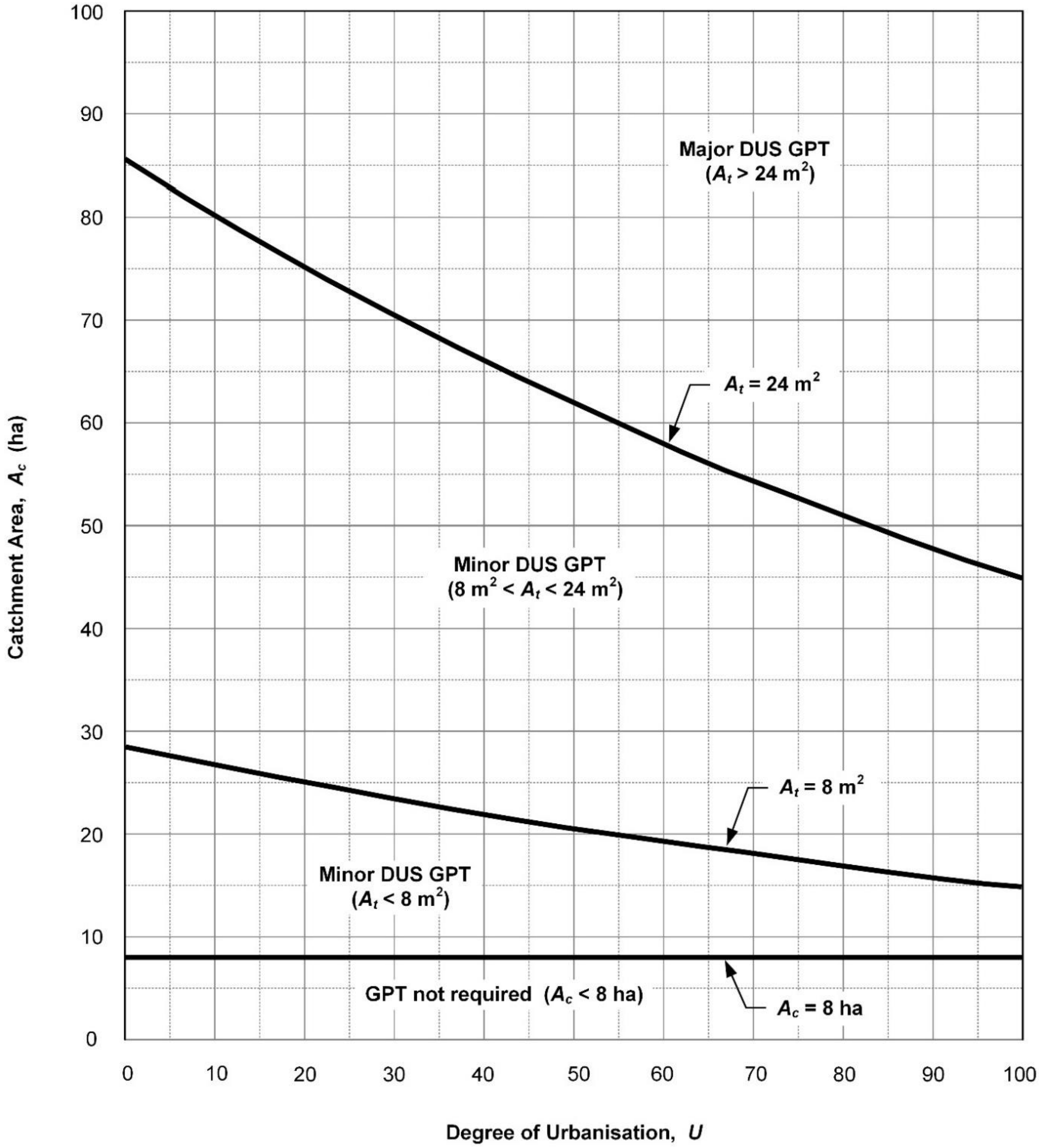


Figure 8- 57 Selection of GPT type against catchment area and degree of urbanisation

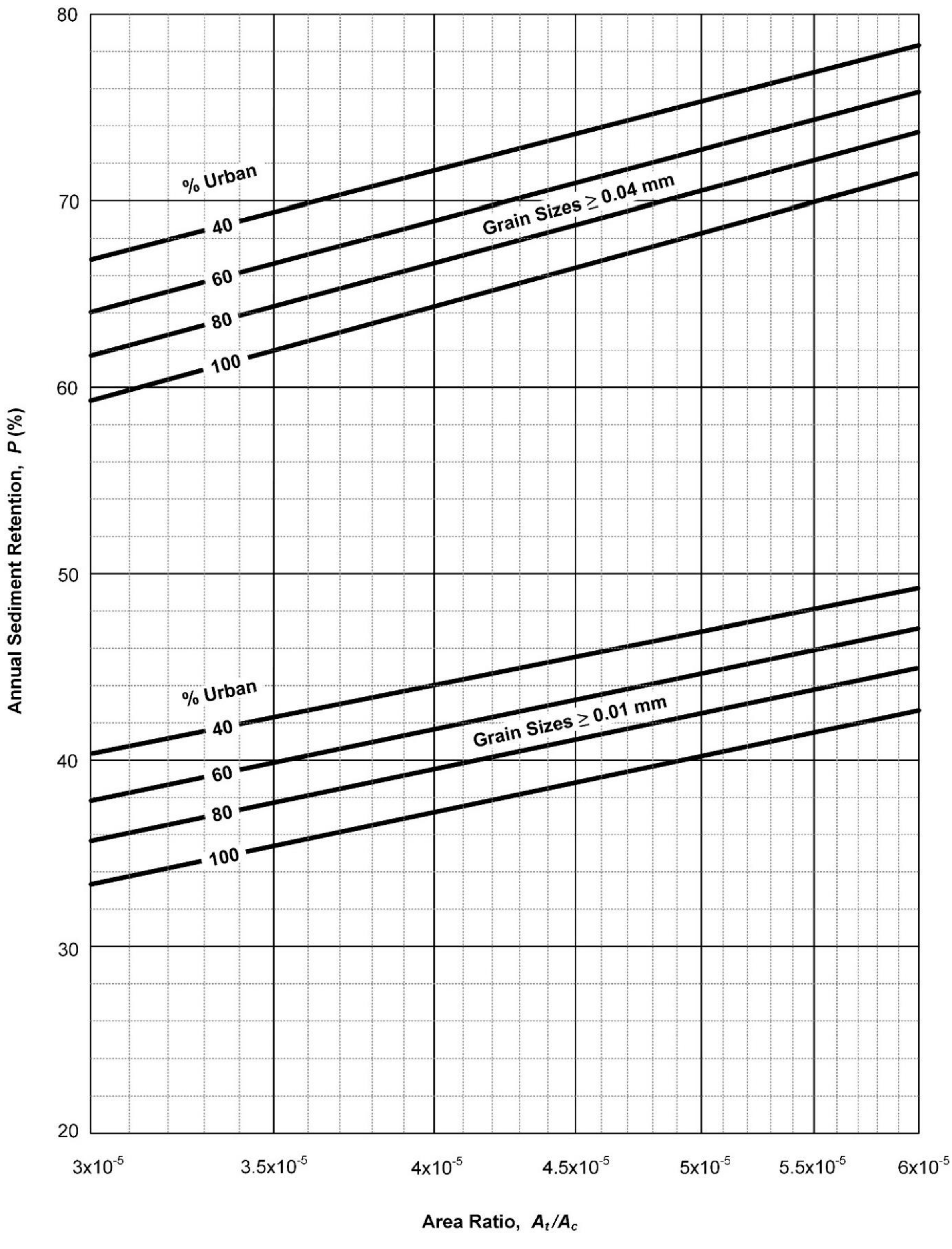


Figure 8- 58 Average annual sediment retention against area ratio

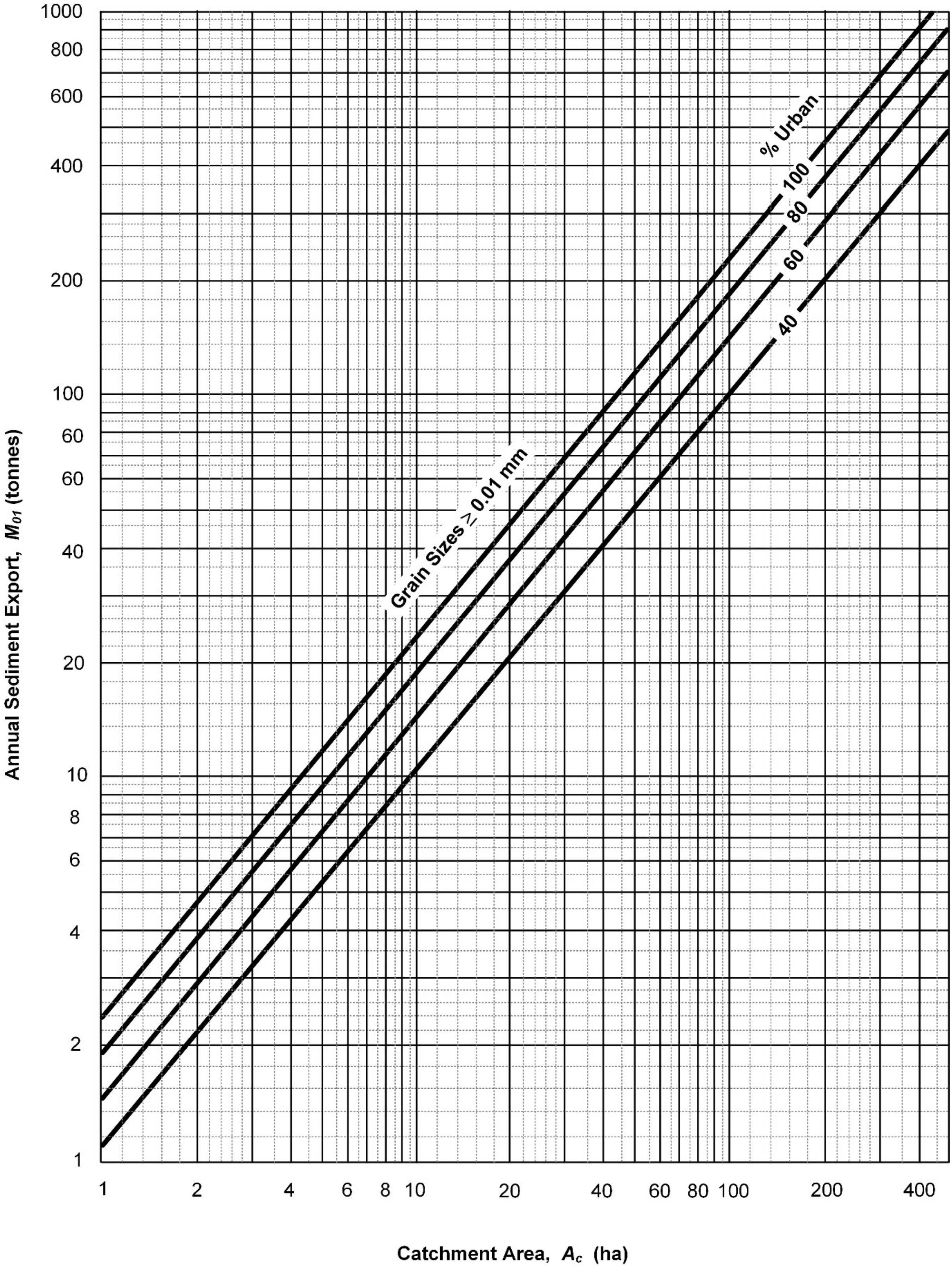
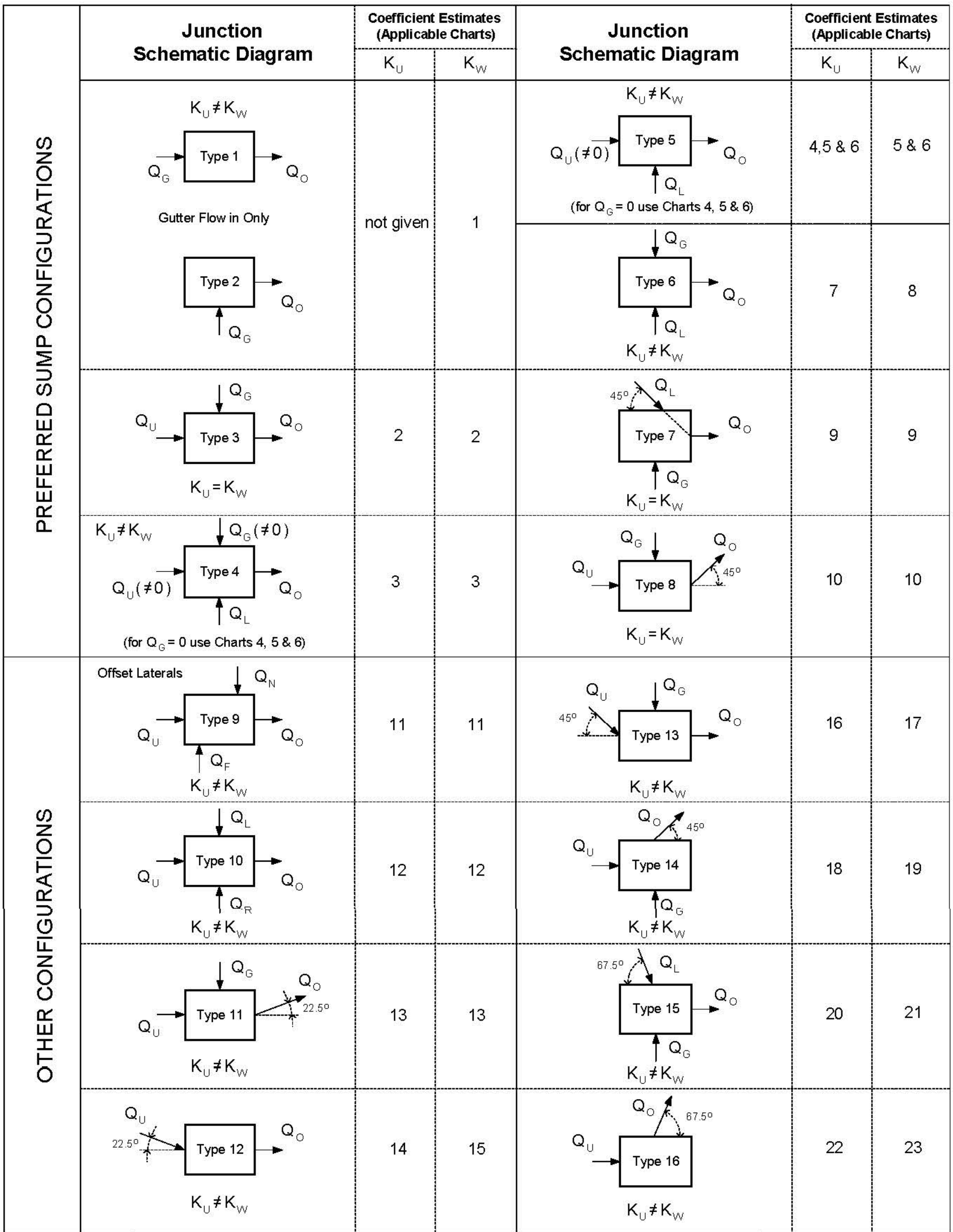


Figure 8- 59 Average annual export of sediments

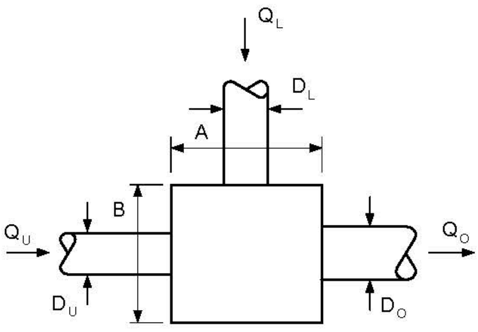
APPENDIX D SUMP AND MANHOLE HEAD LOSS CHARTS

LIST OF CHARTS



Junction Types Covered by the Charts

FIGURE 1



Junction Dimensions

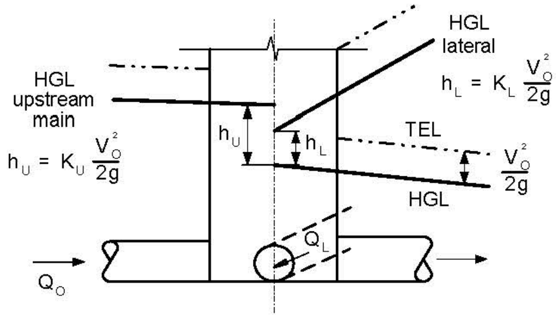


Diagram of HGL elevations at junctions of a lateral with a through main

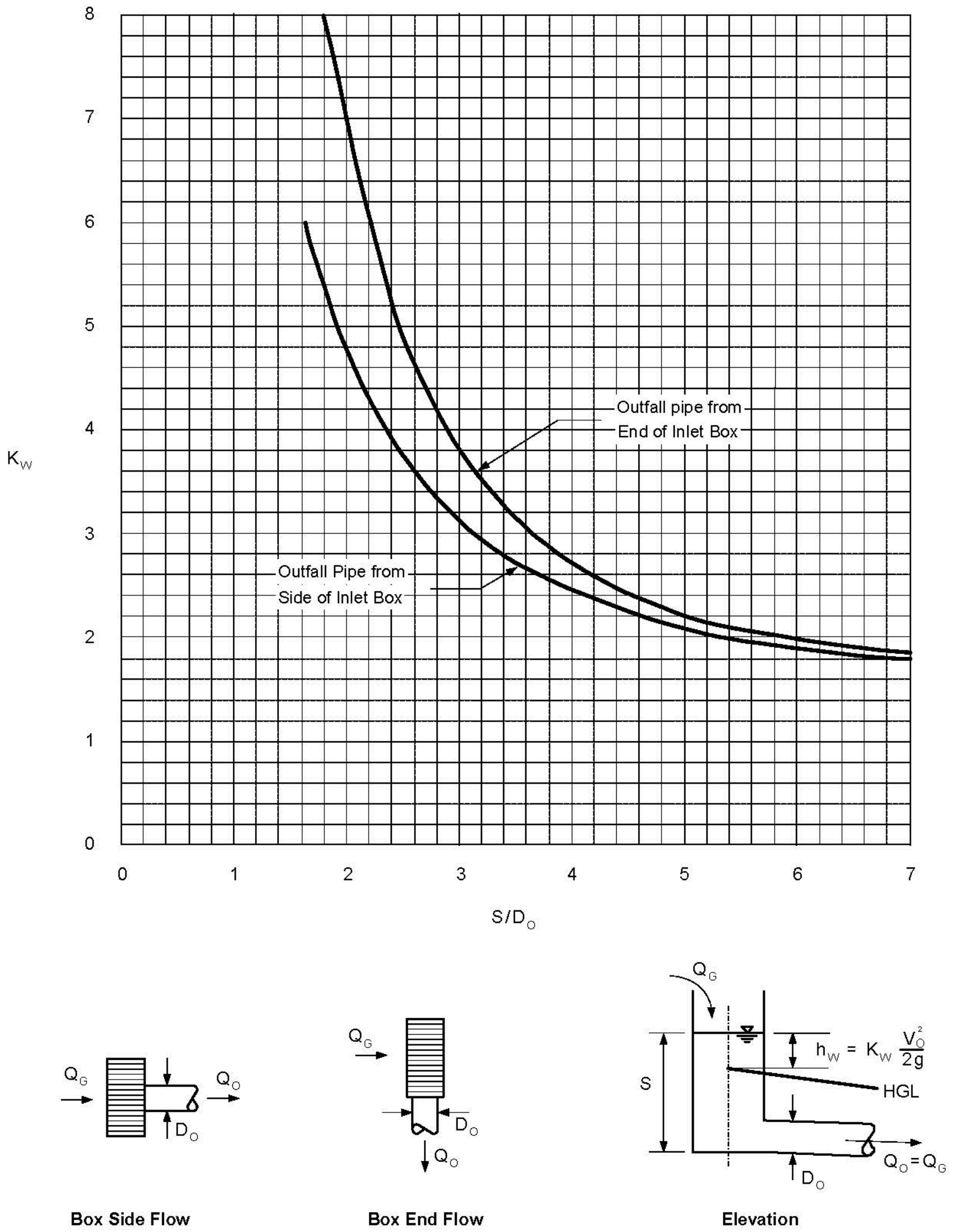
Q	rate of flow
D	diameter of pipe
A	dimension of junction in direction of outfall pipe
B	dimension of junction at right angles to outfall pipe
S	depth of water in sump
HGL	hydraulic grade line
TEL	total energy line
Q_G	flow into sump through top inlet
D_O , Q_O	dia. and flow in outfall
D_U , Q_U	dia. and flow in upstream main
D_L , Q_L	dia. and flow in left lateral
D_R , Q_R	dia. and flow in right lateral
D_N , Q_N	dia. and flow in near lateral } of opposed laterals; designation with reference to position relative to outfall end of junction
D_F , Q_F	dia. and flow in far lateral } of opposed laterals; designation with reference to position relative to outfall end of junction
D_{hv} , Q_{hv}	dia. and flow in lateral with higher-velocity flow } for in-line opposed laterals only
D_{lv} , Q_{lv}	dia. and flow in lateral with lower-velocity flow } for in-line opposed laterals only

Pressure change coefficients for inlet water depth and an upstream pipe pressure relative to the outfall pipe pressure.

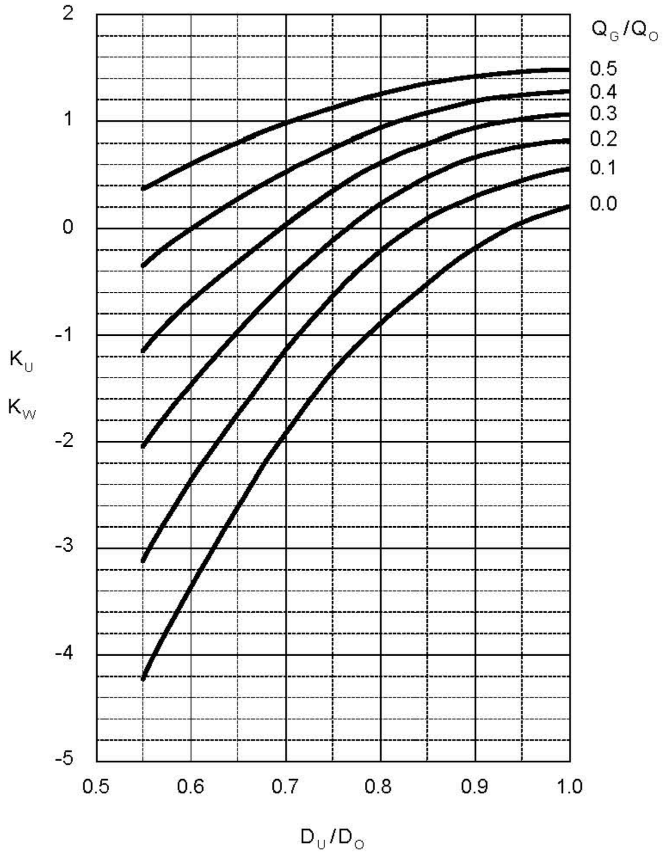
K_G	water depth with all flow through grate
K_U	upstream main pressure
K_R or K_L	lateral pipe pressure
K_N	near lateral pipe pressure } offset opposed laterals
K_F	far lateral pipe pressure } offset opposed laterals
$\overline{K}_U$, $\overline{K}_L$	pressure coefficient at $Q_L = Q_O$
M_U , M_L	multipliers for $\overline{K}_U$ or $\overline{K}_L$ to obtain K_U or K_L

Nomenclature used in the Charts

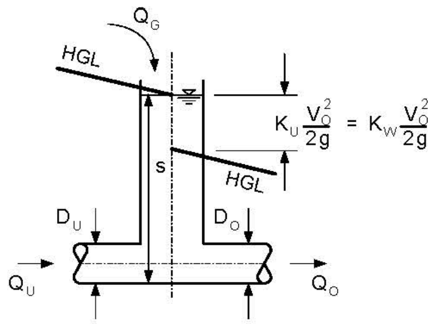
FIGURE 2



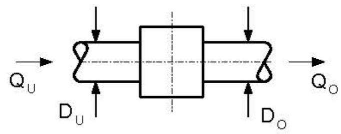
Source : M	**Water surface elevation coefficient (K_W) for rectangular inlet with grate flow**	**CHART 1**



Positive Pressure Head Change ($K_U > 0$)



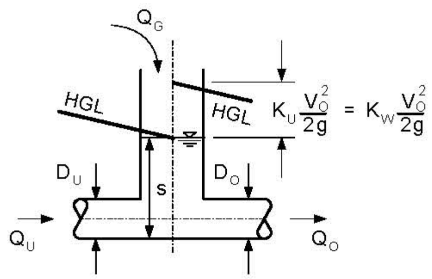
Elevation



Plan

Q_G/Q_O \ S/D_O	0.00	0.10	0.20	0.30	0.40	0.50
1.5	0.00	0.11	0.22	0.33	0.44	0.55
2.0	0.00	0.04	0.08	0.12	0.16	0.20
2.5	0.00	0.00	0.00	0.00	0.00	0.00
3.0	0.00	-0.03	-0.06	-0.09	-0.12	-0.15
3.5	0.00	-0.04	-0.08	-0.12	-0.16	-0.20
4.0	0.00	-0.05	-0.10	-0.15	-0.20	-0.25

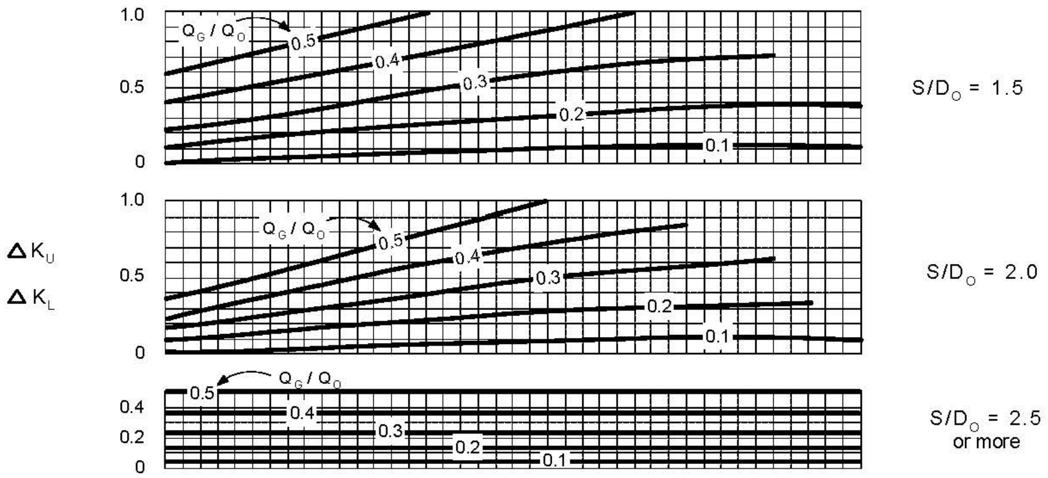
Increment K_U and K_W by the above values for S/D_O ratios other than 2.5



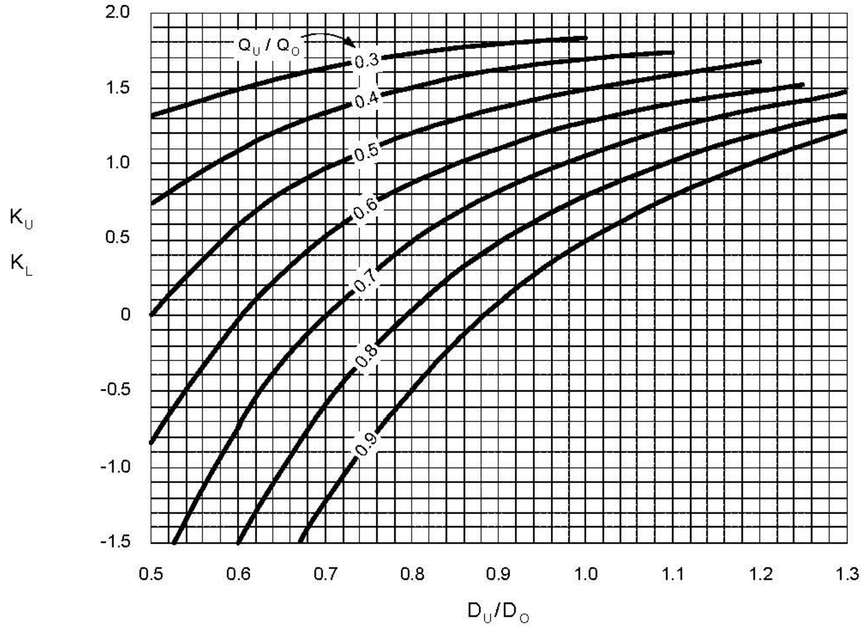
Elevation

Negative Pressure Head Change ($K_U < 0$)

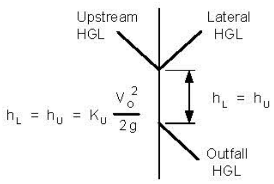
Source : N	Coefficients for straight through flow	CHART 2



Supplementary chart for modification of K_U & K_L for grate flow

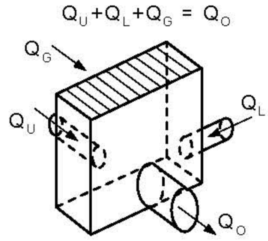


Pressure coefficients for no flow through grate.
(for grate flow, add values from appropriate curve above)



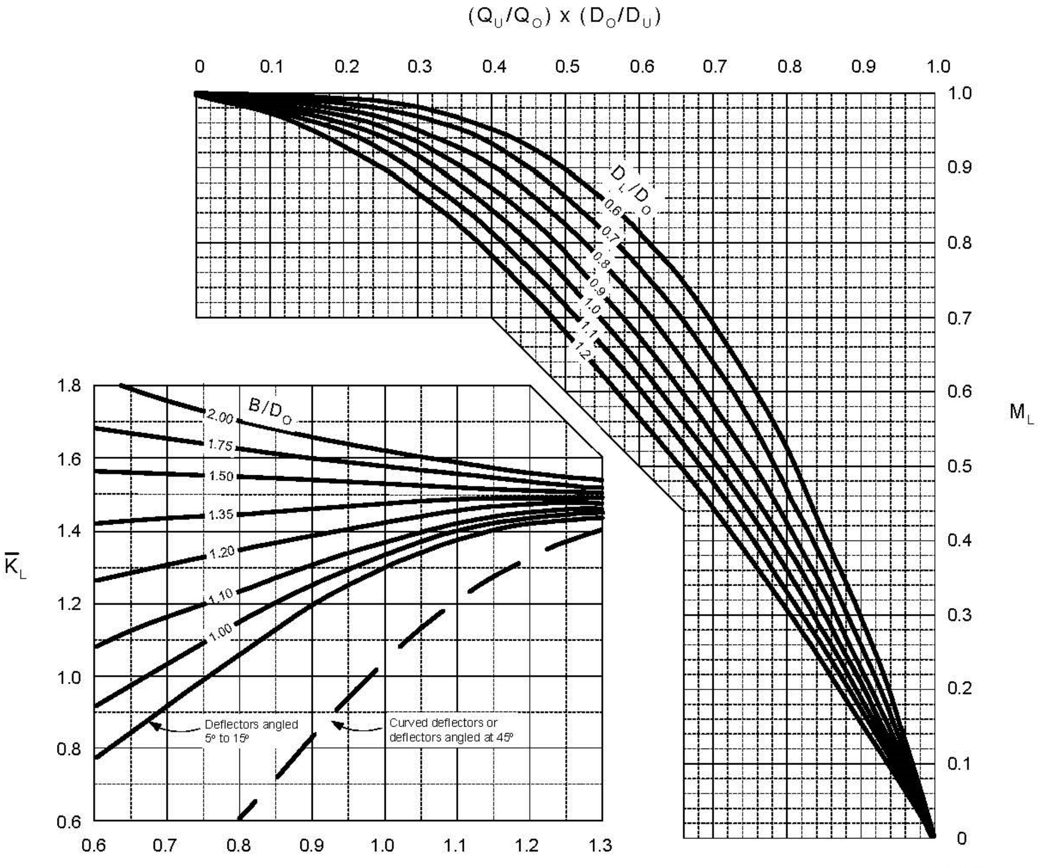
Pressure Line Sketch

$K_W = K_U \, (1.3 - 0.2 \, Q_U/Q_O)$

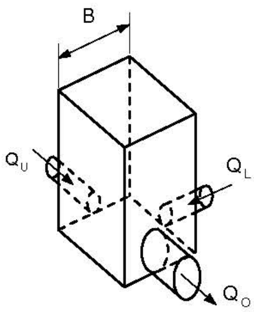


Elevation Sketch

Source : M	**Pressure head change coefficient (K_U) for rectangular inlet with in-line upstream main and 90º lateral pipe (with or without grate flow)**	**CHART 3**



$$M_L = 1 - [(Q_U/Q_O)(D_O/D_U)]^{2(D_O/D_L)}$$



Elevation Sketch

To find K_L for the lateral pipe, first read $\overline{K}_L$ from the lower graph. Next determine M_L. Then,

$$K_L = \overline{K}_L \times M_L$$

Dashed curve for curved or 45º angle deflectors applies only to manholes without upstream inline pipe.

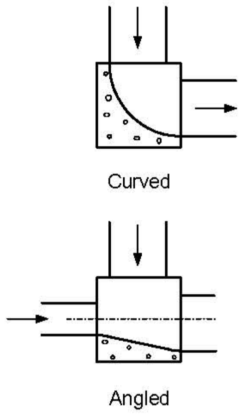
Use this chart for round manholes also.

For rounded entrance to outfall pipe, reduce chart values pf $\overline{K}_L$ by 0.2 for combining flow.

For $(Q_U/Q_O) \times (D_O/D_U) > 1$ use Chart 6.

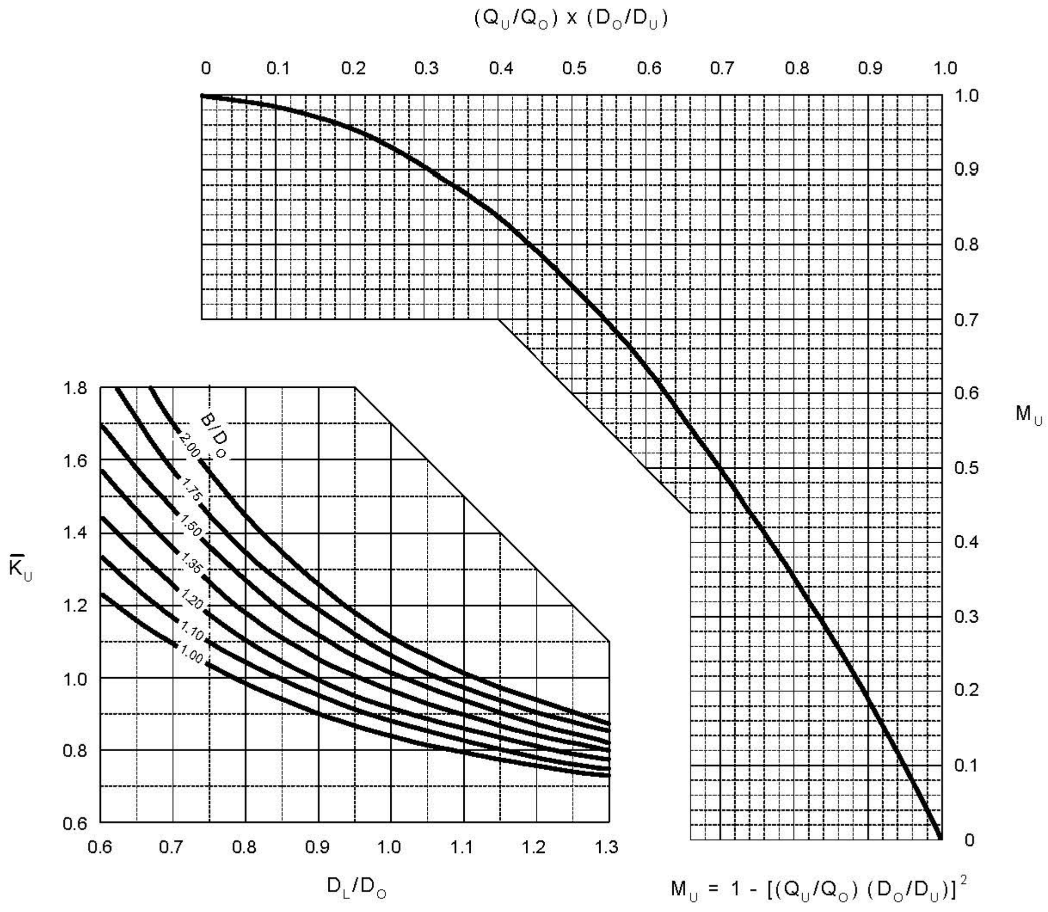
For $D_L/D_O < 0.6$ use Chart 6.

$$h_L = K_L \frac{V_O^2}{2g}$$



Plan of Deflectors

Source : M	Pressure head change coefficient (K_L) for square or round manhole at 90º deflection or on through pipeline at junction of 90º lateral pipe (lateral coefficient)	CHART 4



To find K_U for the lateral pipe, first read $\overline{K}_U$ from the lower graph. Next determine M_U. Then,

$$K_U = \overline{K}_U \times M_U$$

$$K_W = K_U\ (1.3 - 0.2\ Q_U/Q_O)$$

For manholes with deflectors at 0o to 15o read KU on curve for B/DO = 1.

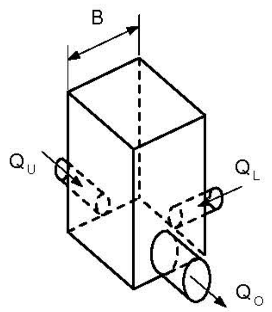
Use this chart for round manholes also.

For rounded entrance to outfall pipe, reduce chart values of $\overline{K}_U$ by 0.2 for combining flow.

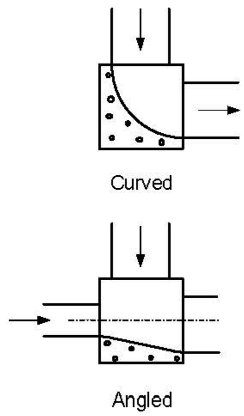
For $(Q_U/Q_O) \times (D_O/D_U) > 1$ use Chart 6.

For $D_L/D_O < 0.6$ use Chart 6.

$$h_U = K_U \frac{V_O^2}{2g}$$

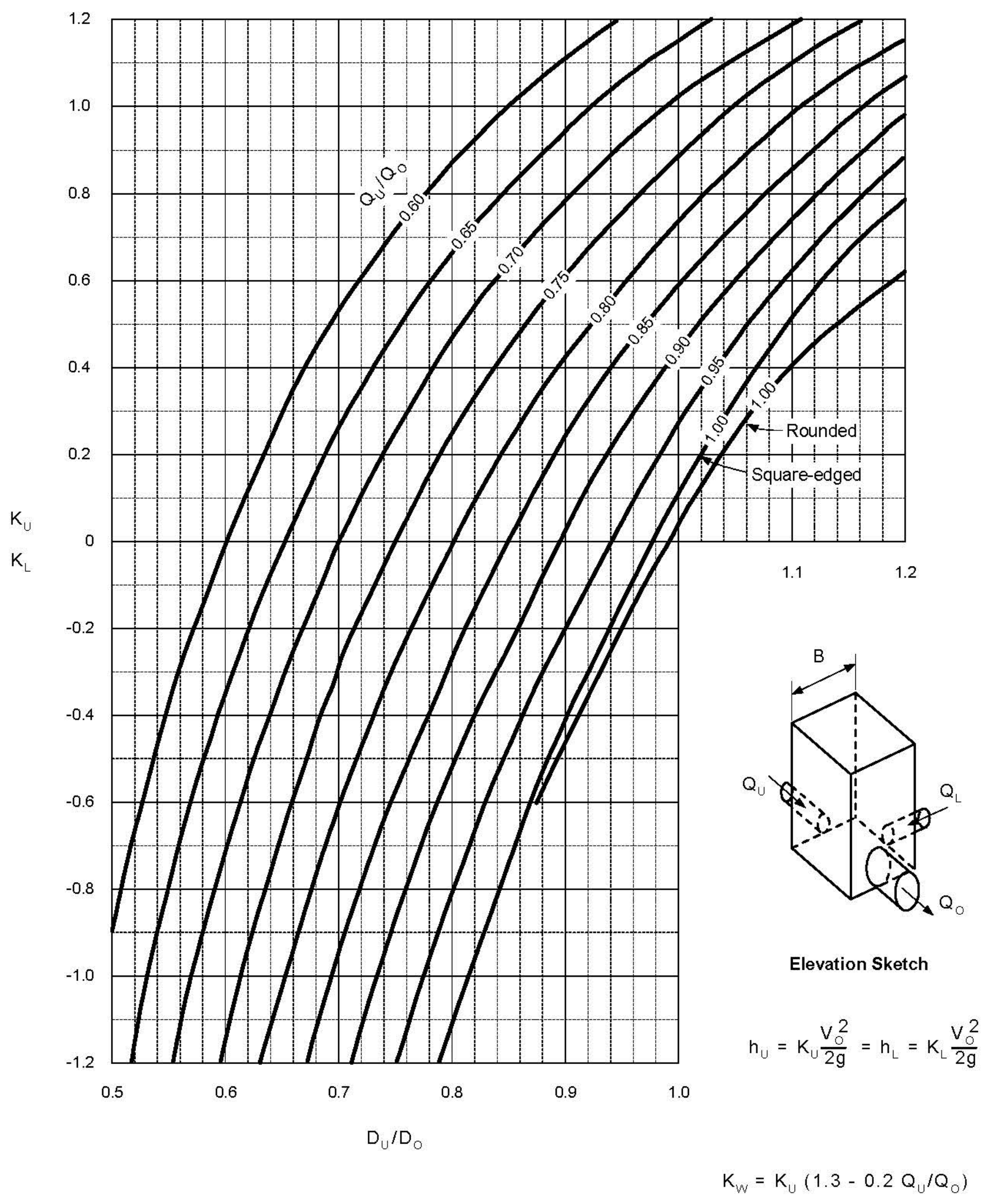


Elevation Sketch

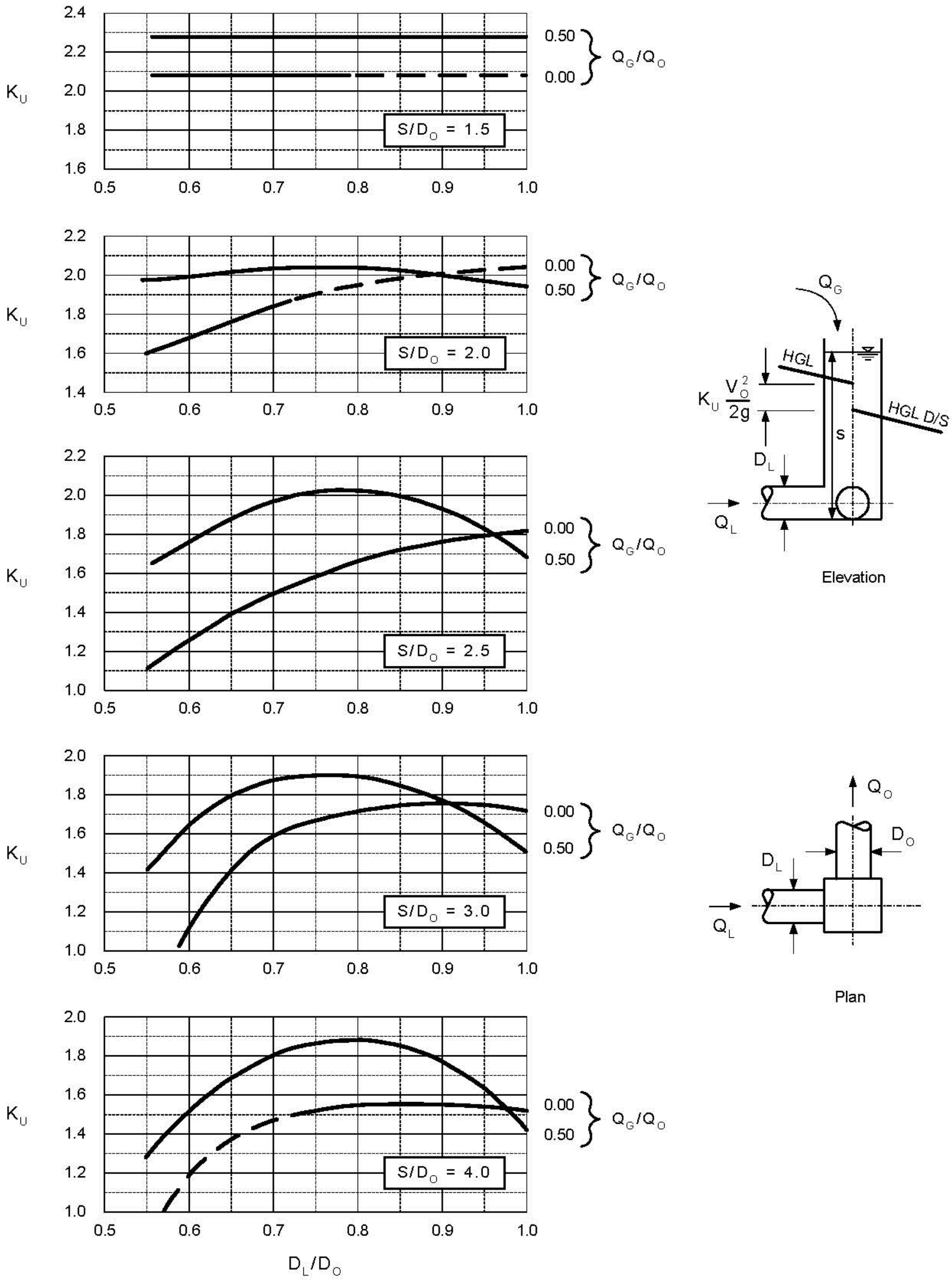


Plan of Deflectors

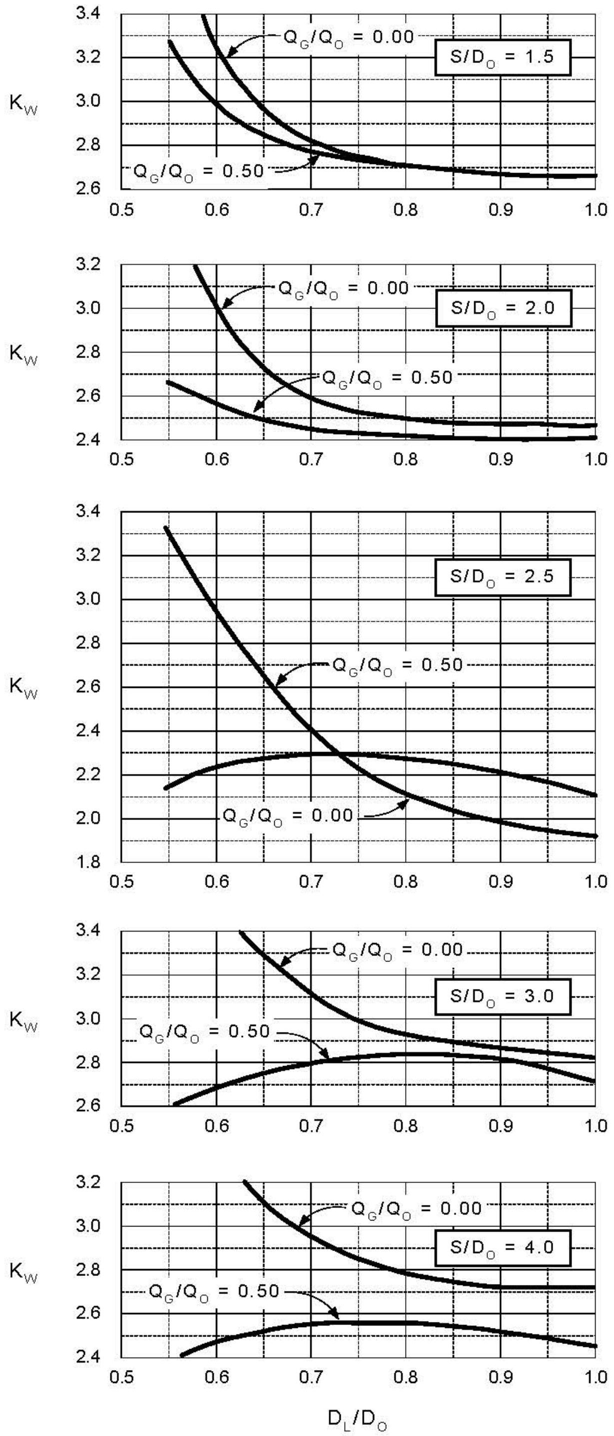
Source : M	Pressure head change coefficient (K_U) for square or round manhole on through pipeline at junction of 90° lateral pipe (in-line pipe coefficient)	CHART 5

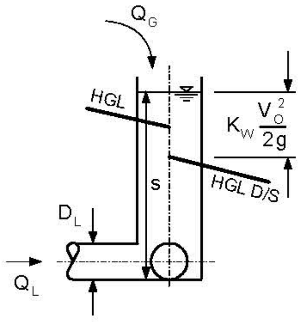


Source : M	Pressure head change coefficient (K_U) for square or round manhole on through pipeline at junction of 90º lateral pipe (for conditions outside the range of Charts 4 & 5)	CHART 6

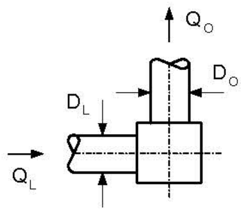


Source : N	**Pressure head change coefficients (K_U) for 90º bends at sump junctions**	**CHART 7**



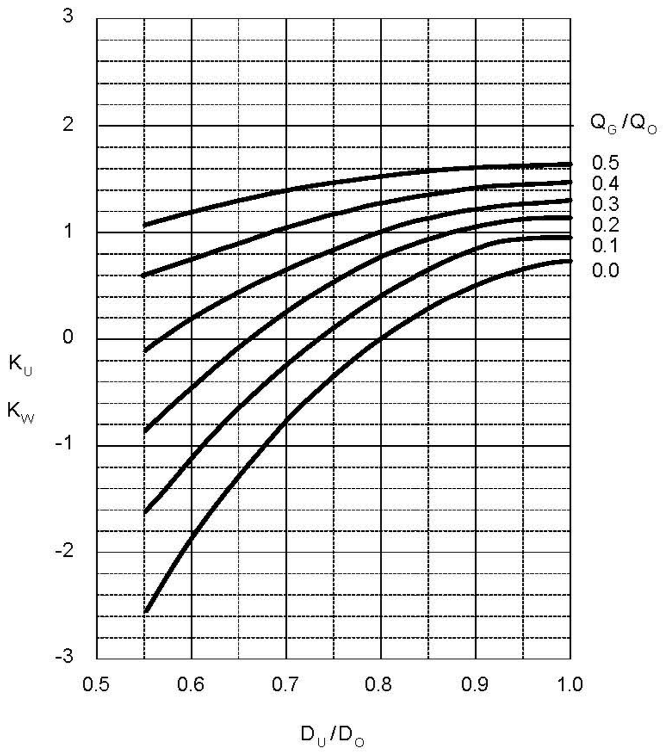


Elevation

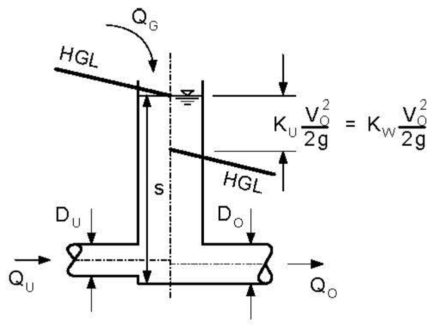


Plan

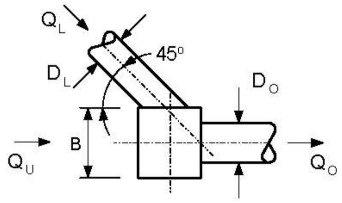
Source : N	**Pressure head change coefficients (K_W) for 90º bends at sump junctions**	**CHART 8**



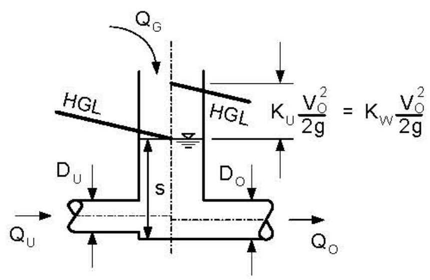
Positive Pressure Head Change ($K_U > 0$)



Elevation



Plan



Elevation

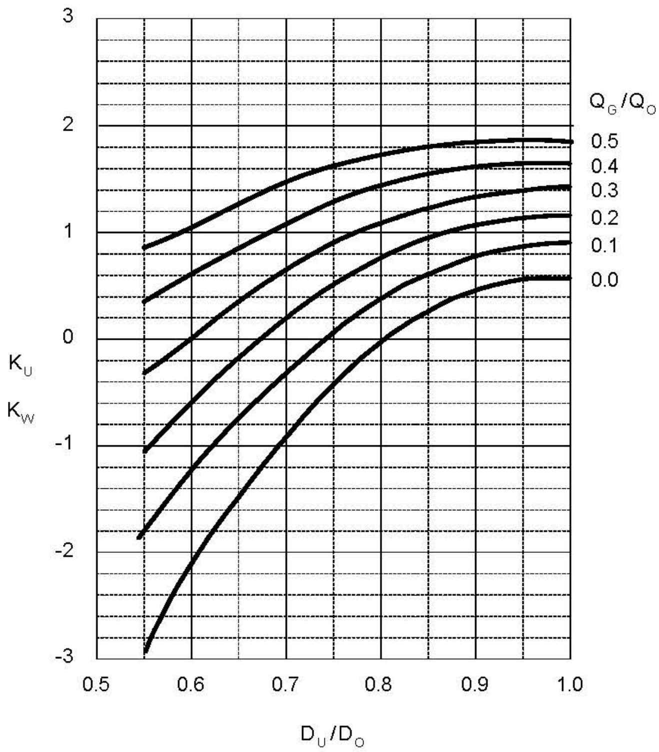
Negative Pressure Head Change ($K_U < 0$)

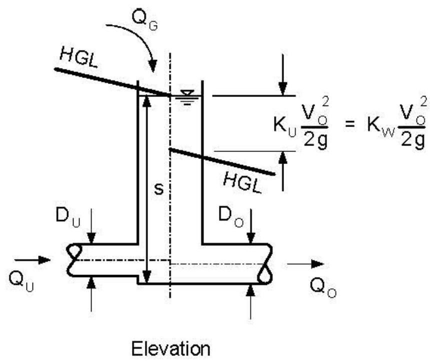
S/D_O \ Q_G/Q_O	0.00	0.10	0.20	0.30	0.40	0.50
1.5	0.00	0.11	0.22	0.33	0.44	0.55
2.0	0.00	0.04	0.08	0.12	0.16	0.20
2.5	0.00	0.00	0.00	0.00	0.00	0.00
3.0	0.00	-0.03	-0.06	-0.09	-0.12	-0.15
3.5	0.00	-0.04	-0.08	-0.12	-0.16	-0.20
4.0	0.00	-0.05	-0.10	-0.15	-0.20	-0.25

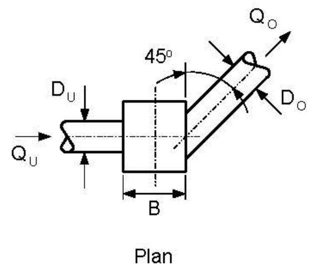
Increment K_U and K_W by the above values for S/D_O ratios other than 2.5

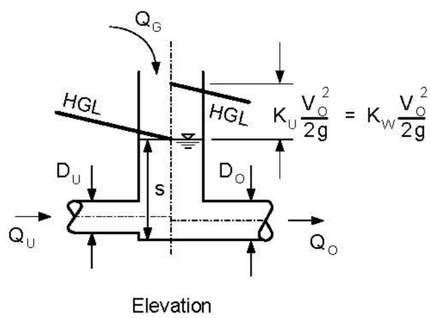
Source : N	Coefficients for 45^O bends at sump junctions with branch point located on downstream face of sump	CHART 9

Positive Pressure
Head Change
($K_U > 0$)







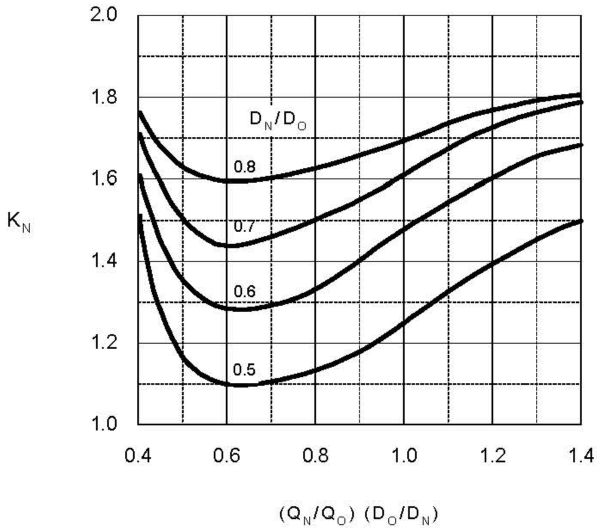


Negative Pressure
Head Change
($K_U < 0$)

S/D_O \ Q_G/Q_O	0.00	0.10	0.20	0.30	0.40	0.50
1.5	0.00	0.11	0.22	0.33	0.44	0.55
2.0	0.00	0.04	0.08	0.12	0.16	0.20
2.5	0.00	0.00	0.00	0.00	0.00	0.00
3.0	0.00	-0.03	-0.06	-0.09	-0.12	-0.15
3.5	0.00	-0.04	-0.08	-0.12	-0.16	-0.20
4.0	0.00	-0.05	-0.10	-0.15	-0.20	-0.25

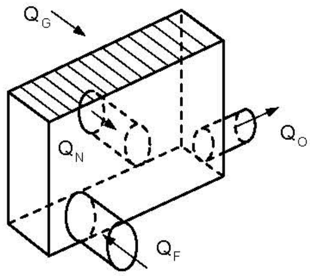
Increment K_U and K_W by the above values for S/D_O ratios other than 2.5

Source : N	Coefficients for 45° bends at sump junctions with branch point located on downstream face of sump	CHART 10



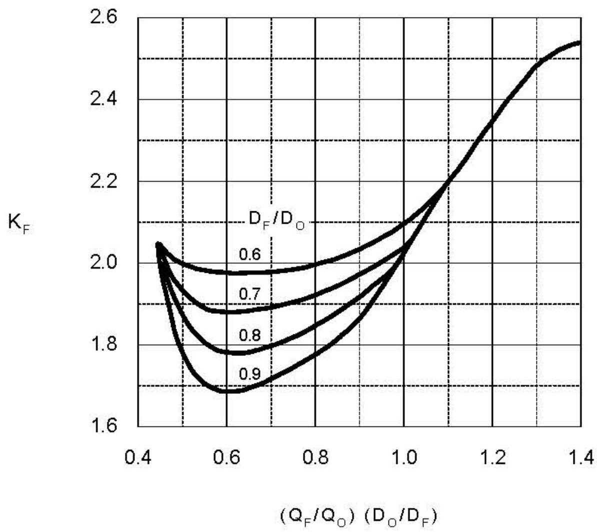
Near Lateral

$$h_N = K_N \frac{V_O^2}{2g}$$



$$Q_F + Q_N + Q_G = Q_O$$

Elevation Sketch



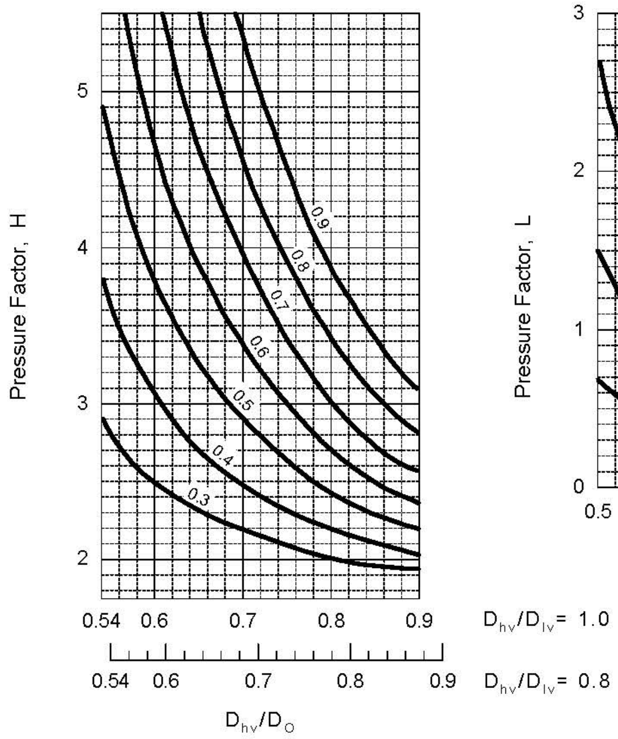
Far Lateral

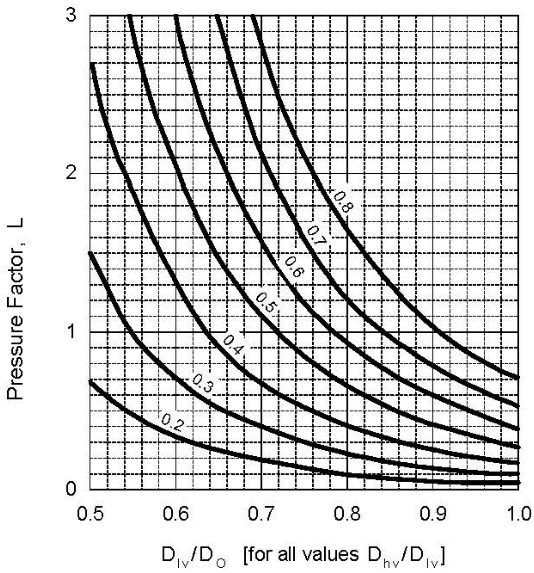
$$h_F = K_F \frac{V_O^2}{2g}$$

Note

1. For $Q_G = 0$ reduce K_N & K_F by 0.2
2. $K_W = 1.3\,K_F$

Source : M	Pressure head change coefficients (K_N & K_F) for rectangular inlet with offset opposed lateral pipes each at 90° to outfall (with or without grate flow)	CHART 11



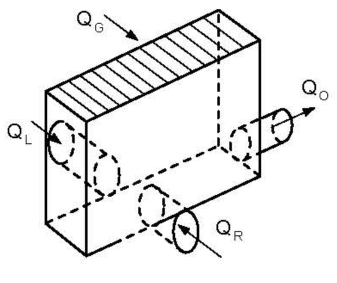


D_{hv} = diameter of lateral with higher-velocity flow.

Q_{hv} = rate of flow in lateral with higher-velocity flow.

D_{lv} = diameter of lateral with lower-velocity flow.

Q_{lv} = rate of flow in lateral with lower-velocity flow.



$Q_F + Q_N + Q_G = Q_O$

Elevation Sketch

To find KR or KL for the right or left lateral pipe with flow at a lesser velocity than the other lateral, read H for the higher velocity lateral D and Q, then read L for the lower velocity lateral D and Q;

Then;

$$K_R (\text{or } K_L) = H - L$$

K_R or K_L for the lateral pipe with higher velocity flow is always 1.8.

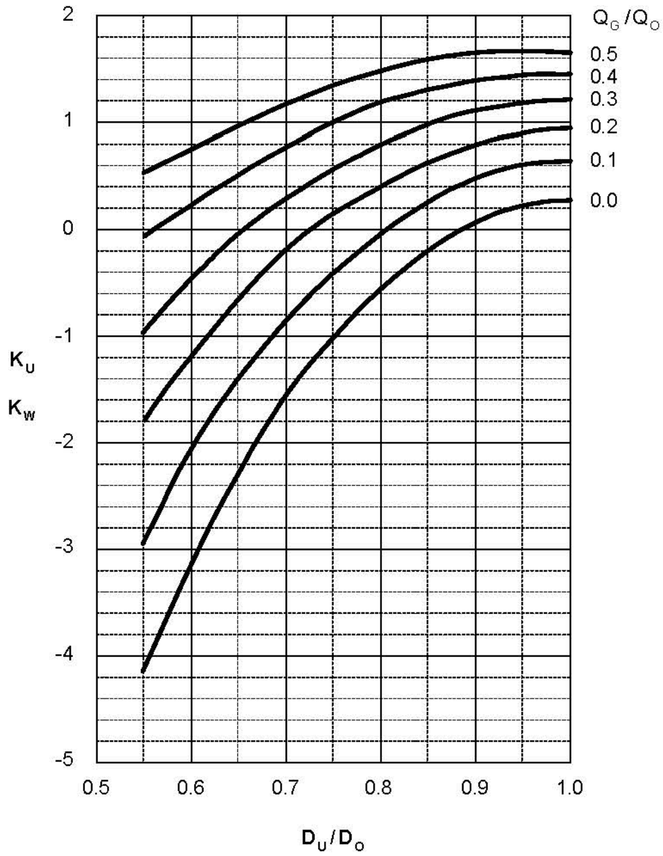
$$h_L = K_L \frac{V_O^2}{2g} \qquad h_R = K_R \frac{V_O^2}{2g}$$

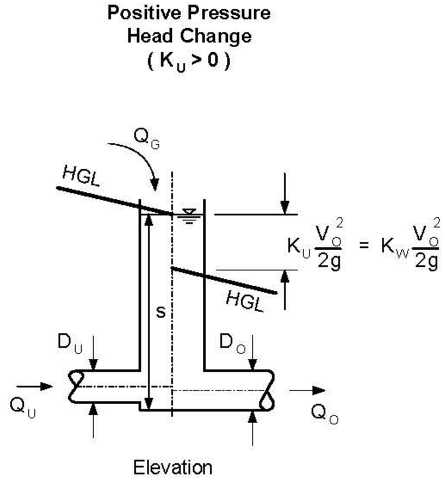
For $Q_G = 0$ reduce K_R & K_L by 0.2.

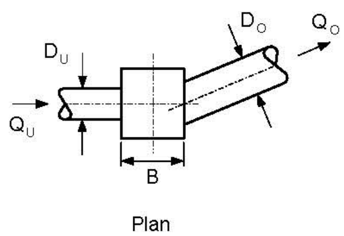
$K_W = 1.3 (K_R \text{ or } K_L)$

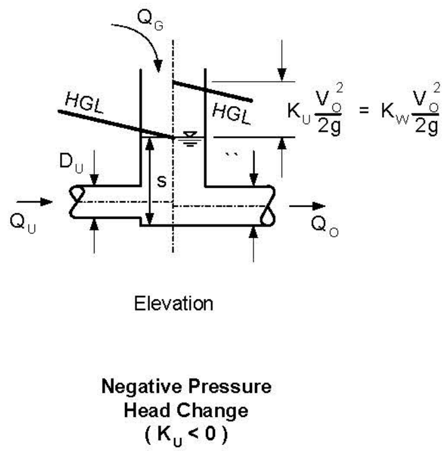
Use coefficient for highest velocity lateral.

Source :M	**Pressure head change coefficients (K_L & K_R) for rectangular inlet with in-line opposed lateral pipes each at 90° to outfall (with or without grate flow)**	**CHART 12**





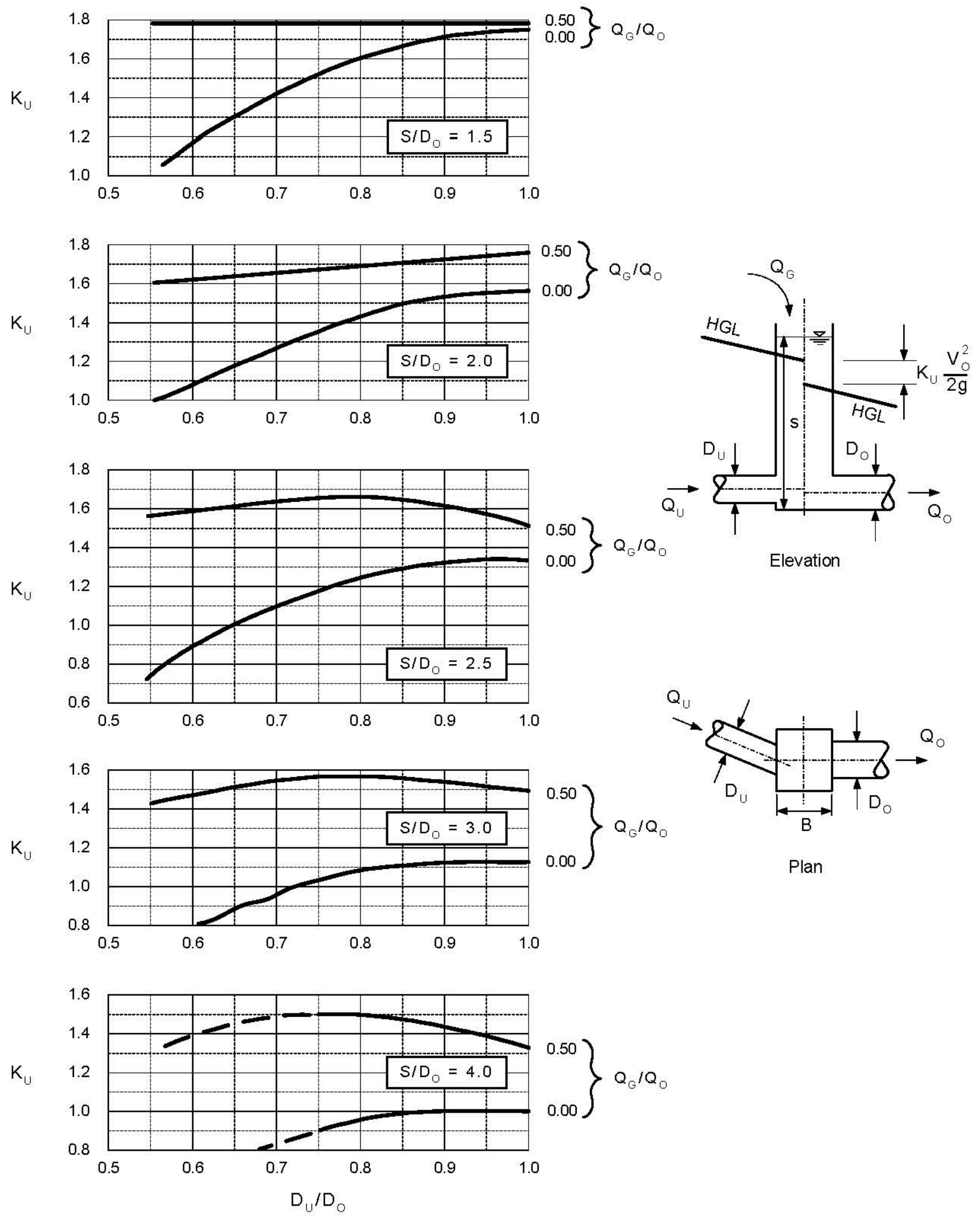




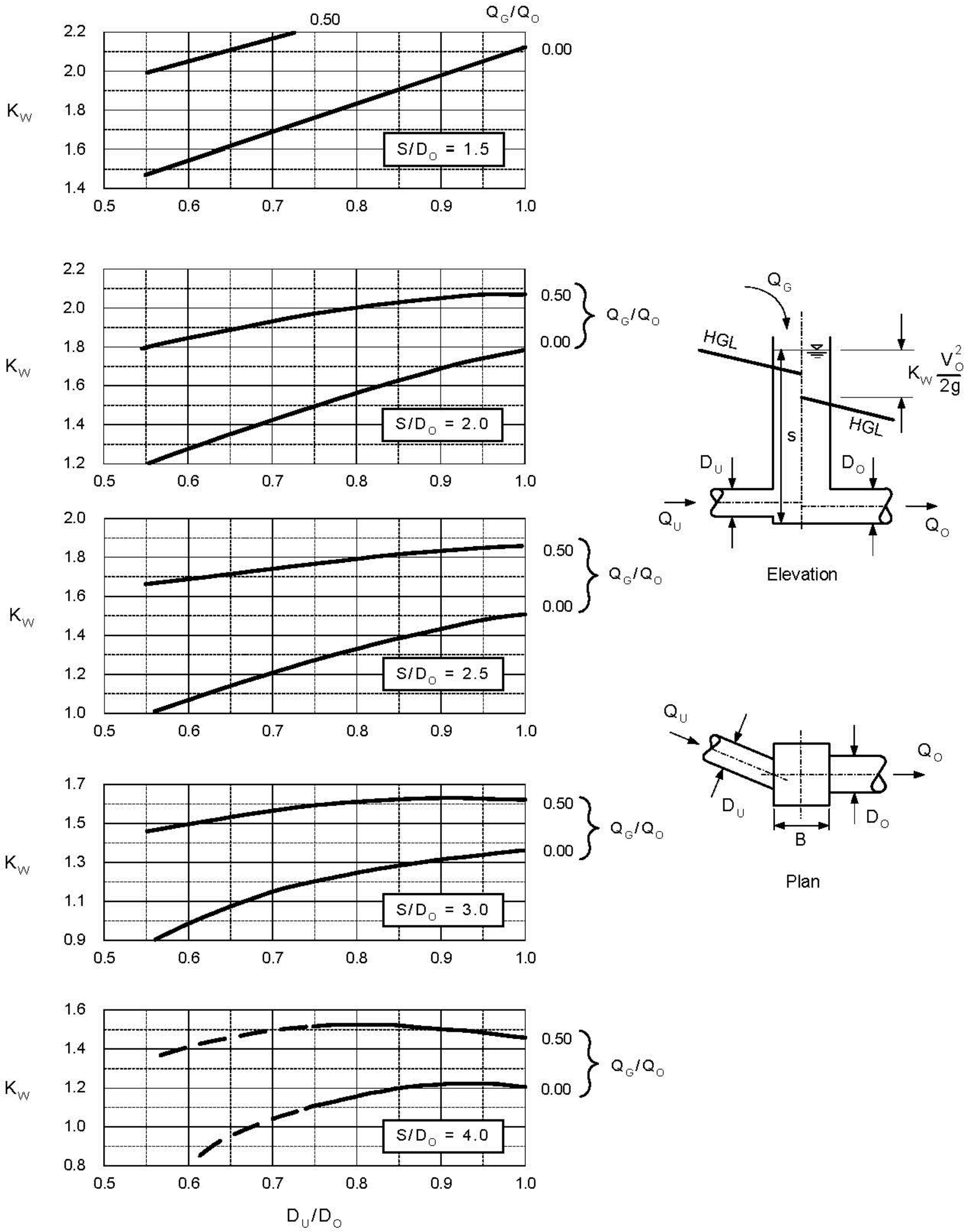
Q_G/Q_O / S/D_O	0.00	0.10	0.20	0.30	0.40	0.50
1.5	0.00	0.11	0.22	0.33	0.44	0.55
2.0	0.00	0.04	0.08	0.12	0.16	0.20
2.5	0.00	0.00	0.00	0.00	0.00	0.00
3.0	0.00	-0.03	-0.06	-0.09	-0.12	-0.15
3.5	0.00	-0.04	-0.08	-0.12	-0.16	-0.20
4.0	0.00	-0.05	-0.10	-0.15	-0.20	-0.25

Increment K_U and K_W by the above values for S/D_O ratios other than 2.5

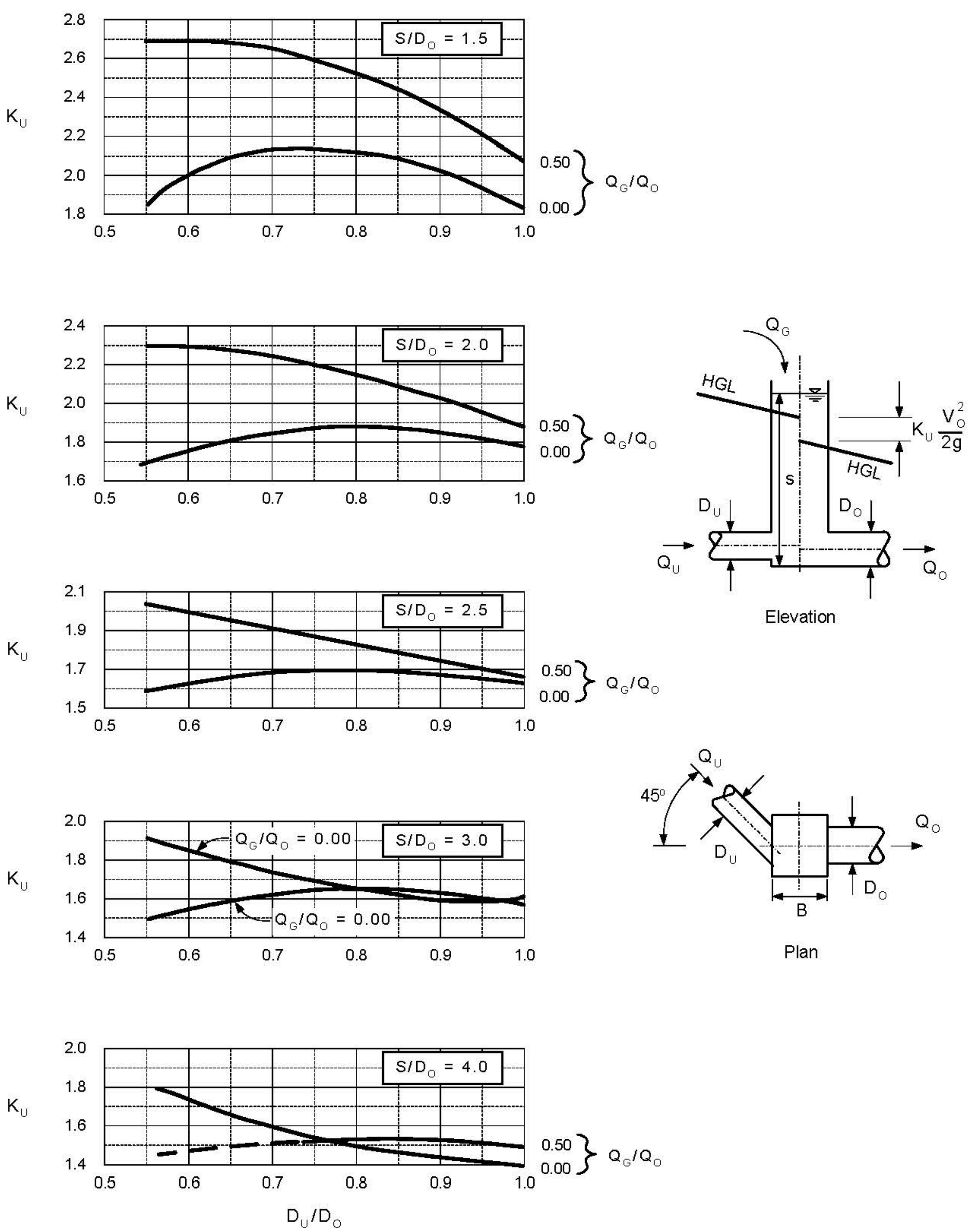
Source : N	Coefficients for 22.5º bends at sump junctions with branch point located on downstream face of sump	CHART 13



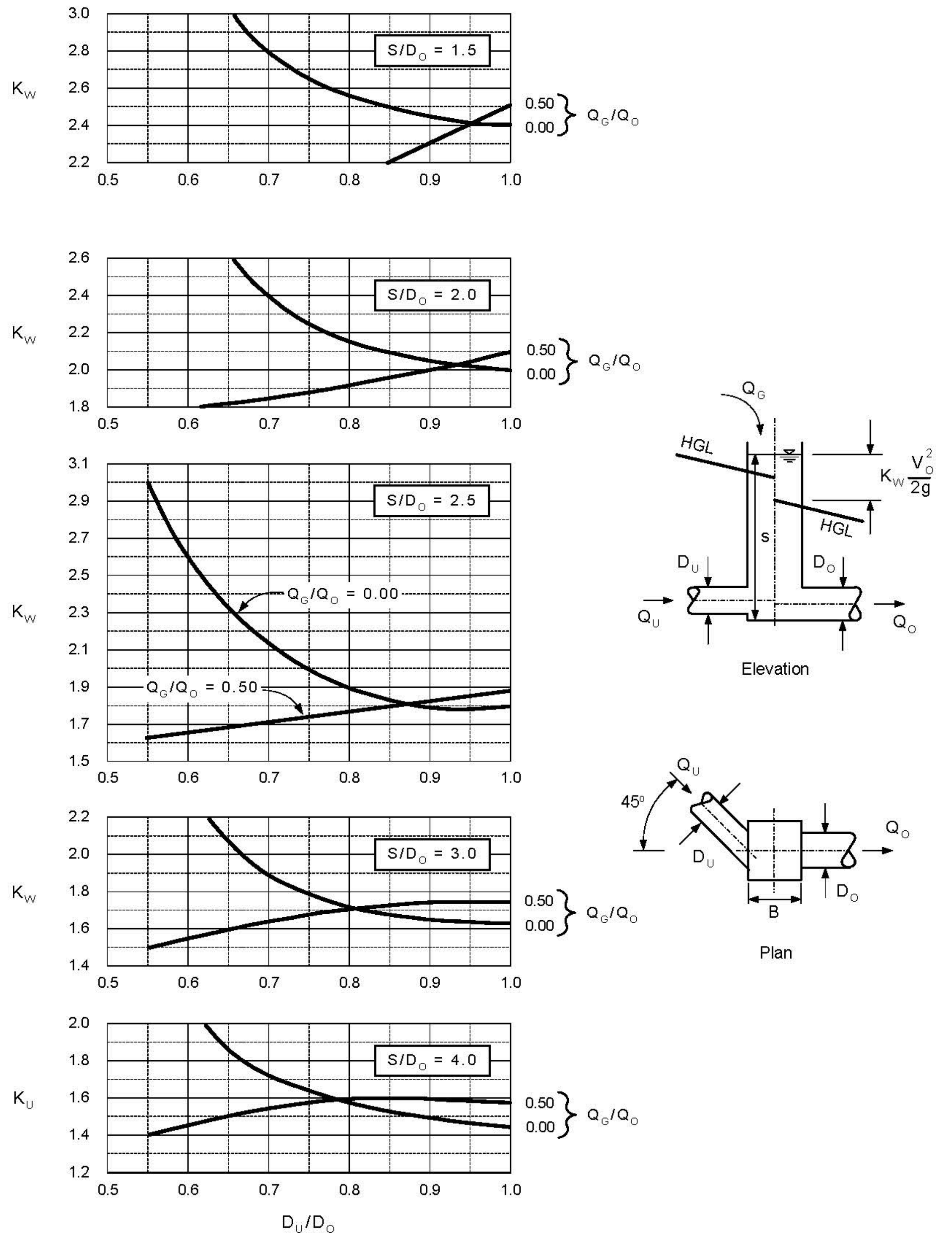
Source : N	**Pressure change coefficients (K_U) for 22.5º bends at sump junctions with branch point located on upstream face of sump**	**CHART 14**



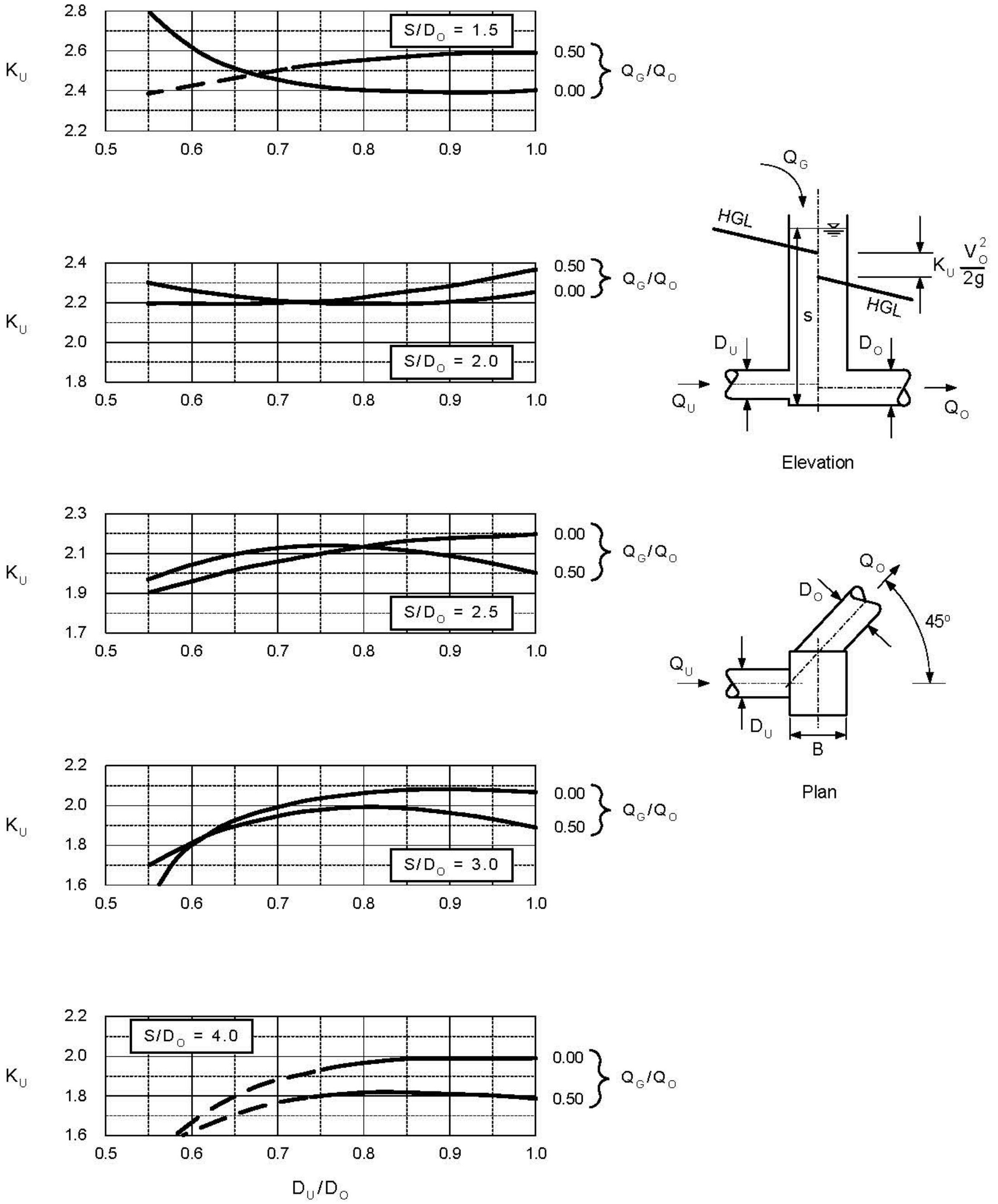
Source : N	**Pressure change coefficients (K_W) for 22.5º bends at sump junctions with branch point located on upstream face of sump**	**CHART 15**



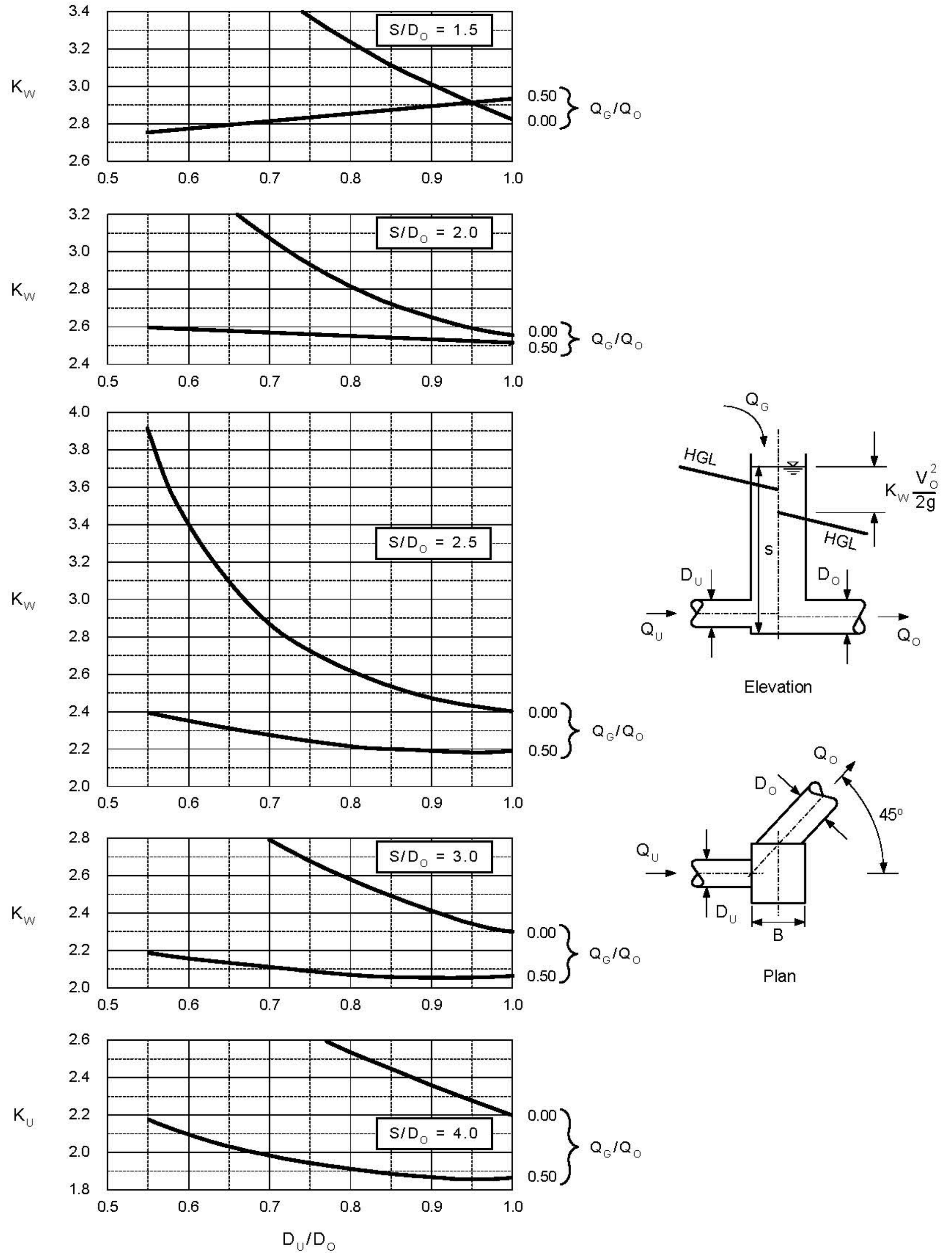
Source : N	**Pressure change coefficients (K_U) for 45º bends at sump junctions with branch point located on upstream face of sump**	**CHART 16**



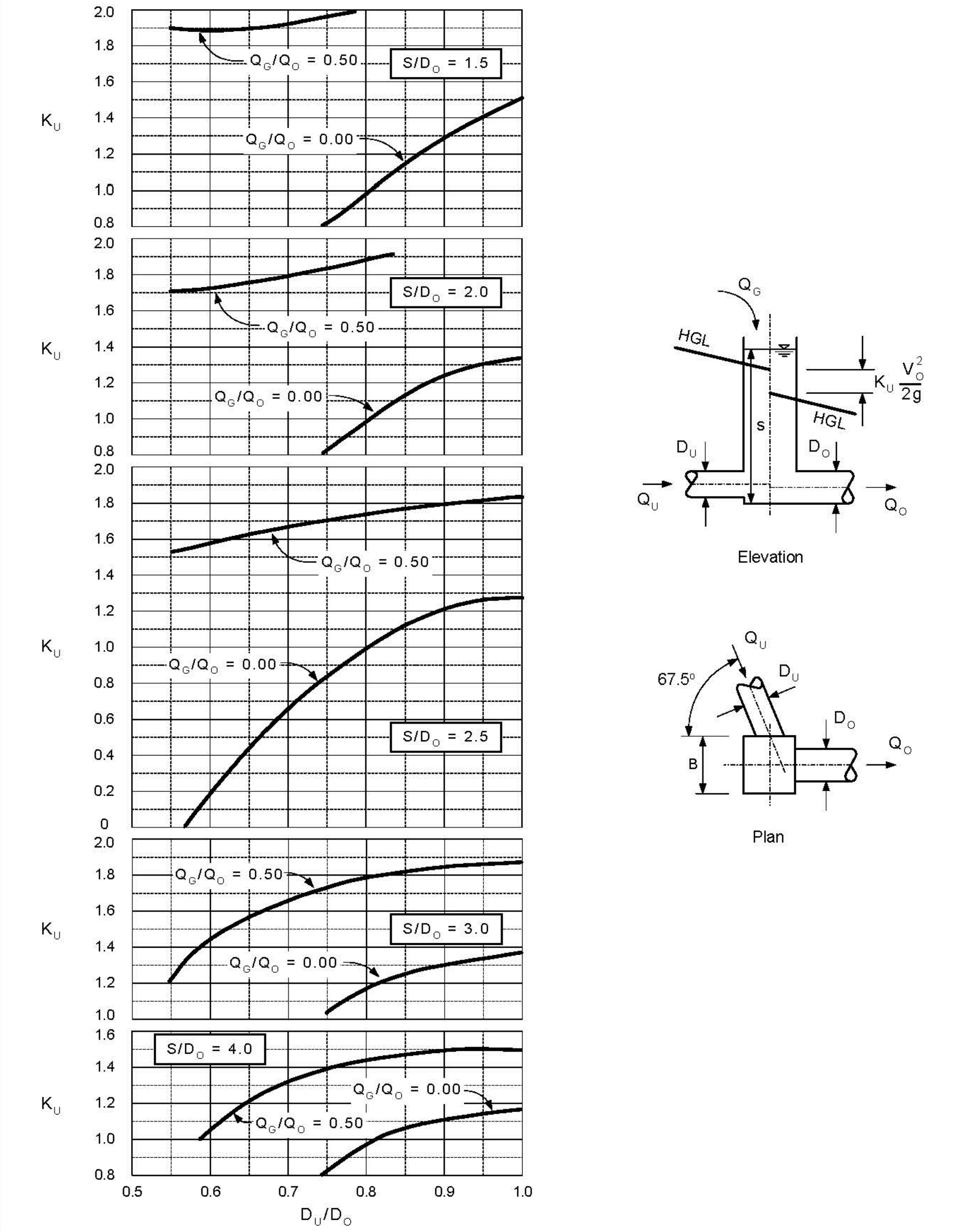
Source : N	Pressure change coefficients (K_W) for 45º bends at sump junctions with branch point located on upstream face of sump	CHART 17



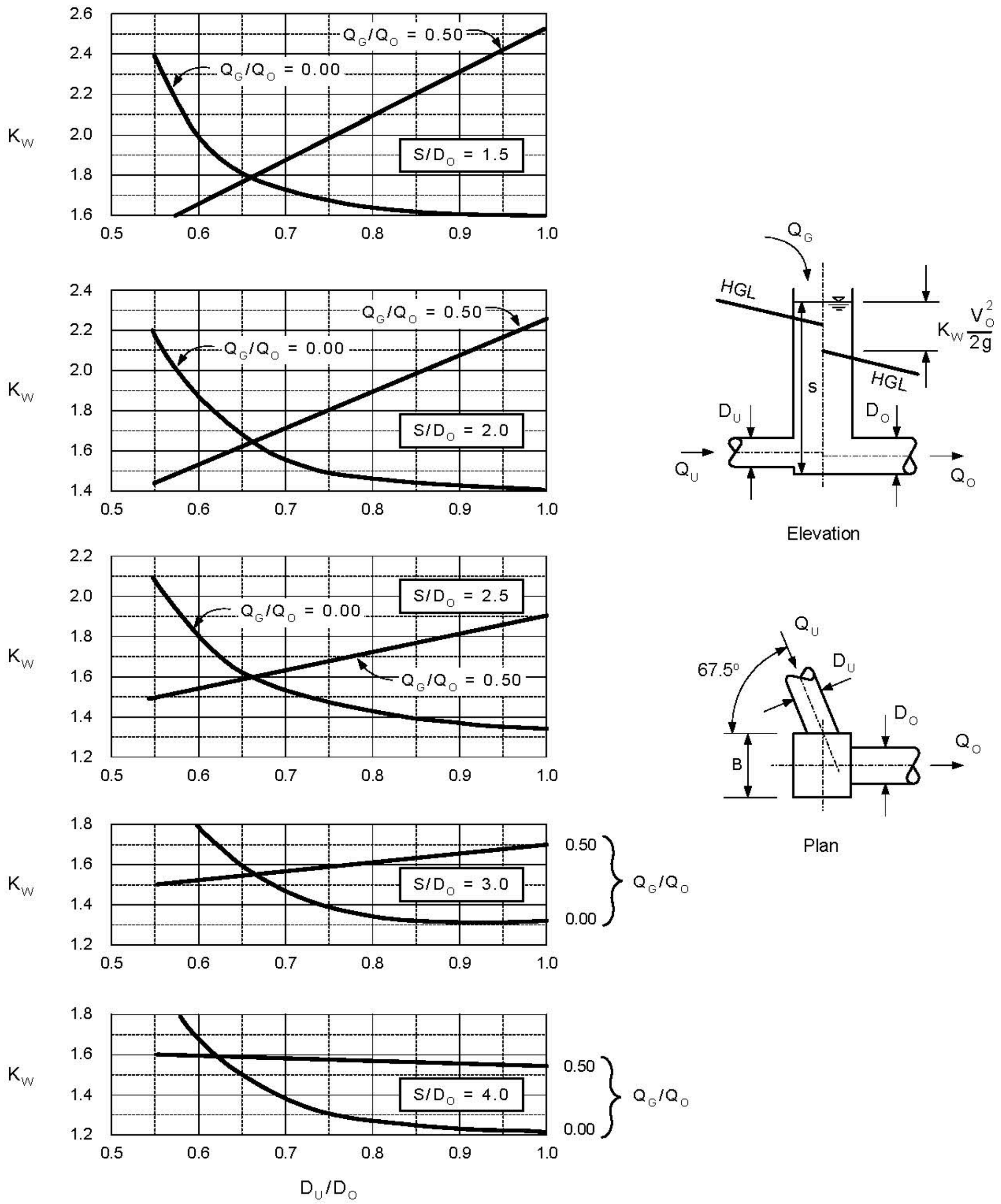
Source : N	Pressure change coefficients (K_U) for 45º bends at sump junctions with branch point located on upstream face of sump	CHART 18



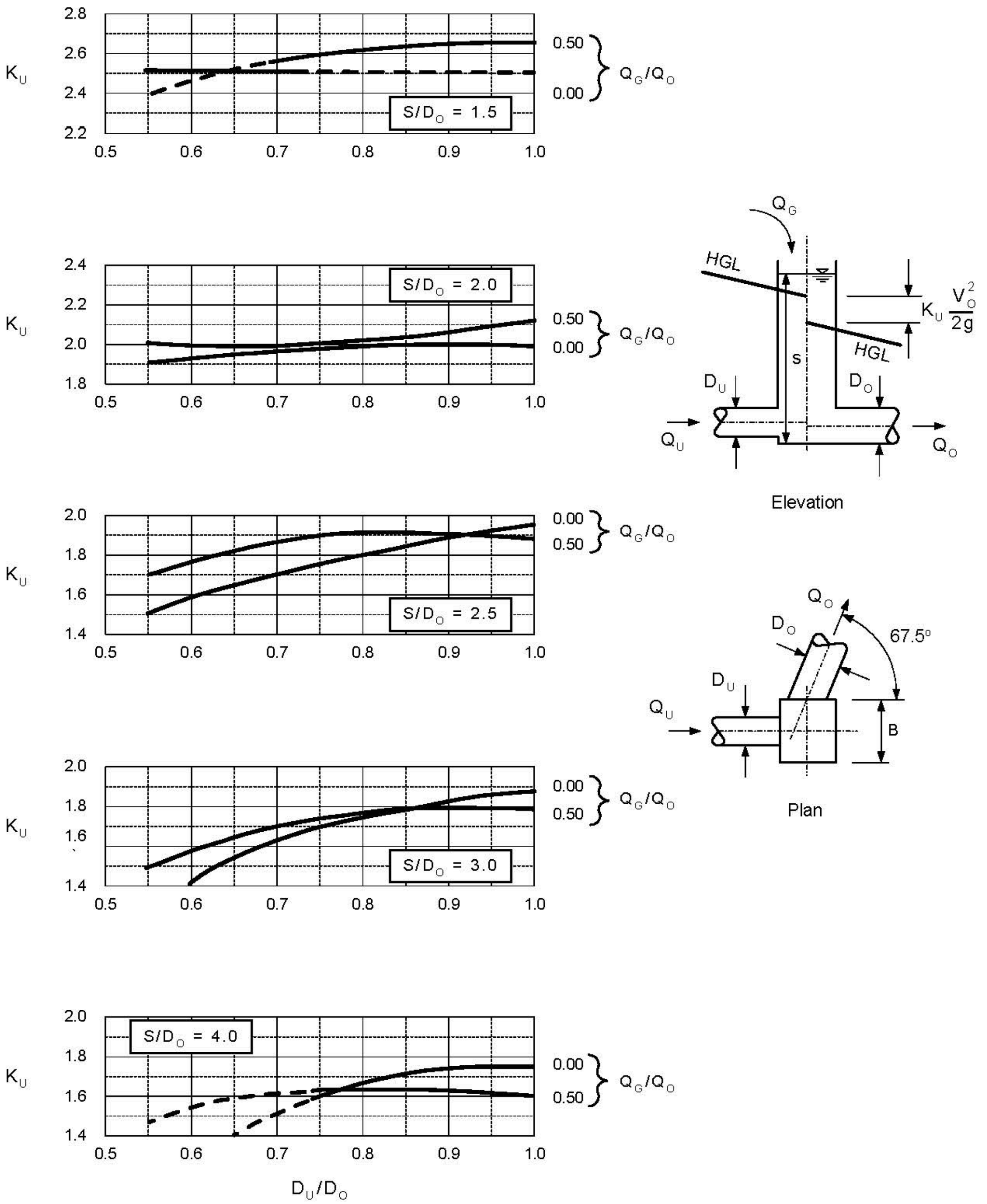
Source : N	Pressure change coefficients (K_W) for 45º bends at sump junctions with branch point located on upstream face of sump	CHART 19



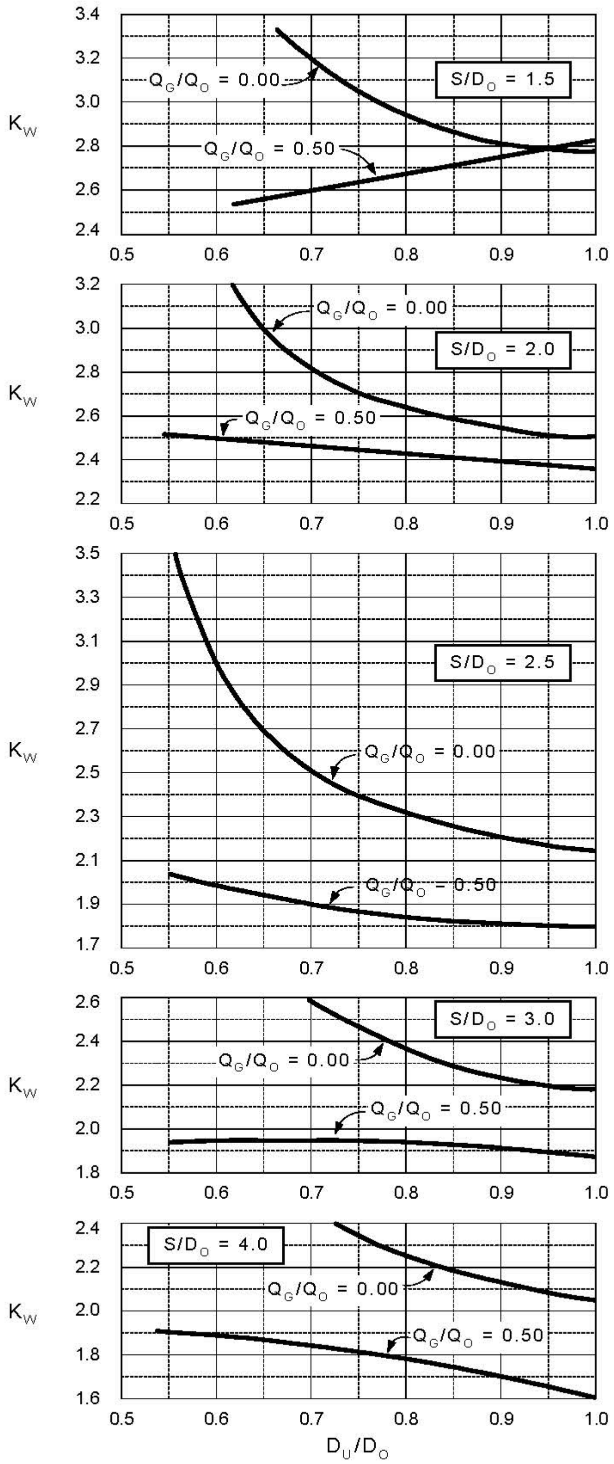
Source : N	Pressure change coefficients (K_U) for 67.5º bends at sump junctions with branch point located near downstream face of sump	CHART 20

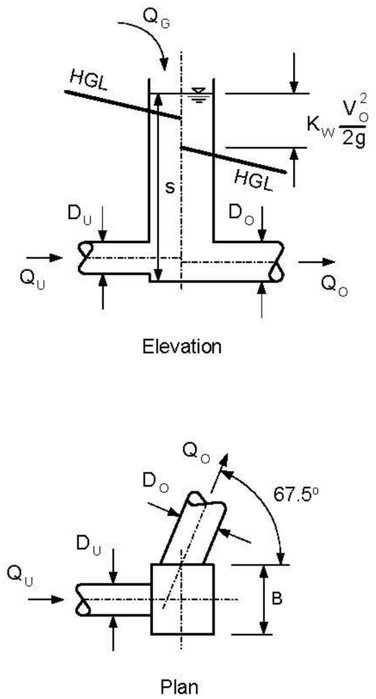


Source : N	Pressure change coefficients (K_W) for 67.5º bends at sump junctions with branch point located near downstream face of sump	**CHART 21**



Source : N	Pressure change coefficients (K_U) for 67.5° bends at sump junctions with branch point located near upstream face of sump	CHART 22





Source : N	**Pressure change coefficients (K_W) for 67.5° bends at sump junctions with branch point located near upstream face of sump**	**CHART 23**

APPENDIX E MUSIC MODELLING GUIDELINES

The following guidance on modelling WSUD facilities in MUSIC has been based on the *Draft NSW MUSIC Modelling Guidelines, August 2010* prepared for the Sydney Metropolitan Catchment Management Authority by BMT WBM Pty Ltd. These are interim guidelines pending further investigation into MUSIC modelling parameters for these systems specific to ACT conditions.

E 1 Vegetated waterways

Flow in a vegetated waterway is modelled in the USTM as uniform flow in a trapezoidal channel (although a triangular channel can be simulated by setting the base width to 0 m).

The modelling of the performance of vegetated waterways will be similar to that for a wetland (with 10 CSTRs) but probably subjected to a more variable hydraulic loading of between 500 m/yr and 30,000 m/yr. Intuitively, owing to a higher aspect ratio, vegetated waterways will experience higher velocities even when subjected to relatively low hydraulic loading. The Fair and Geyer equation will not be able to simulate this and it will be necessary to qualitatively account for this process when selecting the appropriate value of C* for vegetated waterways.

Although vegetated waterways are somewhat similar to wetlands in their flow regime, they are more similar to sedimentation basins in their position in the treatment train, and hence in their likely particle size distribution. For the time being, it seems appropriate to adopt the same k and C* parameters as for sedimentation basins, but with higher N (number of CSTRs) to reflect the more plug-like flow behaviour.

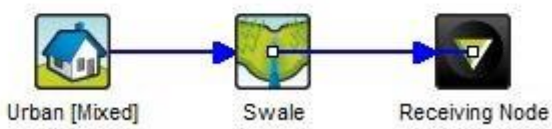


Figure 8- 60 Example of vegetated waterway node application in MUSIC

The MUSIC variables listed in **Table 8- 50** should be used for modelling vegetated waterways.

Table 8- 50 MUSIC parameters for vegetated waterways

Parameter	Value
Number of CSTR cells	Refer **Figure 8-15** and **Table 8-35**
Total suspended solids	
k (m/yr)	8000
C* (mg/L)	20.00
C (mg/L)**	14.00
Total phosphorus	
k (m/yr)	6000
C* & C (mg/L)**	0.13
Total nitrogen	
k (m/yr)	500
C* & C (mg/L)**	1.40
Threshold Hydraulic Loading for C (m/yr)**	3500

E 2 Constructed wetlands

Constructed wetlands are simulated in MUSIC as surface wetlands with permanent or ephemeral water bodies in the upstream inlet (sediment) pond and main wetland (macrophyte) zone. The diagram belowshows how they are conceptually represented within MUSIC.

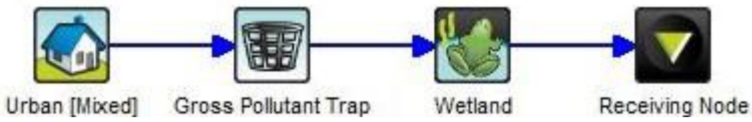


Figure 8- 61 Example of constructed wetland node application in MUSIC

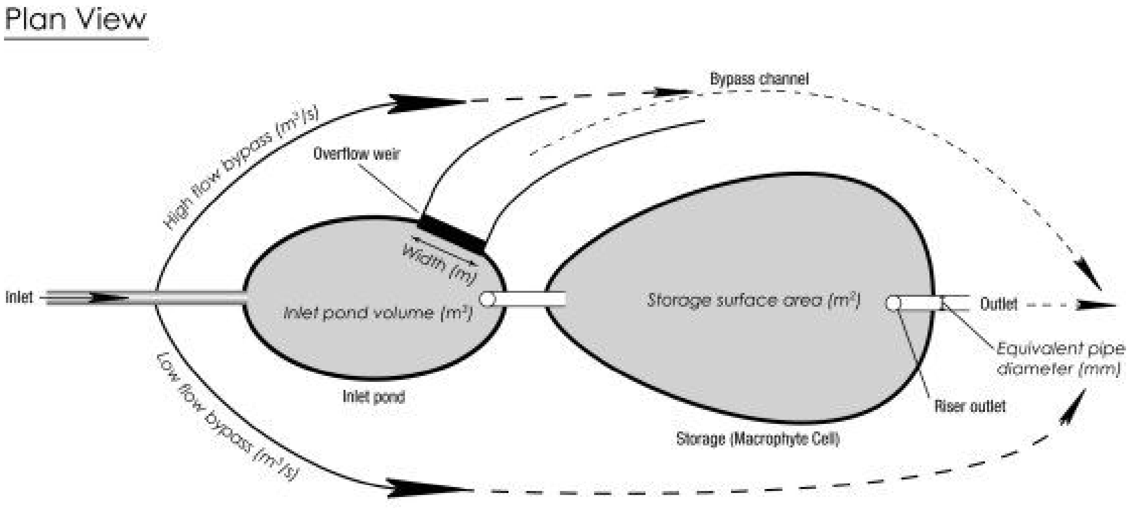


Figure 8- 62 Conceptual plan view of wetland (as used in MUSIC v4)

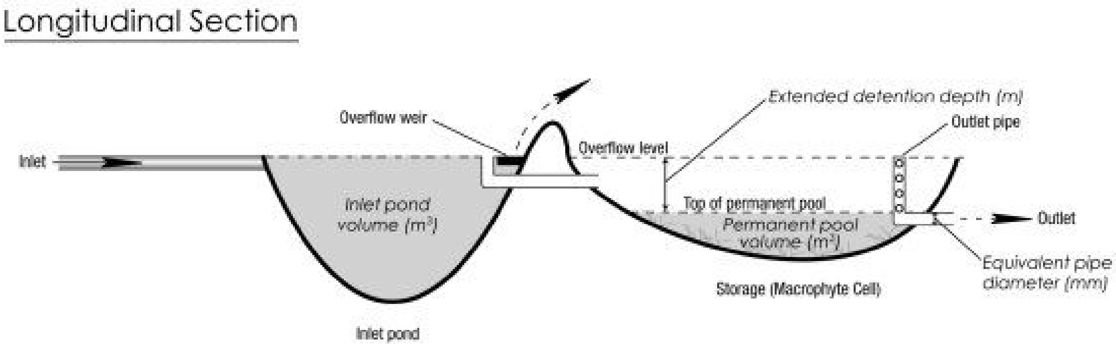


Figure 8- 63 Conceptual cross section of wetland (as used in MUSIC v4)

Constructed wetlands have a higher proportion of shallow water zones when compared to ponds, and aquatic vegetation is distributed more widely across the wetland (within ponds vegetation is primarily limited to the fringes of the pond). They also include low flow and high flow bypass channels. The low
flow bypass channel offtake is located upstream of the wetland zone, while the high flow bypass offtake islocated within the inlet pond and operates when the wetland (macrophyte) zone is full.

If the high flow bypass is located at the outlet, the measure should be modelled as a pond and k and C* parameters in the pond node adjusted to be equivalent to the corresponding wetland parameters.

Calculate the surface area of input for this treatment node when the water level is approximately half ofthe extended detention depth. This assumes trapezoidal banks for the wetland. If the wetland is surrounded by vertical or near vertical walls, the surface area is likely to be almost equivalent to the surface area when the permanent storage is full.

In situations where a GPT is not provided for pre-treatment, a constructed wetland should be modelledwith an inlet pond with a volume not less than 10% of the permanent pool volume.

A fixed default 50% coverage of vegetation applies to the constructed wetland node. If less vegetation isproposed, the constructed wetland node k and C* values should be modified to the pond node values torepresent a lower level oftreatment.

The EDD shall not exceed 500 mm unless it can be demonstrated that a higher depth is achievablewithout adversely affecting emergent macrophytes or causing adverse flooding impacts.

The permanent pool in the constructed volume should not exceed the surface area (at permanent pool level) multiplied by 1m unless more detailed information is provided of the wetland configuration.

The seepage loss should be 0mm/hr unless it can be demonstrated that infiltrated runoff would not contribute to observed flows downstream either through surface runoff, seepage into drainage lines,interflow or groundwater.

The evaporative loss should be the default value of 125% of PET.

The notional detention time should typically be between 48 to 72 hours to ensure optimal treatment of nutrient species. The value can be set by adjusting the equivalent pipe diameter, as this is simply a way ofcontrolling the nominal outlet size.

E 3 Ponds

MUSIC adopts a default vegetation coverage of 10% for ponds which essentially represents a predominantly open water pond with fringing vegetation. A pond is represented conceptually in MUSICidentically to sediment basins.

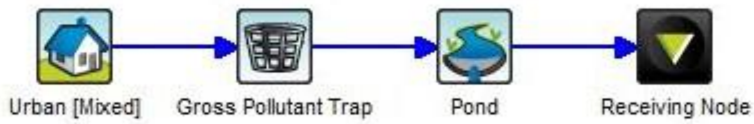


Figure 8- 64 Example of pond node application in MUSIC

It is preferred that the pond treatment node is not used in MUSIC. It is considered that the potential for water quality issues to occur in ponds which have limited vegetation coverage/biological treatment exceeds the benefit of providing these measures. If ponds are modelled in MUSIC, the modelled performance should be confirmed utilising a more detailed pond/lake model (e.g. DYRESM-CAEDYM) and the modeller should demonstrate that appropriate pre-treatment measures would be provided to minimise organic and nutrient loading on the pond.

A GPT and a vegetated treatment node should be incorporated into the model to ensure that water quality entering a pond will minimise potential problems.

If the weir overflow or high flow bypass for a pond is to be located near the inlet, the measure should be modelled as a constructed wetland and the C* and k parameters adjusted to the default MUSIC values for a pond. This is because the weir overflow from a pond is assumed to be located at the downstream end of the pond and therefore spills from the pond are assumed to be partially treated (which is not the case for this scenario).

MUSIC currently assumes that the extended detention storage has vertical sides. Therefore, if the system modelled does not have vertical sides an estimate of surface area needs to be calculated. If the system modelled has a trapezoidal shaped extended detention storage, the surface area should be calculated as the detention depth when it is at half of the maximum EDD.

E 4 Bioretention systems

The following guidance on the modelling of WSUD measures in MUSIC has been adopted from the Draft NSW MUSIC Modelling Guidelines, August 2010 prepared for the Sydney Metropolitan Catchment Management Authority by BMT WBM Pty Ltd. These are interim guidelines pending further investigation into MUSIC modelling parameters specific to ACT conditions.

Bioretention systems can be represented as a single node in MUSIC as shown in the following diagrams.

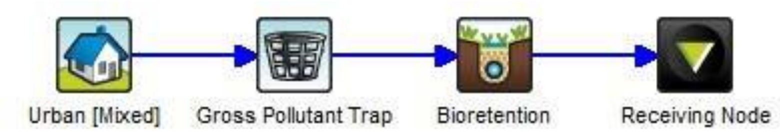


Figure 8- 65 Example of bioretention node application in MUSIC

E 4.1 Modelling parameters

MUSIC Version 4 included significant revisions to the bioretention node to reflect studies undertaken byFAWB. This has also resulted in significant changes to the parameters needed to model these systems inMUSIC. The key parameters which have changed are related to the filter media properties and any exfiltration which are summarised below.

E 4.1.1 Filter media properties

Surface area (m^2)

As a general rule, the filter surface area will be between 0.5-2% of the contributing catchment area.

Unlined filter media perimeter (m)

All bioretention basins are required to be lined to prevent exfiltration. The unlined filter media perimetershall be set to zero.

Saturated hydraulic conductivity (mm/hr)

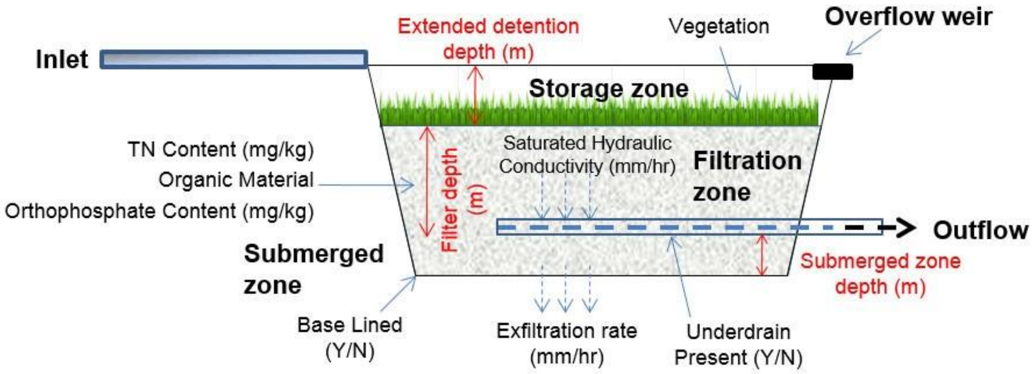
It is recommended that a loamy sand be used as the filter media for bioretention systems, with aneffective particle diameter of around 0.45 mm and a hydraulic conductivity of 200 mm/hr.

Filter depth (m)

The recommended bioretention filter depth is between 0.4 m and 1.0 m. The adopted depth will depend on the available depth based on the inlet and outlet levels and the species of plants being used. Any filtermedia depth greater than 0.8 m will require the planting of deep-rooted plants. If a filter media depth greater than 0.8 m is proposed, expert advice from a landscape architect or ecologist is required at the conceptual design stage with adequate justification for plant selection lodged with applications for designapproval.

Note: Do not model the depth of the drainage layer or intermediate layer as part of the filter media depth.

Longitudinal Section



Plan View

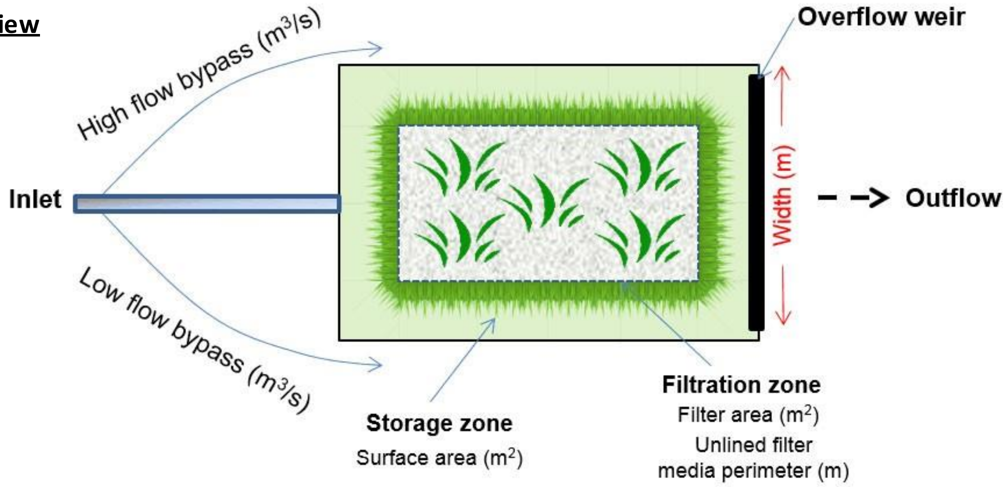


Figure 8- 66 Conceptual view of bioretention system (as used in MUSIC v6)

TN content in the filter media (mg/kg)

Where this is unknown, use the default value of < 800 mg/kg. The TN content is the amount of nitrogen available within the filter media consistent with the latest edition of the *FAWB Guidelines for Soil Filter Media in Bioretention Systems*.

Proportion of organic matter in the filter media (%)

Where this is unknown, use a value of < 5%. While some organic matter in filter media is desirable,excessive amounts can cause leaching of nutrients.

Orthophosphate content of filter media (mg/kg)

Where this is unknown, use a value of range < 55 mg/kg. This is the amount of phosphorus availablewithin the filter media defined by testing consistent with the latest edition of the *FAWB Guidelines for Soil Filter Media in Bioretention Systems*.

E 4.1.2 Other properties

Extended detention

MUSIC currently assumes that the extended detention storage has vertical sides. Therefore, if the system modelled does not have vertical sides an estimate of surface area needs to be calculated. If the system modelled has a trapezoidal shaped extended detention storage, the surface area should be calculated as the detention depth when it is at half of the maximum EDD. The filter area should not be greater than 70% of the surface area unless specific calculations are provided to indicate otherwise.

Lining properties

Is the base of the bioretention system lined?: Tick "Yes" and then set the exfiltration rate (mm/hr) to zero.

Vegetation properties

Plant types have a significant impact on reducing nutrient loads with root morphology and associated physiochemical processes being key factors. Bioretention systems perform best with deep-rooting plants and these are to be modelled using the option 'Vegetated with Effective Nutrient Removal Plants'. Where the vegetation is turf for example, then the 'Vegetated with Ineffective Nutrient Removal Plants' option must be used.

E 4.1.3 Infiltration and outlet properties

Overflow weir width (m)

The length of the overflow weir controls the discharge rate when the water level in the bioretention system exceeds the top of extended detention. An undersized overflow weir results in water backing up, effectively adding additional extended detention. To avoid this, it is recommended that the overflow weir length (m) is initially set as the maximum extended detention surface area (m^2) divided by 10.

Exfiltration rate (mm/hr)

If a bioretention system is modelled with exfiltration, the pollutant loads in the water lost to exfiltration are included in the reduction of pollutant loads achieved across the treatment node (as shown by the mean annual loads and treatment train effectiveness statistics). Objectives for reducing stormwater pollutants relate to all runoff leaving the site, including that exfiltrating to groundwater. Where an exfiltration rate is set greater than 0 mm/hr, sum all losses at any node that has exfiltration (using the node water balance statistics option at each node) as per the guidance provided in the Infiltration Node section, and add them to the total pollutant loads reported leaving the site when demonstrating compliance with stormwater pollutant load reduction objectives.

If exfiltration is used the rate must be justified through in-situ soil testing. The designer must suitably demonstrate that in-situ soils will not be compacted during earthworks.

When a system is designed and modelled to exfiltrate, lining is still required to the sides of the bioretention filter media to ensure that stormwater is properly treated through the filter before it enters the receiving environment, i.e. exfiltration should only occur either at the level of the drainage layer or through the base of the bioretention.

Underdrain present?

Usually the 'Yes' option as Bioretention systems are generally configured with collection pipes. If not, then the infiltration node should be used to model the system.

Submerged zone with carbon present (depth (m))

To improve the potential for denitrification in bioretention systems, and to provide a moisture storage for the plants, where practicable include a zone with the underdrain.

E 4.2 Lifecycle cost analysis

The proponent should submit the overall life cycle costs for all elements in the treatment train and split these into Total Acquisition, Typical Annual Maintenance and Renewal/Adaptation Costs. In the majority of cases, a decommissioning cost should not be included and this should be set to the same value as the Typical Annual Maintenance cost.

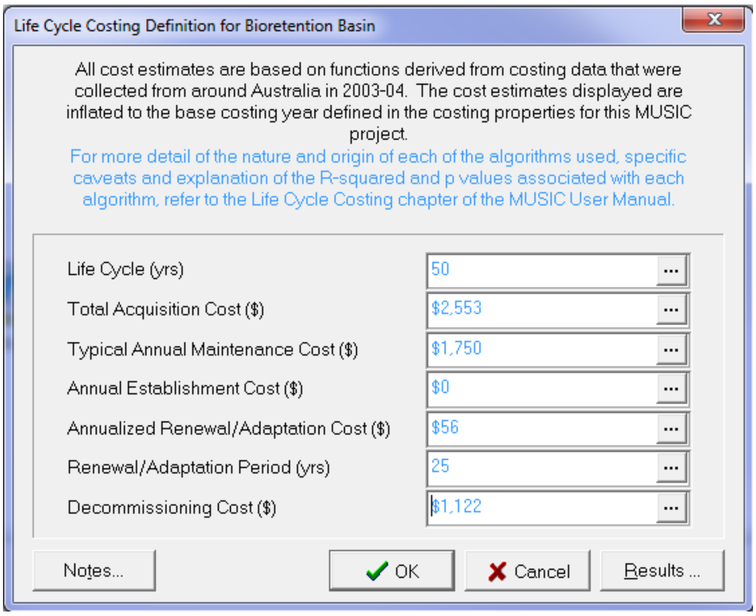


Figure 8- 67 Life cycle costing entry dialog

While some of the individual costing elements are shown in this entry dialog, the results screen summarises these and also accounts for any renewal adaption period to present total costs.

Life cycle costing information in MUSIC is able to be extracted when setting up the life cycle costing properties at each node. To extract this information, the MUSIC model must have been run and individual node costing elements established. Once this is completed, the user needs to select the Results button onthe life cycle costing entry dialog as shown below.

The user should treat the current life cycle costs as indicative only as the data used to develop the algorithms for this module are dated. MUSIC automatically adjusts the costs according the Base Year forCosting (set in the Edit-> Costing Properties Dialogue). While these costs are indicative, they can be of assistance to TCCS in planning maintenance resources and expenditure for future contributed assets.

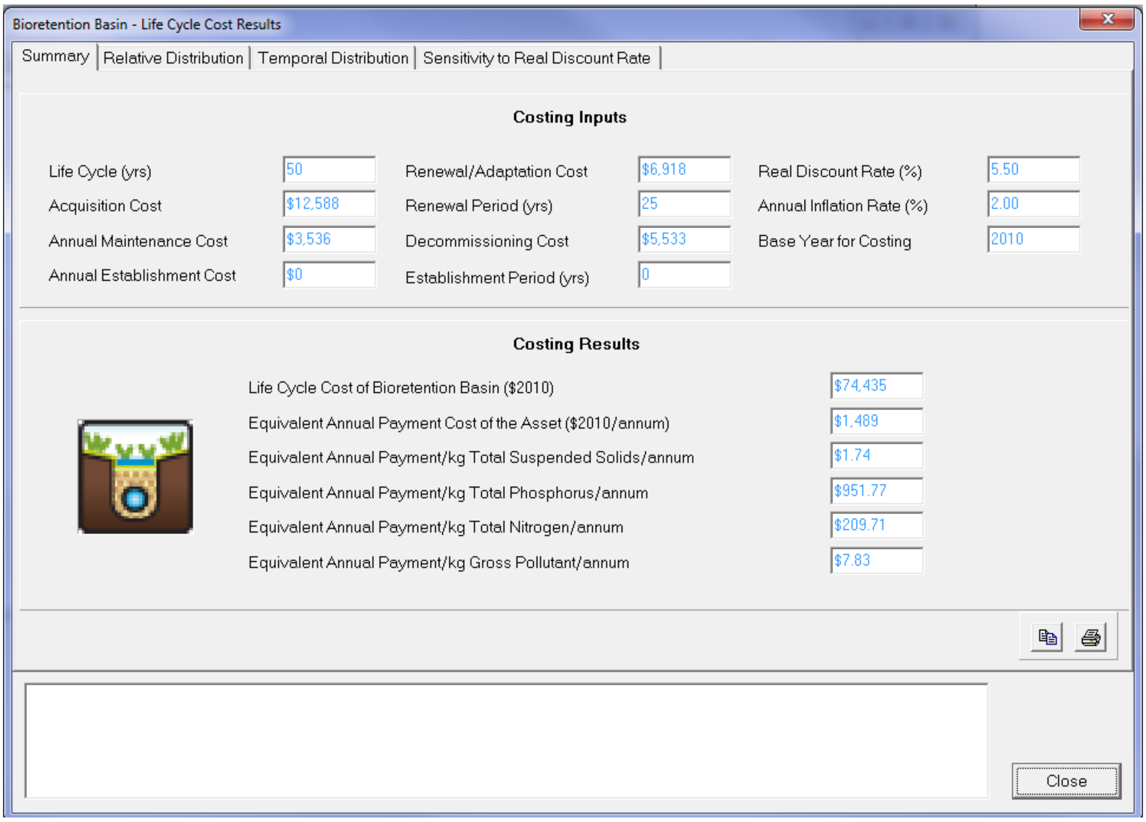


Figure 8- 68 Final costing results (single node)

E 5 Gross pollutant traps

GPTs are usually modelled at the sub-catchment scale in MUSIC as pre-treatment for a pond, constructed wetland or bioretention system. However, at the lot scale, management of gross pollutants may still be necessary and could include screening measures such as first flush diverters (for rainwater tanks) or stormwater pits with inclined outlet screens (for infiltration measures) to minimise the potential for the treatment mechanism of the device to be impeded.

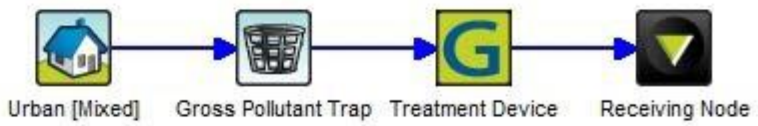


Figure 8- 69 Example of GPT node application in MUSIC

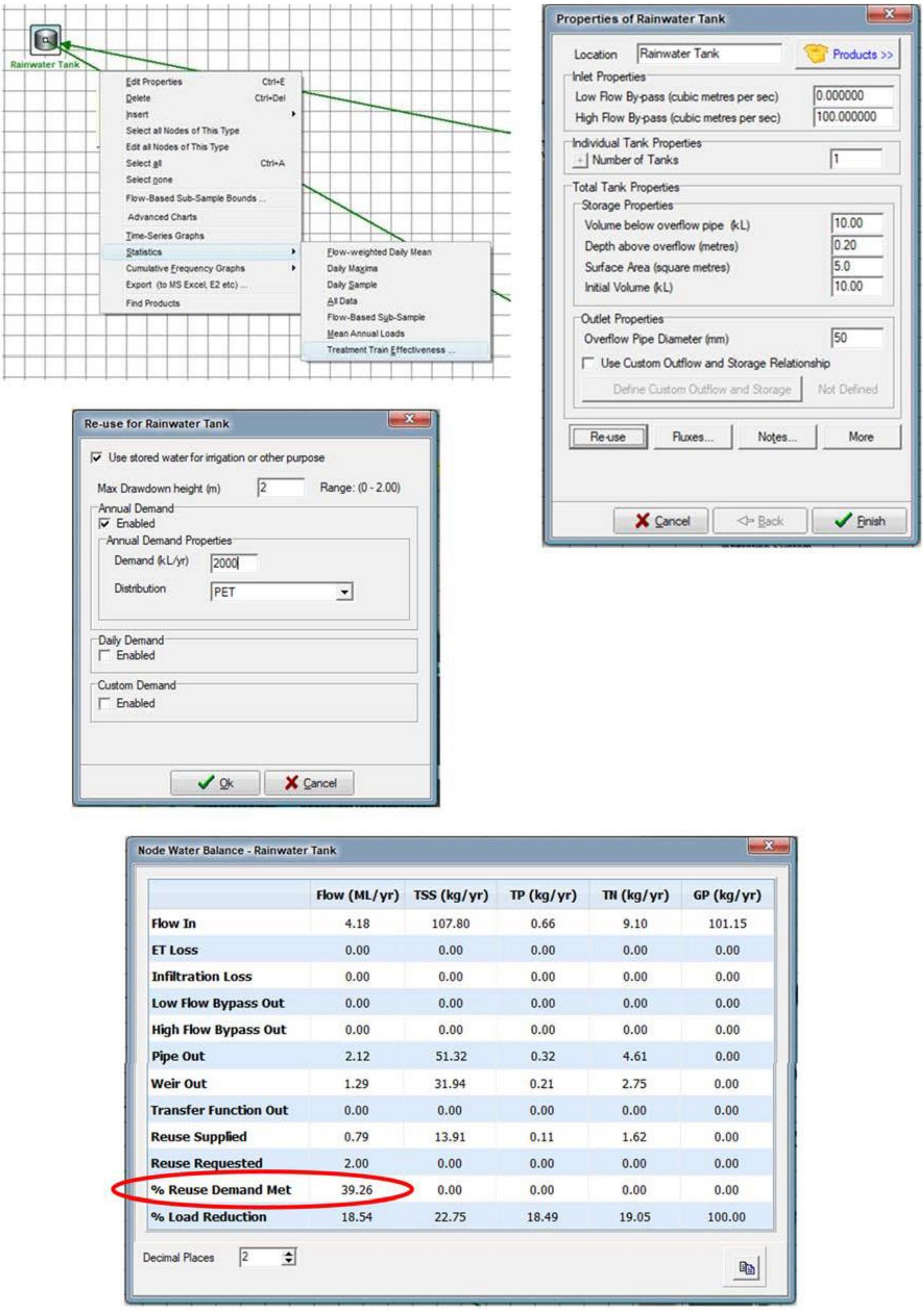
Where a GPT is necessary and is designed to remove sediment in addition to gross pollutants, it shall be selected or designed to achieve the minimum performance criteria outlined in **Table 8- 51** If alternative data is to be relied upon for estimating the performance of the GPT, this shall be included in the report for review with the MUSIC model. This data should be derived from an independent, published source (i.e. not simply based on proprietor supplied data).

Where a GPT is to be implemented only for gross pollutant capture (e.g. a trash rack or pipe net), then only the gross pollutant removal component as shown in **Table 8- 51** shall be used (i.e. no sediment or nutrient removal is to be attributed to the device). If a proprietary device is noted as being an oil and grit/sediment separator, ***no*** gross pollutant removal is to be attributed to the device, nor should it be used for this purpose.

Table 8- 51 GPT treatment node concentration based capture efficiency inputs (adapted from Alison et al 1998)

Parameter	Inlet properties	
Low flow bypass	0	
High flow bypass: **DUS GPT** **Proprietary GPT**	 1 EY 4 EY	
Pollutant	Input (mg/L)	Output (mg/L)
TSS	0	0
	75	75
	1000	350
TP	0.00	0.00
	0.50	0.50
	1.00	0.85
TN	0.0	0.0
	0.5	0.5
	5.0	4.3
Gross pollutants	0	0
	15	1.5

E 6 Water balance output



	Flow (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	GP (kg/yr)
Flow In	4.18	107.80	0.66	9.10	101.15
ET Loss	0.00	0.00	0.00	0.00	0.00
Infiltration Loss	0.00	0.00	0.00	0.00	0.00
Low Flow Bypass Out	0.00	0.00	0.00	0.00	0.00
High Flow Bypass Out	0.00	0.00	0.00	0.00	0.00
Pipe Out	2.12	51.32	0.32	4.61	0.00
Weir Out	1.29	31.94	0.21	2.75	0.00
Transfer Function Out	0.00	0.00	0.00	0.00	0.00
Reuse Supplied	0.79	13.91	0.11	1.62	0.00
Reuse Requested	2.00	0.00	0.00	0.00	0.00
% Reuse Demand Met	39.26	0.00	0.00	0.00	0.00
% Load Reduction	18.54	22.75	18.49	19.05	100.00

Figure 8- 70 Typical MUSIC water balance output

APPENDIX F INTERIM FLOODPLAIN PLANNING AND DESIGN GUIDELINE

F1 Introduction

This guideline is intended to provide an interim approach to land use planning and flood design issues in urban floodplains in the ACT. Specific guidance is provided on development planning and design of infrastructure for both public and private land. The guideline will be of use to planners, designers and engineers who may not be familiar with flood planning and design issues.

The document does not attempt to cover all aspects of floodplain planning and design. Many of these issues are covered in a number of national and ACT specific guidelines listed in the References section of this document. Similarly, the document does not cover the other social and environmental values and issues on floodplains such as recreation use, habitat protection, water quality and visual qualities.

The primary objective of this guideline is to provide advice relating to land use planning and design for development to assist in protecting human life and property from flooding. It aims to provide planning and design guidance on how to best achieve this while allowing for the growth and renewal of Canberra. The various challenges of floodplain management will become particularly apparent as Canberra moves towards a more compact city form where more urban infill and redevelopment is likely to occur, in addition to greenfield development.

The activities these guidelines apply to include all planning and developments on land below the 1% AEP flood level plus an appropriate freeboard. The activities include;

- Greenfield land development
- Urban infill and redevelopment
- Dwelling/building replacement or extensions
- Residential, commercial, industrial and community developments
- Infrastructure such as drainage, sewers, water supply and other utility infrastructure
- Parking, basements, garages, roads, paths, driveways, fences, walls, and landscaping in flood-affected land.

F2 Selected terms

Some of the terms used in this guideline require a brief introduction as there are occasionally differing interpretations between jurisdictions and stakeholder/interest/professional groups. This is not an exhaustive list and definitions for other common flood related terms can be found in the references.

Defined Flood Event: The flood event selected for the management of flood hazard for new development.

Flood affected area: Area covered by a particular flood. Most commonly, the area is defined as that land area covered by the 1% AEP flood.

Flood planning level: The defined flood event plus freeboard chosen for a particular planning or development purpose. For most development, the 1% AEP plus a 300mm freeboard is the flood planning level used to set the minimum habitable floor level for most development. It is important to understand that floods greater than the flood planning level can occur.

F3 Guiding principles

The following guiding principles apply to the requirements in this guideline:

- Risk to people and property must be minimised;
- Potential for adverse impacts on adjacent, upstream or downstream areas must be identified andprevented;
- Any appropriate development within a flood-affected area must be designed accordingly; and
- Reduce reliance on emergency services interventions when flooding does occur.

F3.1 Flood planning level

The selection of the appropriate flood planning level is required to best match the flood risk with the levelof exclusion or protection for a particular development or activity. Current national guidance to the setting of appropriate flood planning levels suggest a risk-based approach. In lieu of a detailed risk assessment, for greenfield developments in urban areas of the ACT, a minimum lease boundary level of 1%AEP plus a 300mm freeboard is acceptable. For urban infill and redevelopment in existing developmentareas, a minimum habitable floor level of 1% AEP plus a 300mm freeboard is acceptable.

For land uses such as temporary parking, temporary storage of equipment not affected by water and other non-habitable and non-commercial purposes, a lower flood planning level can be adopted comprising a lower defined flood event and possibly a lower freeboard.

For land uses such as hospitals, aged persons units, child care centres and emergency services, where theconsequences of flooding are more severe and where emergency access and mobility is constrained, a higher flood planning level should be considered. For these more sensitive types of development, a floodplanning level of 0.2% AEP should be considered.

For major projects or those particularly sensitive to the effects of flooding, a site specific risk assessment,should be undertaken to determine the selection of the appropriate flood planning level. Guidance is provided in *ISO 31000:2009 Risk Management – Principles and Guidelines*, *Australian Disaster Resilience Handbook collection, Handbook 7 – Managing the Floodplain 2016* and, *Engineers Australia ARR 2016*.

F3.2 Freeboard selection

For development in the ACT, a freeboard of 300mm above the flood planning level is used to set the minimum lease boundary level for greenfield development and the minimum floor level for urban infill and redevelopment sites. This accommodates a factor of safety for the uncertainty of the analysis (e.g. short history of floods information), future changes in catchment conditions (e.g. urbanising catchments),climate change risks and protection from wave action.

Prior to site specific flood investigations, a freeboard of 500mm may be used as a rule of thumb for earlyplanning or preliminary design purposes.

F4 Floodplain planning and design requirements

F4.1 Floodway protection, storage and overland flows

Protection of floodways involves the exclusion of certain, inappropriate activities and types of development from areas that convey flood waters so that they continue to serve to protect human lifeand property from the deleterious effects of flooding. The following guidelines should apply:

- Sensitive development, that is – development adversely impacted by flooding, should be excludedfrom floodways. This would usually include all residential and commercial development.

- Less sensitive development such as sporting grounds, public open space and short-term parking may be allowable in those parts of floodways not affected by more frequent storm events up to and including 20% AEP.

Filling and obstructing the floodway should be avoided. This includes any filling or obstruction that encroaches on the floodway cross-sectional area, bridge waterway area or culvert opening.

Any filling that is necessary in floodways should ensure both the 20% AEP and 1% AEP average flow velocities are not increased and should be accompanied by compensatory excavation so that the flood storage volume in the floodway is preserved. This is an important design principle as floodways, as well as conveying floodwaters, play an important role in attenuating floods through flood storage – reducing the severity (elevation and velocity) of flood flows. This is achieved by holding back some of the flood flow and releasing this over a longer period of time and at a reduced rate. This is similar to how a retarding basin works to reduce flood flows downstream by holding back water temporarily within a reservoir.

Fences and similar structures across flow paths should also be avoided as they often become blocked with debris, increasing upstream flood levels.

Overland flow paths, such as from overflows of the stormwater pipe system or pre-existing flows through leased land, should also be protected from filling or blockage in a manner that may impact on adjacent properties.

Activities that significantly alter flow paths and/or flood levels upstream or downstream of development require approval from Environment Planning and Sustainable Development Directorate (EPSDD) and Transport Canberra and City Services (TCSS).

F4.2 Blockage of pipelines and culverts for setting habitable building floor levels

Previous flood studies used to predict flood levels have used differing approaches to the degree of blockage of pipelines, culverts and bridge waterway areas. ARR 2016 suggests a risk based approach to determining the degree of blockage that should be adopted for determining flood levels. Major developments and developments that are particularly sensitive to the effects of flooding should undertake a risk based approach. For other development, the following is recommended for interim use in the ACT as an alternative to undertaking a development and catchment specific risk assessment;

- In establishing what land should not be developed for any residential or commercial and related purposes, land flooded in the 1%AEP as determined with no blockage of drainage structures, should be used as the guide.
- No blockage of bridge waterway areas is recommended for urban areas, unless a risk assessment concludes that blockages are likely to occur.
- Development sites greater than 2000 m^2 adjacent to floodways must consider the impacts of a 100%blockage of pipelines and culvert structures in the design of buildings and other infrastructure.
- In setting floor levels, ramps to basement car parking, pedestrian escape routes etc, the 1% AEP with 100% blockage of drainage structures must be considered and accounted for.
- The 100% blockage analysis is not to be used to establish what land can and can not be developed.

F4.3 Access and egress

Considerations in planning and design for pedestrian access and egress within the floodplain must include:

- Design of subdivision block layouts, roads, driveways, walls, stairs and fences that consider the needs of pedestrians, including those with impaired mobility, during flood events.
- Provision of adequate access and egress from and around buildings including basements.
- Provision of overland flow paths around all buildings including overflow paths required if

basementpumps fail.

- Avoidance of dead ends, islands and submerged drop-offs when paths are flooded.

- ‘Permeable’ pedestrian path networks and multiple escape/access options are included to ensure alternative access and escape routes during rising floodwater.
- Avoidance of escape routes that lead people into deeper water or are against the flow of floodwaters.
- Attention to details of fencing and walls that have potential to create unanticipated barriers that retain flood debris that can cause flood waters to backup (rise) or divert to neighbouring properties.

F4.4 Climate change and sensitivity analysis

ARR 2016 contains methods for estimating the impact of climate change on rainfall estimates. A broad simplification of this is that for every 1 degree centigrade of temperature rise, the intensity of design rainfall increases by 5%.

For major structures and development within or adjacent to floodways and with an expected life of 50 years or longer, a sensitivity analysis of rainfall intensity is to be undertaken to explore the possible consequences of climate change. A plus 15% increase in rainfall intensity for the critical duration storm is to be undertaken, representing a notional 3 degree rise in global average temperature.

If the 1% AEP flood plus a 20% increase in rainfall intensity results in a flood level that is greater than the 1% AEP flood level plus the standard 300mm freeboard, then the structure design, floor level or freeboard should to be adjusted for the particular proposal.

F5 References

F5.1 ACT Standards and Guidelines

1. EPSD, ACT Government, WSUD General Code
2. ACT Government – Office of the Legislative Assembly, Risk Management Policy and Framework, Nov 2016.
3. ACT Government, Utilities (Technical Regulation) ACT, Dam Safety Code 2018 https://www.legislation.act.gov.au/di/2018-202/

F5.2 National Standards and Guidelines

1. Engineers Australia ARR, 2016
2. Australian Disaster Resilience Handbook collection, Handbook 7, Handbook 7 – Managing the Floodplain, 2016
3. ISO 31000 Risk Management – Principles and Guidelines
4. Melbourne Water Guidelines for Development in Flood-prone Areas, 2018

F5.3 Other guidelines (not current)

1. NSW Government Floodplain Development Manual 2005
2. ACT Floodplain Protection Guidelines 1995

Transport Canberra
andCity Services

SEPTEMBER 2021