Assets Planning and Delivery Group
Engineering

DESIGN STANDARD DS 66

Urban Main Drainage Standard

VERSION 3
REVISION 1

JULY 2023

FOREWORD

The intent of Design Standards is to specify requirements that assure effective design and delivery of fit for purpose Water Corporation infrastructure assets for best whole-of-life value with least risk to Corporation service standards and safety. Design standards are also intended to promote uniformity of approach by asset designers, drafters and constructors to the design, construction, commissioning and delivery of water infrastructure and to the compatibility of new infrastructure with existing like infrastructure.

Design Standards draw on the asset design, management and field operational experience gained and documented by the Corporation and by the water industry generally over time. They are intended for application by Corporation staff, designers, constructors and land developers to the planning, design, construction and commissioning of Corporation infrastructure including water services provided by land developers for takeover by the Corporation.

Nothing in this Design Standard diminishes the responsibility of designers and constructors for applying the requirements of the Western Australia's Work Health and Safety (General) Regulations 2022 to the delivery of Corporation assets. Information on these statutory requirements may be viewed at the following web site location:

Overview of Western Australia's Work Health and Safety (General) Regulations 2022 (dmirs.wa.gov.au)

Enquiries relating to the technical content of a Design Standard should be directed to the Senior Principal Engineer, Water Conveyance Section, Engineering. Future Design Standard changes, if any, will be issued to registered Design Standard users as and when published.

Head of Engineering

This document is prepared without the assumption of a duty of care by the Water Corporation. The document is not intended to be nor should it be relied on as a substitute for professional engineering design expertise or any other professional advice.

Users should use and reference the current version of this document.

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Any interpretation of anything in the Standards/Specifications that deviates from specific Water Corporation Project requirements must be referred to, and resolved by, reference to and for determination by the Water Corporation's project manager and/or designer for that particular Project.

REVISION STATUS

The revision status of this standard is shown section by section below:

REVISION STATUS						
SECT.	**VER./ REV.**	**DATE**	**PAGES REVISED**	**REVISION DESCRIPTION (Section, Clause, Sub-Clause)**	**RVWD.**	**APRV.**
All	**3.0**	**Sep 2019**	**New Doc**	**New Standard, Scope Reduced to detailed design requirements only. Concept Planning, drain capacity and modelling and land matters moved to standalone guidance document.** **Reordered into general design requirements and requirements for specific drainage components**	**AA**	**AA**
All	**3.1**	**July 2023**	**Various**	**Scheduled review of full document. Clarification of inlet and outlet screening requirements. Metallic pipework requirements updated.** **Other minor updates**	**AA**	**JD**
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DESIGN STANDARD DS 66
Urban Main Drainage Standard

CONTENTS

1 Introduction

1.1 Purpose

The Urban Main Drainage Standard sets out requirements and provides guidance for Design Engineers involved in the design and construction of drainage assets for the Water Corporation within the Perth Metropolitan Region Planning Scheme. The Standard is aimed at ensuring that the drainage assets of the Water Corporation provide developments with effective flood protection consistent with Water Corporation's level of service requirements. The Standard also acknowledges principles of Liveable Cities and encourages designs that integrate works within the urban environment to enhance water conservation and minimise the transport of pollutants to valuable receiving waters.

1.2 Scope

The standard covers the criteria and rules applicable to the design and construction of new drainage systems as well as extensions and modifications to existing urban systems.

This standard is intended to provide the requirements for components and structures within the Corporation's drainage system. This document lists general requirements for drains and then addresses in later sections the requirements for specific drainage components. This standard does not address the planning or determination of which type of drainage system is to be provided or the required levels, size and capacity of the drain.

Drainage and Liveable Communities, within the Water Corporation's Asset Investment Planning Group AIP, is responsible for the Water Corporation's planning and preliminary design requirements and must be referred to for planning and concept design considerations. This includes the type of drain, such as open drains, piped drain or landscaped stream. It also includes the capacity requirements such as the level and size or setting the hydraulic design parameters for others to use to determine levels, sizes etc.

It is expected the drainage concept plan, the drain capacity/sizing, land matters and maintenance agreements are all finalised or agreed in principal prior to undertaking detailed design of the components.

DWER is responsible for strategic drainage policy and strategic drainage planning across Western Australia.

The Water Corporation is a licensed service provider for urban drainage within the Perth Metropolitan Region Scheme (MRS) and provides a main drainage services to an estimated 40% of the MRS catchment with local government providing the drainage services to the catchment that connects to the main drains.

Local governments manage the drainage services in the remaining areas of Perth that require urban drainage management, and provide urban drainage services in country towns across Western Australia.

Water Corporation's requirements should be obtained by the developer for any development within Water Corporation Drainage Operating areas at the preliminary planning stage to determine the detailed drainage requirements to protect the drainage system.

2 General

2.1 General Design Principles

The design of Main Drains must comply with this Standard. In addition, design principles in other Water Corporation Design Standards must be complied with where they can be reasonably applied to drainage assets.

2.1.1 Design Life

The design must:

- Consider the assets as permanent assets and the drainage function as permanent. Assets that deteriorate over time, such as concrete or metallic structures, require planning for replacement and planning to keep the drain functioning during replacement;
- Ensure assets have a minimum of 100 years design life; and
- Select components based on obtaining long asset life with the lowest ongoing maintenance and replacement costs. For example, concrete retaining wall basins will need eventual replacement due to concrete degradation. However, an excavated earth basin with stable slopes has no defined end of life due to deterioration.

2.1.2 Standards

The design must comply with all relevant Australian Standards and Water Corporation Design Standards.

2.1.3 Safety

The design must:

- Prioritise safety and comply with all regulatory requirements;
- Allow for safe access, construction, maintenance, operation & replacement activities. The design shall eliminate, where practicable, maintenance or operation activities. Maintenance is to be minimised where elimination is not possible. For example, slopes to be shallow to eliminate erosion damage and repairs;
- Minimise manual handling and allow for safe access for machinery to undertake the tasks. For example, screens to be located with suitable access by vehicles with mounted cranes and be within the load and reach capabilities of the crane mounted vehicle. It shall also prioritise use smaller machinery over large machinery. For example a design solution that requires only a small truck mounted crane for maintenance takes precedence over a solution that requires a 100T crane to maintain; and
- Be safe not only for construction, operation, and maintenance purposes, but also for the general public and any other person or people that may be affected by the drain.

2.1.4 Allowance for Future Upgrades

The design must incorporate allowances for safe, simple and cost-effective future replacement of assets and components

2.1.5 Cost Effectiveness

The design must be developed to minimise whole of life cost whilst complying with all other requirements.

2.1.6 Environment, Aesthetics & Community Enhancement

The design must:

- Not detract from the aesthetics of the surrounding environment, and where practicable, enhance aesthetics and community value;
- Be consistent with other relevant Water Corporation initiatives and policies, such as the Drainage for Liveability program;

- Minimise potential for breeding grounds for pest and vectors such as mosquitos to form, as well as propagation of declared weeds; and
- Meet environmental regulations

2.2 Example Drawings

The example drawings in this standard provide an outline and/or concept of some of the Water Corporation's requirements only, are not suitably detailed for construction purposes, and are complementary to the information contained in the text of this design standard. For example, concrete reinforcement is not shown on the example drawings, but this is not to be interpreted as there not being a need for reinforcement in concrete structures. The designer must incorporate all design requirements into their detailed drawings rather than simply referring to a drawing from this standard.

The Designer shall ensure that they have the latest issue of the drawings.

2.3 Brand Names

Where a brand name is indicated, a similar material or product may be used if approved by the Water Corporation.

2.4 Design Responsibility

The Design Engineer shall be responsible for the design of the works irrespective of the requirements of the standard.

2.5 Safety

The design must identify, consider and suitably mitigate all health and safety risks as part of the design. This must extend not only to occupational risks, but also the general public, including children. Hazards to be considered include, but are not limited to:

- Operational risks;
- Maintenance risks;
- Construction risks;
- Risks to the general public;
- Drowning;
- Falls;
- Entrainment into flowing water
- Entrapment (e.g. held against safety screens);
- Interacting with assets;
- Biological

Irrespective of the risk assessment outcomes, the final design shall not have lesser safety requirements than the minimum required by this standard and other referenced documents.

The detailed information in Royal Life Saving Society Australia – Guidelines for Water Safety in Urban Water Developments (2004) are to be considered in developing risk mitigation strategies.

The following design criteria apply:

(a) Locate public areas and bicycle paths above the design top water level for 1:10 year ARI storm events.

(b) In addition to any other asset owner requirements, the underside of crossings in POS to be a minimum of 300 mm above the design top water level for 1:100 year ARI storm events.

(c) Provide edge protection from where there is a risk of falls.

(d) Ensure visibility of water from access to all crossings.

(e) Avoid any features that invite or encourage access to water (purpose designed flora plants and bird refuge islands are acceptable).

(f) Design the system to enable a person to readily exit a drain or a waterway before being drowned or swept into unsafe areas such as pipe/culvert inlets.

(g) Avoid sudden change of water depth in open drains and compensating basins by limiting embankment slopes and heights of any retaining system incorporated on the slopes.

(h) Provide benches of adequate width to allow emergency egress and recovery.

(i) Screen all pipe and culvert inlets >300mm diameter

2.5.1 Risk Assessment

Risk assessment shall be carried out by Design Engineers in accordance with AS/NZS ISO 3100 – Risk Management Principles and Guidelines and the Water Corporation's Risk Assessment guidelines.

2.5.2 Safety in Design

Designers shall provide the client with a Safety in Design Report in accordance with statutory and regulatory requirements. The Water Corporation's "Safety in Design" work instruction shall be followed, which provides instruction on the compilation of this report, can be requested by email to Engineering.StandardsEnquiries@watercorporation.com.au.

2.5.3 Signage

Signs shall be provided at drainage infrastructure in accordance with the requirements in Water Corporation's standard S197- Site Security, Public Safety and OSH Signage Standards.

As a minimum, enclosed drainage areas with fencing shall have "No Entry Trespassers Prosecuted" signs on all public facing sides and property entry points.

Where drainage areas have specific safety hazards such as "confined spaces; fall from height risks and edges", then they shall be specifically signed with the hazard on the hazard area. These warning signs shall be provided at appropriate locations in consultation with Local Authority to warn people of possible dangers.

2.5.4 Safety Related Water Corporation Standards and Guidelines

All requirements in the following safety related Water Corporation Standards/Guidelines shall be complied with in developing design for a main drain.

- S081- Site Security and Public Safety
- S389- Risk Assessment Criteria
- S151- Prevention of Falls Standard
- DS 62- Site Security & Public Safety Design Guidelines
- DS100 – Suspended Flooring (Grid Mesh and Chequer plate)
- S197 – Site Security, Public Safety and OSH Signage Standards

3 Design Events

The Design rainfall events to be used are derived from the Water Services Licence (WSL) issued by the Economic Regulation Authority. The method for derivation of design events must match the method used in the WSL. No other methods are permitted. The designer shall check these requirements at the time of design, however at the time of publishing of this document, the requirements include:

(a) design of new urban drainage scheme infrastructure protects against flooding from peak flows of stormwater runoff from rainfall events with intensities up to:

i. Residential – 5 year average recurrence interval

ii. Commercial, mixed use and industrial land – 10 year average recurrence interval.

Note: Average recurrence interval is used rather than annual exceedance probability, to reflect the Water Services Licence requirements.

(b) The following flood protection works will be operated and maintained to cater for the peak flows of stormwater runoff from individual rainfall events set out below.

iii. Preston River levees (Bunbury – Leschenault Inlet to Picton Bridge – 1 in 100 year Average Recurrence Interval

iv. Vasse River Diversion – Busselton – 1 in 20 year Average Recurrence Interval

4 Asset Design Requirements

4.1 Open Drains

4.1.1 General Requirements

(a) The creation of new steep sided open drains is not consistent with the principles of Liveable Communities adopted by Water Corporation. Public access must be denied from steep sided open drains and these drains shall be located in a fenced reserve. Proposals for this type of drain will not be approved by the Water Corporation if better methods can be implemented. Approval shall be sought at the preliminary investigation stage.

(b) Natural water courses shall be retained and where possible, degraded watercourses should be rehabilitated.

(c) Levees shall be avoided wherever practical, due to the need for ongoing inspection and maintenance. Levees will only be accepted if it can be demonstrated to the Water Corporation's satisfaction that all other options are not practicable.

(d) A vegetated drain can perform various important tasks, including filtering of various forms of particulate pollutants, providing bank stabilisation to limit erosion, enhancing habitat value, providing potential wildlife corridors and improving the appearance of a development site. The use of vegetation to achieve such outcomes shall be optimised.

(e) The design of steep sided open drains will vary with the types of soil encountered. As a general rule to minimise scour, the range of allowable design peak velocities is 1.2 m/s for drains constructed in sand and 1.5 m/sec for drains constructed in clay. Note that some drain profiles may result in maximum velocities not coinciding with peak design storm scenarios.

(f) Erosion protection approved by the Water Corporation shall be provided at all outlets, drop and junction structures, at all bends, in unsuitable ground conditions, transitions of depth of flow and surface slope and elsewhere as required by the Water Corporation.

(g) Drains shall be designed to flow with a minimum freeboard to top of bank of 0.3 metre with the flow from a design storm. Design depths of flow shall be calculated having due regard to the hydraulic grade lines of the upstream connecting pipelines or culverts.

(h) Where a subsidiary open drain enters a larger deeper drain, the drop shall be constructed on the subsidiary drain and the junction made grade to grade.

(i) A berm, with a minimum width of 4.0 metres, must be provided on at least the entirety of one side of the drain suitable for maintenance vehicles, such as excavators, cranes and full size rigid trucks with highway legal loads in wet weather conditions. A walkway at least 1.0 metre wide must also be provided on the opposite side at a minimum, and where possible a 4.0 metre berm shall be provided on each side of the drain. If operational and maintenance activities are greater than typical (e.g. due to a larger than normal area), then access to that area must be via a continuous berm of minimum 4m width. Berms shall be graded between 1% and 2% to address local drainage. A surface drainage system shall be provided and directed to suitable collector drains where directed by the Water Corporation (e.g. in soils with poor soakage characteristics).

(j) The design must allow vehicles to both enter and exit the site without requiring vehicle reversing movements.

(k) Riffles shall be incorporated into the base flow channel design at minimum 150m spacings to aid with oxygenation of the water

(l) Lateral connections shall only be located at drop, inlet or outlet structures.

(m) Any structure (e.g. bridge, culvert, pipe bridge, etc) must not project into the flow for the Design Event apart from elements required for structural purposes (e.g. intermediate bridge pylons). The design of all structural components must consider flow cases where the flow conditions (water level, velocity, etc) exceed the Design Event to allow for less frequent flooding events of greater severity.

(n) The base flow shall be contained within the base flow channel at a depth not greater than 250 millimetres or within a base flow pipe that is just flowing full. A base flow channel shall be a minimum of one metre wide. The minimum size of a base flow pipe shall be 300 mm nominal diameter.

(o) Vegetated bank protection is required. Non-vegetation protection (i.e. hardscaped) toe protection is only permitted where it can be demonstrated that vegetative methods are impractical. Fully developed vegetation will enhance surface stability and control erosion of the drain. The vegetation must not significantly restrict flow capacity.

4.1.2 Guidelines for Open Drains Accessible to the Public

(a) Landscaped drains should be used:

i. Where natural watercourses have been severely degraded and cannot be retained due to planning constraints;

ii. To control the potential for post-development groundwater rise to levels above the Control Groundwater Level (CGL);

iii. Where required for aesthetics reasons; or

iv. Where it is estimated that the base flow will occur for more than six months of the year.

(b) An unfenced open drain accessible to the public may be a natural watercourse, a landscaped open drain or a swale drain. The watercourse should be integrated with the landscaping for the open space.

(c) Where public access is uncontrolled, side slopes of 1 vertical to 6 horizontal or flatter are required. Steeper side slopes (up to gradients used for open drains in fenced reserves) are permitted elsewhere only when safety fencing/edge protection is installed in accordance with the rest of this standard.

v. Landscaped open drains shall have a vegetated floodway with a base flow channel.

(d) Swale drains should be used where base flows only occur for short duration each year and the need to control the groundwater is not a significant factor. Swale drains consist of a grassed floodway with or without a base flow pipe constructed below the invert of the channel. The base flow pipe shall not be less than 300 mm nominal diameter and shall not exceed 900 mm diameter and must be agreed with Water Corporation.

(e) Base flow pipes shall only be used where:

vi. They are required to control probable rise in groundwater; and

vii. Non-piped base flows are likely to cause a public health or safety risk.

4.1.3 Guidelines for Open Drains in Fenced Reserves

(a) Side slopes for open channels to be designed to be stable in all conditions and shall be no steeper than 1 vertical to 2.5 horizontal.

(b) When vehicular access is required from the road reserve to the maintenance berm, access slopes steeper than 1 vertical to 6 horizontal are not permissible.

(c) The centreline of the excavation shall normally be parallel to the reserve boundaries.

4.1.4 Crossing Railways and Other Services

4.1.4.1 Crossing of railways

Where it is proposed to construct an open drain across a railway property, the drain shall be constructed to comply with the requirements of AS4799 and the Rail Authority's published requirements.

Liaison with the appropriate responsible person representing the rail owner is necessary at all stages.

4.1.4.2 Service Crossings

(a) Crossing Existing Services

Where it is proposed to construct an open drain over a service, the proposal shall comply with the following conditions:

i. Written approval for the crossing shall be obtained from the service authority.

ii. Open drains must be located so that crossings of other services are approximately at right angles to the service or the service realigned to suit.

iii. In the case of the drain passing over the service, a minimum clearance of 600 mm below the design invert of the open drain and the crown of the service must be maintained. The asset owner's minimum cover shall also be maintained for the service.

iv. Scour and mechanical protection must be provided over a buried service to prevent erosion and exposure of the service as well as to provide protection from machinery such as excavators cleaning the drain to the satisfaction of both the Water Corporation and the service owner.

v. The requirement for earthing of infrastructure shall be evaluated

(b) New Services Crossing Existing Drainage Assets

Where it is proposed to construct a new service across an existing open drain, the proposal shall comply with the following conditions:

vi. The new service and all associated infrastructure (e.g. supports, valves, chamber lids, etc) must be installed either a minimum of 300mm above the 1% Annual Exceedance Probability (AEP) flow level or below the drain invert such that a minimum of 600 mm cover is maintained between the infrastructure and the drain invert.

vii. The new service and associated infrastructure must not negatively affect access along the drain.

viii. Where the service carries any substance with potential to pollute or contaminate the drain, special permission is required from Water Corporation, and may require additional requirements for public health and safety purposes.

ix. Marker posts shall be provided at the location of all services crossing a Water Corporation open drain on both sides of the drain.

4.1.5 Services Parallel to Open Drains

Services parallel to open drains shall be laid no closer than the alignments shown in Figure 1.

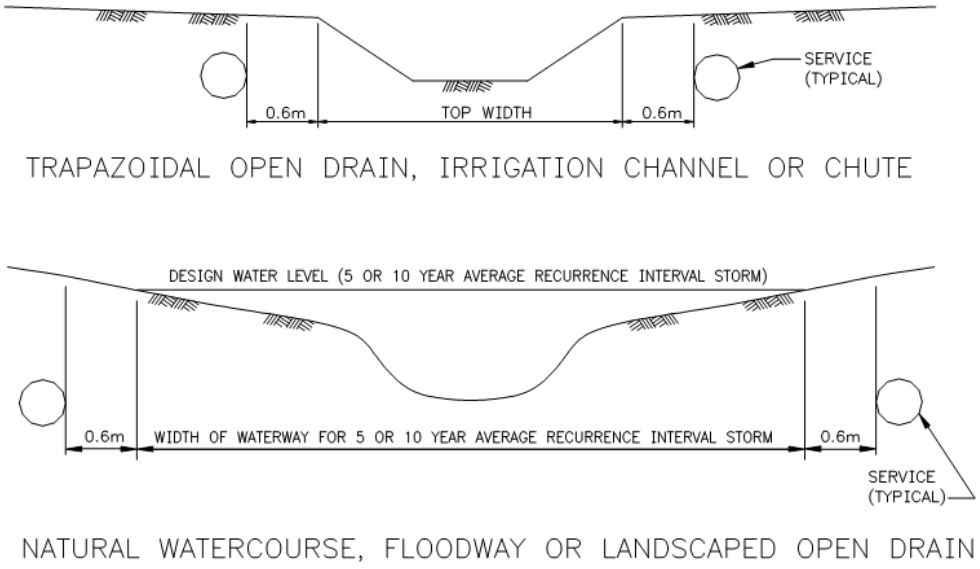


Figure 1

4.1.6 Protection of Existing Flora General Section

Drainage installations shall be planned to minimise the damage to existing flora. In the case of trees and understorey located in close proximity to the drain, the structural root zone must be preserved. This may require the use of retaining and related fall prevention measures in cases where the ground would otherwise be profiled to match the upstream and downstream drain profile.

4.2 Compensating Basins

4.2.1 General

(a) Compensating basins may either located in a fenced reserve or be unfenced and located in POS or similar with side slopes suitable for public safety.

(b) Steep sided slopes are not permitted unless shallower slopes are demonstrated to be impractical. Slopes of 1vertical:6horizontal are typically required.

(c) Compensating basins offer opportunities to provide valuable visual and recreational amenity for humans.

(d) If a compensating basin is to have a permanent water area, then objectives must be set as to what functions (other than peak flow compensation) the basin must be designed to achieve. These could include functions such as:

(e) Enhancement of natural habitat area near an existing small, isolated area of natural habitat.

(f) Creation of a particular type and area of habitat which is not represented nearby

(g) Re-creation of some of the original conditions if the basin is located in a severely degraded area which was once a natural wetland.

(h) In order to reduce mosquito breeding as well as nuisance odours, basins must be designed to either permanently contain water, at a minimum depth of 300 mm, or to have a completely dry base surface in between times of inundation when flows are compensated. Base flow pipes and sub soil drains may be required to maintain the dry condition. The Design Engineer shall confirm that the groundwater level is suitable to maintain the necessary minimum depth of water in the basin where shallow groundwater is the source of the permanent water body. If the groundwater level is not suitable for long term maintenance of a “permanent” water body within the basin then the basin shall be designed as a “dry" basin.

(i) For new works, the invert level of the outlet from a compensating basin shall be no lower than the CGL for the site.

(j) To allow for the control of basin water levels, stop boards must be incorporated into inlet and outlet structures. Particularly in regard to “wet” basins, the ability to vary water level and also to completely drain the basin is a valuable operational and management tool.

(k) Lateral connections to compensating basins shall be made in accordance with the Water Corporation's standard details. All 3rd party connections shall be trapped to prevent unnecessary debris entering the basin.

(l) The written approval of the Water Corporation's Manager, Drainage and Liveable Communities shall be obtained for the use of any alternative storage technique.

(m) The potential for fire hazard in and around vegetated compensating basins must be recognized and appropriate firebreaks provided.

4.2.2 Fenced Compensating Basins

Steep sided compensating basins are discouraged. New proposals for steep sided basins will be approved only where it can be demonstrated that other options are not appropriate. The design must:

(a) Have a minimum maintenance berm width of 4 metres from the top of the compensating basin bank to the boundary fence.

(b) Have side slopes that are stable, and no steeper than 1 vertical to 2.5 horizontal.

(c) Have an earth access ramp at a slope no steeper than one vertical to four horizontal.

4.2.3 Unfenced Compensating Basins

Unfenced compensating basins must meet the following requirements:

(a) The maximum slope not to exceed 1vertical:6horizontal.

(b) There must be no sudden depth changes (e.g. such as from a limestone wall) that could become concealed underwater in the 1% AEP storm event.

(c) All pipes inlets shall be screened.

(d) Outlets that have elevated risk profiles must also be screened

(e) Have a minimum maintenance berm width of 4 metres from the top of the compensating basin bank to the boundary

(f) The depth of the permanent water body in an ornamental lake or pond shall be a minimum of 300 mm to minimise odour and pest (e.g. mosquitos)

4.3 Drainage Pipes and Conduits

4.3.1 General

(a) The use of pipes to transport drainage flows shall be avoided wherever possible. Above ground streams with base flow channels are preferred.

(b) Gravity piped drains shall either be constructed using a minimum Class 3 reinforced concrete pipes to AS 4058 or Fibre Reinforced Polymer (FRP) pipes to AS3571. FRP must be considered where concrete pipes could encounter problems (e.g. low pH soil/aggressive groundwater conditions). PVC pipes are permitted for small diameter (≤DN300) slotted sub-soil drains only.

(c) Pipe systems that include metallic components (e.g. jacking pipe with metallic collar) are not permitted unless they either:

i. A pipe system fully compliant with SPS100 and the installation arrangement eliminates the risk of damage to the protective coatings (an example of an unacceptable arrangement is a Sintakote pipe thrust through soil using trenchless techniques); or

ii. are used solely as an encasement pipe and the annulus between the carrier pipe and encasement pipe is fully grouted with cementitious grout. Any jacking pipe ≥DN800 must also be grouted on the exterior of the jacking pipe to completely fill any potential voids.

(d) Except at compensating basin outlets, parallel subsoil drain pipes and swale drain base flow pipes, the minimum size pipe allowable in a main drainage system is 450 mm nominal diameter. Box culverts shall have a minimum cross section of 450 mm by 300 mm.

(e) Pipe diameters along a main drain must not decrease in the downstream direction (other than at compensating basin outlets) irrespective of steeper grades. If a decrease of diameter occurs due to a staged upgrading, a special transition section shall be provided.

(f) Where an existing open channel is being replaced with a piped drain, any groundwater control function of the open channel must be maintained by the piped drain to avoid subsequent groundwater rise.

(g) The minimum horizontal wall to wall clearance between parallel services is 600 mm, except in the case of parallel subsoil drains supplementing a larger piped drain, which may then be reduced to 300mm.

(h) Lateral connections shall be at crown to crown with the outlet pipe except where maximising depth is necessary (e.g. maximising the effectiveness of sub-soil drain). In such cases, the connection may be installed with its invert 150 mm above the invert of the larger pipe.

4.3.2 Pipe structural design and installation

The structural design and installation of reinforced concrete pipes shall be in accordance with Australian Standard AS 3725. Pipes shall be designed for "Type U" support and installed for a minimum of “type H” support.

Fibre Reinforced Polymer Pipes must be designed and installed in accordance with AS 2566.1 and AS 2566.2.

4.3.3 Cover to Pipes or Conduits

(a) The minimum cover to drainage pipes or conduits other than the base flow pipes in swale drains shall be 750 millimetres.

(b) The minimum cover to drainage pipes or conduits under roads and trafficable right of ways shall be 900 millimetres

(c) The minimum cover to the base flow pipe in a swale drain shall be 300 millimetres.

(d) The maximum cover and pipe Class (as per AS4058) shall be determined by the Designer.

4.3.4 Pipe Grades

Permissible pipe grades are as follows:

Pipe Diameter (DN, mm)	Minimum Pipe Grade (vertical:horizontal)	Maximum Pipe Grade (vertical:horizontal)
300	1:200	1:6
450	1:300	1:10
600	1:500	1:15
750	1:650	1:20
900	1:800	1:25
1050	1:1000	1:30
1200	1:1000	1:40
1500	1:1000	1:50
1800 and greater	1:1000	1:60

In addition to the specified minimum grades, the pipe grade must also yield annual velocities in excess of self-cleansing velocity (i.e. >0.75m/s).

4.3.5 Concrete Encasement

(a) Drainage pipes and conduits shall be concrete encased in the circumstances indicated below:

i. Where considered necessary for reducing abnormal maintenance such as at river or ocean outfalls.

ii. To provide structural strength when cover has been increased or reduced when a concrete rafting slab is proven to not be practical.

iii. When future access or maintenance will be difficult.

iv. As required by the Water Corporation.

(b) Concrete used for encasement shall be minimum 32 MPa and be reinforced. Minimum thickness of concrete around the pipe barrel and collar shall be 150 mm.

4.3.6 Crossing of Roads, Railways and Other Services

4.3.6.1 General

(a) Crossings under freeways, controlled access roads and railways are not permitted unless no other viable options exist.

(b) Drains must be located so that crossings under all roads and railways are approximately at right angles (±5°) to the road or railway reserve boundary.

(c) Road and rail crossings shall be straight and avoid any deflections or changes of direction. Each end of the crossing shall feature an access chamber and sufficient accessible and clear land to facilitate future relining of the pipe.

(d) Where it is proposed to lay drains crossing under freeways, controlled access roads and rail land the following conditions shall be complied with:

i. Written approval for the crossing shall be obtained from the controlling authority.

ii. Unobstructed access to access chambers within the road or rail reserve shall be available from outside the reserve, and the access does not require ongoing authorisation from external parties.

(e) Drains crossing railway reserves shall be laid to comply with the requirements of the "Railways of Australia Code for the Installation of other Parties' Services and Pipelines within Railway Boundaries" and the rail authority's published requirements.

(f) Subject to more stringent requirements by the owners of the other service, a minimum vertical clearance of 150 mm must be maintained between drainage pipes or conduits and all other services

(g) Pipe systems incorporating metallic components (e.g. metallic coupling ring) are not permitted

4.3.6.2 Services passing through drainage pipes or conduits

Intersecting services can be prone to damage, limit hydraulic capacity and often have reduced asset lives. Services are not permitted to intersecting a drainage pipe or conduit unless there is no other feasible solution.

Where a service must pass through a drainage system, it must occur through an access chamber and is not permitted to pass through a pipe, culvert, conduit or similar. Any such access chamber must be assessed and designed such that the hydraulics of the system are not reduced and any impedance of flow are duly considered and quantified in this assessment. Additionally, the cross-sectional area of flow at the intersecting service must be equal or greater than the cross-sectional area in the adjoining downstream pipe/culvert, for a given water level.

Services must intersect perpendicular (±10°) to the drain. Any intersecting services shall be sleeved in a robust, non-corrodible, self-supporting sleeve such as reinforced concrete. Any other materials must receive Water Corporation Engineering Branch approval. No joints or intermediate supports are permitted for the sleeve within the access chamber.

Services passing through drainage pipes or conduits shall be constructed to the lines shown in Figure 2. While a pipe is shown, the principles apply to box culverts and other conduits.

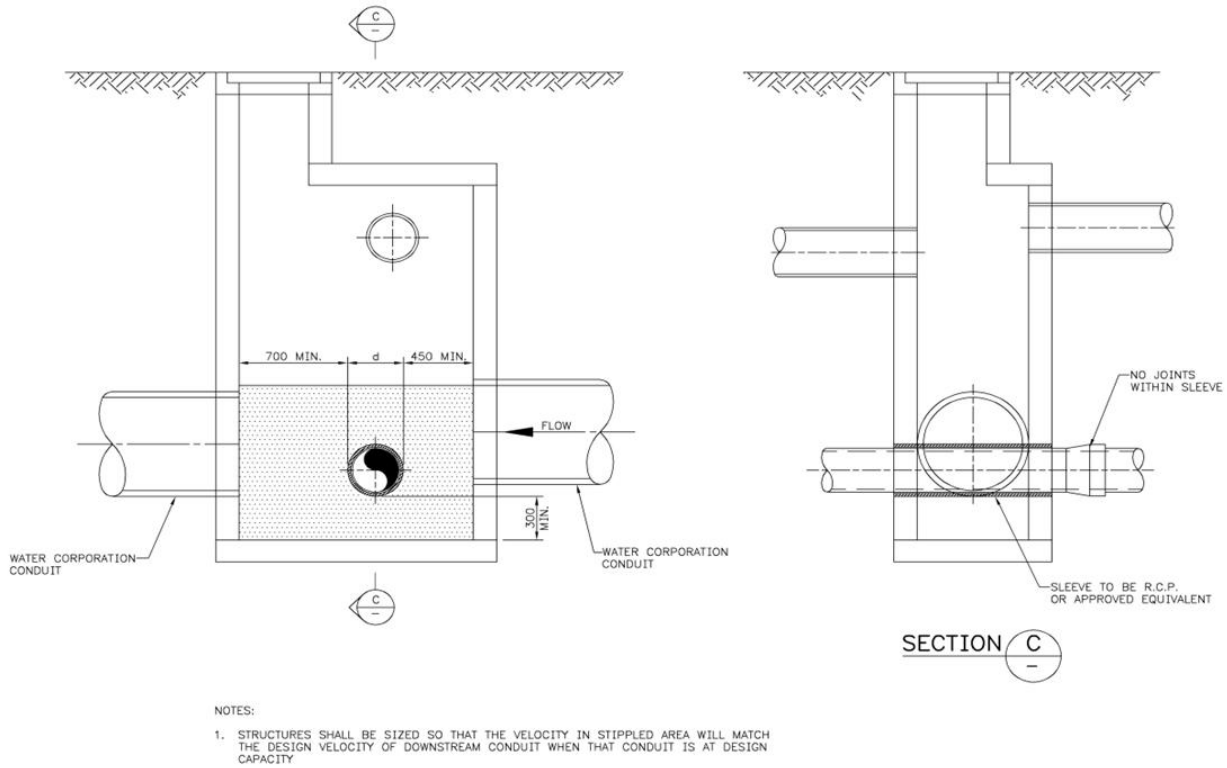


Figure 2

4.3.6.3 Siphons under services

Siphons, or any other arrangement that requires any section of the pipe to operate under pressure are not permitted.

4.3.7 Junctions

Junctions, other than cut-in junctions, shall be at an access chamber or a structure.

Cut-in junctions are only permitted on any main drainage conduit where the ratio of the nominal size of the main drain to the nominal size of the lateral drain is equal to or greater than 3:1. Junctions must finish flush with the internal wall of the drain and must not be re-entrant. The angle measured between flow directions (as measured horizontally) shall be between 45° and 90°.

4.3.8 Pipes, Fittings and Joints

Only one type of pipe shall be used between any two access chambers.

Sub soil drains shall be constructed using reinforced concrete, FRP or PVC pipe.

PVC pipe shall be Class SN8 minimum to Australian Standard AS 1260.

FRP pipes shall be in accordance with Australian Standard 3751.

Pipe joints shall be rubber ring joint.

4.3.9 Splay Pipe Bends

The minimum size pipe that shall be manufactured as a splay pipe shall be 900 millimetres.

Splay pipe bend must be accomplished by using factory made splay pipe units fabricated from rubber ring jointed pipes.

Each splay pipe in a splay bend shall incorporate only one change of direction. The maximum change of direction in each pipe length shall be 22.5o. Where a splay bend incorporates more than one splay pipe unit the change of direction at each pipe shall be equal.

Each splay pipe bend shall be installed so that the socket is located on the upstream end of the pipe.

4.3.10 Subsoil Drains

4.3.10.1 General

Subsoil drains form part of a Water Corporation main drain only when they are installed as the main drain itself or to act as a ground water control when a drain is piped.

The extent of subsoil drain intended to be the responsibility of the Water Corporation shall be clearly delineated on the drawings.

4.3.10.2 Pipes

Only approved perforated or slotted circular pipes shall be used in Water Corporation subsoil drains. Solid pipes laid with open joints in lieu of slotted pipes will not be approved.

4.3.10.3 Filters

Slotted pipes shall be laid in a granular filter which has a cloth filter surround as shown on the Drawings.

4.3.10.4 Box culverts

Box culverts may be used as subsoil drains as shown on the Drawings.

4.4 Access Chambers

4.4.1 General

At any access chamber on a main drain, the main drain outlet (downstream) pipe must be no higher than crown to crown with the main drain inlet (upstream) pipe.

Inlet pipes other than main drains (e.g. connections) shall be located completely under the corbel (or conversion) slab and to Water Corporation approval. The preferred level for these inlets is such that the crown is at the same level as the main outlet pipe's crown and the minimum inlet pipe's springline shall not be lower than springline of the main outlet pipe.

The maximum allowable distances between access chambers are shown in Table 1

Table 1

Pipe Diameter (mm)	Max. Allowable Distance Between Access chambers (m)
300	100
375	120
450	140
525	160
600	180
675	200
750	220
900	240
1050	260
1200	280
1350	300
1500	350
1650 & OVER	400

It must be possible to view any point in a pipe drain from at least one access chamber and only up to one change of direction (i.e. splay bend) can be included between access chambers. Consequently access chambers shall be provided on pipe drains at the following locations:

(a) At a change of grade.

(b) At a change of direction if a splay bend is not permissible.

(c) At a change of pipe diameter.

(d) At intersections of main drains.

(e) At connections, where the inside diameter of lateral drain is greater than 30% of the main drain diameter.

(f) Within one hundred metres of a splay bend.

The location and orientation of access chambers shall permit the removal of covers without being restricted by existing or proposed fences and retaining walls or other structures.

Within road reserves, access chambers' centre line shall be positioned in accordance with the Utility Providers Code of Practice for Western Australia and as agreed with relevant authorities.

Access chamber covers shall be clear of the kerb.

Fixed ladders and step-irons are not permitted in access chambers.

The access chamber segments shall be reinforced concrete spun sections to AS4058 and must be designed to withstand all dead and live loads, as well as differential settlement, construction, floatation loads and any other forces that may affect the structural integrity of the chamber.

The designer must ensure that the structural integrity of the chamber is maintained, including consideration of the effect of penetrations in the access chamber walls.

A minimum wall width of 250mm shall be allowed between holes cut for pipe openings at similar elevations. A minimum distance of 150mm is required between any access chamber joint and pipe penetration.

4.4.2 Access chamber Covers

Access chamber covers shall be rectangular, cast iron and conform with Australian Standards AS3996

Minimum load classifications of the covers shall be as follows:

- Road pavements, road verges, driveways, car parks and trafficable right-of-ways – Class D.
- Lots, parks and reserves – Class C.

4.5 Culverts

4.5.1 General

Culverts shall extend past each boundary of a road reserve beyond the usual setbacks for buildings in the area, in order to allowing the erection of a fence in line with the surrounding building setbacks.

A minimum berm width of 1.0 metre shall be provided between the back of the culvert inlet/outlet structures and the reserve boundary.

4.5.2 Box Culverts and Link Slabs

For spans up to 1200 mm, box culvert sections shall comply with AS 1597.1, Small culverts (not exceeding 1200 mm span and 1200 mm height). For spans over 1200 mm, box culvert sections shall comply with AS1597.2, large culverts (from 1500 mm span and up to and including 4200 mm span and 4200 mm height) for carrying roadway and railway loading specified by AS 5100.

Because of the difficulty in bedding precast invert and base units, crown units must be installed on cast in-situ base slabs. Precast bases are not permitted.

Link slabs may be used with box culverts.

4.5.3 Installation and Joints

Culverts shall be installed with a joint gap of 5 mm to 10 mm between units. Joints shall be made good in accordance with the standard drawings.

4.5.3.1 Base slabs

The slab shall be laid on a minimum of a 100 mm thick layer of compacted coarse clean sand or crushed granite.

To prevent the legs of crown units being forced inwards by consolidation of the backfill material cast in-situ reinforced concrete base slabs shall have rebates cast into the slab to provide a recess for the legs. Rebates shall not be formed by pouring a concrete infill after the crown units have been laid on the base.

The minimum rebate depth for box culverts up to 1200 mm span is 10 mm. For box culverts with spans of 1200 mm and over, the minimum rebate depth shall be 25 mm. Allowance for dimensional tolerances in culvert span and leg width shall be made when locating and sizing rebates.

The length of the slab shall be sufficient to allow for a 10mm joint gap between units.

The slab shall be designed as a one way slab in accordance with Australian Standard AS 3600, Concrete structures. The main reinforcement shall be normal to the legs of the box sections and the minimum slab thickness shall be 150 mm.

4.5.3.2 Bends

Splay bends shall be accomplished by using factory made splay cut box culvert units.

4.6 Inlet and Outlet Structures

Structures are required for all inlets and outlets. Simple outlet structures consisting of a concreted spillway are permitted at open-drain outlets.

Inlet and outlet structures require screens in accordance with Clause 4.7.3.

Vehicle access to inlet and outlet structures is required, comprising a minimum 4m wide berm and slopes no steeper than 1 vertical to 6 horizontal longitudinally.

Structures must not rely upon weepholes for structural integrity.

Refer the Drawings for further details of inlet and outlet structure requirements.

4.7 Safety

4.7.1 Fencing

Fencing shall be a minimum of 1.8m high and in accordance with the standard fences detailed on Drawings GX54-4-2 & 4-3. Alternatively, private property boundaries may be fenced with 1.8m high, uncapped, free-standing HardieFence or Colorbond. More expensive fencing options that have equivalent security functionality can be considered by the Corporation if the additional cost is born by the 3rd party.

Where strong aesthetic drivers are present and the risk profile allows, a 1.2m fence can be considered, subject to acceptance from Water Corporation.

Fencing at all access points must feature gates that open inwards towards the drain to avoid the need to open them into traffic. Additionally, sufficient area must be provided in front of gates to allow the vehicle to park without being in traffic.

4.7.2 Edge protection

Type E1 edge protection shall be used at locations accessible to only adults and:

- Where a person could fall more than 1.0 metre; or
- Where the slope is steeper than 1V:2.5H; or
- If the surface on which the fall could occur has protrusions or other features to cause injury (e.g. rock armouring); or
- Has a depth of water more than 400mm during normal flow conditions; or
- Has base-flow water flowing at a velocity greater than 0.2m/s.

Type E2 type edge protection shall be used at locations accessible to children where:

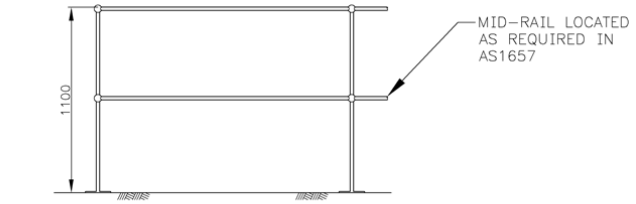
- Type E1 edge protection would otherwise be required; or
- A child could fall more than 400 mm.

For the purposes of determining edge protection requirements, the fall height is not less than the vertical distance between two level surfaces of sufficient width to be considered safe. For example, in the case of a vertical retaining wall on the top of a 1:2 rock armoured bank, the combined heights would be considered the total fall height.

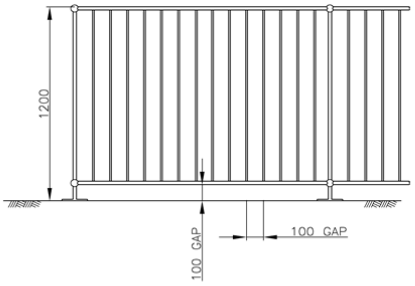
4.7.2.1 Edge Protection Types

Type E1 - This type of edge protection shall include posts top rail, mid rail as per details in AS 1657 but designed to the loading requirements for barriers in AS1170.1. The height from base/floor shall not be less than 1,100mm.

Type E2 - This type of edge protection shall include posts top rail , bottom rail at height 100 mm from the base/floor, vertical members spaced with gaps not exceeding 100 mm as per details in AS 1926.1 and designed to the loading requirements for barriers in AS1170.1 . The height from base/floor shall not be less than 1.2 metres.



TYPE E1
(TOE BOARD NOT SHOWN)



TYPE E2
EDGE PROTECTION

4.7.3 Screens

Screens must be provided on all pipe and culvert inlets. Outlets typically do not require screening, which reduces the risk of a person becoming trapped with an enclosed space. Where a specific site may have an elevated risk of public entry specific into a drain (e.g. adjacent to a playground, evidence of antisocial behaviour, etc), then a risk assessment must be undertaken to determine the overall benefit of an outlet screen. Any potential non-conformance with these requirements must undertake a formal and recorded process, obtaining written acceptance from the Water Corporation Asset Manager after referral to them for an objective risk assessment incorporating all relevant factors, including, but not limited to, operational impacts, flooding, debris loading, drain surroundings and occupational and public safety.

It must be positively verified that all upstream inlets are screened before an outlet screen can be designed/installed.

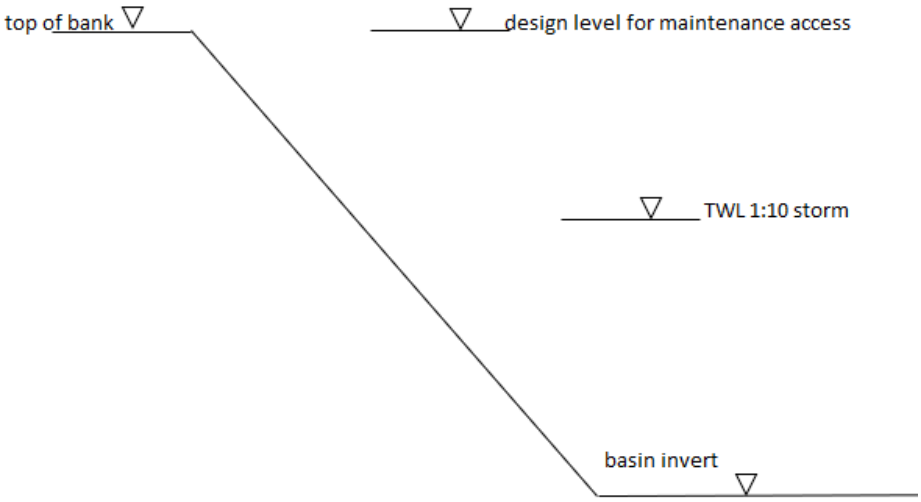
The vertical clear opening between screen bars shall be 150mm.

A clear opening of 150mm must be provided between the base of the screens and the invert of the drain.

Screens shall not be steeper than 45° to the horizontal.

The maximum length of individual screens is 2.5 metres. For larger screening requirements, multiple screens must be designed, each not exceeding 2.5m in length. The design must also include safe access for operational and maintenance purposes for each individual screen (e.g. horizontal working platform). This access must permit emergency operation and maintenance activities (e.g. unblocking a screen) to

be conducted safely from an unflooded location. Note that in the case of a blocked screen, water levels can rise significantly higher than the design top water level. Unless detailed hydraulic assessments conducted on the basis of a fully blocked screen determine a different TWL, then the design must assume water levels can rise to the level of the surrounding floodplain for the purposes of considering where operation and maintenance personnel can access from.



Screens shall not feature crossbars that may interfere with raking activities.

The maximum permitted design flow velocity through the openings of screens is 0.9 metre/second, assuming 50% of the screen is blocked.

The minimum area of openings on screens must be 3 times the area of the pipe/conduit.

Screen structural design must allow for personnel loading as well as hydrodynamic and hydrostatic loadings, including a full screen blockage.

4.7.4 Road Safety

The design must incorporate road safety barriers, bridge delineator signs and all other relevant traffic safety requirements required by either the road owner or Austroads.

4.8 Flow control

The ability to control the water level can often be useful for operation of the drainage network. Where required by Water Corporation, inlet and outlet structures must feature a provision for installation of stop boards. The designer shall specifically get clarification from the Water Corporation whether provision for the installation of stop boards are required.

Design of pipe outlet structures requires that the effects of turbulent flow be minimised by the provision of a combination of:

- A suitable stilling basin to dissipate excess kinetic energy;
- A downstream cut-off wall to prevent damage to the structure by scour;
- Toe protection to protect the adjacent section of drain against scour;
- Provision of an upstream cut-off wall to prevent failure of the structure by "piping" is not normally necessary except in the case of short culverts where there is a large differential head between upstream and downstream discharge levels;

- Control of the velocity acceleration due to drawdown in the upstream channel at a structure shall be considered. A notched inlet weir is the preferred method of control.

4.9 Road Bridges, Access Crossings and Occupational Crossings

4.9.1 General

The requirement of a bridge crossing of an open drain shall be justified by economic comparison with the alternatives such as a culvert.

Bridges shall be at right angles to the drain or natural watercourse.

Levels of roadways at bridges should conform as far as possible with levels of the adjacent roads subject to the requirements for clearance of bridges above water level. Where it is necessary for the road level to rise over a bridge, the grades and vertical curves shall conform to relevant road design practice. On access crossings and occupational crossings a lesser standard can be adopted, but proper approaches with grades and radii appropriate to the expected use shall be provided. The impact on the flow path of the major storm event shall be considered.

4.9.2 Design

All vehicular bridges across drains or natural watercourses shall be designed in accordance with AS 5100- Bridge Design in conjunction with current MRWA or Local Authority requirements.

Where a vehicular bridge is to be located in a road reserve, provision shall be made to separate pedestrian traffic from vehicular traffic. Where a vehicular bridge is to be used for an occupational crossing the minimum trafficable width shall be 2.4 metres.

The provision of pedestrian occupational crossings or walkways across drains or watercourses is subject to agreement between the developer, the Local Authority and the Water Corporation. The design shall provide safe access across the drain as well as adequate waterway to pass the design flow. The minimum width of any pedestrian occupational crossing shall be 1.2 metres.

4.10 Connections

4.10.1 General

Any part of the connection upstream of the drain reserve boundary remains the property of the property owner or the Local Authority. Connection structures within POS (including CB connections) remain the property of the property owner or Local Authority

Any property connected to a drain shall have a maximum of one connection and the number of connections to drains shall be minimised.

Any third party connection to a Water Corporation drain shall be via a section of piped drain and shall be trapped to prevent debris entering the Water Corporation drain. Trapped structures must be located as close as possible, but not within, Water Corporation property and must be downstream of any sources of water ingress. The trapped structure, including the baffle, must be designed to maximise durability and also to facilitate maintenance activities, including but not limited to, debris and sediment removal.

Drains carrying trade waste shall not be connected to a Water Corporation drain. Prevention of accidental overflow to a Water Corporation drain shall be implemented by the Design Engineer. The design shall incorporate any necessary safety features required by the Water Corporation.

Water from swimming pools is considered to be a trade waste.

4.11 Bank Stabilisation

4.11.1 General

Cleared banks must be stabilised using jute matting and planted with suitable native vegetation for banks unless they feature “hard’ engineered scour protection.

For high velocity, large drops, high energy, inlet and outlet structures or significant flow redirection locations, “hard” engineered scour protection is required. This may be in the form of rock armouring, limestone blockwork, reinforced concrete, or concrete panel-and-post structures.

Maximum allowable velocities not requiring “hard” engineered scour protection:

- Non-vegetated banks – 0.5m/s
- Vegetated Banks – 2.0 m/s

Rock armouring must be mortared in locations accessible to the general public to prevent vandalism and/or damming that can result in drainage path redirection.

4.11.2 Bank preparation

Prior to bank treatment, banks must be evenly graded to avoid ridges and depressions to ensure good contact of the bank with matting, and topsoil shall not be respread to avoid reseeding with embedded weeds.

4.11.3 Matting

Biodegradable matting shall be used, plastic or other such materials are not permitted as they have a tendency to eventually degrade into smaller portions that introduce maintenance issues in later years. Matting shall have a density between 600-700 g/m2.

4.11.4 Planting

Planting stabilises the banks, improves aesthetics for the local community, improves water quality and can promote biological controls for pests such as mosquitos. The full extents of the bank are to be planted with native tubestock equally spaced at a density of at least 8 plants per square metre. Holes are to be cut into the jute matting and the seedlings planted so that the rootball is level with or below the underlying soil surface.

Plants selected must be native and suitable for the environment, including proximity of water, inundation and dry/wet cycling profiles.

Commonly used plants include sedges and rushes as follows:

Lower Banks (bottom 1 m):

- Baumea articulata
- Baumea juncea
- Schoenoplectus validus

Upper Banks (1-2.5m):

- Ficinia nodosa
- Juncus pallidus
- Juncus kraussii

4.12 Services Crossing Water Corporation Land

4.12.1 General

Services crossing under Water Corporation land shall have a minimum of 0.75 metre cover unless approved otherwise by the Water Corporation.

Markers shall be provided at the location of all buried and above ground services crossing Water Corporation land.

4.12.2 Location of Markers

Markers shall be located as follows:

- Above any buried service at points of entering or leaving the Water Corporation property;
- Adjacent to any above ground service at points of entering or leaving the Water Corporation property;
- Above all horizontal changes of direction within Water Corporation property; and
- At points along the route at not greater distance than 200 metres between consecutive markers or at any lesser distance when directed by the Water Corporation.

4.12.3 Marker Specification

Where the authority responsible for the service being installed does not have a standard marker, markers shall be similar to that shown in Drawing KA76-1-2 and:

- Be made from incombustible material
- Have legible permanent incombustible wording comprising:
  - (a) The name and phone number of the owner of the service
  - (b) A description of the service
  - (c) The depth of the service below ground level

Details of the markers, their form of construction and the wording to be shown thereon shall be submitted for approval and shall accompany the application for any service to cross Water Corporation property.

Markers shall be oriented to be read from inside Water Corporation property.

5 Design Drawings Criteria

5.1 Drawing Requirements

The drawings shall be prepared in accordance with the Water Corporation's Design Standard DS80.The drawing standards detailed in this Section shall also apply to all Design Drawings and As Constructed Drawings.

Drawings shall have a north point and appropriate scale bars.

Plans and details or sections on drawings shall be oriented so that the direction of flow is from right to left.

Street names and lot boundaries shall be shown along with the lot numbers of all lots affected by the works.

Levels shall be based on the Australian Height Datum (AHD) and shall be shown to the nearest 0.01 m.

Contours shall be to AHD with a maximum interval of 0.5 m for plans to a scale of 1:1000, 1.0 m for plans to a scale of 1:2000 and 2.0 m for plans to a scale of 1:5000.

Batters, slopes and grades shall be given as ratios of vertical distance to horizontal distance with the vertical distance equal to unity.

Pipe grades of 1:50 and steeper shall be shown to the nearest 0.1. Grades flatter than 1:50 shall be shown to the nearest whole number.

The invert levels, sizes, positions and types of existing and proposed works and obstructions shall be shown where applicable.

Existing and proposed works, structure levels, services, existing surface levels and finished surface levels shall be separately identified.

Cut and fill shall be separately identified.

A locality plan shall be included on the drawing where necessary.

All reference drawings and standard drawings relevant to a particular drawing shall be listed on that drawing.

A "Dial Before You Dig" symbol shall be included on all Longitudinal sections, General Arrangements and Site Plans.

A notice certifying that all services have been checked with all the relevant authorities shall be included on a site plan drawing.

Warning notices shall be included on a drawing when applicable

5.2 Locality Plan

The plan shall be similar to Drawing DG16-1-1 and shall be supplied when the longitudinal section for the works is on more than one sheet.

Where a longitudinal section is not required the supply of a separate Locality Plan is optional. However, where a Locality Plan is not supplied, the requirements listed below shall be included on whichever drawing is the most suitable.

The Locality Plan may be combined with the Design Data Plan. The title of the combined drawing shall be Locality Plan and Design Data Plan.

The scale should be 1:5000.

The plan shall be orientated so that the direction of north is straight up the drawing and shall include the following information:

- The routes of existing and proposed drains.
- Drain names and compensating basin names.
- Local Authority boundaries and the names of the relevant Local Authorities.
- The extent of each Longitudinal Section and a reference to the appropriate drawing number.
- A list of all drawings and standard drawings included in the submission, along with their respective plan numbers.

5.3 Design Data Plan

The plan shall be similar to Drawing DG16-1-2.

The Locality Plan may be combined with the Design Data Plan. The title of the combined drawing shall be Locality Plan and Design Data Plan.

The scale should be 1:5000.

The plan shall be orientated so that the direction of north is straight up the drawing.

The plan shall indicate the basis of design for the section of drain being submitted and shall show the following information:

- The routes of existing and proposed main and lateral drains and the boundary of the areas served by the section of drain.
- Ground level data showing:
  - (a) Contours of the existing natural surface.
  - (b) The extent, level and contours (separately identified) of any proposed cut or fill.
  - (c) Surface levels at all significant low points within sub catchments.
  - (d) Ground water levels at relevant locations and the estimated maximum ground water level contours if available.
- Street names, lot boundaries and lot numbers.
- Residential and non-residential areas defined separately.
- Boundaries of each of the internal sub catchments included in the catchment area (which shall be separately identified) and their areas and runoff coefficients.
- Flow direction and volume indicated by an arrowhead on the drain line and a number giving the flow in litres per second at:
  - (a) Relevant design points. (Points of confluence or interest).
  - (b) Entry points for all gravity flows originating in the overall catchment but outside the area being designed.
  - (c) Entry points for all pumped flows entering the area being designed.

The following attachments shall be provided with the design data plan where applicable.

- For all compensating basins, an attachment containing the following design data:
  - (a) The design method
  - (b) For basins:

A	Area of Catchment (ha)

C	Weighted Coefficient of Runoff
S10	10 Year Storage Capacity Required (m3)
S100	100 Year Storage Capacity Required (m3)
TWL10	10 Year Top Water Level (m AHD)
TWL100	100 Year Top Water Level (m AHD)
LWL	Low Water Level (m AHD)
WSA	Normal Water Surface Area (m2)
CGL	Control Groundwater Level (m AHD)

(c) Time of Concentration

(d) Runoff Coefficients

(e) Groundwater assumptions

(f) Actual Storage Volume to Design TWL (Sa)(m3)

(g) Inflow (controlled or uncontrolled) (L/s)

(h) Information on any outlet control device

(i) Open drains not to be piped

(j) Upstream Local Authority Compensating Basins to be retained

(k) Soakage rate assumption

(l) Extreme storm event comments (e.g. For 100 year storm event the Main Drain will surcharge at certain locations, upstream and downstream of compensating basins, hence TWL100 should be reassessed for artificial compensation)

(m) Extent of vegetation plantings (e.g. reed beds) within the basin

- For relevant design points, (points of confluence or interest), an attachment containing the following design data:

(a) The design method

A	Area of Catchment (ha)
C	Weighted Coefficient of Runoff
S10	10 Year Storage Capacity Required (m3)
S100	100 Year Storage Capacity Required (m3)
TWL10	10 Year Top Water Level (AHD)
TWL100	100 Year Top Water Level (m AHD)
LWL	Low Water Level (m AHD)
CGL	Control Groundwater Level (m AHD)

(b) Time of Concentration

(c) Runoff Coefficients

- For the entry points of all gravity flows entering the area being designed from within the overall catchment, an attachment containing the following design data:

(a) The design method

A	Area of Catchment (ha)
C	Weighted Coefficient of Runoff
Q	Total Design Discharge (L/s)
S10	10 Year Storage Capacity Required (m3)
S100	100 Year Storage Capacity Required (m3)
TWL10	10 Year Top Water Level (AHD)
TWL100	100 Year Top Water Level (m AHD)
LWL	Low Water Level (m AHD)
CGL	Control Groundwater Level (m AHD)

(b) Time of Concentration

(c) Runoff Coefficients

- An attachment, for the entry points of all pumped flows entering the area being designed, containing the following design data:

A	Area of Catchment (ha)
As	Area of Sub catchment (ha)
C	Weighted Coefficient of Runoff
P	Pump Rate (L\s)

5.4 Major Event Plan

The plan shall be similar to Drawing DG16-1-3.

The scale should be 1:1000 or 1:2000.

The plan shall be orientated so that the direction of north is straight up the drawing.

The plan shall summarise the design parameters, assumptions and calculations for a one in one hundred year storm event.

The plan shall show the route, and where property other than road or drainage reserves are affected, the extent of the flow paths for the major event.

The plan shall show the area flooded during a major event.

The plan shall show ground level data including:-

- Contours of the existing natural surface.
- The extent, level and contours (separately identified) of any proposed cut or fill.
- Finished spot heights along the centreline of the flow path.
- Street names, lot boundaries and lot numbers where lots are within the flow path or area flooded.
- At relevant points on major flow paths, the direction of flow indicated by an arrowhead in the flow path, the quantity of flow in m^3/s, the velocity in m/s and the estimated flood levels. For a compensating basin or low point the estimated flood level and the volume stored in m3.
- The outline and floor level of affected buildings and recommended minimum floor levels for future buildings.

5.5 Longitudinal Section

The drawing shall be similar to Drawing DG16-2-1.

The scales should be 1:1000 horizontal and 1:100 vertical.

Distances and open drain base widths shall be in metres to the nearest 0.1m. Pipe, box culvert and other conduit sizes shall be in millimetres.

Batters, slopes and grades shall be given as ratios of vertical distance to horizontal distance with the vertical distance equal to unity.

The drawing shall include a plan covering the relevant section of drain and a longitudinal section of the drain through the intersection points of all bends.

The plan shall be oriented so that the downstream end of the drain is on the left hand side of the drawing and shall show:-

- Existing and proposed drains.
- Drain alignments and position of access chambers and structures.
- Street names, lot boundaries, lot numbers and structure numbers.
- The direction of north.
- Details of the existing drain to which the proposed drain will be connected.
- Reserve and easement boundaries and dimensions where applicable.
- All existing and proposed services and obstructions shall be shown and described.

The longitudinal section shall have a Datum line related to AHD and shall be orientated so that the downstream end of the section is on the left hand side of the drawing.

The information shown below the Datum Line in tabular form on the longitudinal section, and where applicable plotted on the section itself, shall include:

- The running distance in metres with the lowest distance on the left. Distances at structures are at pipe ends or at inside structure faces.
- The natural surface level.
- The finished surface level where it differs from the natural surface level.
- The existing invert, when applicable.
- The designed invert.
- The Hydraulic Grade Line for the design storm event.
- The Hydraulic Grade Line for the 1 in 100 year storm event.

The section itself shall be plotted to scale above the Datum line and shall depict:

- Existing and proposed surface levels.
- Existing and proposed inverts and crowns of all conduits.
- Existing and proposed services and obstructions.
- Existing and proposed connecting drains.
- The Hydraulic Grade Line for the design storm event.
- The Hydraulic Grade Line for the one in one hundred year storm event.
- Cut or fill.

Shown above the longitudinal section in dimension form shall be the following information:-

- The location of the drain.
- The pipe (or box culvert) size, type, class and grade shown above the dimension line and the joint type (for Reinforced Concrete Pipes) shown below the dimension line.
- A notation indicating where a particular type of pipe material is mandatory.
- Open channel base width, side slope and grade.
- The design flow and velocity for each section of drain
- A statement detailing the design basis of the drain.

The following information shall be shown above the dimension lines referred to in the preceding clause:-

- Structure type and number and a reference to the drawing detailing that structure.
- The diameter, invert level and direction of any connection.
- The angle of any bends in a pipe or open drain not at an access chamber or structure.

Where a pipe drain consists of multiple pipes or conduits, or the pipe has special bedding a typical cross section shall be drawn.

Where an open drain or channel is lined, or is in fill, or has side slopes with more than one batter a typical cross section shall be drawn.

5.6 Access Chambers, Splay Bends, Junctions and Intersecting Services

5.6.1 Access chambers

For all access chambers fitting the standards, a detailed arrangement to a minimum scale of 1:25 shall be provided. The arrangement shall be similar to those shown on Drawing DG16-8-1 and shall include the following:

- A plan of the access chamber showing the type of construction, the location of the corbel slab opening.
- The location, size, class and invert level (to the nearest 0.1m) of all pipes and the intersection of their centre lines at a common point known as the IP (intersection point). For straight through access chambers with no inlets the centre of the access chamber can be taken as the IP.
- The IP located with respect to cadastral boundaries and the access chamber dimensioned about the IP.
- The location of the access chamber cover relevant to cadastral boundaries.
- The Access Chamber Number, number of corbel slab, type of cover and any necessary surround.

- The proposed top of cover level.

5.6.2 Splay Bends

For all splay bends, a detailed arrangement to a minimum scale of 1:25 shall be provided. The arrangement shall be similar to that shown on Drawing DG16-8-1 and shall show pipe size and class, drain centreline, the offsets from cadastral boundaries, the IP (intersection point) and the angle of the bend.

A detail of each type of splay cut pipe (or box culvert) shall be provided.

For elliptically reinforced drainage pipes, top of pipe shall be clearly indicated on any detail of a splay cut pipe.

5.6.3 Intersecting Services

Where other services intersect a drain a minimum of a plan and two views or sections shall be provided.

5.7 Structures

The preferred scale is 1:25.

The structure number shall be included in the title block and under each plan where more than one structure is included on the drawing.

Structures shall be drawn to scale, fully dimensioned and located with reference to cadastral boundaries.

A minimum of a plan and two views or sections are required.

Earthworks, fill, backfill, surface drainage, bank treatment and bank protection shall be specified or detailed.

Construction materials, reinforcement, protective coatings on steel components, foundations, compaction, concrete curing and formwork shall be specified.

Screens, gratings, stop boards and weepholes shall be detailed where applicable.

Any bridge, access way, occupational crossing shall be treated as a structure. Any connection which is not covered by a standard drawing shall be treated as a structure.

5.8 Compensating Basins

The preferred scale is 1:250. The minimum scale is 1:1000.

A minimum of a plan and one section shall be provided.

Compensating basins shall be drawn to scale with the plan orientated so that the direction of flow is from right to left. The following shall be complied with:-

Adequate information for setting out the excavations shall be provided.

All pipes and structures shall be fully located. Banks, channels and subsoil drains shall be detailed and dimensioned.

Top water level and low water level shall be specified.

The Control Groundwater Level (CGL) for the site shall be included on the drawing.

Existing and proposed surface levels shall be shown and any earthworks, surface drainage, bank treatment and protection, fencing and maintenance access shall be clearly specified.

The design data for compensating basin as shown in Clause 7.4 of this section shall be included on the drawing.

Staged construction shall be indicated where applicable.

The path and estimated water level for the design of major "event" shall be indicated on the drawing.

Where the basin is required to provide a nutrient stripping function, the plan shall be detailed to show the requirements of that function.

The extent of any vegetation to be planted within the basin shall be included on the drawing.

5.9 Open Drains and Natural Watercourses

The preferred scales are from 1:25 to 1:250. The minimum scale is 1:1000.

Details are required of:

- Fencing.
- Protection of existing flora.
- Berm drainage.
- Earthworks, levees and surface drainage connections through levees (including details or specification of flap gate installation).
- Bank and toe protection.
- Extents of planted vegetation (including reed beds, fringing vegetation and riffle zone vegetation) required for water quality management purposes.

5.10 Pump Stations

Wherever practical, drainage pump stations are to be designed in accordance with the principles outlined in DS51 (*The Design and Construction of Wastewater Pumping Stations and Pressure Mains 4.5 to 180 Litres Per Second Capacity*). Departures from DS51 may be required due to differences between drainage and wastewater (e.g. debris, pipe sizes, flowrates, set-points, etc), however any such departures must be necessary and must also be accepted by the Senior Principal Water Conveyance Engineer, of Engineering Branch).

6 Glossary

In the standard the following words, expressions and abbreviations shall have the meanings or interpretations assigned to them below and do not necessarily apply to the meanings or interpretations given in any relevant legislation or other Water Corporation publications.

Access Chamber	A chamber constructed in a piped drainage system in which a person can enter to inspect or maintain the drain
AHD	Australian Height Datum
AMG	Australian Mapping Grid
AEP	Annual Exceedance Probability
Area Served	The area served by a section of drain is the area from which water flows or can be made to flow to the section of drain concerned
ARI	Average Recurrence Interval
ARR16	Australian Rainfall & Runoff, 2016 Revision
ARRB	Australian Road Research Board
Arterial Drain	An arterial drain is an existing or proposed conduit or channel, whether nature or constructed, which is essential to the safe discharge of surplus stormwater, now or in the future. It is a planned drainage facility which, if limited or restricted by land use developments, would result in significant storm flow damage to existing or future residential or commercial property development, or have social and/or environmental consequences for a community if not adequately managed or maintained. * All Water Corporation main drains are Arterial Drains or portions of Arterial Drains * A drain or drainage course becomes an Arterial Drain when designated as such by the Department of Water & Environmental Regulation (DWER), acknowledged by the responsible Local Authority and is shown on the Arterial Drainage Scheme Plan compiled by the DWER * An Arterial Drain is not necessarily controlled by the Water Corporation but may be comprised wholly or partially of drains for which Local Authorities or other bodies are responsible
Arterial Drainage Scheme	The arterial drainage scheme is a legislative responsibility of the DWER whereby, practical and economic provision is made, by, on behalf of, or in consultation with, the DWER the planning, management, maintenance, financing extending and improving of drainage services to serve the Perth Metropolitan Scheme Area
Arterial Drainage Scheme Plan	The arterial drainage scheme plan is a document compiled by the DWER and amended and reviewed from time to time to show the essential components of the Scheme including: * Drainage catchments

	* Lakes, swamps, wetlands, watercourses and other features related to natural drainage * Areas of existing, proposed and potential development * The major components of the existing drainage systems identifying arterial drains and differentiating as to the kinds of drains * Declared drainage courses * The major components of the proposed drainage systems identifying arterial drains and differentiating as to the kinds of drains and the persons or bodies to be liable for the provision and maintenance of that drainage * Land subject to a charge and land likely to be subject to a charge (existing or proposed Drainage Areas) by the Water Corporation for main drainage
Australian Height Datum	Australian height datum is the datum that shall be used for all levels included in any submission to the Water Corporation
Biotic	Relating to living things or to biological matter
Branch Drain	See Main Drain
Baseflow Channel	A channel at the base of the drain that is only exceeded ten times per year, on average.
Catchment	The catchment of a drain or section of drain is the area of land from which water flows or can be made to flow to a main drain or pumping station by gravity drains
CB	Compensating Basin
Compensating Basin	A compensating basin is a drainage structure or feature that is designed to delay the passage of stormwater by providing surcharge storage
Concept (conceptual) plan	A preliminary plan of a development or proposed works showing general elements only and how they inter-relate. Is usually a precursor to more detailed planning and/or design
Conduit	A conduit is a pipe, tunnel or artificial channel above, on or under the ground used or intended to be used for the conveyance of surplus water.
Connection	A connection is the structure or fitting by or at which a non Water Corporation drain is connected to a main drain
CGL	Control Groundwater Level determined following the requirements of the DWER. Values used for CGL shall be to the approval of the DWER.
DWER	Department of Water and Environmental Regulation in Western Australia
Design Engineer	The Engineer or Engineering firm appointed by the Principal to design a drainage system for submission to the Water Corporation
Design Event	See Minor event

Detention basin	A compensating basin – a drainage structure or feature that is designed to delay the passage of stormwater by providing surcharge storage
Developer	The person or organization that has made an arrangement with the Water Corporation to provide drainage infrastructure
Developers Manual	A manual published by the Water Corporation
Development	Proposed works that will alter the pre-existing natural or built environment
Distance between access chambers	The distance between access chambers is the horizontal length between the intersection points of drains at access chambers or the centre points of straight through access chambers measured through the intersection points of any intermediate bends
Drain	A drain is a conduit that may be used permanently or intermittently or a watercourse or other natural channel, used or intended to be used for the removal of surplus storm water or for the diversion of water that might flow onto any land and includes compensating basins structures and other appurtenances used in connection with such a conduit
Drainage Area	A Drainage Area is an area of land in the State of Western Australia declared by legislation to be a drainage area
Drop Structure	A drop structure is a structure provided on an open drain or channel that achieves an immediate or sudden or local drop in the invert level of that drain or channel
Edge Protection	Edge protection is used to reduce the risk of fall of a person from one level to another.
Engineer	A person qualified to be a Chartered Professional Engineer and who has appropriate engineering experience
Engineering firm	An organization which has in its employment an Engineer
Floodway	The floodway of an open drain or a landscaped open drain is that part of the waterway required to carry the stormwater when the capacity of the base flow channel or low flow pipe is exceeded
Freeboard	The freeboard for any particular section of drain is the vertical distance from the lowest natural surface level at that section to the design top water level at that section
FRP	Fibre Reinforced Polymer
Gauging weir	A gauging weir is a structure provided on a channel that is fitted with a gauge and a means of measuring the flow in that channel
Greenbelt	A relatively wide strip of undeveloped, reserved land in an urban area that acts as a barrier or provides a break to unrestricted urban expansion
Groundwater	Water that occupies the pores and cavities within the soil and rocks of the earth's surface. Bouwer[1] states that not all underground water is

	groundwater. Groundwater has a pressure that is greater than atmospheric pressure – it will flow freely into a hole exposed to atmospheric pressure.
HGL	Hydraulic Grade Line
IFD	Intensity Frequency Duration
IL	Invert Level
IPWEA	Institute of Public Works Engineering Australia
Industrial waste	Industrial wastes include all waterborne waste, discharged from an industrial process or other waterborne waste except waste of the kind and quality ordinarily discharged from residential premises.
Inlet structure	An inlet structure is a structure provided at the upstream end of a conduit, pipe drain or culvert.
Invert level	The invert level is the lowest level of a drain at any particular cross section
IP	Intersection Point
Junction	A junction is a fitting provided in a conduit or pipe drain to allow for the connection of a lateral drain
Landscaped natural watercourse	A landscaped natural watercourse when used as a Water Corporation Main Drain consists of a natural watercourse that is combined with a grassed floodway to dispose of the runoff of flows from storms greater than the minor design storm event
Landscaped open drain	A landscaped open drain when used as a Water Corporation Main Drain is an unfenced publicly accessible open drain that comprises a landscaped floodway and an incorporated base flow channel flow pipe
Lateral drain	A lateral drain is any stormwater drain, that is not controlled by the Water Corporation, which is connected to a main rain
LWL	Low Water Level
Main Drain	A main drain is an existing or proposed drain within the Metropolitan Area that is declared under legislation and controlled by the Water Corporation. Any Branch Drain that has been declared as above is also a Main Drain.
Major event	A major event is a large magnitude storm during which stormwater flows exceed the designated level of service capacity of any part of a drainage system operated by the Water Corporation and the resulting stormwater overflow has the potential for damage to life or property
Major system	ARR16 defines the major drainage system as the many planned and unplanned drainage routes which convey runoff arising from major storms. The major drainage system generally follows the natural pattern, sometimes causing damage along the way.

Metropolitan Area	The Metropolitan Area is the area encompassed by the boundary of the Perth Metropolitan Region Planning Scheme.
MH or AC	Access chamber
Minor event	The maximum storm event that is required to not overflow or breach the designated freeboard of the drainage infrastructure, as defined in the Water Corporation's Licence
Minor system	ARR16 defines the minor drainage system as the gutter and pipe network capable of carrying runoff from minor storms. The routes of minor systems may differ from the natural drainage path, to conform with street layouts and other obstructions
MRWA	Main Roads Western Australia
Outlet structure	An outlet structure is a structure provided at the downstream end of a conduit or pipe drain
PAW	Pedestrian Access Way
Pollution	Pollution is the addition to or concentration in the environment, by direct or indirect means, or any dangerous, injurious or obnoxious substance, whether solid or liquid or gaseous
POS	Public Open Space
Predevelopment conditions	Conditions that prevail prior to a development
Principal	The person, organization, Local Authority or Government Authority responsible for funding the construction of a main drainage scheme
Property drain	A property drain is a drain that connects a property to a main drain or a lateral drain. (A property drain is also a lateral drain)
Proponent	A key stakeholder in the process of land development or development of proposed works. The proponent is usually the initiator of a particular proposal (cf. service provider, approval agencies). The proponent may be a person, Local Authority, Government Authority, agency or organisation (including the Water Corporation) that proposes a scheme to be implemented. The proponent is generally responsible for stewardship of development of the scheme.
Runoff	Stormwater that exceeds interception losses and "runs off" into the drainage system
Sedges	Plants of the family *Cyperaceae,* mostly herbs (plants which do not produce a woody stem), can be tall and grass-like (such as papyrus) common to damp habitats and wetlands
Shall	Shall refers to a mandatory requirement

Should	Should, refers to a requirement to be adopted unless otherwise accepted by the Water Corporation EBU Advisory team.
Siltation	Accumulation of sediments deposited by moving water
Stakeholders	Any person, organization, landowner, agency or authority that will be affected by or has a significant interest in the outcomes of a development
Steep sided	A slope that is geologically and structurally stable, but does not make suitable allowances for access, operational and maintenance activities. Slopes steeper than 1V:6H automatically classify as steep sided.
Structure plan	A broad development plan which generally forms the basis of an application for rezoning of land. Describes how the land is to be allocated between various uses and how the various services (roads, drainage, etc) are to be provided
Surplus water	Surplus water is storm water, surface water or underground water which accumulates or may accumulate to the detriment or disadvantage of any person or property
Swale	A natural swale is a linear depression formed by wind erosion or by the build up of ridges either side of an area of land. Swale drains are shallow depressions or channels of linear form with gentle side slopes used for collecting, treating and transporting stormwater runoff.
TWL	Top Water Level
WAPC	Western Australian Planning Commission
Waste	Waste includes any matter or thing of whatever kind or in whatever form that if discharged, causes or is likely to cause pollution and also includes any matter or thing described in the bylaws to be waste.
Water Corporation	Water Corporation is the body corporate known as the Water Corporation of Western Australia
Water Sensitive Urban Design	Water Sensitive Design is a design philosophy and techniques which aim to harmonise urbanization and effective water resource management: * to reduce changes to natural water balances that affect aquifer recharge and wetland ecology, * to protect groundwater, surface waterways and wetlands from urban pollution, * to promote urban forms that encourage water conservation
Works	Works are defined as any physical activity carried out to construct, operate, maintain or remove any structure or asset of a main drainage system
WSUD	Water Sensitive Urban Design

Zone of construction	Zone of construction is the cross section of earth about the centreline of a main drain that is deemed to be disturbed during the construction of that main drain

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