



Stormwater management manual for Western Australia

Chapter 11 Further information



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Preface

A growing public awareness of environmental issues in recent times has elevated water issues to the forefront of public debate in Australia.

Stormwater is water flowing over ground or built-up surfaces and in natural streams and drains, as a direct result of rainfall over a catchment (ARMCANZ and ANZECC 2000). Stormwater consists of rainfall runoff and any material (soluble or insoluble) mobilised in its path of flow. Stormwater management examines how the runoff quantity, and these pollutants, can best be managed from source to the receiving water bodies using the range of management practices available.

In Western Australia (WA), where there is a superficial aquifer, drainage channels can commonly include both stormwater from surface runoff and groundwater that has been deliberately intercepted by drains installed to manage seasonal peak groundwater levels. Stormwater management is unique in WA as both stormwater and groundwater may need to be managed concurrently.

Rainwater has the potential to recharge the superficial aquifer, either before runoff starts or throughout the runoff's journey in the catchment. Urban stormwater on the Swan Coastal Plain is an important source of recharge to shallow groundwater, which supports consumptive use and groundwater-dependent ecosystems.

With urban, commercial or industrial development, the area of impervious surfaces within a catchment can increase dramatically. Densely developed inner-urban areas are almost completely impervious, which means less infiltration, the potential for more local runoff and a greater risk of pollution. Loss of vegetation also reduces the amount of rainfall leaving the system through the evapo-transpiration process. Traditional drainage systems have been designed to minimise local flooding by providing quick conveyance for runoff to waterways or basins. However, this almost invariably has negative environmental effects.

This manual presents a new comprehensive approach to management of stormwater in WA, based on the principle that stormwater is a resource – with social, environmental and economic opportunities. The community's current environmental awareness and recent water restrictions are influencing a change from stormwater being seen as a waste product with a cost, to a resource with a value. Stormwater management aims to build on the traditional objective of local flood protection by having multiple outcomes, including improved water quality management, protecting ecosystems and providing livable and attractive communities.

This manual provides coordinated guidance to developers, environmental consultants, environmental/community groups, industry, local government, water resource suppliers and State Government departments and agencies on current best management principles for stormwater management.

It is intended that the manual will undergo continuous development and review. As part of this process, any feedback on the series is welcomed and may be directed to the Urban Water Branch of the Department of Water and Environment Regulation at urbanwater.enquiry@dwer.wa.gov.au

Western Australian stormwater management objectives

Water quality

To maintain or improve the surface and groundwater quality within the development areas relative to pre-development conditions.

Water quantity

To maintain the total water cycle balance within development areas relative to the pre-development conditions.

Water conservation

To maximise the reuse of stormwater.

Ecosystem health

To retain natural drainage systems and protect ecosystem health.

Economic viability

To implement stormwater management systems that are economically viable in the long term.

Public health

To minimise the public risk, including risk of injury or loss of life, to the community.

Protection of property

To protect the built environment from flooding and waterlogging.

Social values

To ensure that social, aesthetic and cultural values are recognised and maintained when managing stormwater.

Development

To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

Western Australian stormwater management principles

- Incorporate water resource issues as early as possible in the land use planning process.
- Address water resource issues at the catchment and sub-catchment level.
- Ensure stormwater management is part of total water cycle and natural resource management.
- Define stormwater quality management objectives in relation to the sustainability of the receiving environment.
- Determine stormwater management objectives through adequate and appropriate community consultation and involvement.
- Ensure stormwater management planning is precautionary, recognises inter-generational equity, conservation of biodiversity and ecological integrity.
- Recognise stormwater as a valuable resource and ensure its protection, conservation and reuse.
- Recognise the need for site specific solutions and implement appropriate non-structural and structural solutions.

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Introduction

This chapter provides a glossary of terms used in the manual and some useful contacts, websites and references for more information.

Glossary

- **Adaptive environmental management:** A type of environmental management where the approach to managing water resources in urban areas will evolve over time as new ideas, information, drivers for change and technologies emerge.
- **Adsorption:** The adhesion of a substance to the surface of a solid or liquid; often used to extract contaminants by causing them to be attached to adsorbents such as activated carbon or silica gel. Hydrophobic or water repulsing adsorbents are used to extract oil from waterways when oil spills occur. Heavy metals such as zinc and lead and nutrients such as phosphorus often adsorb onto sediment.
- **Aeration:** The injection of air through diffusers into water bodies, or rapid mixing (e.g. via riffles) of the surface of water bodies to promote transfer of atmospheric air into the water column. A treatment process adopted in situations of high loading of oxygen demanding substances. (ARMCANZ & ANZECC 2000.)
- **Aerobic or oxic zone:** An environment in which there is free oxygen (ARMCANZ & ANZECC 2000).
- **Annual exceedance probability (AEP):** The probability or likelihood of an event occurring or being exceeded within any given year, usually expressed as a percentage.
- **Anaerobic or anoxic zone:** An environment devoid of oxygen (ARMCANZ & ANZECC 2000).
- **Aquifer:** A geological formation or group of formations capable of receiving, storing and transmitting significant quantities of water (Water and Rivers Commission 2000a).
- **Armouring or stabilisation:** The use of rock, geotextile and/or vegetation to bind the soil forming the bank or bed of channels such as to resist erosion by elevated flow velocities (ARMCANZ & ANZECC 2000).
- **Atmospheric deposition:** Contaminants accumulating across urban surfaces as a result of deposition of fine airborne solids (ARMCANZ & ANZECC 2000).
- **At-source controls:** Non-structural or structural best management practices implemented at the site where stormwater runoff is created, to minimise the generation of excessive stormwater runoff and/or pollution of stormwater.
- **Attenuation:** The reduction in the magnitude of flows, concentrations or loads of contaminants (ARMCANZ & ANZECC 2000).
- **Average recurrence interval (ARI):** ARI is defined as the average, or expected, value of the periods between exceedances of a given rainfall total accumulated over a given duration (former terminology, recommended to discontinuing its use) ARI events can be grouped into:
 - Small: Less than and up to 1 year ARI events ($x < 1$ year ARI events).
 - Minor: Greater than 1 year and less than 10 year ARI events ($1 \text{ year} < x < 10$ year ARI events).
 - Major: 10 year to 100 year ARI events (10–100 year ARI events).
 - Extreme: Greater than 100 year ARI events ($x > 100$ year ARI events).

- **Bankfull flow:** The dominant channel forming discharge (Water and Rivers Commission 2001). The flow rate at which a channel is filled from bank to bank. The frequency of bankfull conditions is commonly adopted as the criterion for maintaining the channel cross-section and freedom from sedimentation in the longer term. This frequency will vary according to climatic regions (ARMCANZ & ANZECC 2000), but usually occurs once every 1.5 years (or about 50% AEP).
- **Bank stabilisation:** See ‘armouring or stabilisation’.
- **Baseflow:** The underlying flow rate that cannot be directly attributed to storm events (ARMCANZ and ANZECC 2000). The part of the total flow in a water body derived from groundwater discharge (Department of Environment 2003).
- **Best management practices (BMPs):** Devices, practices or methods for removing, reducing, retarding or preventing targeted stormwater runoff constituents, pollutants and contaminants from reaching receiving waters (Taylor & Wong 2002) and for reducing the volume of stormwater runoff.
- **Biochemical oxygen demand (BOD):** The oxygen consumption (respiration) resulting from bacterial breakdown of organic material, or as a result of some inorganic oxygen reducing species (ammonia) (ARMCANZ and ANZECC 2000).
- **Biodiversity:** The variability among living organisms from all sources (including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part) and the diversity within and between species and of ecosystems (ARMCANZ and ANZECC 2000).
- **Biofilm:** A gelatinous sheath of algae and micro-organisms, including benthic algae and bacteria, formed on surfaces such as gravel, sediment and plants (ARMCANZ and ANZECC 2000).
- **Bioretention:** A stormwater management device that consists of an excavated basin or trench that is filled with porous media and planted with vegetation.
- **Bore:** A narrow, lined hole drilled to withdraw or monitor groundwater.
- **Brownfield:** Areas of land that have been developed into urban land uses.
- **Buffer strip:** Areas of vegetation through which runoff passes while travelling to a discharge point and which are therefore aligned perpendicular to the direction of flow.
- **Capacity building program:** A holistic approach to knowledge building and transfer, which fosters skill development, competency, innovation and confidence. It is also a means to facilitate network building, linkages and training for continuous improvement.
- **Catchment:** A topographically defined area draining surface water to a single outlet point.
- **Channel:** The bed and banks of a stream or constructed drain (ARMCANZ and ANZECC 2000) that carries all flows except floods.
- **Clay:** A fine-grained mineral soil consisting of particles less than 0.002 mm in equivalent diameter (Charman and Murphy 1991).
- **Colloids:** Fine abiotic and biotic particles of typically 0.1 µm to 1 nm in diameter (ARMCANZ and ANZECC 2000).
- **Compaction:** Any process whereby the density of soils is increased. This process results in lower permeability and poorer soil aeration. Charman and Murphy 1991
- **Constructed wetland:** A vegetated detention area designed and built to remove contaminants from stormwater runoff, but which can also provide secondary benefits of habitat enhancement/creation and

active and passive recreational and educational opportunities.

- **Contaminant:** In relation to land, water or a site, means having a substance present in or on that land, water or site at above background concentrations that presents, or has the potential to present, a risk of harm to human health, the environment or any environmental value (Contaminated Sites Act 2003).
- **Controlled groundwater level (CGL):** The controlled (i.e. modified) groundwater level (measured in metres Australian Height Datum) at which drainage inverts are set.
- **Conveyance systems:** A mechanism for transporting stormwater from one point to another, including swales, bioretention systems, living streams, pipes and channels.
- **Denitrification:** The reduction of nitrate or nitrite to nitrogen gas, in the absence of oxygen (ARMCANZ ANZECC 2000).
- **Detention/detain:** The process of reducing the rate of off-site stormwater discharge by temporarily holding rainfall runoff (up to the design rainfall event) and then releasing it slowly, to reduce the impact on downstream water bodies and to attenuate urban runoff peaks for flood protection of downstream areas.
- **Detention (ephemeral/dry) basins:** Areas, usually landscaped, formed by simple dam walls, by excavation below ground level or by utilisation or enhancement of natural swales or depressions, designed to temporarily detain stormwater to attenuate peak flows downstream to acceptable levels.
- **Detention time:** The theoretical time required to displace the contents of a stormwater treatment facility at a given rate of discharge (volume divided by rate of discharge).
- **Directly connected impervious surface:** An impervious surface connected directly to a receiving water body via a hydraulically efficient conveyance device (e.g. pipes or constructed drains/channels).
- **Discharge:** The rate at which a volume of water passes through a cross section in a unit of time (Water and Rivers Commission 2000b).
- **Dissolved fraction:** The part of a water sample passing through a 0.45 µm pore size filter paper. It will include both a truly dissolved and colloidal material fraction (ARMCANZ and ANZECC 2000).
- **Drainage network:** The system of channels and pipes and overland flow pathways which drain a catchment area (ARMCANZ and ANZECC 2000).
- **Drainage water:** Consists of stormwater runoff and/or shallow groundwater that has been intercepted by drains.
- **Ecological values:** Particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health and economic activities, and which require protection from the effects of pollution, waste discharges and deposits (ARMCANZ and ANZECC 2000) and from the effects of altered water regimes.
- **Ecological water requirements (EWRs):** The water regimes needed to maintain ecological values of water dependent ecosystems at a low level of risk (Water and Rivers Commission 2000a). Also see ‘environmental water provisions’.
- **Economic values:** Includes water body uses, stormwater use, economic values of the receiving environment (e.g. fishing and tourism), values of land used for stormwater management and values of land adjacent to stormwater management devices.
- **Education and participation program:** One of the five principal categories of non-structural BMPs for stormwater management. Examples include training programs and involving the community in the

development and implementation of stormwater management plans.

- **Effective imperviousness:** The combined effect of the proportion of constructed impervious surfaces in the catchment, and the connectivity of these impervious surfaces to receiving water bodies (adapted from Walsh et al. 2004).
- **Effectiveness:** The extent to which project outcomes (see ‘outcomes’) are achieving project objectives (Bullen undated).
- **Efficiency:** The extent to which project outputs (see ‘outputs’) are maximised for the given level of inputs. Efficiency is concerned with the processes (activities/strategies/operations) by which the project is delivered and which produce the outputs of the projects. BMP Efficiency: Measures how well a BMP or BMP system removes or controls contaminants. Although ‘per cent removal’ is the most common form of expressing BMP efficiency (when used alone), it is a poor measure of BMP efficiency compared with alternatives such as the ‘effluent probability method’ (US EPA 2002; Taylor & Wong 2003).
- **Effluent:** Sanitary, industrial or agricultural discharge from wastewater treatment plants or treatment lagoons (ARMCANZ and ANZECC 2000).
- **Environmental management systems (EMS):** Part of the management system used to manage environmental aspects, fulfil compliance obligations, and address risks and opportunities.
- **Environmental water provisions (EWPs):** The water regimes that are provided as a result of the water allocation decision-making process taking into account ecological, social and economic impacts. They may meet in part or in full the ecological water requirements (Water and Rivers Commission 2000a). See ‘ecological water requirements’.
- **Erosion:** The process by which the land surface is detached and transported away by the action of water, wind, ice or gravity.
- **Evaluation:** A periodic but comprehensive assessment of the overall progress and worth of a project (Woodhill & Robins 1998). The term used for final assessment of whether a BMP has achieved its pre-defined objectives.
- **Event:** A single precipitation and associated runoff occurrence (ARMCANZ and ANZECC 2000).
- **Event mean concentration:** The average concentration of a contaminant over the period of an event discharge. It is normally determined by the sum of the concentrations (for multiple samples taken during the period of the event discharge) multiplied by the flow weighted volume of the sample, divided by the cumulative volume of the samples (ARMCANZ and ANZECC 2000).
- **Exceedances per year (EY):** The number of times an event is likely to occur or be exceeded within any given year.
- **Filter:** A layer of granular material designed to intercept fine particulate material. It may be used as part of a subsoil drain, or as a structure to treat surface runoff prior to recharge to groundwater or discharge to a drain (ARMCANZ and ANZECC 2000).
- **Filter strip:** See ‘buffer strip’.
- **First flush:** Describes situations when contaminants (e.g. sediments) that have accumulated on impervious surfaces are transported at the beginning of a rainfall event. This results in high pollution concentrations at the start of the runoff hydrograph, reducing to lower levels before the flood peak occurs (Argue 2004).
- **Flashiness:** Where water levels rapidly peak and decline.

- **Floodplain:** The portion of a waterway valley next to the channel which is covered with water when the waterway overflows its banks during major flow events (Water and Rivers Commission 2000c).
- **Freeboard:** The distance between the maximum water surface elevations anticipated in design and the top of retaining banks or structures. Freeboard is provided to prevent overtopping due to unforeseen conditions, and/or events greater than the maximum design event of the structure.
- **Frequency:** See ‘average recurrence interval’.
- **Geomorphology:** Of, or relating to, the forms of the earth’s surface and the processes associated with them (e.g. erosion, weathering, transport and deposition) (Water and Rivers Commission 2002).
- **Geotextile:** A thin, flexible permeable sheet of synthetic material used to allow the transmission of water through the pores of the material, while preventing the transmission of soil particles (ARMCANZ and ANZECC 2000).
- **Goals or aims:** General descriptions of what a project will achieve (Woodhill & Robins 1998).
- **Grain size distribution:** The statistical distribution of grain (by weight) passing a range of sieve sizes (ARMCANZ & ANZECC 2000).
- **Gravel:** A mixture of coarse mineral particles larger than 2 mm, but less than 75 mm in equivalent diameter (Charman & Murphy 1991).
- **Greenfield area:** A large area of land zoned for urban development and located on the fringe of an urban area (DP and WAPC, 2015).
- **Gross pollutant traps (GPTs):** A type of litter and sediment management system. GPTs typically consist of a sediment trap with a weir and trash rack at the downstream end of a piped drainage system.
- **Groundwater:** Water found under the land surface that occupies pores and crevices of soil and rock (Water and Rivers Commission 2000a).
- **Gully pit/inlet pit/side entry pit:** A roadside inlet pit designed to collect stormwater runoff from paved surfaces and to intercept sediment and litter prior to entry into the drainage network (ARMCANZ and ANZECC 2000).
- **Heavy metals:** Metals of high specific gravity ($>5 \text{ g/cm}^3$) that are present in the environment from natural and anthropogenic sources such as municipal and industrial wastes and urban runoff, and pose long-term environmental hazards. Such metals include: arsenic (As), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), mercury (Hg), molybdenum (Mo), nickel (Ni), vanadium (V) and zinc (Zn).
- **Hydraulic conductivity:** A measure of the ease of flow through a pore space or fractures. Hydraulic conductivity has units with dimensions of length per time (e.g. m/s, m/min, or m/d).
- **Hydraulic head:** The energy, either kinetic or potential, possessed by each unit weight of a liquid expressed as the vertical height through which a unit weight would have to fall to release the average energy possessed. Used in various terms such as pressure head, velocity head and head loss.
- **Hydrodynamic condition:** The condition that influences the flow of water.
- **Hydrologic regime:** A description of the variation of flow rate or water level over time (adapted from Water and Rivers Commission 2000a).
- **Hydrological cycle:** The continual cycle of water between the land, the ocean and the atmosphere.
- **Hydrology:** The science of the behaviour of water in the atmosphere, on the surface of the earth and within

the soil and underlying rocks. This includes the relationship between rainfall, runoff, infiltration and evaporation.

- **Illicit connections:** Illegal or improper connections to drainage systems and receiving waters. The most obvious of these connections include trade wastes from commercial and industrial premises and wastewater from domestic premises.
- **Impervious or impermeable surface:** The part of the catchment surfaced with materials, either natural or constructed, which prevent or limit the rate of infiltration of stormwater into the underlying soil and groundwater (ARMCANZ and ANZECC 2000) and subsequently increases stormwater runoff flows.
- **Indicators:** The specific characteristics or phenomena that tell you about the project and what impact it is having on the problem or issue it was set up to tackle (Woodhill and Robins 1998).
- **Indirect drainage:** The breaking of the direct connection of stormwater pipes and impervious area runoff to the drainage network, by their discharge to pervious areas or infiltration devices.
- **Infiltration:** The movement of water from the surface to the subsoil and at times, ultimately to the underlying aquifer.
- **Infiltration system:** A drainage facility designed to use the hydrologic process of stormwater runoff soaking into the ground, commonly referred to as percolation. Examples include infiltration basins and trenches, soakwells and pervious paving.
- **Inlet:** A form of connection between the ground surface and a stormwater structural control for the admission of stormwater runoff.
- **Integrated water cycle management (IWCM):** The integration of water supply, sewerage and stormwater, so that water is used optimally within a catchment resource, state and national policy context. It promotes the coordinated planning, development and management of water, land and related resources (including energy use) that are linked to urban areas and the application of WSUD principles within the built urban environment (National Water Commission 2006).
- **Litter and sediment management (LSM) system:** Any structural device designed to intercept coarse particulate material (by sedimentation) and litter and debris (by physical screening). May also be referred to as a stormwater pollutant trap (SPT). Types of LSM systems include side entry pit traps, gross pollutant traps, trash racks and litter booms.
- **Living stream:** A drainage conveyance system featuring stabilised vegetated banks and a more natural morphology than traditional straight drains, providing diverse habitats for native plants and animals.
- **Loading:** The total mass of a contaminant discharged during a storm event. The term may also be used to describe the mass of contaminant intercepted (g/m^2) by a device during a storm event, or on an annual basis (ARMCANZ and ANZECC 2000).
- **Managed aquifer recharge (MAR):** The controlled infiltration or injection of water into an aquifer. The water can be withdrawn at a later date, left in the aquifer for environmental benefits, or used as a barrier to prevent saltwater or other contaminants from entering the aquifer.
- **Monitoring:** The collection of data by various methods for the purpose of understanding natural systems and features, evaluating the impacts of development proposals on such systems, and assessing the performance of mitigation measures.
- **Monitoring and evaluation program:** Development of monitoring and evaluation activities to determine

the success or otherwise of measures put in place as part of stormwater management projects.

- **Multiple use corridors:** Facilities performing a range of functions (e.g. stormwater management, landscape, recreation and wildlife habitat).
- **Non-point source pollution:** Pollution from diffuse sources without a single point of origin or specific discharge point (ARMCANZ and ANZECC 2000).
- **Non-structural controls:** Institutional and pollution-prevention practices designed to prevent or minimise contaminants from entering stormwater runoff and/or reduce the volume of stormwater requiring management (US EPA 1999). They do not involve fixed, permanent facilities and they usually work by changing behaviour through government regulation (e.g. planning and environmental laws), education and/or economic instruments (Taylor & Wong 2002).
- **Nutrients:** Essential chemicals such as nitrogen (N) and phosphorus (P) needed by plants and animals for growth. Excessive amounts of nutrients can lead to degradation of water quality and algal blooms.
- **Objectives:** Specific statements about what a project intends to achieve.
- **Offline:** A management system located adjacent to but off a stream or major flow pathway, such as to treat low flows or the discharge of a major flow system (ARMCANZ and ANZECC 2000).
- **Oil trap/separators:** A stilling tank configured to separate lighter oily matter, scums and hydrocarbons from stormwater.
- **Online:** A management system located within the original stream or flow pathway/drainage channel to treat event flows (ARMCANZ and ANZECC 2000).
- **On-site and off-site:** On-site facilities are located on individual lots to enhance local stormwater retention/detention and interception of contaminants. Off-site facilities are located on stormwater networks to provide area-wide stormwater retention/detention and interception of contaminants (adapted from ARMCANZ and ANZECC 2000).
- **Outcomes:** The results of the activities or products of a project (Woodhill and Robins 1998). All the impacts or consequences of the project beyond its outputs (see ‘outputs’). Outcomes are often delayed or long term and they may be intended or unanticipated (Bullen undated).
- **Outlet:** Point of water discharge from a waterway or stormwater structural control.
- **Outputs:** The activities completed or products made during a project (Woodhill & Robins 1998). Outputs are within the direct control of the project.
- **Overland flow:** The component of rainfall (excess) that is not removed by infiltration or use and discharges down-gradient as surface flow (ARMCANZ and ANZECC 2000).
- **Peak discharge rate:** The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.
- **Peak flow:** Maximum flow rate in a flood, measured in m³/s (Department of Environment 2003).
- **Performance indicator:** A specific type of indicator that looks at outcomes (see ‘outcomes’) to see if they are meeting the project’s objectives (see ‘objectives’).
- **Performance monitoring:** Gathering of information to measure the success of strategies implemented when compared to objectives (see ‘objectives’).
- **Permeable soils:** Soil materials with sufficiently rapid infiltration rate, therefore reducing or eliminating

stormwater runoff. Coarse textured soils tend to have large, well-connected pore spaces and hence high permeability.

- **Pervious (permeable/porous) pavement:** Pavements comprising materials that facilitate stormwater infiltration and transfer to the underlying subsoil (ARMCANZ and ANZECC 2000).
- **pH:** A measure of the hydrogen ion concentration of water or wastewater; expressed as the negative log of the hydrogen ion concentration $[H^+]$. A pH of 7 is neutral, pH less than 7 is acidic and pH greater than 7 is basic.
- **Point source pollution:** Contamination from a localised source, such as leaky storage tanks and drums or sewage discharge.
- **Pollutant retention:** The proportion of pollutant load intercepted and retained by a device, either on an event or annual basis (ARMCANZ and ANZECC 2000).
- **Pollution prevention procedures:** One of the five principal categories of non-structural BMPs for stormwater management. Examples include maintenance practices (e.g. maintenance of the stormwater drainage network) and elements of environmental management systems (e.g. procedures on material storage and staff training on stormwater management at government, commercial and industrial sites).
- **Porosity:** Porosity is calculated as a ratio of pore volume to total volume.
- **Potable water:** Water generally considered suitable for human consumption.
- **Precautionary principle:** If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.
- **Rational method:** A means of computing storm drainage flow rates (Q) by use of the formula $Q = CIA$, where C is a coefficient describing the physical drainage area, I is the rainfall intensity and A is the area.
- **Receiving environment:** Areas that receive stormwater runoff, including wetlands, waterways, coastal waters/dunes, groundwater and bushland areas.
- **Receiving water bodies:** Include waterways, wetlands, coastal marine areas and shallow groundwater aquifers.
- **Recharge:** Water infiltrating to replenish an aquifer.
- **Recycled water:** Treated stormwater, greywater or black water suitable for a range of uses, e.g. toilet flushing, irrigation, industrial processing or other suitable applications (ARMCANZ and ANZECC 2000).
- **Regulatory controls:** One of the five principal categories of non-structural BMPs for stormwater management. Includes controls such as enforcement of local laws to improve erosion and sediment control on building sites, the use of regulatory instruments such as environmental licences to help manage premises likely to contaminate stormwater or groundwater, and programs to minimise illicit discharges to stormwater management systems (e.g. drains).
- **Remobilisation:** The transformation of sedimented contaminants by microbial or chemical processes into a dissolved form and transfer by diffusion from the sediment pore water into the water column (ARMCANZ and ANZECC 2000).
- **Re-suspension:** The physical entrainment of sedimented particles by elevated flows, or as a result of sediment bio-turbation (ARMCANZ and ANZECC 2000).

- **Retention/retain:** Retention is defined as the process of preventing rainfall runoff from being discharged into receiving water bodies by holding it in a storage area. The water may then infiltrate into groundwater, evaporate or be removed by evapotranspiration of vegetation. Retention systems are designed to prevent off-site discharges of surface water runoff, up to the design ARI event. It is the difference between total precipitation and total runoff.
- **Retrofitting:** Retrofitting employs additional or alternative stormwater management devices or approaches which are installed or undertaken in an existing developed area. Retrofitting can occur at the lot, block/neighbourhood or catchment scale.
- **Riffles:** High points in the channel floor, representing bedrock bars or accumulations of relatively coarse material. Water flow is typically relatively shallow, fast and rough over riffles (Water and Rivers Commission 2002).
- **Riparian vegetation:** Vegetation growing within the channel and the along banks of waterways, extending laterally away from the bank and ending at the extent of the floodplain.
- **Riprap:** Rock riprap consists of a layer or layers of well-graded rocks placed on stream banks to protect them from erosion.
- **Risk:** The effect of uncertainty on objectives (ISO 31000:2019).
- **Risk assessment:** The process of risk analysis and risk evaluation.
- **Roughness coefficient:** A factor in velocity and discharge formulas representing the effect of channel roughness on energy losses in flowing water. Manning's n is a commonly used roughness coefficient.
- **Runoff:** Water that flows over the surface of a catchment area, including streams.
- **Sand:** A soil separate consisting of particles between 0.02 and 2.0 mm in equivalent diameter. Fine sand is defined as particles between 0.02 and 0.2 mm, and coarse sand as those between 0.2 and 2.0 mm (Charman & Murphy 1991).
- **Sediment:** Solid fragment of organic and inorganic material that is transported, suspended and/or deposited by water and wind.
- **Sedimentation:** The physical process of settling of suspended particulates under the force of gravity (ARMCANZ & ANZECC 2000).
- **Sediment trap:** A structure designed to intercept and retain sediment transported by water flow (ARMCANZ & ANZECC 2000).
- **Silt:** A soil separate consisting of particles between 0.002 and 0.02 mm in equivalent diameter (Charman & Murphy 1991).
- **Social/cultural values:** Social values include public health and safety, recreational uses and visual amenity. Cultural values include historical and spiritual significance, and scientific and educational uses.
- **Sodic soils:** Soil sodicity is assessed by the ratings of the exchangeable sodium percentage (ESP). Soils with a relatively high proportion of exchangeable sodium (greater than 6 per cent) are considered sodic (Charman & Murphy 1991). Soil sodicity causes increased soil dispersion and swelling of clays, which adversely impacts the soil structure and results in reduced infiltration, reduced hydraulic conductivity and the formation of surface crusts.
- **Soil amendment:** Involves adding an agent, such as clay or crushed limestone, to the soil to improve its structure, porosity, water holding capacity and nutrient recycling capacity.

- **Soil permeability:** The ease with which gases, liquids or plant roots penetrate or pass through a layer of soil.
- **Soil stabilisation:** The use of measures or materials, such as rock lining or vegetation, to prevent the movement of soil when loads are applied to the soil.
- **Source controls:** Non-structural or structural best management practices designed to minimise the generation of excessive stormwater runoff and/or pollution of stormwater at or near the source and protect receiving environments.
- **Stormwater:** Water flowing over ground surfaces and in natural streams and drains, as a direct result of rainfall over a catchment. Stormwater consists of rainfall runoff and any material (soluble or insoluble) mobilised in its path of flow.
- **Stormwater quality:** The chemical, physical and biological characteristics of stormwater.
- **Stormwater quantity:** The volume characteristics of stormwater.
- **Strategic planning and institutional controls:** One of the five principal categories of non-structural BMPs for stormwater management. Examples include controls such as the use of strategic, regional or citywide urban stormwater management plans and stable funding arrangements to support the implementation of these plans.
- **Street sweeping:** The removal of particulates and litter from street surfaces by sweeping or vacuuming (ARMCANZ & ANZECC 2000).
- **Structural controls:** Engineered devices implemented to manage runoff quality and quantity, to control, treat, or prevent stormwater pollution and/or reduce the volume of stormwater requiring management.
- **Sub-catchment:** A topographically defined area drained by a tributary of a primary stream (ARMCANZ & ANZECC 2000).
- **Subsurface drain:** A drain designed to intercept subsoil water and thereby limit the seasonal maximum groundwater level.
- **Superficial (unconfined) aquifer:** An aquifer containing water with no upper non-porous layer to limit its volume or to exert pressure. The upper surface of the groundwater within the aquifer is called the watertable.
- **Surface water:** Water flowing or held in waterways or wetlands on the surface of the landscape (adapted from Water and Rivers Commission 2000a).
- **Suspended solids:** Organic or inorganic particles that are suspended and transported by water. This includes sand, mud and clay particles (and associated contaminants) in stormwater.
- **Swale:** A drainage interception and conveyance system with relatively gentle side slopes and shallow flow depths.
- **Target:** A numerical concentration limit or descriptive statement relating to an aspect of water management aspired to as part of a stormwater management project.
- **Time of concentration:** The time required for a drop of water to travel from the most hydrologically remote point to the point of discharge.
- **Threat:** An activity or land use with potential to damage the local or receiving environment's social/cultural, ecological or economic values, via impacts to stormwater quantity or quality.

- **Total nitrogen (TN):** The total nitrogen that is contained within the matrix.
- **Total phosphorus (TP):** The total phosphorus that is contained within the matrix.
- **Total suspended solids (TSS):** A water quality measurement referring to the dry-weight of particles in a sample that is trapped by a filter of specified pore size.
- **Town planning controls:** One of the five principal categories of non-structural BMPs for stormwater management. An example includes the use of town planning instruments to promote water sensitive urban design features in new developments.
- **Toxicity:** The quantity or degree to which a substance is poisonous or harmful to plant, animal or human health.
- **Treatment train:** In most situations, a number of management measures may be implemented in series or concurrently forming a treatment train approach to stormwater management. To achieve the best stormwater management outcomes, both structural and non-structural techniques should be used in particular combinations to suit the local conditions. This arrangement will satisfy the water quantity and quality objectives that might be unachievable if relying on a single BMP. Additionally, the impact from the failure of one device will be reduced by the operation of the other devices in the treatment train.
- **Triple-bottom-line assessment:** A process which uses multi-criteria analysis to evaluate the economic, social and ecological costs and benefits of possible BMPs.
- **Underdrain:** Plastic pipes with holes, installed at the base of impervious bioretention systems to collect treated water for conveyance downstream.
- **Urban:** Land used for residential, rural-residential, commercial or industrial development (includes regional towns).
- **Values:** Values may include economic values (e.g. water use, aquaculture and stormwater reuse), ecological values (e.g. aquatic fauna and flora, urban bushland) and social/cultural values (e.g. historical, public health and safety, recreational, visual amenity, spiritual).
- **Vegetated swales:** A swale with vegetation covering the side slopes and base. Vegetation can range from grass to native sedges and shrubs, depending on hydraulic and landscape requirements.
- **Water bodies:** Waterways, wetlands, coastal marine areas and shallow groundwater aquifers.
- **Watercourses:** A river, stream or creek in which water flows in a natural channel, whether permanently or intermittently.
- **Water dependent ecosystems:** Those parts of the environment, the species composition and natural ecological processes of which are determined by the permanent or temporary presence of water resources, including flowing or standing water and water within groundwater aquifers (Water and Rivers Commission 2000a).
- **Water sensitive urban design (WSUD):** A design philosophy that provides a framework for managing water-related issues in urban areas. WSUD incorporates the sustainable management and integration of stormwater, wastewater and water supply into urban design. WSUD principles include incorporating water resource management issues early in the land use planning process. WSUD can be applied at the lot, street, neighbourhood, catchment and regional scale.
- **Waterways:** All seasonal, intermittent or permanent streams, creeks, rivers, estuaries, coastal lagoons, inlets and harbours.

- **Wetlands:** Areas of seasonally, intermittently or permanently waterlogged or inundated land, whether natural or otherwise, including lakes, swamps, playas, damplands, floodplains, barlkarras, palusplains, paluslopes, palusmonts or tidal flats.

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Acronyms

AEP	Annual exceedance probability
ANZAC	Australian and New Zealand Environment and Conservation Council
ARI	Average recurrence interval
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ARQ	Australian Runoff Quality
ARR	Australian Rainfall and Runoff
ASR	Aquifer storage and recovery
ASS	Acid sulfate soils
BMP	Best management practice
BOD	Biochemical oxygen demand
CGL	Controlled groundwater level
DEC	Department of Environment and Conservation (former)
DIA	Department of Indigenous Affairs (former)
DoW	Department of Water (former)
DPI	Department for Planning and Infrastructure (former)
DPLH	Department of Planning, Lands and Heritage
DWER	Department of Water and Environmental Regulation
DWMP	Drainage and water management plan
DWMR	Drainage and water management report

DWMS	Drainage and water management strategy
EMS	Environmental management system
EPA	Environmental Protection Authority
EWP	Environmental water provision
EWR	Ecological water requirement
GIS	Geographic information system
GPT	Gross pollutant trap
LGA	Local government authority
LSM	Litter and sediment management
LWMR	Litter and sediment management
MAR	Managed aquifer recharge
NRM	Natural resource management
POS	Public open space
PRI	Phosphorus retention index
SERCUL	South East Regional Centre for Urban Landcare
SMP	Stormwater management plan
SPT	Stormwater pollutant trap
TDS	Total dissolved solids
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids

UWMP	Urban water management plan
UWMR	Urban water management report
WALGA	Western Australian Local Government Association
WALIS	Western Australian Land Information System
WAPC	Western Australian Planning Commission
WIN	Water Information Network
WSUD	Water sensitive urban design