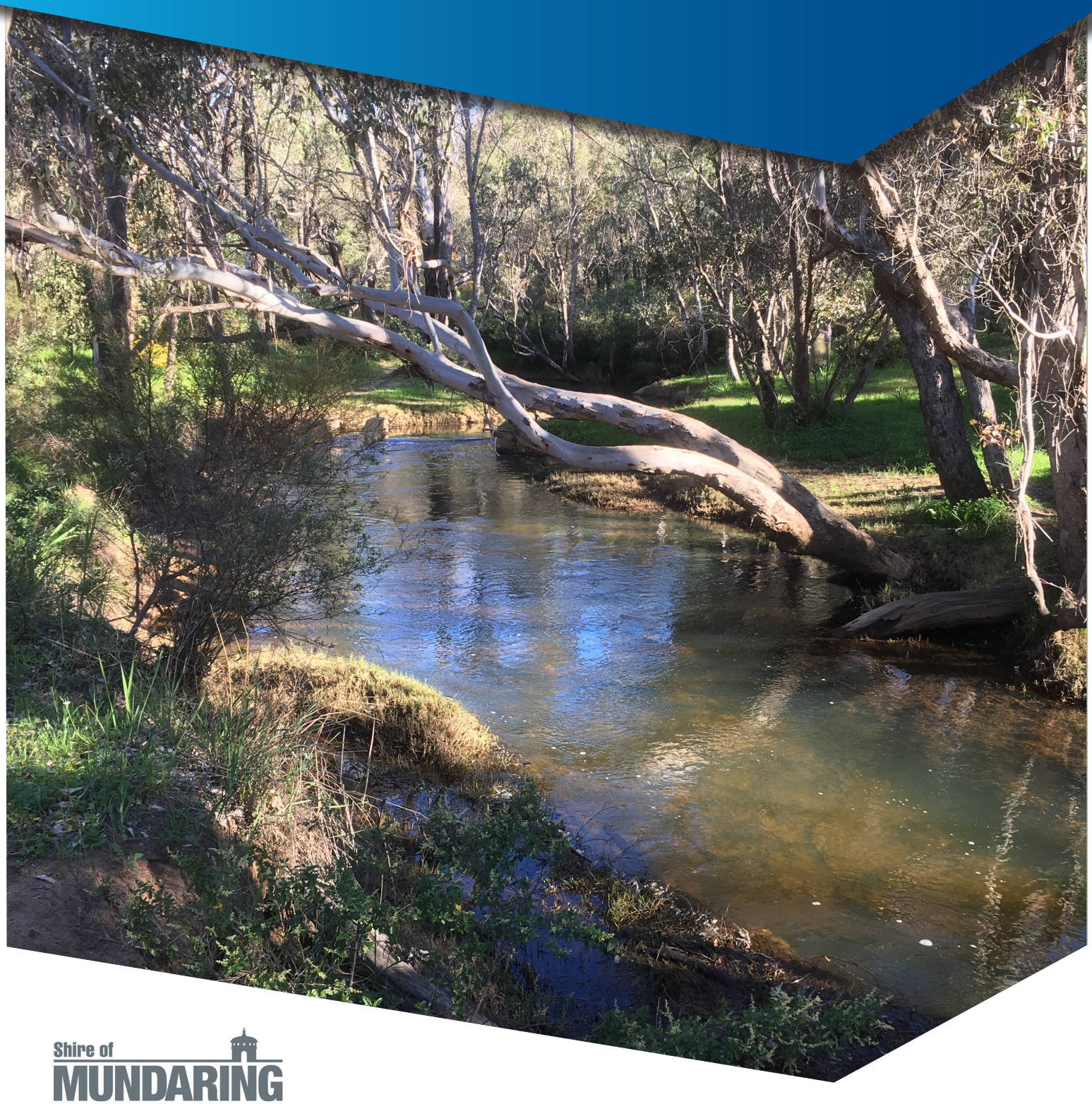
Watercourse Hierarchy Strategy



Shire of MUNDARING

WATERCOURSE HIERARCHY STRATEGY
SHIRE OF MUNDARING
FORESHORE AREA FUNCTION AND MANAGEMENT

Adopted 11 April 2023

Prepared by **urbanplan** and Acacia Springs Environmental

On behalf of Shire of Mundaring

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Acknowledgements

The assistance and advice provided by representatives of the local catchment groups and Shire staff is gratefully acknowledged.

1. EXECUTIVE SUMMARY

The Watercourse Hierarchy Strategy defines the key issues and threats facing the management of watercourses in the Shire and recommends corresponding strategic, planning based and operational actions.

The Shire of Mundaring has an extensive watercourse network, totalling a length of 2307km. Approximately 40% of the watercourses traverse through private land and around 60% through a vast network of public reserves.

Watercourses play a vital role in sustaining biodiversity in the shire. Watercourses also define the shire's distinct landscape amenity and sustain a range of social, cultural and economic values. Healthy waterways are therefore integral to delivering on the Shire's vision - a Place for Sustainable Living.

Watercourses and the foreshore areas along the banks are under threat. Key threats include changing rainfall patterns due to climate change, land use and development pressures and increasing impervious surfaces causing erosion and sedimentation.

Recommendations were developed by first undertaking a geographically-based (GIS) synthesis of issues. This provided the backdrop for informed targeted stakeholder consultations, exploring and documenting what might be possible currently and into the future.

Strategic issues and outlook have been represented spatially across the different catchments (pages 29 to 31 and 37 to 41). A new strategic direction is presented which, amongst other more specific actions, include:

1. Better control of storm flow peak-velocities for improved erosion control.
2. Greater focus on protecting and rehabilitating ecological function and biodiversity along watercourse corridors, especially through urban and rural residential areas.
3. Better coordinate and integrate watercourse corridor protective and restorative efforts between responsible agencies and communities.
4. Provide information about watercourse ecology and function so as to inform and help landowners become responsible land managers.
5. Improve sharing of information about bushfire mitigation works and ecological restoration efforts along corridors.
6. To facilitate and support a greater level of community and agency awareness and involvement with watercourse corridor protections and enhancements to broaden and strengthen local ownership and appreciation of these valuable ecological systems.

Recommendations inform statutory land use decisions under Local Planning Scheme No.4, future investigations, operational priorities and stormwater interventions. The outcomes of this strategy have informed the development of Shire's Local Biodiversity Strategy (particularly the wildlife corridor mapping) and Public Open Space strategies. Further, it is intended that the findings of the Watercourse Hierarchy Strategy shape the future review of the Local Planning Strategy and the next iterations of the Shire's local planning scheme.

2 INTRODUCTION

2.1 CONTEXT

The geomorphology of the Shire of Mundaring consists of incised perennial and intermittent drainage in laterite soils overlying Yilgarn block granite. This landform is entirely different to the coastal plain with its shallow groundwater and nutrient-leaching soils. Agricultural and urban land use on the coastal plain has been largely responsible for the unacceptable nutrient loads reaching and threatening the Swan River Estuary. Stormwater management systems on the coastal plain have been focussed on infiltration and bioretention systems that hold the stormwater for significant periods of time for treatment.

The Mundaring uplands require special consideration and tailor-made solutions. For example, detention systems are required to slow stormwater runoff and reduce its peak velocities which lead to erosion. Infiltration basins on the finer-textured clays and loams are less effective because the coefficient of infiltration is much less than for Swan Coastal Plain sandy soils. Additionally, highly P-fixing soils in the hills bind phosphorus and P levels in runoff from Mundaring catchments are currently within the Department of Biodiversity, Conservation and Attractions' acceptable short and long-term targets. Consequently, water quantity and velocity management are more significant than water quality (nutrient) management.

Land use characteristics also affect watercourse water quality and stream dynamics. Forested catchments need to be considered differently to rural residential areas. Equally, private ownership compared to state and local government tenured and operated catchments, differ.

Depending upon the land use characteristics and erosion potentials, water quality can also be an issue. Non-structural controls including education and awareness for stormwater management would be an effective approach for such catchments. These are institutional and pollution prevention practices designed to prevent or minimise pollutants from entering stormwater runoff and/or to reduce the volume of stormwater requiring management.

These include better practices of local government operations, asset managers, industrial/commercial businesses and householders, through mechanisms such as maintenance practices, regulation, strategic planning and education. They usually work by changing behaviour through government regulation (e.g. planning and environmental laws), education and/or economic instruments. Education and awareness for stormwater management can be developed by various sectors of the community to raise awareness and provide a catalyst for a behaviour change to reduce pollution entering the stormwater system.

2.2 SHIRE PROFILE

The shire is mostly uncleared of remnant vegetation and, in addition to public land such as National Parks, State forest and drinking water supply catchments, Local Natural Areas also occur on private land. There is thus the opportunity, and a significant expectation from Shire residents, that the natural environment will be protected and maintained. The Shire's Local Biodiversity Strategy provides directions for biodiversity protection.

Protection of watercourses within the shire from pollution and sedimentation, from existing and future land use and development is important both for the maintenance of environmental values within the shire itself and because watercourses in the shire flow to the Swan and Helena

Rivers. Local impacts on watercourses may have adverse consequences downstream. There is also a risk of dryland salinity from sub-catchments draining areas to the east and there may be acid sulphate soils in some areas of the shire, notably in proximity to watercourses.

More than 2307.6 km of 3-9th-order streamlines across the shire deliver surface runoff with lesser amounts of groundwater seepage to the Swan River estuary. The Swan and Canning Rivers have been experiencing regular potentially harmful phytoplankton blooms, a symptom of a eutrophic and overloaded system. Urban and rural development within the larger Swan-Avon catchment has reduced the hydrological buffering of the Swan-Canning as a system. This means that the residence time of water within most catchments has been considerably reduced, impeding the natural assimilative processes of foreshore areas.

Unfortunately, the process of reserving land and separating land uses and/or development from creek lines has often failed to deliver the required outcomes. Given the scale and low-density population in the Shire, securing waterways into public ownership and regulation alone cannot address the fragmented ownership, and fragmented management of waterways throughout the Shire. Further, regulation alone does not of itself generate the community mindset or consider adequately, the very significant human and financial resources required to balance and manage operationally, cultural heritage and biodiversity protections, bushfire risks, hydrological functioning, weed infestations, and unauthorised off-road vehicle access, to name a few of the often-competing issues.

The WA EPA (2021), has concluded that the planning framework in WA is important for managing impacts on foreshore areas. To this end the Shire of Mundaring has been developing a more responsive and creative policy approach and have concluded that a broader stakeholder engagement is essential to delivering greater community buy-in and action. This is exampled by the early successes of various sub-catchment '*Friends of*' groups. Given the established science, the prevailing policy context and early community buy-in, a forensic interrogation of the 'system' is now required to determine what has and hasn't worked, where, when, how and why.

The **urbanplan** and ASE team have embarked upon a geographically-based (GIS) synthesis of issues that provides the backdrop for targeted stakeholder consultations, exploring and documenting what might be possible currently and into the future.

2.3 WATERCOURSES HIERARCHY STRATEGY APPROACH

Our joint establishment of a local vision for Mundaring's watercourses is has been guided by contemporary scientific and policy development and stakeholder inclusion. It aims to deliver the required concise Watercourse Hierarchy Strategy, while addressing various streamline hierarchy levels, land tenures and land managers (state and local government and freehold).

To mitigate against changes brought about by land development and other disturbances and the subsequent alterations to landform and foreshore areas, waterway hydrologic and ecological functions need to be maintained as close as practicable to their original state (Section 2.6 provides more detail on impacts). The policy response derived from the empirical research needs to set strategic actions with assigned responsibility. In this regard the catchment groups offer a significant vehicle to guide and support freehold owners in managing watercourses on private property.

A future role for landowners as joint custodians will be significant if improved management practices are to be implemented in all areas of the shire in private ownership. This recognises that around 40 percent of the shire's waterways are proximate to, or within areas of freehold ownership. This requires community actions across the shire, supported by the Shire's communication of information and education materials demonstrating the principles and processes and mitigation techniques that will support appropriate actions by all landowners.

2.4 APPROACH TO ENGAGEMENT

To achieve effective community consultation during the pandemic the **urbanplan** Acacia Springs Environmental team, established an informal focus group with representatives from each of the catchment groups active within the Shire and undertook targeted communications with members of the Shire's Environmental Advisory Committee.

A number of discussions were held between the consultants and Shire staff with officers of the DWER, regarding the use of LiDAR for determining and classifying watercourses. While it was appreciated from comparisons with existing data, that the LiDAR-derived watercourse hierarchy was a significant improvement in available data for the shire, it was recognised that it should not substitute for site-specific assessments of potential impacts and opportunities for particular land development initiatives.

This approach drew on detailed local knowledge of catchment and waterway characteristics and the experiences of mitigation and restoration activities that had been undertaken over the past 20 or so years.

For the purpose of this Mundaring Watercourse Hierarchy Strategy, a watercourse has been defined as ≥3rd order Strahler Streams mapped across a catchment using LiDAR having equal to or better than 5 cm vertical resolution.

2.4.1 ENGAGEMENT OBJECTIVES

The objective of the community engagement with local people was threefold:

a) to glean local understandings of foreshore area function and processes, particularly as they related to issues and restoration and mitigation actions;
b) to share our consulting experience and understanding of waterway functions and process more broadly; and,
c) to explore potential implementation and the required resourcing and support.

The local information that was so freely shared by local 'experts', is gratefully acknowledged and has been crucial in guiding the direction and outcomes of this investigation.

2.5 ISSUES IDENTIFICATION

The development of issues focused on matters aligned with the investigation's scope requirements and were not particularly linked to socio-political implications of future land developments. Issues fell into two groups including:

I. generic issues that applied over much of the shire; and,
II. localised issues that were associated with particular locations and/or situations.

2.5.1 GENERIC ISSUES

The following issues were collated from members of the Shire's Environmental Advisory Group and determined from various reports and documents. They included:

1. Environmental weeds and pests have been observed in many locations across the shire. These include a wide range of introduced grasses and dicotyledons such as nightshade, arum lily and cotton bush and pests such as mosquitos, European wasps, rodents, foxes and feral animals. The Shire has made a number of on-line resources available such as weed identification and control and for pest control.

2. Bank and bed erosion have been observed across the shire. Erosion caused by swiftly flowing storm flows has the potential to damage associated infrastructure such as roads, bridges and paths, and lead to sedimentation and turbidity impacts on aquatic habitats (Photo plates 1 and 2) .

3. House values were seen to be related (positively and negatively) to streamline amenity.

4. Wastewater Treatment Plants. Comprehensive sewage treatment and disposal for Mundaring's highly undulating landscape and widely dispersed settlements is not cost effective. It would require expensive pressure mains and lengthy pipe runs to suitable treatment and disposal sites. Accordingly, a number of small package treatment plants have been commissioned that discharge highly treated wastewater to local waterways. While these discharges are licensed to operate within controlled environmental limits, there is community concern that equipment failure and population creep could lead to adverse impacts on receiving waterways. The lack of cost-effective options for sewage treatment and finite capacities of existing systems have been cited as stifling further population growth and development opportunities.

5. Falling rates of community involvement have been observed for most of the shire's catchment groups. People reported that they have become increasingly time-poor and unable to commit as readily to volunteer opportunities.

6. Community engagement with foreshore areas has been reported as lessening, partly as a consequence of pressures cited for point 5 above.

7. Climate uncertainty was seen as leading to two potentially adverse impacts on the shire's streamlines. This included the predictions of falling overall rainfall for the Perth environs leading to drying of foreshore areas. Predictions of increasing frequencies of extreme weather and rainfall conditions have raised concerns over increased velocities of stormwater runoff and subsequent increases in erosion.

8. Gaps in integration and inconsistency of agency oversight was seen as sometimes leading to less-than-optimal implementation of policies and regulations applying to streamlines.

9. Phytophthora dieback and Myrtle Rust

2.5.2 LOCALISED ISSUES

There was some duplication of issues raised by representatives of the various Catchment groups or gleaned from websites and publications and these have been left here for completeness. Some issues are framed as actions and some interpretation has been applied accordingly.

Blackadder / Woodbridge Catchment Group

- Ecological corridors through urbanised areas are fragmented and require restoration.
- Invasive weeds need removal.
- Local species need to be established utilising local provenance seeds.
- Remnant vegetation needs additional protections and improved management.
- Catchment and waterways need to be protected through management and practices that consider Aboriginal heritage, recreation needs and accessibility.
- Awareness of local environmental issues needs to be raised.
- Environmentally sensitive planning needs to be advocated for development

Helena River Catchment Group

- Improved ecological connectivity on both sides of waterways.
- Better linkages between reserves along foreshore areas.
- Improved flow and erosion control on side tributaries entering the Helena R.
- Greater environmental flows down the main channel of the Helena R.
- Improved regulatory oversight of foreshore areas.
- Improved agency integration and consistency.

Jane Brook Catchment Group

- Better control of storm flows.
- Improved erosion control.
- Improved management of weeds.
- Greater community engagement and participation.
- Greater regulatory oversight.
- Improved agency coordination.

- More sensitive bushfire mitigation.

Susannah Brook Catchment Group

- More regeneration and rehabilitation for biodiversity.
- Greater connectedness of wildlife corridors.
- Improved stream water quality for fauna.
- Improved rubbish removal and less vandalism.
- More people involved and having ownership.
- Better integration with bushfire mitigation.

Wooroloo Brook Land Care Group

Note: This group was inactive. Past representatives were interviewed.

- Salinity arising from eastern catchments needs controlling.
- Revegetation of gullies and recharge areas.
- Control of environmental weeds.
- Channel and bank erosion control.
- Improved mitigation against catastrophic wildfires which lead to massive erosion.
- Greater community engagement and involvement.

2.6 ISSUES PRIORITISATION

Issues raised during the community consultation and desktop research were brought together and prioritised, using Intercom's RICE methodology which is based on the following relationship:

$$\frac{\text{Reach} \times \text{Impact} \times \text{Confidence}}{\text{Effort}} = \text{RICE SCORE}$$

Reach was interpreted as the spatial extent of the issue, Impact was seen as the magnitude of adverse or beneficial changes arising, Confidence was seen as the reliability of predictions of impact and restoration, and Effort was seen as a combination of human, financial and logistical inputs required to manage the issue. Whilst this RICE approach required a level of expert-knowledge of the subject matter for its use, it did serve to invite participants to make explicit many of their implied assumptions.

The resulting streamline priorities included:

Priority 1 Better control of storm flows for erosion control.

Priority 2 Greater levels of regeneration and rehabilitation for biodiversity.

- Greater community engagement and involvement
- Better linkages between reserves.
- Improved bushfire mitigation along corridors to prevent catastrophic wildfires which severely damage vegetation, soil seed stores, soil fertility and stability and which can lead to accelerated erosion.

- Ecological corridors through urbanised areas are fragmented and require restoration.
- Better integration with bushfire mitigation.

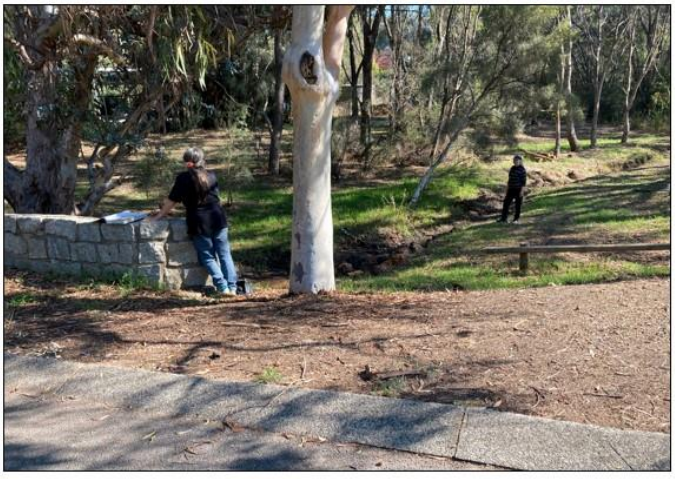
Detention basin industrial area 2002

Detention basin industrial area 2022

Riffle at Bugle Tree Creek 1999

Riffle at Bugle Tree Creek 2022

Road crossing Thornbury Cl 1999



Road crossing Thornbury Cl 2022

Picture plate 1: Photo pairs showing changes in watercourses from 1999 to 2020 (Early photos courtesy Jane Brook Catchment Group).

Gully erosion Bugle Tree Creek Thornbury Cl 2022

Erosion damage Riley Rd crossing 2022

Gully erosion Owen Rd Parkerville 2022

Gully erosion Wooroloo Bk Old Northan Rd 2022

Vegetated channel resisting erosion Wooroloo Bk

Gully erosion Green St Wooroloo Bk 2022

Picture plate 2: Examples of erosion and watercourse condition within the shire

3 CHARACTERISTICS OF FORESHORE AREAS

3.1 BACKGROUND

A significant amount of energy has been expended on the development of policies and regulations for the protection of foreshore areas. There is an extensive global literature on the topic describing many different situations and approaches. This brief review, rather than providing a comprehensive documentation of the range of applied policy instruments, has sought to describe those situations having some similarity to the social, biophysical and political environment of the Shire of Mundaring and its watercourses.

3.2 WHAT ARE FORESHORE AREAS?

The answer to this question (Figure 1), is best summarised by the US National Academy Press:

> *"Lands next to water are fundamental to the livelihood of many species of plants and animals, including humans. Birds and other wildlife aggregate in riparian areas, often in great abundance. At the same time, society values riparian areas for production of food, access to transportation, opportunities for recreation, and natural scenic beauty"* (NRC, 2002).

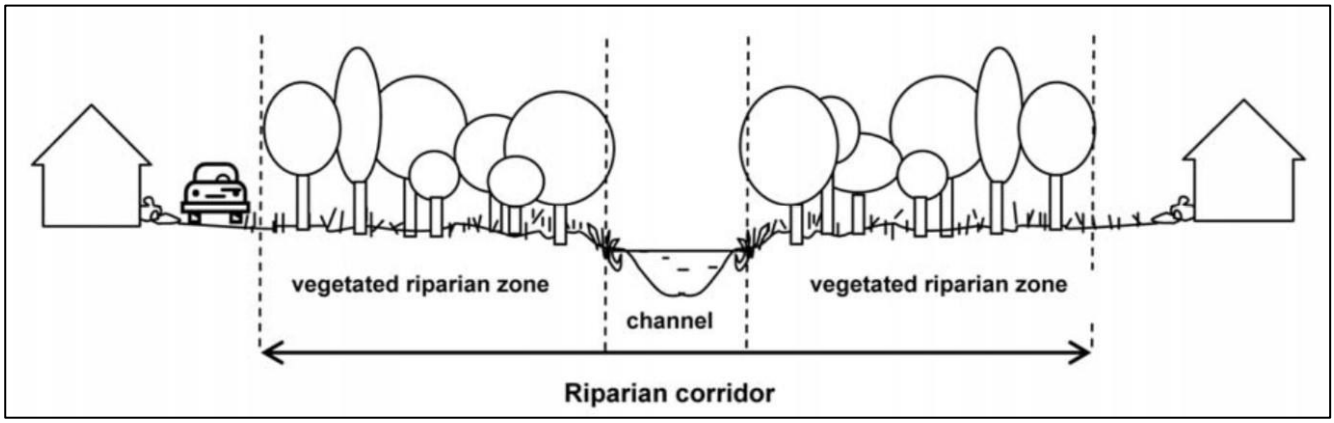


Figure 1 Riparian buffer extends both sides of streamlines

3.3 WHY PROTECT FORESHORE AREAS?

The WA Waterways Commission provided a rationale:

> *"Protection and management of riparian areas is essential for maintaining healthy waterways and wetlands. Protected foreshores preserve aquatic, littoral and terrestrial habitat for native flora and fauna while providing amenity and maintaining scenic quality and landscape values. They also reduce the impacts of erosion, sedimentation and nutrient influx in waterways"* (WRC, 2001b)

3.4 HOW DO FORESHORE AREAS FUNCTION?

The NSW DPI's Office of water (NSWDPI, 2012), described the functioning of foreshore areas:

- providing bed and bank stability and reducing bank and channel erosion;
- protecting water quality by trapping sediment, nutrients and other contaminants;
- providing diversity of habitat for terrestrial, foreshore and aquatic plants (flora) and animals (fauna);
- providing connectivity between wildlife habitats;
- conveying flood flows and controlling the direction of flood flows;
- providing an interface or buffer between developments and waterways; and,
- providing passive recreational uses.

The protection, restoration or rehabilitation of vegetated foreshore areas is important for maintaining or improving the shape, stability (or geomorphic form) and ecological functions of a watercourse and bigger is better. Wider corridors provide greater protection for streamline ecological processes.

3.5 HOW WIDE SHOULD PROTECTED FORESHORE AREAS BE?

A foreshore area consists of the channel which comprises the bed and banks of the watercourse (to the highest bank) and the two sides of the Vegetated Riparian Zone (VRZ) adjoining the channel (Figure 1). It has been recommended that multiple factors such as the biophysical conditions (WRC, 2001b, NSWDPI, 2012, WRC, 2001a) of the streamline, and the nature of the management requirements (NSWDPI, 2018, Price, 2004, Lovett, 2007), should combine to determine the width of protected foreshore areas (Tables 1 and 2).

Table 1 Foreshore area widths in NSW based on stream order (NSWDPI, 2012)

Watercourse type	VRZ width[a] (m)	Total RC width (m)
1st order	10	20 m + channel width
2nd order	20	40 m + channel width
3rd order	30	60 m + channel width
4th order and greater[b]	40	80 m + channel width

VRZ width[a] = Vegetated Riparian Zone each side of watercourse

Greater[b] = includes estuaries, wetlands and any parts of rivers influenced by tidal waters

Table 2 National foreshore area widths based on management objectives (Lovett, 2007)

Management objective	Bank width (m)	Total Corridor width (m)
Improve water quality	10 vegetated plus 5-10 grass strip	2 times 15 + channel width
Reduced stream bank erosion	Minimum width 5 Bank height 4 Erosion rate 0.2 x 20 = 4 Therefore Total = 13	2 times 13 + channel width
Maintaining natural light and temperature regime in streams	2 to 3 tree or tall shrub widths = (5 to 20)	2 times (5 to 20) + channel width
Provide food inputs and aquatic habitat	2 to 3 tree or tall shrub widths = (5 to 20)	2 times (5 to 20) + channel width
Provide terrestrial habitat	10 for small animals 50 for large animals	2 times (10 to 50) + channel width
Preventing stock damage	5 to 20	2 times (5 to 20) + channel width
Foreshore areas to enable agricultural production	10 to 30 wide with 20 times that length	2 times (10 to 30) + channel width
Land clearing for agricultural or urban development	20 to 200	ACT – various, NSW 20, Vic – 30 NT - various, SA – various Qld –1°-2° >50, 3°-4° >100, 5°+ >200

3.6 WESTERN AUSTRALIAN PREFERRED FORESHORE AREAS

The DWER recommends a site specific criteria based approach to identifying riparian buffer widths, rather than simply adopting ‘standard’ widths. Historically, a width of 30 m for waterways and 50 m for estuaries was generally applied. The use of standard widths did not allow for negotiation of narrower or wider foreshore widths where this was appropriate in specific cases.

Operational policy 4.3 is the State government policy on waterway foreshores (DoW 2012). This is described in more detail in Section 5. The recommended method for determining foreshore widths in WA is based on site-specific biophysical criteria (WRC 2001a). The biophysical criteria include: vegetation, hydrology, soil type, erosion risk, geology, topography, function, habitat, climate change impacts, heritage and the risks from the proposed adjacent land use. The criteria are a means of assessing the features, functions, values of and risks to the waterway.

A width of 30 m for waterways and 50 m for estuaries (including the estuarine reaches of rivers) could be considered as a general baseline to which additional width is added when needed based on specific features, functions, values or to mitigate specific risks. A watercourse hierarchy

approach that considers size, flow volumes and position in the catchment helps fine-tune the application of regulations. Sometimes the appropriate width may be much greater than the general baseline. For example, for a high-value pristine or near-pristine river with threatened species, where logging is proposed nearby, an appropriate foreshore/buffer width might be 100 m. For a small degraded creek in a paddock, 15-20 m revegetated foreshore either side may be adequate. Note that 10 m is allowed for edge effects, so this should always be added to the width of intact foreshore area vegetation (Advice for Section 2.6 was provided by the DWER's R Lynch pers com 2022).

A watercourse hierarchy approach helps:

- establish clear and appropriate guidelines on the width of foreshore areas
- provide greater flexibility in urban design by allowing a broader range of uses in foreshore areas, including detention basins, cycleways, roads and recreational areas
- enable works and activities to be offset along the length of a foreshore area
- provide greater flexibility with watercourse crossing design
- remove the need for vegetated buffers in addition to a foreshore area
- introduce a streamlined assessment approach so that compliant proposals can be assessed more quickly.

4 IMPACT OF DEVELOPMENT ON STREAMLINE PROCESSES

4.1 RUNOFF

Clearing native vegetation and establishing rural and urban land uses, has a significant impact on the water balance and on the nature of catchment hydrologic processes. Development leads to an increase in impervious areas in the urban form and the land surface in agricultural areas becomes more impervious because of stock or mechanical compaction. In these situations, rainfall no longer soaks into the ground as readily as before and this results in an increase in the volume and velocity of runoff, particularly during peak flow storm events on wetted catchments.

In addition, extensive networks of artificial drainage are routinely constructed to remove stormwater from land surfaces into receiving waterways as quickly as possible. In addition to preventing unacceptable levels of flooding, this approach has led to drainage networks that maximise local convenience and protection, without adequately considering off-site damage from accelerated flow, water pollution, or even the loss of the water resource. Other problems include increased channel erosion and downstream flooding, deposition of sediment, and a resulting loss of property, wildlife habitat and natural vegetation.

4.2 SEDIMENT TRANSPORT

In their natural state, particulate solids in streams are regulated substantially by the foreshore area vegetation. Removal or damage to vegetative cover has been found to increase the delivery of particulate solids to receiving waterways.

In an undeveloped area, a natural stream normally adjusts so that its cross section and bedslope are in approximate equilibrium, with sub-critical flows of $<0.6\ msec^{-1}$ being dominant. Increased volumes of stormwater runoff brought about by clearing and hardening of the catchment typically reach super-critical velocities in excess of $0.8\ msec^{-1}$, which entrain sediments (erosion) and produce significant changes in the natural stream channel. More frequent high-flow events and flooding can cause bank and streamline erosion, damage and disrupt ecological processes of foreshore areas and damage adjacent property, and infrastructure. Increases in peak velocities and increasing frequency of larger flows following development may also have implications for the processing and recycling of organic carbon and nutrients within foreshore areas.

Accelerated channel erosion can also create downstream damage by the deposition of eroded sediment. Lakes reservoirs and estuaries fill, stormwater pipes and culverts become clogged causing localised flooding and areas adjacent to streams may become covered with mud and debris and weed seeds left after each flood. Processes leading to the remobilization of sediments from upstream reaches of a waterway may, through time, lead to adverse impacts on downstream water quality and damage foreshore areas.

Suspended solids loadings to receiving wetlands and estuaries are likely to adversely impact on biota in a number of ways including physical smothering, increased light attenuation and changes to dissolved oxygen fields if the suspended solids contain a significant proportion of refractory organic matter. Physical smothering results when the loading of suspended solids settling onto

benthic organisms exceeds their clearance rates. For benthic plant communities this may reduce photosynthesis, and for suspension feeders, this may interfere with modes of feeding.

The accumulation of sediment in watercourses may also reduce the available habitat for instream flora and fauna.

4.3 NUTRIENT TRANSPORT

Clearing for urban and agricultural development, combined with the application of artificial fertilizers have been responsible for nutrient enrichment of many Australian estuaries (Deeley, 1999). Nutrients may be discharged to receiving estuaries and wetlands as dissolved or particulate forms, and significant amounts of these inputs are potentially biologically available given appropriate hydrodynamic processes, settling, resuspension and uptake mechanisms (Deeley, 1996).

Recent research undertaken in the southwest of WA (Weaver, 2014, McKergow, 2006a, McKergow, 2006b, Weaver, 2021) compared catchment-scale nutrient loss and attenuation rates from streams without or with vegetated foreshore areas-. Low order streams were found to have the highest nutrient and sediment concentrations and were more dominated by surface runoff. These lower order or smaller watercourses therefore represent the best opportunity to attenuate nutrients and sediment.

For surface flow and hill-slope erosion-dominated streams (like much of the Mundaring Shire), vegetated foreshore areas provided an effective means of reducing suspended solids SS (*i.e.* reducing erosion) (McKergow, 2003) and P transport, consistent with findings for soils with very high P-binding capacities (*i.*e. silts, loams, clays).

Stormflow into the Swan River from rural areas particularly on the coastal plain has long been recognised as a major source of nutrient pollutants. Efforts to date to reduce these nutrients have largely been unsuccessful (OAGWA, 2014). Experience elsewhere shows that it is possible to improve the health of rivers in urban areas, but it requires concerted and coordinated effort by the overwhelming majority of stakeholders, and long-term action. Success was found to depend upon state agencies, local governments and the private sector being aware of and acknowledging what needs to be done and in widespread implementation of restorative solutions (OAGWA, 2014).

4.4 ARE FORESHORE AREAS EFFECTIVE FOR WATER QUALITY IMPROVEMENT?

(Weaver, 2014) raised concerns about the effectiveness of foreshore areas for achieving nutrient reductions where there is a high probability of very high levels of P export such as on the Swan Coastal Plain. The cost-effectiveness of a range of agricultural productivity and stream restoration measures has recently been estimated (Figure 2). The left hand diagram with the orange circles represents sandy areas subject to P transport by subsurface transport mechanisms (leaching) and the right hand diagram with green circles represents areas dominated by surface flows such as the Shire of Mundaring. Management measures at the lower left of both diagrams have the least probability of success. Conversely, measures in the top right of the diagrams have the greatest chance of success.

These diagrams suggest that foreshore areas and associated grass filter strips are successful at enhancing habitat quality, at attenuating erosion and sediment-bound nutrients where surface

runoff is the dominant flow mechanism. Despite their many benefits however, foreshore areas may be less effective at attenuating P where sub-surface flows dominate.

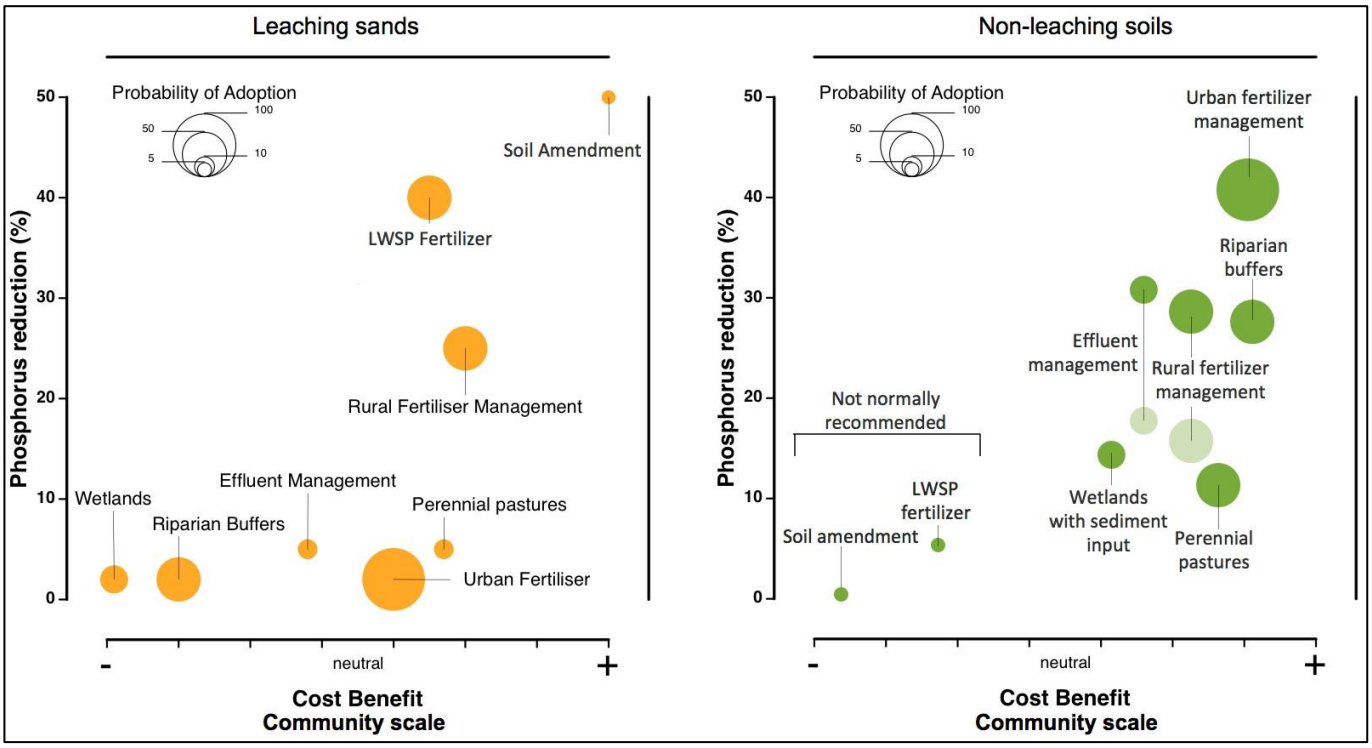


Figure 2 Estimated cost-effectiveness of nutrient management measures Note: coastal plain orange, Mundaring Shire green

4.5 IMPLICATIONS AND APPLICATION TO THE SHIRE OF MUNDARING

Foreshore areas and associated grass filter strips are successful at enhancing habitat quality and attenuating erosion and sediment-bound nutrients where surface runoff is the dominant flow mechanism such as for Mundaring Shire east of the Ridge Hill Shelf.

4.6 IMPACTS ON MUNDARING'S WATERCOURSES

The continuing demand for additional land for housing, industrial development and associated infrastructure necessitated by population increases, exerts significant pressure on naturally vegetated areas along watercourses. These areas may be impacted directly by clearing as part of urban expansion, as well as indirect impacts through human disturbance within foreshore areas, fragmentation of patches and the introduction of weed and pest vectors.

These direct and indirect pressures on naturally vegetated foreshore areas have in many areas, compromised the natural functioning of foreshore areas.

5 LEGISLATIVE, REGULATORY AND POLICY FRAMEWORKS FOR FORESHORE AREAS IN AUSTRALIA

5.1 LEGISLATIVE, REGULATORY AND POLICY FRAMEWORKS - WA

Protection of Lands, Waterways and Foreshore areas in WA is enabled by a number of Legislative Acts administered by a range of NRM and Planning agencies (Appendix 1). The following Section documents the range of legislation and requirements that may apply to landholdings and provide an understanding of how current legislative, policy, and voluntary frameworks guide property and environmental management and the role of government agencies in administering it.

There are several considerations relevant to land management, and water resource management in Catchments of the Mundaring Shire, for which a range of legislation, policies, and regulations apply. The key considerations are:

- Environmentally Sensitive Areas (ESAs) of Native Vegetation
- Threatened Species (Flora and Fauna) and Ecological Communities (Commonwealth listed)
- Threatened Species (Flora and Fauna), Ecological Communities and Threatening processes (State listed)
- Priority Ecological Communities (State listed)
- Areas mapped as potential fauna habitat (Fauna Habitat Zones, DBCA)
- Waste and emissions including discharges
- Contaminated sites
- Clearing of native vegetation
- Wetlands
- Ecological linkages
- Water Resources Management
- Department of Planning, Lands and Heritage (Aboriginal Affairs) Sites and Other Heritage Places
- Soil Conservation
- Land drainage and Acid Sulphate Soils
- Government Sewerage Policy.
- Swan Canning Development Control Area

5.2 LEGISLATIVE, REGULATORY AND POLICY FRAMEWORKS - EASTERN STATES

There are a range of different approaches being used across Australia including (Lovett, 2007):

5.2.1 ACT

Under the *Land (Planning and Environment) Act 1991*, through the *Territory Plan 2002*, land fronting the Murrumbidgee and Molonglo rivers are zoned river corridors and management must be consistent with their respective Management Plan. For other rural land that goes to the water edge, a section of the lease Land Management Agreement will address the management of the foreshore area. Failure to comply with a Land Management Agreement will incur a penalty.

5.2.2 NEW SOUTH WALES

Under the *NSW Native Vegetation Conservation Act 1997*, clearing is generally not permitted within 20 metres of the bed or bank of a stream or any part of a lake. Areas within 20 metres can be cleared only in accordance with development consent, or, if permitted, under a regional vegetation plan. Advice is generally site-specific.

5.2.3 NORTHERN TERRITORY

Under the *NT Water Act 1992*, any interference with a waterway or obstruction of flow requires a permit. A clearing application must include details of foreshore area vegetation and the *Land Clearing Guidelines 2002*, Resource Management Guidelines for the Northern Territory, Technical Report 27/2002 recommends buffer widths according to the nature and order of the waterway. To avoid erosion during activities such as construction, disturbance of banks should be kept to a minimum. In severe cases, legislative provisions under the *Soil Conservation and Land Utilisation Act 1980*, can be enacted to help protect sensitive areas.

5.2.4 QUEENSLAND

The *Queensland State Policy for Vegetation Management on Freehold Land 2000* (Department of Natural Resources and Mines) requires that 50 metres each side of first and second order streams (gullies and small streams) be left uncleared, 100 metres each side of third and fourth order (mid-sized) streams, and 200 metres each side of fifth order and larger streams (rivers).

5.2.5 SOUTH AUSTRALIA

Under the *SA Water Resources Act 1997, Watercourses Section 9 Permits*, (Fact Sheet 27), a permit is required to alter a waterway in any way. Staff from the local natural resources management agency can provide advice about the width of foreshore area that should be protected and the appropriate plant species to be used in the process. Where possible, the foreshore area should be fenced off if stock are on the property. Foreshore area vegetation is recommended to:

- slow overland movement of water allowing the settling of soil before water enters a watercourse, thereby reducing sediment deposits into the watercourse;
- slow flood waters;
- stabilise watercourse banks, reducing erosion;

- provide shade to watercourse to reduce water temperature and algal blooms; and
- provide habitat for animals living on land and in the water.

5.2.6 TASMANIA

The *Tasmania Land Use Planning and Approvals Act 1993, (Wetlands and Waterway Schedule)* has variable widths, depending on the particular Planning Scheme, which, in turn, has to be consistent with State Policies. However, removing vegetation within 30 metres of the outer boundary of permanent wetlands, waterway or shoreline or estuary is generally prohibited. Local government Planning Schemes must be consistent with Tasmania's Resource Management and Planning System.

5.2.7 VICTORIA

Under the *Victoria Planning and Environment Act 1987*, a permit is required where proposed activity is within 30 metres of a watercourse.

5.3 HOW ARE FORESHORE AREAS IDENTIFIED?

DWER's Operational policy 4.3 - Identifying and establishing waterways foreshore areas requires that after defining catchment boundaries and streamlines at an appropriate scale, the next step is in defining the foreshore area with the appropriate level of precision (DoW, 2012). This includes:

- Indicative foreshore area at a regional level;
- Refined foreshore area at the district planning level if risks are low and there are no significant site constraints; and,
- Final foreshore area at the local planning level, or at the district level if the risks are high, there are significant site constraints and if detailed district structure planning is being undertaken.

A foreshore area that has been defined appropriately will::

- allow compatible land uses and related development activities to occur
- maintain or improve the functions, services and biological and physical features of the waterway
- enable future restoration when restoration is recommended for degraded waterways. This may include restoring meanders in a straightened waterway.

5.3.1 PRIORITISATION STEPS

There are three steps to prioritising of management:

- Conservation precedes rehabilitation.

- Mimic ‘natural’ behaviour of waterway to minimise maintenance and be cost-effective.
- Consider more difficult tasks – often sustained period of readjustment, inordinate expense without corresponding substantive outcomes and impacts on community confidence in terms of waterway management effort.

While decision making on actual management will be through consultative processes with wide ranging agendas, rigour needs to be applied to procedures to determine priorities for protection and management of watercourses. Emphasis should be on return for dollars spent, working at sites with a high likelihood of success and prove sound management following a strategy that meets biophysical, socio-economic and environmental terms.

5.3.2 STREAM BUFFER WIDTHS

The following should be considered in developing stream buffer widths:

- Geology, geomorphological processes, soil types;
- Topography (elevation and landscape units) – allowing for retention, peak flows and erosion/accretion events, hydrology and rate/variation in discharge – river processes;
- Slope, valley confinement, channel geometry, channel shape; and,
- Hydrogeology – protection of hilltop springs and Surface and groundwater interactions.
- protection of flora and fauna, critically endangered, threatened, May not be consistent with standardised buffer widths.
- Original vegetation persistent or significantly altered, major species, groundcover, linkages, foreshore area/aquatic interactions
- Fauna distribution, rarity, diversity
- Aquatic ecosystems – persistent flora, fauna, distribution, movement, location of refuge pools and maintaining aquatic connectivity
- Nutrient status
- Foreshore area condition and channel form
- Associated wetlands
- Ecological linkages

5.3.3 ADJACENT LANDUSE AND MANAGEMENT

Principles depend on percentage of the catchment that is hard stand, point source inflows, diffuse nutrient sources and relationship to stormwater inputs.

- Changes in land use patterns – rural transition to rural residential, to urban - residential, industrial, commercial;
- Changes in river form – geometry, geomorphology, natural and human induced;
- State protected lands – reserves, national parks, state forests, dams, weirs, reservoirs; • Freehold title; and,
- Waterway Crossings – impact on buffer widths.

- surrounding land uses may also generate point source pollution and the discharge of contaminants into waterways.

5.3.4 BUSHFIRE RISK MANAGEMENT

Management of bushfire risks needs to be considered when planning for vegetated foreshore areas. It is important the revegetation strategies do not exacerbate bushfire risks for adjoining built and habitable assets. There can also be risk of increased sedimentation post fire if reserves are too narrow.

Riparian vegetation is generally considered to have an extreme fire risk and require appropriate hazard separation distances. Consideration of bushfire risk management in accordance with State Planning Policy 3.7 Planning in Bushfire Prone Areas and the development of a bushfire management plan is likely to be required.

The implementation of fire breaks and turn arounds are to be planned in conjunction with community groups and minimise the impact on remnant vegetation and revegetation wherever possible.

5.4 STATE PLANNING POLICY 2.9

Draft State Planning Policy 2.9, Planning for Water, and associated Planning for Water Guidelines (DPLH, 2021a, DPLH, 2021b) provides guidance to decision-makers regarding integrated water resource and land use planning management; how land and water related provisions are implemented. The draft SPP 2.9 has status and will replace the following policies and guidance:

1) State Planning Policy 2.1 Peel-Harvey Coastal Plain Catchment
2) State Planning Policy 2.2 Gnangara Groundwater Protection
3) State Planning Policy 2.3 Jandakot Groundwater Protection
4) State Planning Policy 2.7 Public Drinking Water Source Policy
5) Draft State Planning Policy 2.9 - Planning for Water Guidelines (2021)
6) State Planning Policy 2.10 Swan-Canning River System
7) Better Urban Water Management
8) Government Sewerage Policy
9) Government Sewerage Policy Explanatory Guidelines.

The *Planning and Development Act 2005* empowers Local Planning Schemes with the same force and effect of the Act. This enables a scheme or strategy to make integrated land use and water resource policy.

The Planning and Development Act takes into consideration allied regulatory frameworks of agencies including the Department of Water and Environmental Regulation, Environmental Protection Authority,and the Department of Biodiversity, Conservation and Attractions . Accordingly, SPP 2.9 and Planning for Water Guidelines outlines how water resource management should be integrated into the planning processes and, amongst other things, applies to the preparation of Local Planning Strategies.

The SPP 2.9 Guidance provides generic suite of management guidance for the preparation of the Mundaring Watercourse Hierarchy Strategy, the implementation of which is likely to be through

pragmatic strategies and actions to improve waterways. These strategies and actions are to inform and interrelate with the Biodiversity Strategy and Public Open Space Strategy, the environmental components of the future Local Planning Strategy.

SPP 2.9 applies to all proposals, throughout the planning procedures, prepared and assessed under the *Planning and Development Act 2005*. The essential policy outcome of significance for the Mundaring Watercourses Hierarchy Strategy is Parts 6.1 (ii) and (iv): to Protect…. and support healthy ecosystems through the:

(ii) protection of existing vegetation and or restoration of cleared or degraded vegetation, preferably with endemic species;
(iv) maintenance of natural flows in waterways, groundwater levels and inundation of wetlands to sustain aquatic and terrestrial habitats through the delivery of appropriate stormwater and groundwater management systems.

Proposals should, in accordance with the Guidelines and accordingly have been used to devise and apply strategic actions to the Mundaring Watercourse Hierarchy Strategy:

a) identify wetlands and their buffers and waterways and their foreshore areas and/or reserves;
b) facilitate the transfer of wetland buffers and waterway foreshore areas to public ownership, where appropriate;
c) retain and/or restore vegetation important for the long-term health of water resources within wetlands buffers and waterway foreshore areas with the restoration of vegetation should preferably using endemic species;
d) where possible, maintain and restore ecological linkages;
e) identity appropriate wetland buffers and foreshore areas to protect public health from mosquito borne diseases;
f) ensure that land uses that have the potential to significantly alter the hydrological regime are managed to protect water resources and associated ecological and aquatic values.

5.4.1 VALUES

Guidance notes related to environmental social and cultural values foreshore areas should be planned with sufficient distance between the waterway and adjacent land use(s) to allow for:

1. unimpeded movement of floodwaters during large flood events;
2. conservation of the waterway environment, including foreshore area vegetation;
3. maintenance of the natural hydrology of the waterway;
4. accommodation of elevated water levels and storm surges due to climate change;
5. management of pests and weeds, ;
6. public access and recreational use of the foreshore and the waterway, where appropriate;
7. no new installation or placement of public utility infrastructure (for example electricity, gas and sewerage) or on-site wastewater management systems;
8. views of the waterway from public places (the clearing of vegetation (or avoiding planting native vegetation) will not be justified to provide water views);
9. rising river levels and storm surges;

10. protection and enhancement of landscape and landform, where needed;
11. adequate separation distance from disease vector and nuisance insects such as mosquitoes and midges; and
12. no direct discharge of stormwater runoff and/or mobilised groundwater (via pipes and drains for example), consistent with the *Decision Process for Stormwater Management in Western Australia* (DWER 2017).

It is acknowledged that the management of mosquitoes/midges and other nuisance insects is dependent on minimising areas of stagnant water and maintaining restoration areas, in addition to the implementation of adequate separation distances that are preferably vegetated.

5.5 SHIRE OF MUNDARING PLANNING SCHEME

Unlike most local authorities, the Shire of Mundaring's Local Planning Scheme No. 4 has a series of related clauses that implement waterways management. These are:

5.7.5 Development requirements
5.7.6 Stormwater water provisions
5.7.7 Effluent disposal
5.7.9 Construction sites
5.7.12 Vegetation protection
5.7.14 Rehabilitation of land
5.8.1 Building envelope provisions
5.8.2 Dams
6.6 Flood Prone Areas
Part 6 - Special Control Areas (Water Catchment areas) and flood prone areas.

urbanplan examined the most significance clauses that stipulate mandatory requirements and offers the following commentary regarding implementation:

5.5.1 CLAUSE 5.7.5

Development requirements stipulate the minimum setback for all buildings and earthworks (including landfill) from the top of the bank of any watercourse shall be:

a) That specified for a watercourse as given in a watercourse hierarchy and protection strategy; and
b) in the absence of a specific setback, 20 metres in the Residential Zone and 30 metres in all other zones

Within that setback:

- native vegetation is to be retained
- natural water flow maintained
- measures to minimise runoff and erosion
- apply conditions of approval to require rehabilitation, ceding of land and conservation management.

5.5.2 CLAUSE 5.7.6

Subdivision and development shall employ best water management practices to affect the retention of stormwater within the development area to:

- minimise velocity and quantity of stormwater; and
- prevent sediment and pollution load.

5.5.3 CLAUSE 5.7.7

Clause 5.7.7 stipulates the requirements for the type of on-site effluent disposal, setbacks to waterways or sources and potential for additional setbacks where appropriate.

5.5.4 CLAUSE 5.7.9

Construction sites are required to minimise soil erosion, sedimentation and/or the degradation of any water resource and stipulate the management to be applied to a construction site.

5.5.5 CLAUSE 5.7.12

To reinforce the powers of clause 5.7.5, clause 5.7.12 prevents the destruction of native vegetation with the exception of lot within the required waterway setback.

5.5.6 CLAUSE 5.7.14

Clause 5.7.14 gives the Shire the powers to require an owner or occupier of any land to rehabilitate land in relation to soil erosion or dust, or the alteration of surface water flows

5.5.7 CLAUSE 5.8.1

Clause 5.8.1 enables the Shire to stipulate building envelope provisions across the various zones.

5.5.8 CLAUSE 5.8.2

There is a presumption against dam construction however regard shall be given to the maintenance of natural stream flow, under base flow (non- rain) conditions within the watercourse.

5.5.9 CLAUSE 6.6

Flood Prone Areas are defined by a Special Control Area planning mechanism and all building development or earthworks within Flood Prone Areas shall require planning approval and in doing so may refuse or apply conditions.

5.5.9.1 COMMENTARY

In unison, the clauses of the Local Planning Scheme No. 4 (of same force and effect as the *Planning and Development Act*) give the Shire the lead statutory authority, the powers to stipulate and apply integrated waterways management to minimise soil erosion, sedimentation pollution and or the degradation of any water resource.Particularly within an identified setback currently set at 20 to 30 metres, whether it be by stipulation in a strategy or by condition approval.

What remains is establishing appropriate waterways or foreshore areas and appropriate stormwater detention mechanisms for various Strahler stream orders, employing best water management practices for urban or rural residential or rural land use (Refer section 6.0).

5.6 SHIRE OF MUNDARING LOCAL PLANNING STRATEGY

The Local Planning Strategy sets out the long-term planning directions for the Shire of Mundaring over the next ten to fifteen years, applies the wide range of applicable State, regional and local planning policies and strategies, and provides the rationale for the land use and development control proposals in Local Planning Scheme No. 4.

It is intended that the Local Planning Strategy will be read in conjunction with Local Planning Scheme No. 4 and vice versa. The Local Planning Strategy is to guide the operation of Local Planning Scheme No. 4. It is a requirement of the Scheme that, except to the extent of any inconsistency between the two, determinations under the Scheme are to be consistent with the Local Planning Strategy. Moreover, an adopted Local Planning strategy is taken to be a document to be taken into account when making determinations.

5.6.1 OBJECTIVES AND AIMS

The objectives and aims of this Local Planning Strategy relevant to the Watercourse Hierarchy Strategy are:

<u>Function of Local Planning Strategy</u>

a) to set out the long-term planning directions for the Shire of Mundaring
b) to outline, interpret and, as appropriate, apply State and regional planning policies and strategies
c) to provide the rationale for zones and reserves, Special Control Areas and other provisions of the Shire's accompanying Local Planning Scheme No. 4.

<u>Key strategic objectives</u>

a) to set promote and support sustainable development within the Shire
b) to protect, manage and enhance the environment.

<u>Subsidiary aims and objectives</u>

a) to identify and respond to significant medium and longer-term challenges facing the Shire

b) to manage development to actively contribute to the Shire's unique character and to protect and enhance its natural hills environment
c) to protect and enhance key environmental assets
d) to protect and manage biodiversity within the Shire and reduce threat to the diverse forms of life within the district
e) to identify, enhance and preserve elements of cultural significance.

6 MOVING FORWARD: STRATEGIES AND ACTIONS

6.1 CONTEXT

The following strategies and actions have been promulgated with reference to the SPP 2.9 Guidelines, namely:

a) identify wetlands and their buffers and watercourses and their foreshore areas and/or reserves;
b) facilitate the transfer of wetland buffers and waterway foreshore areas to public ownership, where appropriate;
c) retain and/or restore native vegetation important for the long-term health of water resources within wetlands buffers and waterway foreshore areas with the restoration of vegetation should preferably using endemic species;
d) where possible, maintain and restore ecological linkages;
e) identify appropriate wetland buffers and foreshore areas to protect public health from mosquito borne diseases;
h) ensure that land uses that have the potential to significantly alter the hydrological regime are managed to protect water resources and associated ecological and aquatic values. These proposed strategies and actions are supported by the current provisions in Local Planning Scheme No. 4, those being identified in section 5.3 above.

6.2 STRATEGIC CONTEXT

6.2.1 STATE POLICY SAYS

State Planning Policy 2.9 states:

- Local Strategies should map all water resources within a local government, assign each type of resource a priority or hierarchy of significance and identify appropriate setbacks or buffers.
- Application of WSUD should be integrated early into the planning progress, preferably in the structure planning phase.
- Post development stormwater conditions should approximate predevelopment conditions.

6.2.2 INTENDED APPROACH TO MANAGEMENT

The intended approach to Watercourses management includes:

- Map all waterways above stream order 3 and assign a hierarchy.
- Stormwater detention is an integral component of the urban and peri-urban landscape.
- Maintain stream biodiversity, waterway health and habitat values.
- Improve stream flow and ecological environments.
- Identify and implement setbacks to all watercourses.

6.2.3 KEY ISSUES AND THREATS INCLUDE

Altered stream environments accelerate erosion and nutrient loss.

Loss of biodiversity and damage to ecosystems occurs through:

- clearing for development
- habitat fragmentation
- introduction of invasive weeds.
- uncontrolled wildfires
- inappropriate burning regimes.

6.2.4 WATERCOURSES HIERARCHY STRATEGY OBJECTIVES

The objectives of the Mundaring Watercourse Hierarchy Strategy comprise:

- Identify and map waterway and ecological corridors in defined catchments through urban and peri-urban areas that require restoration.
- Establish appropriate setbacks and buffers to waterways according to Strahler stream hierarchy and priority.
- Apply stormwater detention structures strategically throughout levels of the Strahler stream hierarchy.
- Design and install stormwater structures for areas with extensive areas of hardscape to manage flow velocities and volumes.
- Establish and protect waterway corridors to maintain ecological connectivity.
- Determine appropriate separation buffers for on-site wastewater apparatus.
- Manage bushfire fuel loads and invasive weed species within waterway corridors. Retrofit stormwater flow compensation structures to manage peak flow velocities where erosion has been observed.

6.3 GIS-BASED STREAMLINE ASSESSMENT AND MAPPING

A LiDAR system flown over the Shire filled gaps in spatial information and improved the resolution of some existing coverages. LiDAR, which stands for *Light Detection and Ranging,* is a remote sensing method that uses light in the form of a pulsed laser to measure distances to features on the Earth's surface. Many thousand of light pulses combined with other data recorded by the airborne system, generate precise, three-dimensional information about the shape of the Earth and its surface characteristics. The LiDAR instrument principally consists of a laser, a scanner and a specialized GPS positioning receiver fitted into airplanes or helicopters for acquiring LiDAR data over broad areas.

A high resolution digital elevation model (DEM) was constructed from the LiDAR data which facilitated the computer synthesis of a Strahler stream network. Small streams that have no tributaries are categorised as first order. The stream order only increases when two streams of the same category converge. A 9th order stream is only formed when two 8th order streams converge and so on. The hierarchy of streamlines described in this report was generated automatically by the Shire's GIS staff and provided to the consulting team. Automatically-

generated spatial data are entirely reliant on the quality of the method of data gathering employed and the level of ground truthing used to verify and calibrate the output.

The automatically-derived data for the Shire were combined with a wide range of other spatial coverages provided by the Shire and State WALIS agencies. It is understood that there was only a limited amount of ground-truthing undertaken and resulting coverages can always benefit from additional calibration and verification. Accordingly, it should be appreciated that the 1st and 2nd order streams that are very small, were not included in the analysis presented here, because of greater levels of uncertainty associated with small differences in elevation recorded by the LiDAR laser for the smaller streams. The positioning and connectedness of the higher order streams (i.e., ≥3rd order), was considered to be reliable enough for the current investigation and an improvement of previously available sparse streamline data for the Shire.

Strategic issues have been collated as a strategic overview (Figure 3). In addition to the spatial spread of streamline-related issues across the shire, this map also shows the main waterway sub-catchments within the Shire, the Strahler stream orders 3-9 for mid-sized and larger streams, Perth Biodiversity Priority areas and the shire's existing and proposed urban cells. Total 3-9th-order watercourse lengths by landcover zone have been included as Appendix 4.

A strategic outlook has been developed (Figure 4), based on recommended actions to address the identified issues within the Shire's current and evolving legislative, regulatory and policy framework. This figure also shows a clearer depiction of the Strahler streamlines and strategic directions for the various zones across the Shire. A cross-sectional elevation profile was developed for the Shire from the provided contours (Figure 5). This acts as a key for describing and identifying zones for the Strategic outlook (Figure 4), and also presents a conceptual stormwater and an erosion management strategy highlighting slope-zones. Slopes are the dominant factor driving stream flow velocities and hence erosive potential. The implementation of policies and actions to address the determined issues and opportunities, are discussed in more detail in Section 6.

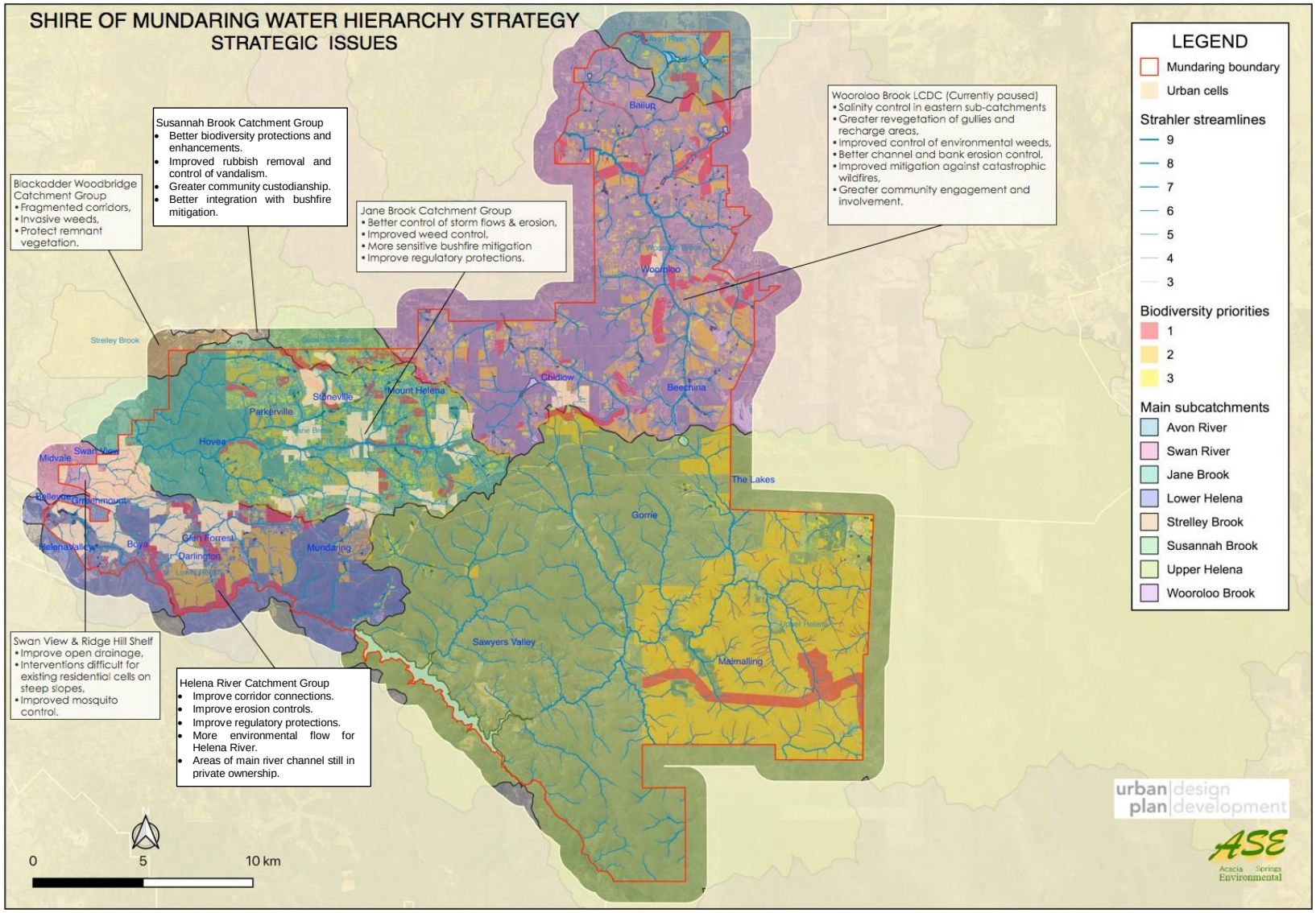


Figure 3 Strategic issues raised by community catchment group members and desktop research.

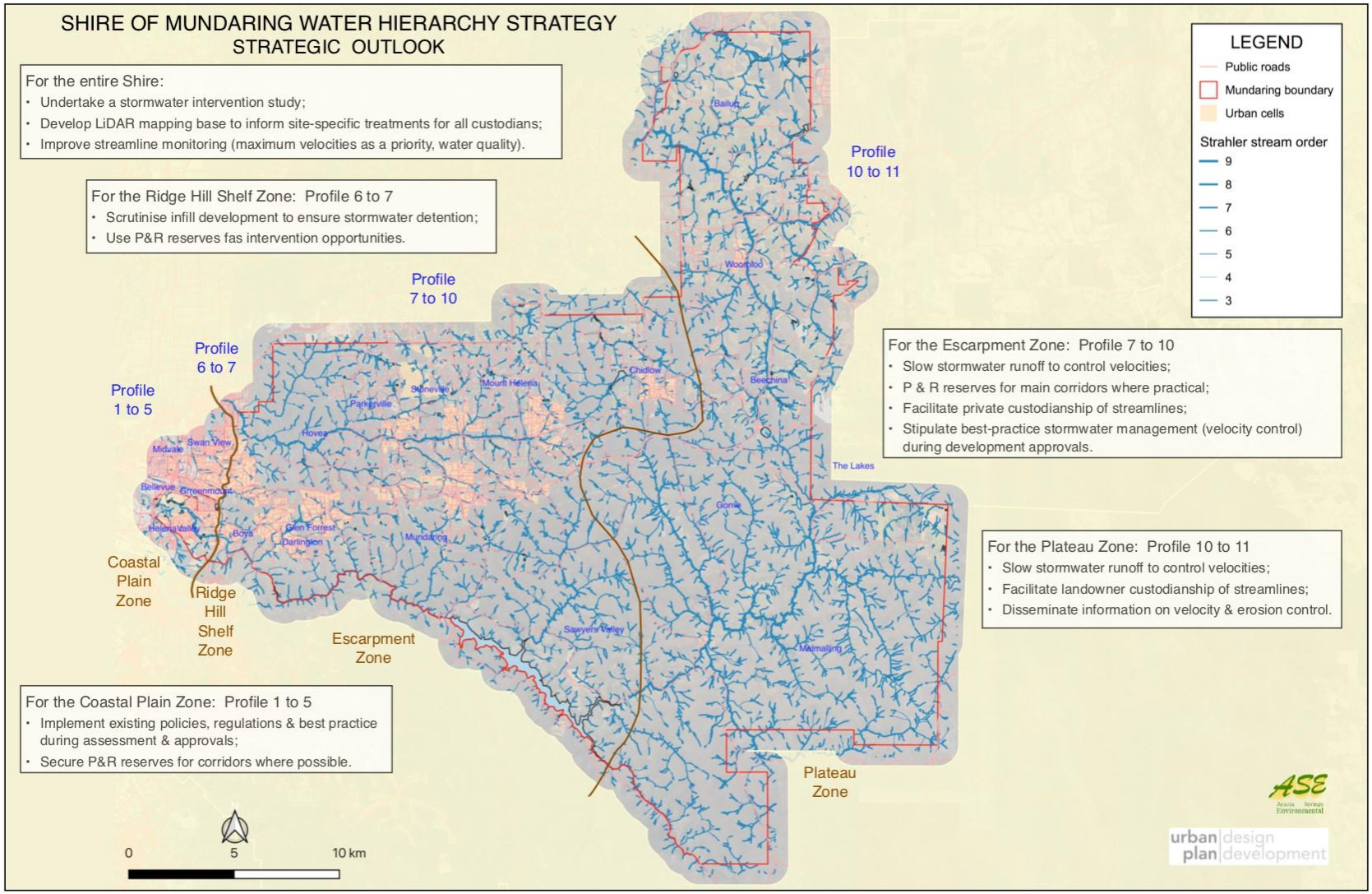


Figure 4 Strategic outlook for streamline management

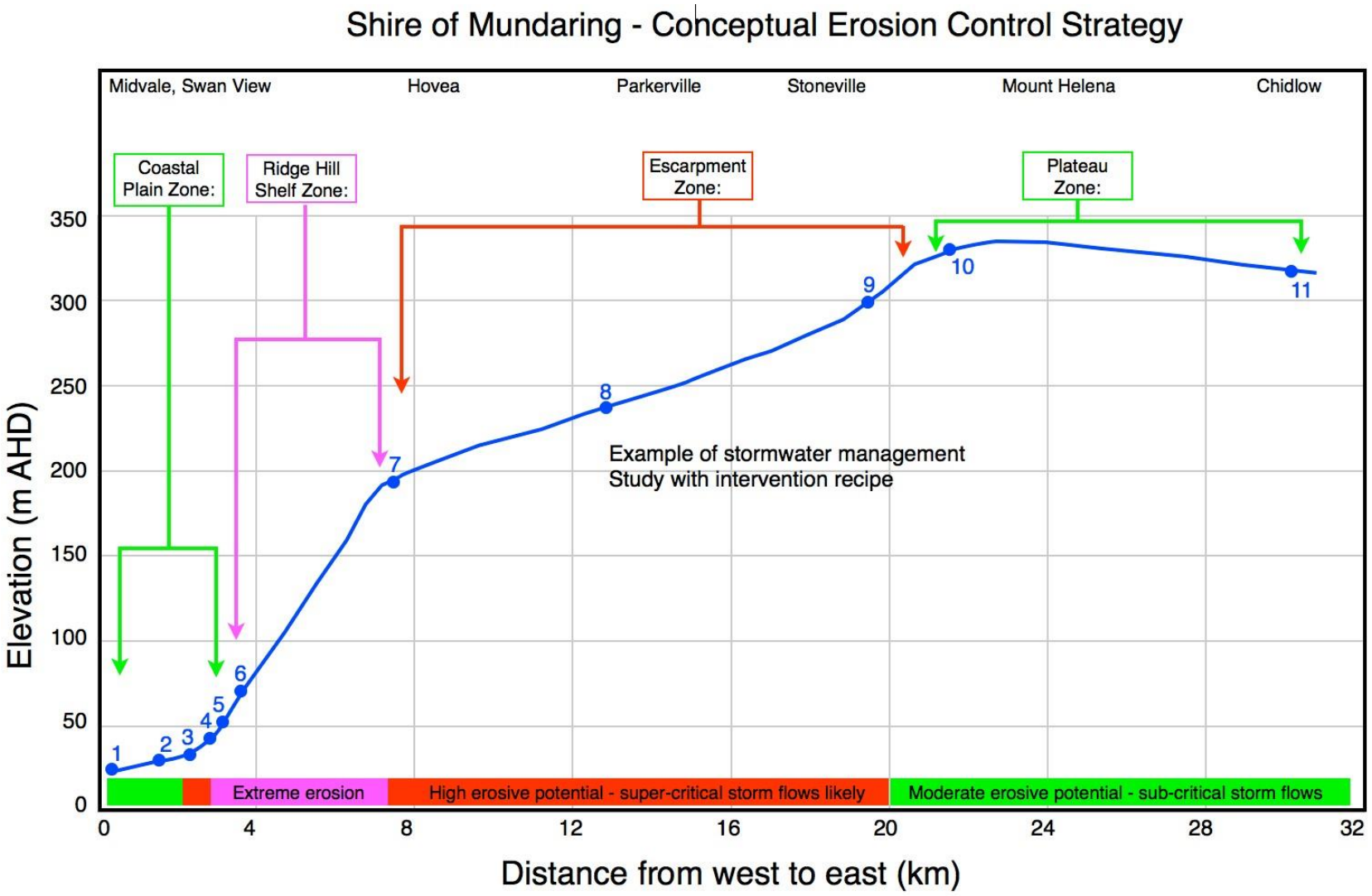


Figure 5 Profile through the shire and key to Strategic outlook diagram at Figure 4.

7 RECOMMENDED PRIORITISED AND ASSIGNED STRATEGIES AND ACTIONS

7.1 GENERIC PRINCIPLES

In consideration of the priorities derived during this investigation, this Watercourse Hierarchy Strategy for the Shire of Mundaring has in essence been distilled to:

1. Better control of storm flow peak-velocities across the shire for improved erosion control.
2. Greater focus on protecting and rehabilitating ecological function and biodiversity along watercourse corridors, especially through urban and rural residential areas.
3. To better coordinate and integrate watercourse corridor protective and restorative efforts between responsible agencies and communities.
4. To provide information about watercourse ecology and function so as to inform and educate people living near to and visiting the shire's watercourses.
5. Improve sharing of information about bushfire mitigation works and ecological restoration efforts along corridors.
6. To facilitate and support a greater level of community and agency awareness and involvement with watercourse corridor protections and enhancements so as to broaden and strengthen local ownership and appreciation of these valuable ecological systems.

Five case studies were established across the shire to demonstrate where and how actions and activities might improve the ecological function and protections for watercourses and their corridors (Figure 6). The case studies were chosen to represent various locations and scales in order to appropriately address watercourse hierarchy issues across the shire.

These included:

I. a range of WSUD best management practices at various scales targeted to Mundaring's topography and hydrological processes (Figures 7 to 11);
II. Identification of locations to improve corridor biodiversity outcomes;
III. Locations where multiple-agency outcomes need to be met;
IV. Applying Strahler stream order classification to the watercourses and their associated buffers throughout the shire to help target protection and rehabilitation opportunities; and
V. To provide a database of maps and geo-located photographs of issues and opportunities.

7.2 RECOMMENDED PRIORITY ACTIONS FOR VARIOUS CATCHMENT SITUATIONS (APPENDIX 5).

- Undertake a Stormwater Intervention Study.
- Develop and disseminate a LiDAR mapping data base to inform site specific stormwater treatments for all user groups.

In applying these principles, it is recommended the Shire of Mundaring implement the following strategies and actions:

7.2.1 WATER QUALITY

- Maintain Planning Scheme provisions that require proposals with the potential to impact on water quality to demonstrate that appropriate design, infrastructure and management regimes can manage water quality risks: Shire of Mundaring (SoM).
- Implement a new clause in the Planning Scheme to require Agriculture Intensive uses with high phosphorus export hazard or very low to low land capability undertake site specific soil and land capability assessment, including testing of soils for phosphorus buffering: SoM.
- Implement a new clause in the Planning Scheme requiring the preparation of a nutrient management plan for uses that propose irrigation with nutrient rich wastewater or fertigation to ensure uses are in accordance with Water Quality Protection Note No. 33 of DWER: SoM.

7.2.2 WATERWAY SETBACKS AND BUFFERS

When considering a proposed reduction to the setback stipulated under clause 5.7.5.1, the Shire shall have regard to the following:

a) The nature and scale of the proposed land use and/or works.
b) The potential for erosion as a result of any proposed works.
c) The likely flow amount and frequency the watercourse receives.
d) The type, extent and health of all existing native vegetation adjacent to the watercourse.
e) Whether revegetation is required, and the types of species which should be used.
f) Whether the watercourse has been historically modified or if the watercourse is in its natural state and alignment.
g) The effluent disposal system location requirements of the Government Sewerage Policy.
h) Whether any improvements are proposed which would improve the health of the watercourse or mitigate any impacts introduced by the development.
i) Whether there are any implications for bushfire risk and, if applicable, achieving the BAL-29 rating for future development.
j) Whether any livestock access to the foreshore exists, is proposed, or if there is the potential of this occurring.
k) Whether the watercourse is on existing or proposed public open space, or on private property.
l) The zoning of the land and the possible future land uses within the locality.
m) Any adopted local planning policies and state planning policies.
n) Any recommendations in the Shire's adopted Watercourse Hierarchy Strategy.
o) Any other consideration the Shire considers appropriate.

- When considering a proposed reduction to the standard minimum setback of 100 m from watercourses for septic wastewater disposal apparatus (Department of Health) may be varied where it can be demonstrated that soils within the leach field have sufficient hydraulic permeability and P-retention characteristics. Soil amendment may be required.

- The on-going management of watercourses on freehold land is embedded in planning approvals as per Local Planning Scheme No. 4 requirements.

- Identify and map 20 metre and 30 metre watercourses setbacks in urban and peri-urban areas respectively and include in the Shire's Local Planning Strategy.

- Protect and improve management of remnant vegetation in waterway corridors by empowering catchment groups and all landowners.

- Identify and map important biodiverse rich areas and preclude inappropriate uses with a view to establishing Special Control Areas.

7.2.3 BUSHFIRE RELATED

- Ensure that the Shire's district level Bushfire Risk Management System (BRMS) and mitigation targets adequately address:
    - bushfire fuel loads and invasive weed species within waterway corridors;
    - acceptable approaches to remnant vegetation restoration planning and management, as applied to waterway buffers and setbacks identified in the Local Planning Strategy: SoM.
    - the impacts of too frequent or infrequent and intense bushfires or prescribed burns on native vegetation.

Note: Native revegetation designed to maintain low bushfire risk (eg. plants less than 20cm height) is not usually compatible with foreshore improvement.

7.2.4 STORMWATER DETENTION

- Retrofit in-line and off-line stormwater treatment mechanisms to reduce erosion by peak storm velocities: SoM.
- Stormwater management systems should apply endemic vegetation to promote filtering, reduce velocity of stormwater runoff to approximate pre-development conditions: SoM and Proponent.

7.2.5 WATERWAY CORRIDOR VEGETATION

- Revegetate gaps in 'foreshore areas 'to reduce habitat fragmentations: SoM and Proponent.
- Replant sedges and rushes along gently sloping road drains to reduce erosion: SoM and Proponent.

7.2.6 INFORMATION DISSEMINATION:

- Establish and disseminate an electronic platform that creates a data base for the mapping of all related waterway corridor inputs. The purpose of the data base is to focus attention on stormwater intervention at the intersection of wildfire, public open space and biodiversity corridors.
- Disseminate information to the public describing the value and means of installing vegetated watercourses at all levels of the waterway hierarchy: SoM.
- Create an awareness and publicity campaign about implications of ecological corridor vandalism and benefits of rubbish removal: SoM

- Incentivise greater community participation and custodianship in waterway and ecological corridor management by prioritising Officer site visits for waterway custodians: SoM
- Create feedback loop on Shire Webpage to obtain the location of observed invasive weed infestations and occurrence of erosion: SoM and Catchment Groups.

7.2.7 CULTURAL HERITAGE

- Approach Aboriginal Elders for advice and involvement in their cultural heritage approach to watercourses and ecological corridor management, and bushfire management: SoM.

7.2.8 PREVIOUS STRATEGY CONSIDERATIONS

Of the previous strategic considerations for inclusion into the Watercourses Hierarchy Strategy is the following provision:

- Include the Helena River Salinity Situation Statement into Local Planning Scheme No. 4, matters to be taken into account, in determining applications for planning approval within the Mundaring Weir Catchment.

7.2.9 COMMENTARY

As empowered by the provisions of Local Planning Scheme No. 4, we recommend that:

- the above strategies and actions become part of the Watercourse Hierarchy Strategy;
- cross fertilize these strategies with those in the Biodiversity and Public Open Space Strategies; and
- be implemented by way of inclusion in the future review of the Local Planning strategy to give force and effect.

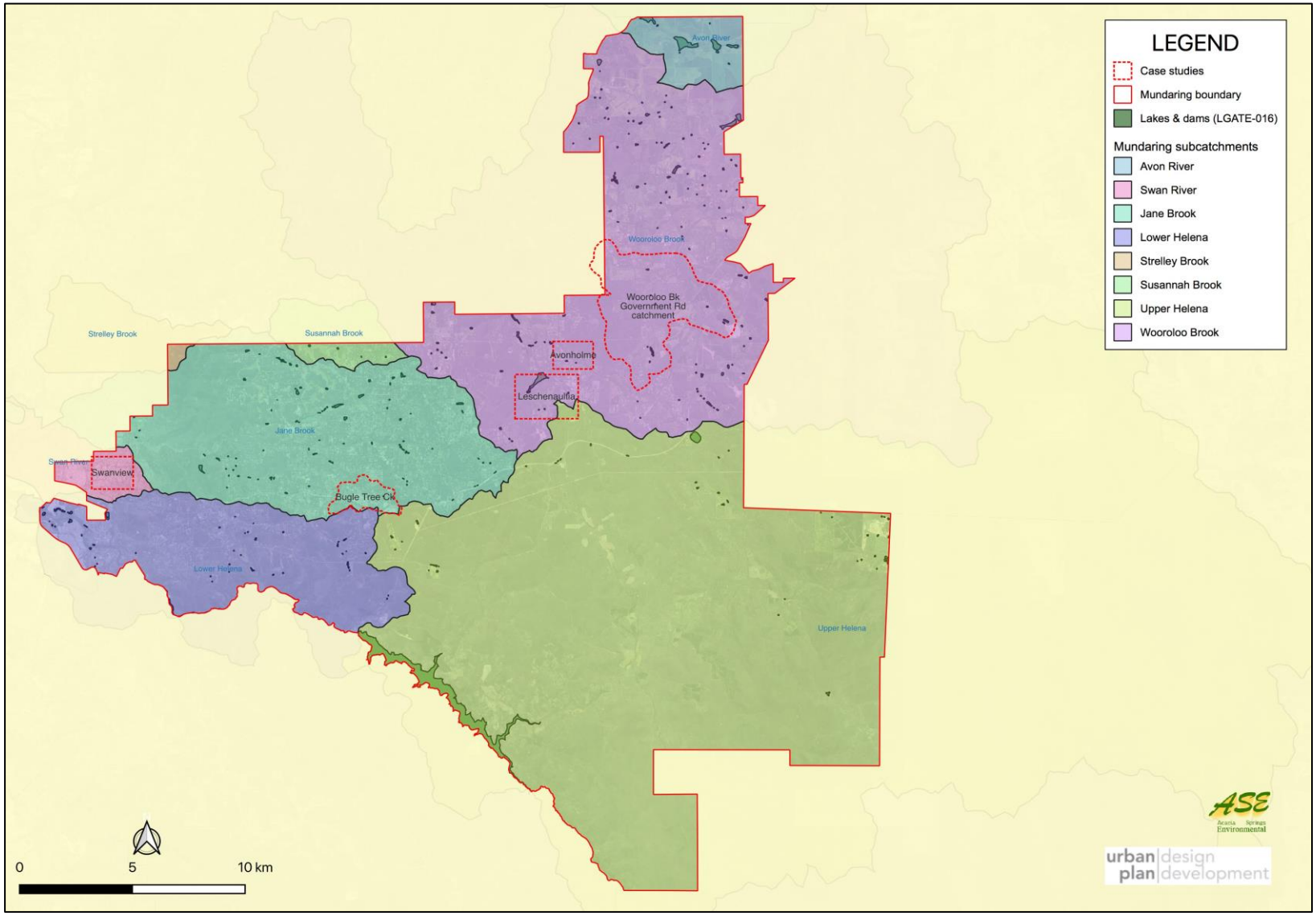


Figure 6 Location of case example areas

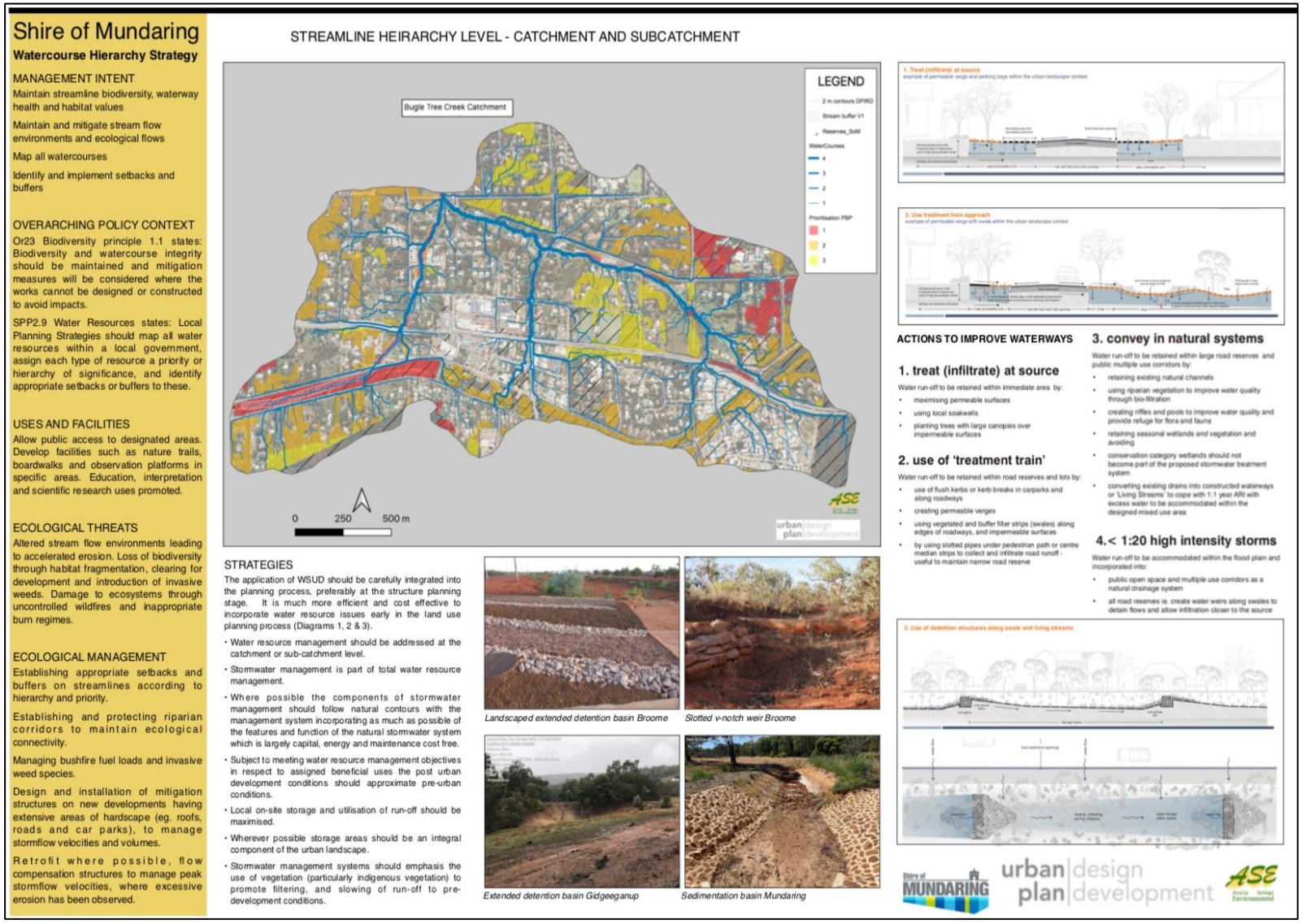


Figure 7 Catchment-scale watercourse management measures – Bugle Tree Creek

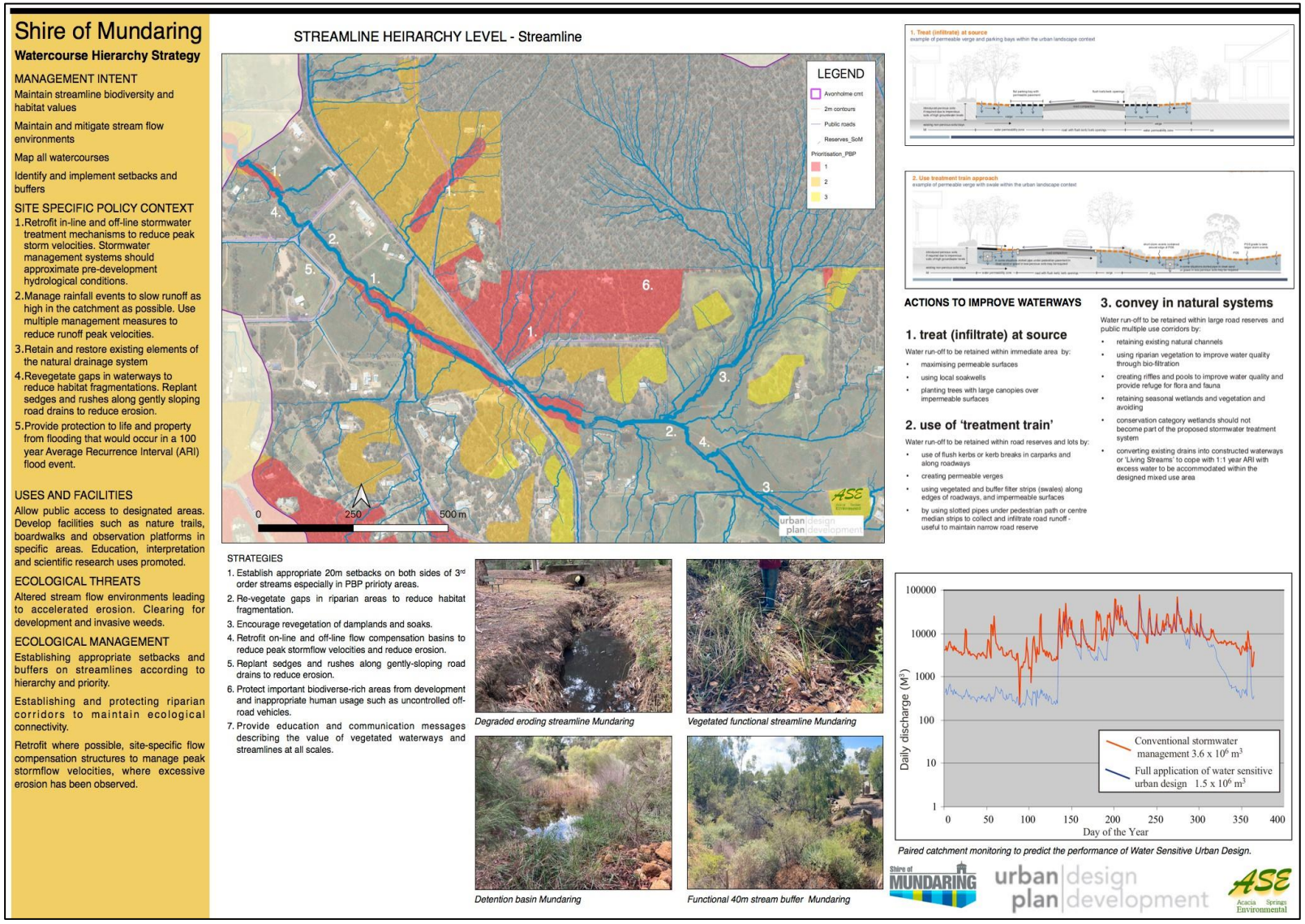


Figure 8 Watercourse management measures for the Avonholme precinct

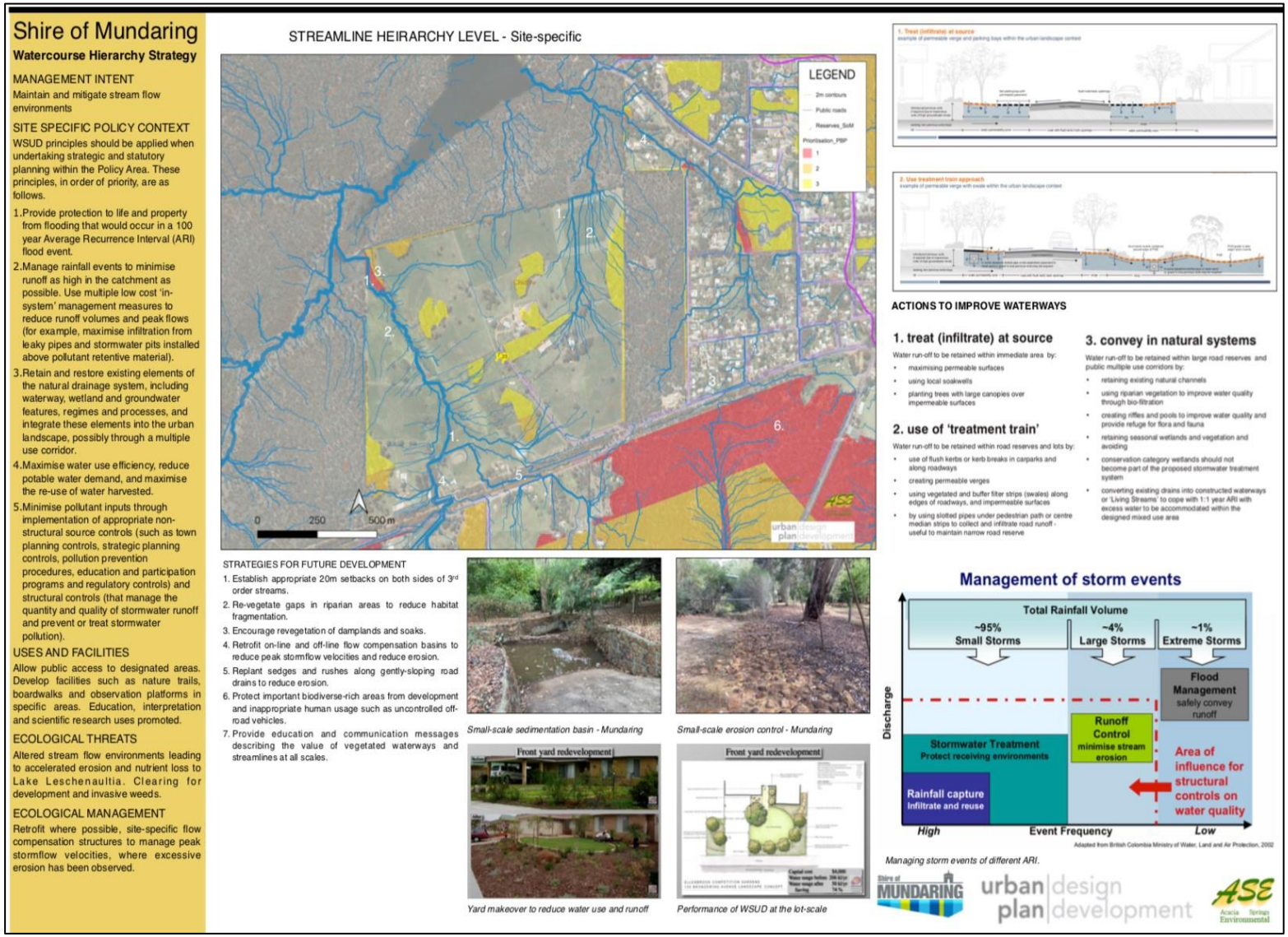


Figure 9 Watercourse management measures for the Leschenaultia precinct

Shire of Mundaring

Watercourse Hierarchy Strategy

MANAGEMENT INTENT

Maintain streamline biodiversity and habitat values

Maintain and mitigate stream flow environments

Map all watercourses

Identify and implement setbacks and buffers

SITE SPECIFIC POLICY CONTEXT

1. Construct on-line and off-line stormwater detention structures to reduce peak storm velocities. Stormwater management should approximate pre-development hydrological conditions.
2. Manage runoff events to slow runoff as high in the catchment as possible. Use multiple management measures to reduce runoff peak velocities.
3. Revegetate gullies and recharge areas for salinity control.
4. Revegetate gaps in waterways to reduce habitat fragmentations.
5. Provide protection to life and property from flooding that would occur in a 100 year Average Recurrence Interval (ARI) flood event.
6. Ensure bushfire fuel-load mitigation is undertaken regularly and is sensitive of watercourse ecological plantings.
7. Use Strahler mapped corridors to inform developement and watercourse corridor protections and rehabilitation.

USES AND FACILITIES

Allow public access to designated areas. Develop facilities such as nature trails, boardwalks and observation platforms in specific areas. Education, interpretation and scientific research uses promoted.

ECOLOGICAL THREATS

Altered stream flow environments leading to accelerated erosion. Clearing for development and invasive weeds.

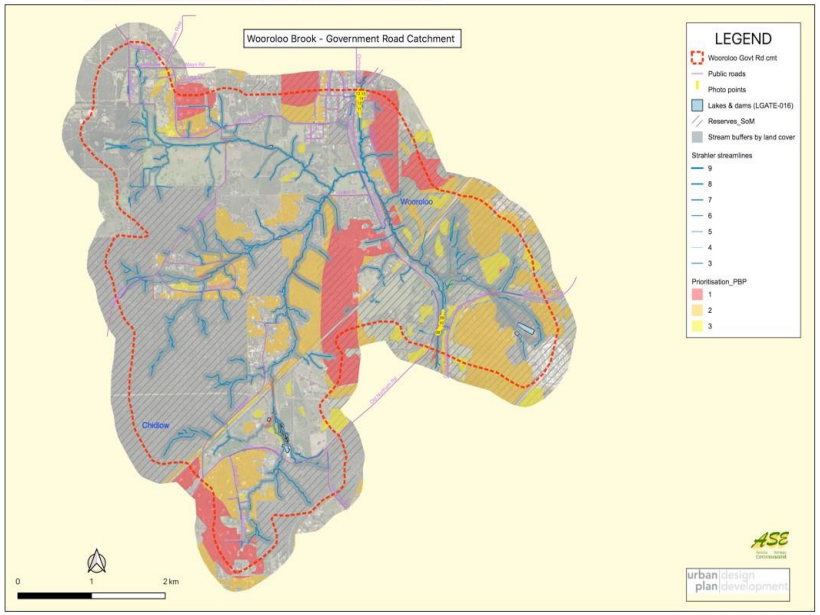
ECOLOGICAL MANAGEMENT

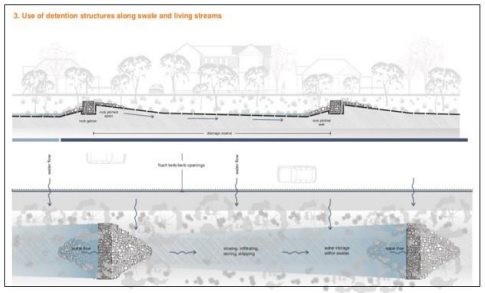
Establishing appropriate setbacks and buffers on streamlines according to hierarchy and priority.

Establishing and protecting riparian corridors to maintain ecological connectivity.

Retrofit where possible, site-specific flow compensation structures to manage peak stormflow velocities, where excessive erosion has been observed.

STREAMLINE HEIRARCHY LEVEL - Streamline





ACTIONS TO IMPROVE WATERWAYS

1. treat (infiltrate) at source

Water run-off to be retained within immediate area by:

- maximising permeable surfaces
- using local soakwells
- planting trees with large canopies over impermeable surfaces

2. use of 'treatment train'

Water run-off to be retained within road reserves and lots by:

- use of flush kerbs or kerb breaks in carparks and along roadways
- creating permeable verges
- using vegetated and buffer filter strips (swales) along edges of roadways, and impermeable surfaces
- by using slotted pipes under pedestrian path or centre median strips to collect and infiltrate road runoff - useful to maintain narrow road reserve

3. convey in natural systems

Water run-off to be retained within large road reserves and public multiple use corridors by:

- retaining existing natural channels
- using riparian vegetation to improve water quality through bio-filtration
- creating riffles and pools to improve water quality and provide refuge for flora and fauna
- retaining seasonal wetlands and vegetation and avoiding
- conservation category wetlands should not become part of the proposed stormwater treatment system
- converting existing drains into constructed waterways or 'Living Streams' to cope with 1:1 year ARI with excess water to be accommodated within the designed mixed use area

STRATEGIES

1. Establish appropriate buffers along both sides of all streams, especially in PBP pririority areas.
2. Re-vegetate gaps in riparian areas to reduce habitat fragmentation.
3. Encourage revegetation of recharge areas and soaks.
4. Establish on-line and off-line detention basins to reduce peak stormflow velocities and reduce erosion.
5. Replant riparian vegetation in areas where it has been lost.
6. Protect important biodiverse-rich areas from development and inappropriate human usage such as uncontrolled off-road vehicles.
7. Provide education and communication messages describing the value of vegetated waterways and streamlines at all scales.

Degraded eroding streamline Wooroloo Bk

Slotted basin outlet structure to slow stormflows

Vegetated stream resists erosion Wooroloo Bk

Functional 50m stream buffer Wooroloo Bk

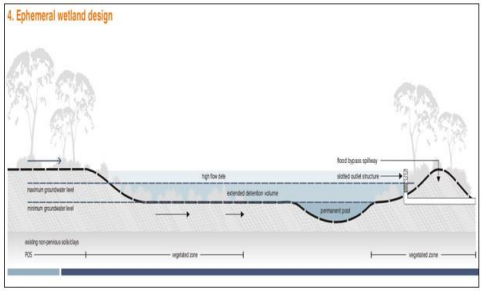


Figure 10 Watercourse management measures for the Wooroloo Bk Government Road precinct

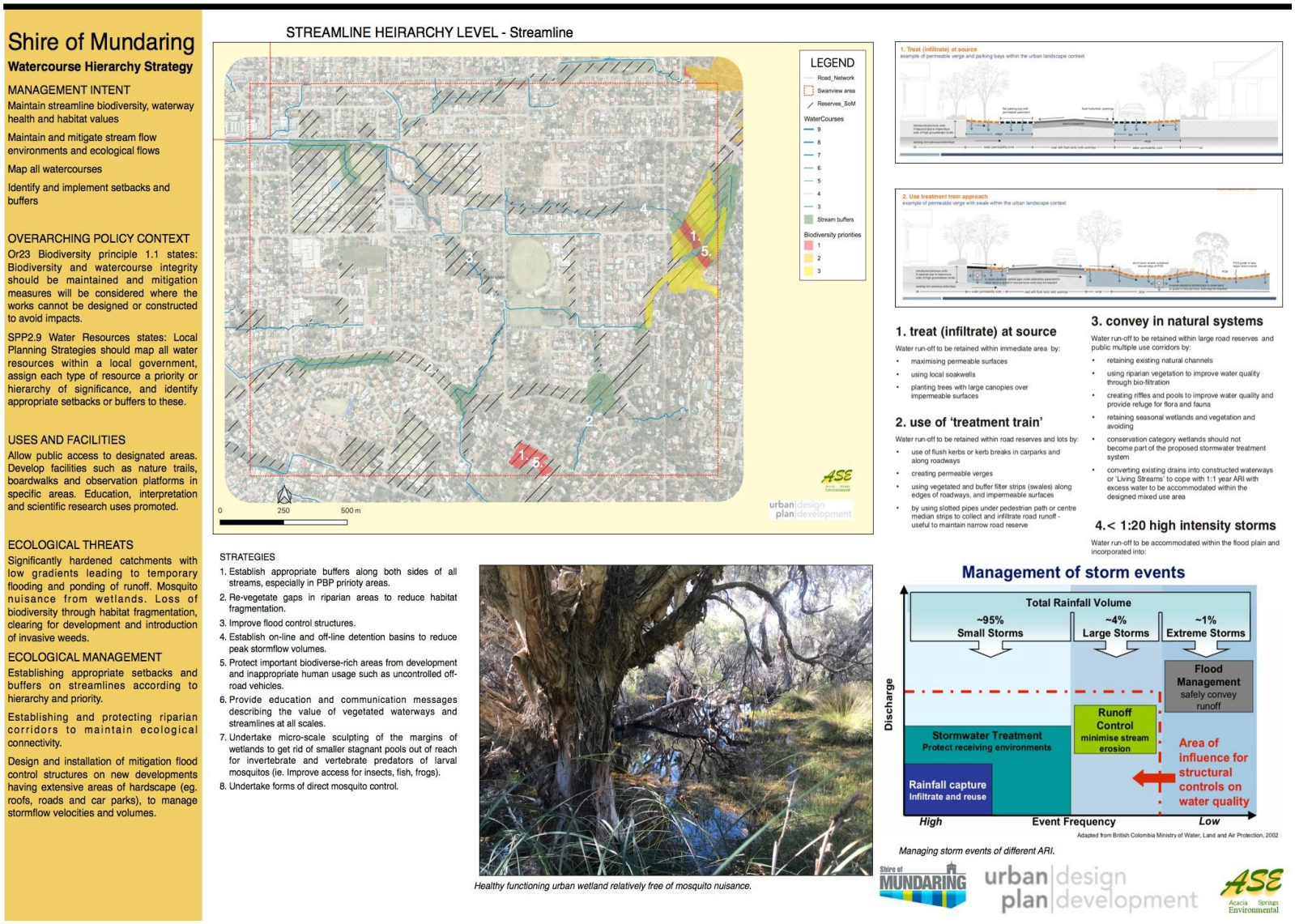


Figure 11 Watercourse management measures for the Swanview precinct.

8 REFERENCES

DEELEY, D. M., PALING, E. I. 1996. Assessing the ecological health of estuaries in southwest Australia. *In:* MCCOMB, A. J. (ed.) *International Association of Ecology.* Perth.

DEELEY, D. M., PALING, E.I. 1999. Assessing the ecological health of Estuaries in Australia. *Occasional Paper Urban sub-program report.* Land and Water Resources Research and Development Corporation

DOW 2012. Operational policy 4.3: Identifying and establishing waterways foreshore areas. Perth: Department of Water.

DPLH 2021a. Draft State Planning Policy 2.9 Planning for Water. Perth: Department of Planning, Lands and Heritage.

DPLH 2021b. draft State Planning Policy 2.9 Planning for Water Guidelines. Department of Planning, Lands and Heritage.

LOVETT, S. P., P. (EDS) 2007. Principles for riparian lands management. *In:* LOVETT, S. P., P. (ed.). Canberra: Land and water Australia.

MCKERGOW, L. A., PROSSER, I.P., WEAVER, D.M., GRAYSON, R.B., REED, A.E.G. 2006a. Performance of grass and eucalyptus riparian buffers in a pasture catchment, Western Australia, part 2: water quality. *Hydrological processes,* 20**,** 2327-2346.

MCKERGOW, L. A., PROSSER, I.P., WEAVER, D.M., GRAYSON, R.B., REED, A.E.G. 2006b. Performance of grass and eucalyptus riparian buffers in a pasture catchment, Western Australia, part 1: riparian hydrology. *Hydrological processes,* Hydrological processes**,** 2309-2326.

MCKERGOW, L. A., WEAVER, D.M., PROSSER, I.P., GRAYSON, R.B., REED, A.E.G. 2003. Before and after riparian management: sediment and nutrient exports from a small agricultural catchment, Western Australia. *Journal of Hydrology,* 270**,** 253-272.

NRC 2002. Riparian Areas: Functions and Strategies for Management. National Research Council.

NSWDPI 2012. Controlled activities on waterfront land - Guidelines for riparian corridors on waterfront land. NSW Office of Water.

NSWDPI 2018. Determining stream order Fact sheet. NSW Office of Water.

OAGWA 2014. Our Heritage and Our Future: Health of the Swan Canning River System. *Western Australian Auditor General's Report.* Perth.

PRICE, P., LOVETT, S. and LOVETT, J. 2004. Managing riparian widths. *Fact sheet.* Canberra: Land and Water Australia.

WEAVER, D. 2022. *RE: BMP effectiveness.* Pers Comm. 18/01/2022

WEAVER, D. M., SUMMERS R. 2021. Phosphorus status and saturation in soils that drain into the Peel Inlet and Harvey Estuary of Western Australia. *Soil Research,* 59**,** 699-714.

WEAVER, D. S., . 2014. Fit-for-purpose phosphorus management: do riparian buffers qualify in catchments with sandy soils? *Environ Monit Assess,* 186**,** 2867-2884.

WRC 2001a. Determining foreshore reserves. *River Restoration Report.* Water and Rivers Commission Perth.

WRC 2001b. Determining foreshore reserves pamphlet. *Report.* Water and Rivers Commission Perth.

WA EPA 2021. Guidance for planning and development: Protection of naturally vegetated areas in urban and peri-urban areas. WA Environmental Protection Authority.

9 GLOSSARY

Adverse consequences	A potentially damaging impact.
Assimilative processes	Uptake and transformation of materials into other forms.
Biodiversity	A measure of variability within animal, plant and microbial communities, that applies at the level of species, family or guild, population and habitat. The concept is based on the principal that greater variability leads to more resilient and adaptable natural areas.
Bioretention	Is the process by which nutrients, sediments and other contaminants are removed from stormwater runoff using wet basins to hold runoff and allow physical and biological processes to occur.
Catchment	The area of land above a particular point that contributes stormwater runoff and streamflow. Sub-catchments are smaller areas of land that contribute runoff via individual tributaries within a larger catchment.
Coefficient of infiltration	The ratio of rainfall falling onto an area that infiltrates into the soil rather than moving over the surface as runoff. Sandy soils have much larger coefficients of infiltration than clay soils.
Dryland salinity	Dryland salinity is the build-up of salt in surface soil in non-irrigated areas, usually because of rising groundwater tables. As the soil surface dries out, salt brought to the surface where it accumulates.
Entrain sediments	To cause sediments to break from stable channel surfaces and be transported by water.
Environmental values	The range of ecosystem services provided by natural areas including water supply, flood control and mitigation, biodiversity, aesthetics amenity and spiritual nourishment.
Eutrophic	Too much available nutrient in waterways leads to excessive growth of aquatic plants such as larger macroalgae and phytoplankton. Such waterways are classified as eutrophic.
Finer textured soil	Soils are classified by the distribution of particle sizes. Sands are coarse textured soils and loams and clays are finer-textured soils.
Fertigation	The technique of supplying dissolved fertiliser to crops through an irrigation system.
Foreshore areas	The areas each side and along streams.
Geomorphology	The physical features of the surface of the earth and their relation to the underlying geology.

Groundwater seepage	The slow percolation of groundwater out of a soil.
Harmful phytoplankton	Particular types of phytoplankton or microscopic plants in waterways, that contain toxins that have the potential to harm animals and humans by either ingestion of contact with skin. Dinoflagellates (red tides) and blue-green algae are two such types of potentially harmful phytoplankton.
Hydrological buffering	The process of damping down extremes of water movement. Catchments having much of their original vegetation intact, have greater levels of infiltration into the soil, lower peak flow velocities and erosion and more flow seeping out during summer. All of these processes increase a catchment's hydrological buffering and benefit plant and animal communities.
Incised	Cut into a surface.
Infiltration	Permeation of rainfall into soil.
Intermittent drainage	A stream or waterway that flows only at certain times of the year.
P leaching	When P is lost from the soil into surface runoff or groundwater.
LiDAR	Stands for Light Detection And Ranging. A remote sensing technique using Laser pulses to accurately measure distance from the light source to reflecting surfaces. LiDAR is typically used to create images of the land surface at fine scale.
Peak velocities	Peak velocities of stormwater flowing in natural channels during intense rainfall events are the periods when erosion is greatest. Controlling peak velocities through design reduces erosion.
Perennial	Lasting or existing for a long time.
P-fixing soils	P is an essential nutrient and a soil's P-fixing capacity governs its ability to bind P for either release to plants or to be lost by leaching.
Refractory	Readily decomposable.
Residence time	When applied to water falling on a catchment, residence time is a measure of how long the water stays within a catchment. Short residence times usually mean higher flow rates and erosion and greater amounts of runoff moving offsite to the ocean.
Sedimentation	The process of settling or deposition of small and large soil particles being transported in stormwater.

Strahler stream order	The Strahler system classifies the joining of streams and tributaries. A first order stream has no other streams flowing into it. When two streams with different orders join, the resulting stream has the same order as the highest order of the two joining streams.
Stream dynamics	The way streams flow during high and low-flow periods is influenced by the slope of the land, soil types, vegetative cover and the degree of disturbance to natural processes.
Land tenure	Land ownership or management by private citizens, companies and Government agencies.
Watercourse	For the purpose of this Mundaring Watercourse Hierarchy Strategy, a watercourse has been defined as ≥3rd order Strahler Streams mapped across a catchment using LiDAR having equal to or better than 5 cm vertical resolution.
Waterway	Any stream, river, canal or lake. Also called watercourses.
Water Hierarchy Strategy	For the purposes of the Shire's Local Planning Scheme No.4, represents the *'watercourse hierarchy and protection strategy'* as referred to in clause 5.7.5

Appendix 1: Legislation relevant to managing foreshore areas by agency

ENVIRONMENTAL PROTECTION

Commonwealth

The Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) is the Australian Government's central piece of environmental legislation. It provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places — defined in the EPBC Act as "matters of national environmental significance". EPBC listed threatened species and Threatened Ecological Communities (TEC) can be searched from the Department of Climate Change, Energy, the Environment and Water website: Threatened Species and Ecological Communities page. The listing of threatened species and communities identifies species that are at greater threat and risk of extinction.

State Government

The three pieces of state legislation that protect environmental assets and that are relevant to the waterway within the Shire of Mundaring are the:

- Planning and Development Act 2005
- Biodiversity Conservation Act 2016
- Environmental Protection Act 1986
- Conservation and Land Management Act 1984.

The *Planning and Development Act 2005* and associated *Planning and Development (Local Planning Schemes) Regulations 2015* empower local authorities through local planning schemes to undertake land use and development management with the same force and effect of the *Planning and Development Act* itself. The Act enables the creation of State Planning Policies. SPP 2.9 recently released envelopes all previous water resource policy into one integrated state policy that interrelates other agency legislative policy.

The *Biodiversity Conservation Act 2016* provides for the listing of threatened native plants (flora), threatened native animals (fauna) and threatened ecological communities that are in need of greater protection. Those listed as being critically endangered, endangered or vulnerable species are under increased identifiable threat of extinction (species) or collapse (ecological communities). Threatened, Extinct and Specially Protected fauna or flora are species which have been adequately searched for and are deemed to be, in the wild, threatened, extinct or in need of special protection, and have been gazetted as such. Possible threatened species or ecological communities that do not meet survey criteria are added to DBCA's Priority Species and Ecological Community lists.

The Act also provides for, or outlines the process for (e.g., what is in them and how they are approved), recovery plans and other modern features of biodiversity conservation and management. The *Biodiversity Conservation Act 2016* applies to all tenure in the State. The Act also provides for recovery plans and other modern features of biodiversity conservation and management. The *Biodiversity Conservation Act 2016* applies to all tenure in the State.

The Wildlife Conservation (Specially Protected Fauna) Notice 2018 and the Wildlife Conservation (Rare Flora) Notice 2018 have been transitioned under regulations 170, 171 and 172 of the *Biodiversity Conservation Regulations 2018* to be the lists of Threatened, Extinct and Specially Protected species under Part 2 of the 2016 Act.

According to these regulations, it is an offence to "take" or disturb threatened species (flora and fauna) (any species but fines are greater for damage or disturbance to threatened species) or their critical habitats unless the person is authorised (by the Minister) under Section 40 and complies with the conditions. The *Conservation and Land Management Act 1984 (WA),* applies to DBCA managed land only, and establishes a comprehensive set of legislative provisions dealing with state conservation and land management matters. Department of Biodiversity, Conservation and Attractions (DBCA)

DBCA administers a number of Acts and associated regulations including the abovementioned *Conservation and Land Management Act 1984* and the *Biodiversity Conservation Act 2016*. DBCA promotes biodiversity and conservation through sustainable management of WA's species, ecosystems, lands and the attractions in its care. DBCA has responsibility for on-ground management of *CALM Act* lands (DBCA-managed lands). DBCA provides specialist advice and information on biodiversity and off sets to the EPA for its assessments under Part IV of the EP Act, to the Commonwealth Department of the Environment and Energy under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and to proponents. DBCA may also implement off sets that arise as outcomes of these processes. Clearing provisions of the *Environmental Protection Act 1986 (EP Act)* are administered by DWER with advice sought from DBCA.

The *Swan and Canning Rivers Management Act 2006* (SCRM Act) aims to ensure that land use planning and development protects and enhances the ecological health, amenity and heritage value of the Swan Canning river system. DBCA has overall planning, protection and management responsibility for the Swan Canning river system under the SCRM Act. The Swan River Trust is an advisory body created by the SCRM Act and provides independent, high-level, strategic advice to the Minister for Environment and DBCA on matters affecting the Swan and Canning rivers.

Department of Water and Environmental Regulation (DWER)

DWER also has responsibilities related to the protection of the environment. These responsibilities are set out below.

Clearing of native vegetation:

Under Section 51C of the *EP Act,* clearing of native vegetation is an offence unless undertaken under the authority of a clearing permit, or the clearing is subject to an exemption.

Clearing is not permitted in Environmentally Sensitive Areas (ESAs) except for maintenance of existing railways or roads, or in accordance with the *Environmental Protection (Clearing of Native Vegetation) Regulations 2004*. There are ESAs in proximity to waterways within the

Shire of Mundaring. ESAs are declared by the Minister for Environment under Section 51B of the EP Act.

Contaminated sites:

The *Contaminated Sites Act 2003 (CS Act)* is administered to ensure contamination is identified, recorded, managed, and remediated. Under the CS Act, landowners occupiers, and persons who caused contamination must report known or suspected contaminated sites. Anyone else may report suspected contamination. DWER assesses each report and determines the appropriate classification for the site in consultation with the Department of Health.

Unauthorised discharges:

Under the *Environmental Protection (Unauthorised Discharges Regulations 2004) (UDR),* it is an offence to cause or allow certain materials to enter the environment in connection with a commercial or business activity. The purpose of the UDR is to cover discharges into the environment from business or commercial activities; which individually are not serious enough to cause pollution and breach the provisions of the Environmental Protection Act 1986 but cumulatively can cause harm. The UDR are intended to ensure that all people engaged in a commercial activity take responsibility for preventing the escape of contaminants from their business into the environment.

Drainage, Salinity and Soil Conservation

The principal Act is the *Soil and Land Conservation Act 1945*. This can be used to create covenants to protect vegetation in foreshore areas. Concerning land drainage for the purpose of controlling salinity, *SLC Regulations (1992*) which sits under the *SLC Act (1945*) require owners or occupiers to notify the Commissioner of Soil and Land Conservation before any groundwater drainage takes place. The Commissioner does not approve 10 h, p://www.water.wa.gov.au/licensing/water-licensing/types-of-licenses 11

Note: DWER also grants permits under the *Country Areas Water Supply Act 1947* to clear native vegetation near water. h, p://www.water.wa.gov.au/licensing/water-licensing/types-oflicenses cawsdrainage. The Commissioner will either object or not object based on the assessment of the proposed works. To date, the Act has been used concerning drainage linked to salinity concerns in the Wheatbelt rather than to urban situations. Drainage that does not need to be notified applies for most surface water management.

WATER RESOURCES MANAGEMENT

State Government

The *Water Agencies (Powers) Act 1984* is the lead legislation for water resources management: coordinating across government: conserving, protecting and managing water resources; assessing water resources; planning for the use of water resources; promoting the efficient use of water resources; promoting the efficient provision of water services; preparing plans for and providing advice on flood management.

The *Rights in Water and Irrigation Act 1914* (as amended) provides for the regulation, management, use, and protection of water resources. Under Division 1A (Ownership and control of waters) of this Act, the right to the use and flow, and the control, of the water at any time in any watercourse, wetland or underground water source is vested in the Crown (Division 1, 5A of the Act). The Act provides for a licensing system for taking water; and a permitting system for activities that may damage, obstruct or interfere with water flow or the beds and banks of watercourses and wetlands in proclaimed rivers, surface water management areas, and irrigation districts.

Licensing only applies to certain watercourses in WA that are proclaimed under the Act. In relation to the Jane River and its tributaries, this Catchment is unproclaimed and there is no licensing regime in place currently. However, there are general restrictions that apply to these areas under the legislation; for example, owners of foreshore area land may only take water to the extent that flow in the watercourse is not sensibly diminished (Sec. 20, 1, c of the Act). A permit is required to interfere with waters or bed and banks of the watercourse where the river is situated on Crown land. It is also an offence to obstruct the watercourse on Crown land, including the discharge of mud, earth, gravel etc. into the watercourse without authorisation. Landholders do not require a permit for works where the river is on freehold property.

This Act provides for the power to prohibit drainage works that are likely to affect the water in a watercourse, wetland or underground water source.

Relevant to this Plan is the legislation, regulations and by-laws dealing with waterways and groundwater which are administered by DWER. The Department of Water and Environmental Regulation (DWER) assists the Minister for Water in administering current legislation.

The WA Department of Water and Environmental Regulation (DWER) issues licences and permits under the *Rights in Water and Irrigation Act 1914* to:

- Take water
- Construct wells (including bores and soaks)
- Interfere with the bed and banks of a watercourse.

DWER looks at the potential risks of each groundwater license application on a case by case basis in deciding whether to grant or refuse a licence, and also the terms and conditions that may be imposed.

To mitigate risks to water resources or the environment associated with the take and use of water, DWER often require that licensees monitor and report on their abstraction activities and where necessary implement contingency programmes where trigger levels are exceeded or unexpected changes to water quality or aquifer response are observed.

Water monitoring and reporting requirements for Scott River landholders are established on an individual basis. Generally, commercial water users are required to implement a monitoring program which includes metering their abstraction volumes and monitoring both surface water (where relevant) and groundwater quality. In terms of groundwater quality both the pumping aquifer and shallow groundwater up and down hydraulic gradient of the water use activity are considered.

Department of Primary Industries and Regional Development (DPIRD)

Legislation dealing with the land surrounding some of the waterways is administered by DPIRD. The Department of Primary Industries and Regional Development (DPIRD) carries out the requirements of the *Soil and Land Conservation Act 1945* to mitigate and prevent land degradation throughout Western Australia.

DPIRD set its priorities for declared pests by a declaration under the *Biosecurity and Agriculture Management Act 2007 (BAM Act)* through the Minister for Agriculture. All species that were declared under the *Agriculture and Related Resources Protection Act 1976* have been transitioned to have equivalent declarations under the BAM Act.

Regulation 7 of the *Biosecurity and Agriculture Management Regulations 2013* allows for the establishment of categories of declared pests for both animals and plants. Regulations have been implemented since May 2013. It is the landholders' legal obligation to manage/control invasive species (weeds and feral animals) on their land. Under the Act, there is a greater responsibility for the community and industry to identify, prioritise, and control already established biosecurity threats, with the support of DPIRD. The new focus of the Department will be on preventing the emergence of new pests and diseases within WA and controlling those that do slip in.

Heritage

Aboriginal heritage sites are afforded protection under statutory law. Under the *Aboriginal Heritage Act, 1972*, the Department of Planning Lands Heritage (this used to be a competency of the former Department of Indigenous Affairs) (DPLH) works with Aboriginal people to protect and manage places of significance.

The new Aboriginal Cultural Heritage Act 2021 (ACH Act) will provide a modern framework for the recognition, protection, conservation and preservation of Aboriginal cultural heritage while recognising the fundamental importance of Aboriginal cultural heritage to Aboriginal people.

Department of Planning Lands and Heritage (DPLH)

The DPLH provides advice to the public and private sectors and the community about Aboriginal heritage management and maintains a Register of Aboriginal sites. The Department's role is to ensure that Aboriginal heritage and engagement with Aboriginal people is built into planning and management processes. Information about heritage sites can be obtained through the Aboriginal Heritage Inquiry System (AHIS), an internet-based search tool. The AHIS provide details about the location, extent, and assessment status of each place under the Aboriginal Heritage Act 1972. Statutory requirements for undertaking specific works in registered areas apply.

An Aboriginal site means any place to which the AHA applies by operation of Section 5 of the AHA. The Act is currently under review. https://www.dplh.wa.gov.au/information-andservices/aboriginal-heritage/protection-under-the-aboriginal-heritage-act-1972 community about Aboriginal heritage management and maintains a Register of Aboriginal sites. Landholders who own the land where an Aboriginal site (registered or not) is present and who want to use this land e.g., for development, may need to apply for consent from the Minister for Indigenous Affairs to do so under Section 18 of the Aboriginal Heritage Act 1972.

After the Minister considers the recommendations of the Aboriginal Cultural Material Committee (ACMC) and also regards the general interest of the community, he or she will either grant consent to the use of the land for the purpose sought or decline to give consent to the use.

If the Minister consents, conditions may be attached to the use of the Section of land. "Where land users conclude that impact to a site is unavoidable, the consent of the Minister must be sought under Section 18 (s18) of the Act. Notice must be given to the Aboriginal Cultural Material Committee (ACMC) accompanied by the information as to the intended use of the land and sites on the land." Also: If you are planning to enter, excavate, examine or remove anything on an Aboriginal site, you are required to seek authorisation under Section 16 (s16) of the Act.

Non-Mandatory Guidelines

Codes of Conduct

For the dairy industries the WA Practice for Dairy Shed Effluent (Western Dairy, 2012) is voluntary. It is part of their Dairying for Tomorrow initiative which supports dairy farmers to increase their farm productivity while at the same time reducing their environmental footprint. The plantation industry has a Code of Practice with guidelines to regulations and legislation specific to WA. This is the Code of Practice for Timber Plantations in Western Australia. Some requirements are mandatory and others are voluntary.

The purpose of this Code is to provide goals and guidelines to plantation managers so that plantation operations in Western Australia are conducted in a manner that is in accordance with accepted principles for good plantation management, whilst recognising that a primary aim of plantations is to be economically competitive and sustainable. Standards also include the Forestry Stewardship Council (FSC) Standard (FSC, 2018) and the Australian Standard

for Sustainable Forest Management (AS 4708) (AFS, 2013) which provides forest managers with economic, social, environmental and cultural criteria.

DBCA Conservation Programs

Roadside Conservation Program

Roadside vegetation plays an important role in the conservation of Western Australia's plants and animals and particularly in the peri-urban areas where there are many species only existing in these thin remnant strips. The native vegetation in roadsides is sometimes far more important than in other areas.

In heavily cleared landscapes, the vegetation in the road reserve acts as a wildlife highway, enabling animal movement between large patches of bush. It also provides essential habitat to flora and fauna. The visibility of roadside vegetation can provide locals with a defined sense of place based on easily identifiable characteristics they recognise as "home". Roads cut across the landscape, giving a cross Section of vegetation communities within the landscape. Thus, wide road reserves fulfil dual roles: transport and conservation.

It should be noted that the Western Australian Roadside Conservation Committee has been disbanded and DBCA no longer has responsibility for a roadside conservation program.

Nature Conservation Covenant Program

The Nature Conservation Covenants Program began in the Metropolitan area. DBCA offers landowners the opportunity to use conservation covenants to protect the nature conservation values of their properties. The Nature Conservation Covenant is a voluntary, legally binding document that has provisions restricting activities that might threaten the land's conservation values. There are also non-voluntary covenants. Every conservation covenant is individually negotiated between DBCA and the landowner, and aims to maintain the conservation values of the bushland whilst allowing for flexibility to reflect the landowner's wishes for the land. Typically, there are restrictions such as no clearing, mining, grazing or cats and dogs must be on leashes. Often no one is allowed to enter property. The landholder may get a tax concession and in some cases a rate concession.

DBCA Land for Wildlife

DBCA's Land for Wildlife program began in 1997. There are registered Land for Wildlife properties in the Mundaring Catchment.

Soil and Land Commission Conservation

Landowners who wish to protect and manage native vegetation on their property may enter into an agreement (covenant) with the Commissioner of Soil and Land Conservation under s30 of the Soil and Land Conservation Act 1945.

The Soil and Land Conservation Act provides for two types of covenants:

- Conservation Covenant which is irrevocable. The term of these covenants is usually specified for perpetuity or a period of time. Once finalised, the Commissioner does not have statutory authority to vary or discharge these covenants.
- Agreement to Reserve (ATR) which is not expressed as irrevocable. These covenants may be in perpetuity or for a specified time and may be varied or discharged by the Commissioner.

Appendix 2 Regulatory and other actions

Table 3 below summarises the nutrient loadings to the Swan Estuary from within the Mundaring Shire and adjoining areas. It shows only modest export of N and P from these hills catchments compared to the coastal plan catchments. Appendix 3 provides a preliminary list of legislatively protected land and foreshore areas within the Mundaring Shire. In considering options to improve stream water quality and the environmental quality of foreshore areas, it is prudent to review how recent changes in regulations have impacted on foreshore area management.

Urban water management plans do not allow for management of issues such as:

- inadequate fall from the stormwater detention basin into the natural waterway;
- influx of extremely hot water from hardstand bitumen roads during summer storms into waterways causing direct invertebrate and flora kills due to excessive water temperatures – insufficient containment away from the receiving water bodies;
- insufficient space for habitat and recreation to co-exist;
- edge effect issues increasing the cost of maintenance and management for councils – need to improve ratio of vegetation depth to length to reduce weed impacts;
- no gross pollutant or chemical traps and these are no longer a standard installation in the stormwater management system;
- Width of reserve needs to allow for at least four/six metre management access (use firefighting arguments including turning circles), plus conservation and sufficient room for groundwater penetration and retention to encourage groundwater recharge rather than surface flow disappearing from high in the catchment as fast as possible.

Smart regulations

Establishing by-laws, regulations, incentives and policies to link rights and responsibilities to better management of waterways and contributing lands. Regulation can be effective for localised issues such as pollution.

Higher levels of government are actively seeking to devolve responsibility/delegate many aspects of land management to local government, community groups, Landcare groups and individuals. Many of these people feel they lack the skills, finances and technical knowledge to achieve what is being asked of them. Developer contributions can assist here.

Table 3 Average annual flow, nitrogen and phosphorus loads and loads per unit cleared area for Jane Brook and the Helena River from 1997 to 2006.

Catchment	Area (km^2)	Cleared area (%)	Average annual discharge (ML)	Average annual nitrogen load (tonnes)	Nitrogen load per cleared area (kg/ha)	Average annual phosphorus load (tonnes)	Phosphorus load per cleared area (kg/ha)
Jane	137.7	49	14800	11	1.65	0.58	0.09
Helena	175.7	36	4880	5.8	0.92	0.23	0.04

It may be time to step back if possible, and get beyond simplistic 10% multi-use corridors that include conservation, water management, recreation, bushfire management, emergency access amalgamated within them.

Weed control to protect existing vegetation communities is one of the most cost-effective and cheapest options. Enhancement of remnant vegetation and protection of “waterlogged” peripheral land – beyond the floodplain are also important priorities.
Conservation incentives

Rate reductions, assistance with fencing, weed management proportional to scale of foreshore reserve can all assist local land holders.

Appendix 3 List of legislatively protected areas in the Mundaring Shire

BUSH FOREVER SITES Outside the MRS

- BF Site 215 – over the Helena River

DBCA LEGISLATED LANDS AND WATERS

- Beechina North Nature Reserve
- Beelu National Park
- Mundaring State Forest
- Greenmount National Park
- John Forrest National Park
- Leschenaultia Conservation Park

FUTURE SUBDIVISION ISSUES – main suburbs where there is space

- Bailup
- Malmalling (Postcode 6556)
- Wooroloo
- Gorrie

FORESHORE CONDITION REPORTS (1999)

- Wooroloo Brook
- Helena River
- Jane Brook
- Blackadder Creek

ENVIRONMENTALLY SENSITIVE AREAS

- Beechina
- John Forrest National Park
- Three small areas on western boundary of shire

EXISTING LOCAL STRUCTURE PLANS (WITH WATERWAYS ADJACENT)

- Hayden Street Trimble Road, Mt Helena
- Coothalie Road Chidlow
- Thomwick Cres, Betty, Northcote Street, Old Northam Road, Chidlow
- Beacon and Richardson Road Parkerville
- Woodlands Road Stoneville

Appendix 4 Total watercourse length by land cover zone.

Landcover zones were inferred from the SLIP region scheme and LPS zones and reserves data

SLIP zone	∑ watercourse length	Percentage of Shire total
Commercial, Industrial	4.8	0.2
Infrastructure cleared	46.5	2.0
Infrastructure vegetated	40.1	1.7
Parks, Recreation, Schools	3.1	0.1
Residential	124.2	5.4
Rural	204.7	8.9
Rural residential	573.1	24.8
Reserves	1310.0	56.8
Waterways	1.1	0.0
TOTAL	2307.6	100

Watercourses include Strahler stream orders from 3 to 9.

Appendix 5 Stormwater management measures for various catchment situations

1 water sensitive urban design
for low intensity events <1:1ARI

grid reinforced lawn

pervious and open cell pavement

soakwells and rainwater tanks

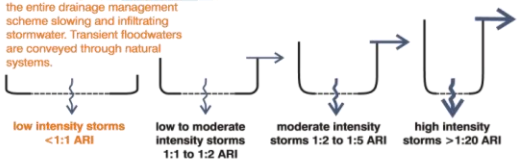
permeable gravels

wsud principals

The model below demonstrates the concept of a 'Treatment Train'.

A series of Best Management Practices (BMPs) in pervious soils act like leaking cups throughout the entire drainage management scheme slowing and infiltrating stormwater. Transient floodwaters are conveyed through natural systems.

1. treat (infiltrate) at source ✓
2. use of a 'treatment train'
3. convey in natural systems



permeable surfaces

Pervious pavement is an infiltration system where storm water runoff is infiltrated into the ground through a permeable layer of pavement or other stabilized permeable surface. These systems can include porous asphalt, porous concrete, modular perforated concrete block, cobble pavers with porous joints or gaps or reinforced/stabilized turf (Urbonas and Strecker, 1996))
A new mind set is needed when designing stormwater management systems.

Rather than designing a system to transfer storm events from an area, water management planners should consider the benefits of capturing and recharging water from the smaller, more frequent rain intervals.

The ecosystem survives on daily events.

A stormwater system incorporating pervious pavement will be much more effective in reducing total runoff and increasing the amount of filtered groundwater.

The material's ability to retain stormwater while improving water quality and enhancing groundwater infiltration and vegetation growth, makes this material an exciting example of sustainable building practice.

There is also a range of non-structural controls that should be considered.

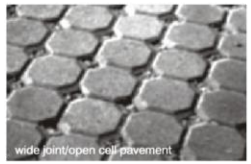
pervious pavements

Pervious pavements can be made of concrete, asphalt, open-celled stones, and gravel, that are mixed in a manner that creates an open cell structure allowing water and air to pass through.

Certain types of pervious pavement can pass 15-20 litres of water per minute, which is far greater than most conceivable rain events and highly effective in controlling stormwater drainage.

Pervious pavements can be used in parking lots, access areas and other paved areas and can greatly reduce the amount of runoff and associated pollutants leaving the area. Porous pavement systems are suitable for a limited number of applications.

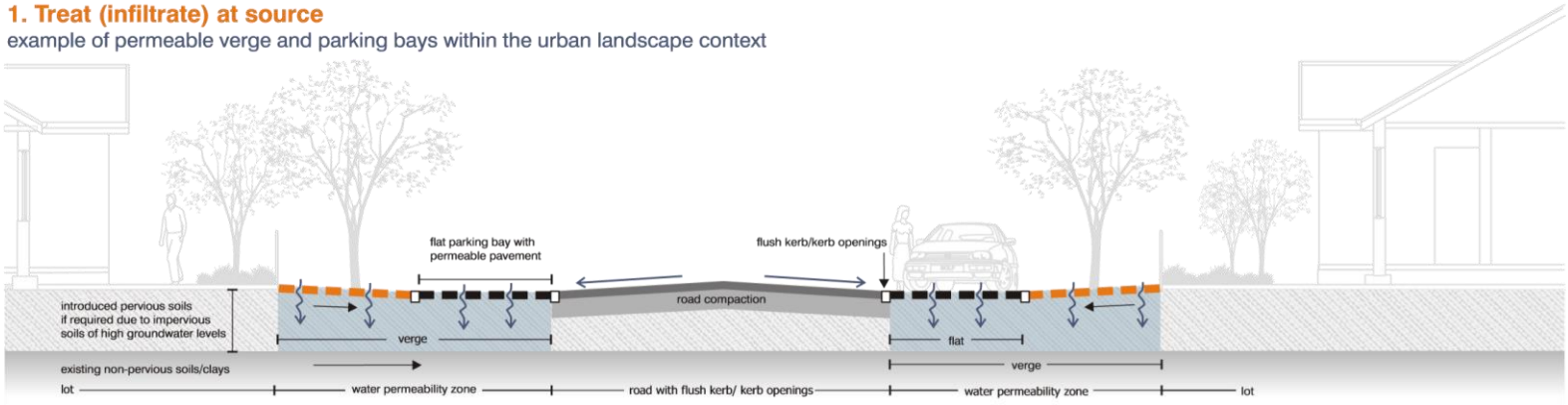
Typically, pervious pavement can only be used in areas that are not exposed to high volumes of traffic or heavy equipment.



Pervious pavements are particularly useful for crossovers, driveways, streets and in residential areas, also parking in commercial areas. This type of pavement is not effective in areas that receive runoff with high amounts of very fine sediment due to the tendency of the pores to clog.

Pervious pavements require maintenance including periodic vacuuming or jet-washing to remove sediment from the pores.

1. Treat (infiltrate) at source
example of permeable verge and parking bays within the urban landscape context



2 water sensitive urban design
for low to moderate events 1:1 - 1:2 ARI

small storm events

flush kerb / kerb openings

pollutant removal

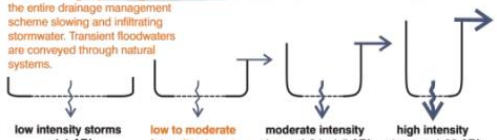
pervious naturestrips

wsud principals

The model below demonstrates the concept of a 'Treatment Train'.

A series of Best Management Practices (BMPs) in pervious soils act like leaking cups throughout the entire drainage management scheme slowing and infiltrating stormwater. Transient floodwaters are conveyed through natural systems.

1. treat (infiltrate) at source ✓
2. use of a 'treatment train' ✓
3. convey in natural systems



swales

Swales are linear depressions or channels that provide for stormwater collection conveyance and infiltration. Swales may simply be grass-lined or more densely vegetated and/or landscaped. Slotted pipes or part of the verge being permeable will serve the same purpose as swales.

While swales provide for stormwater conveyance and infiltration, they also lend themselves to the screening or removal of

Gross pollutants, such as litter and coarse sediment, from stormwater runoff.

In urban areas, swales may be used as an alternative to the conventional street naturestrip, central median strips or runoff collection points in carpark areas. Swales can reduce run-off volumes and peak flows. Current designs involve the use of grass or other vegetation (such as native plants or rushes) to carry out this function.

(Information MelbourneWater 2002)

Advantages of Swales

- can reduce and delay storm run-off
- retains particulate pollutants close to source
- more aesthetically appealing than kerb and gutter
- relatively inexpensive to construct

swale pollutant removal

Swales initially immobilise pollutants, by binding them to organic matter and soil particles.

Settling, filtration and infiltration into the subsoil achieve effective pollutant removal. Certain pollutants, such as hydrocarbons,

may be digested and processed by the soil microorganisms in the filter strip.

Consequently, adequate contact time between run-off and vegetation and soil surfaces is required to optimise pollutant removal.

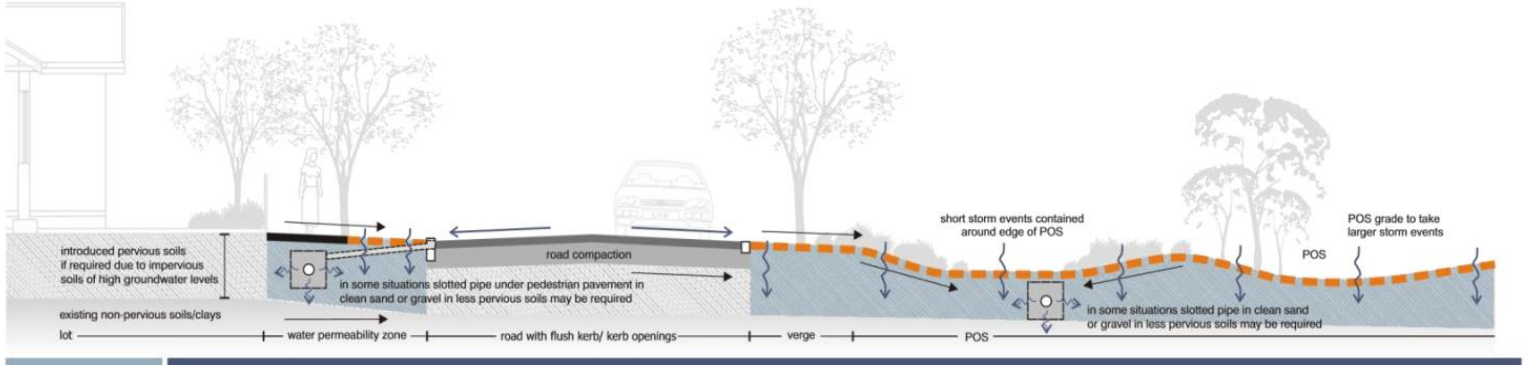
(Information MelbourneWater 2002)

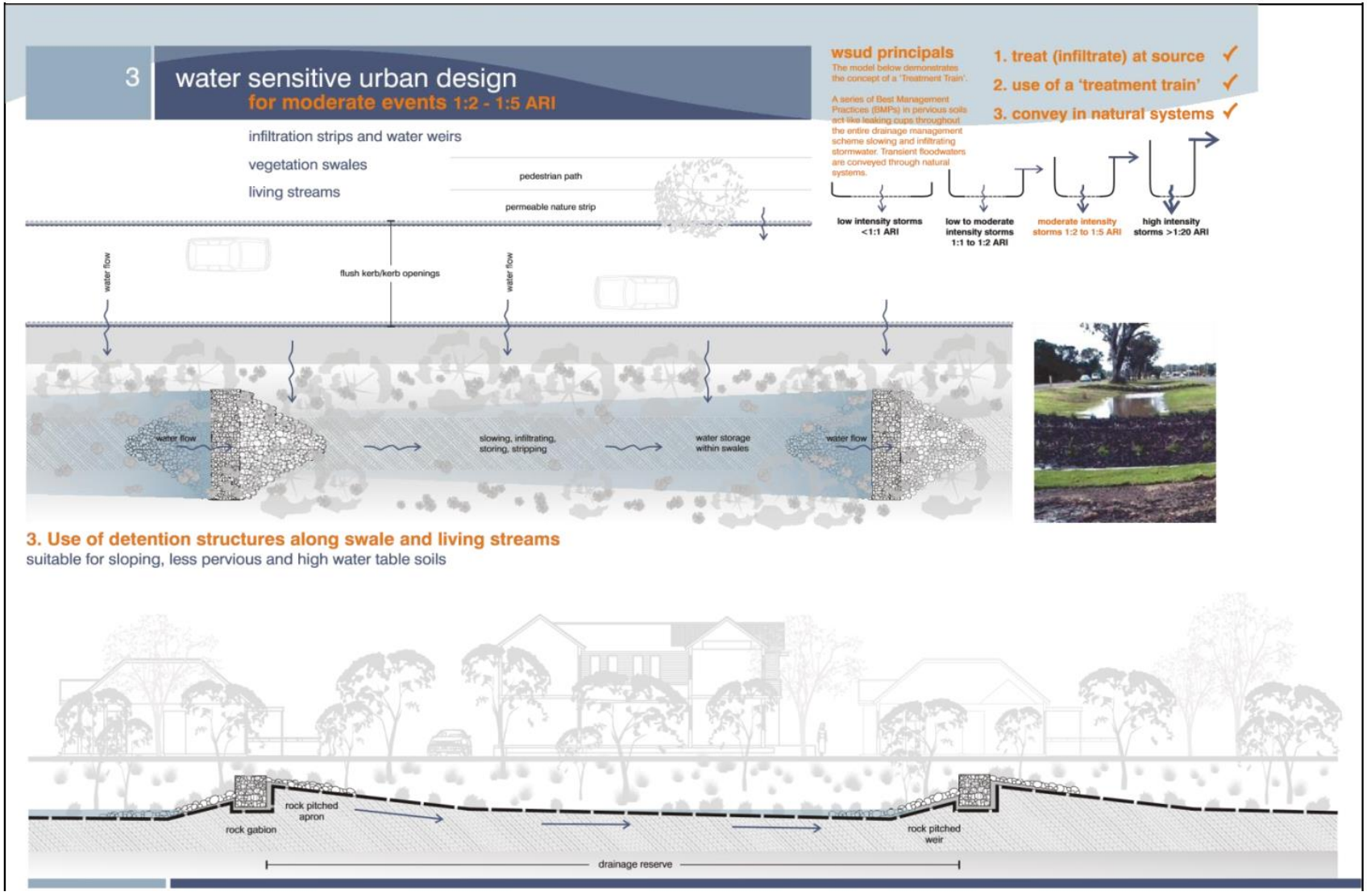
Limitations of Swales

- Limited removal of very fine sediment and dissolved pollutants
- Requires larger land area than kerb and gutter, with certain activities restricted (for example, car parking)
- Sunny aspect is required for plant growth, limiting its application in shaded areas,
- Only suitable for gentle slopes (less than five per cent)
- Regular inspections are required

2. Use treatment train approach

example of permeable verge with swale within the urban landscape context




3
water sensitive urban design
for moderate events 1:2 - 1:5 ARI
infiltration strips and water weirs
vegetation swales
living streams
pedestrian path
permeable nature strip
flush kerb/kerb openings
water flow
water flow
water flow
slowing, infiltrating, storing, stripping
water storage within swales
water flow
wsud principals
The model below demonstrates the concept of a 'Treatment Train'.
A series of Best Management Practices (BMPs) in pervious soils act like leaking cups throughout the entire drainage management scheme slowing and infiltrating stormwater. Transient floodwaters are conveyed through natural systems.
1. treat (infiltrate) at source
2. use of a 'treatment train'
3. convey in natural systems
low intensity storms <1:1 ARI
low to moderate intensity storms 1:1 to 1:2 ARI
moderate intensity storms 1:2 to 1:5 ARI
high intensity storms >1:20 ARI
3. Use of detention structures along swale and living streams
suitable for sloping, less pervious and high water table soils
rock gabion
rock pitched apron
rock pitched weir
drainage reserve

4

water sensitive urban design
for high intensity events <1:20 ARI

ephemeral wetlands

living streams

infiltration basins in public open space

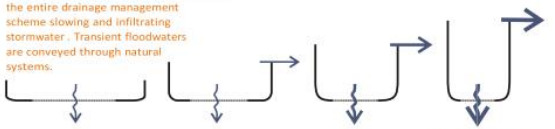
natural waterways and floodplains

wsud principals

The model below demonstrates the concept of a 'T reatment T rain'.

A series of Best Management Practices (BMP s) in pervious soils act like leaking cups throughout the entire drainage management scheme slowing and infiltrating stormwater . Transient floodwaters are conveyed through natural systems.

1. treat (infiltrate) at source ✓
2. use of a 'treatment train' ✓
3. convey in natural systems ✓



ephemeral wetlands and living streams

Putting native vegetation back along streamlines and wetlands, or incorporating it into new drains, not only achieves the narrow objective of creating biofilters, it also creates a more attractive landscape, as well as comletely in summer. These features may

The realisation of this has fostered the broader objective of creating living streams of native plant and animal communities, natural stream. In an urban context, it may be a narrow freshwater crayfish, fish, frogs and waterbirds In this way these features may become a permanent creek. Whatever its size, a living stream has characteristics that distinguish it rather than just an essential, and often from a simple flow of water.

A living stream is a complex ecosystem supporting a wide range of plants and animals.

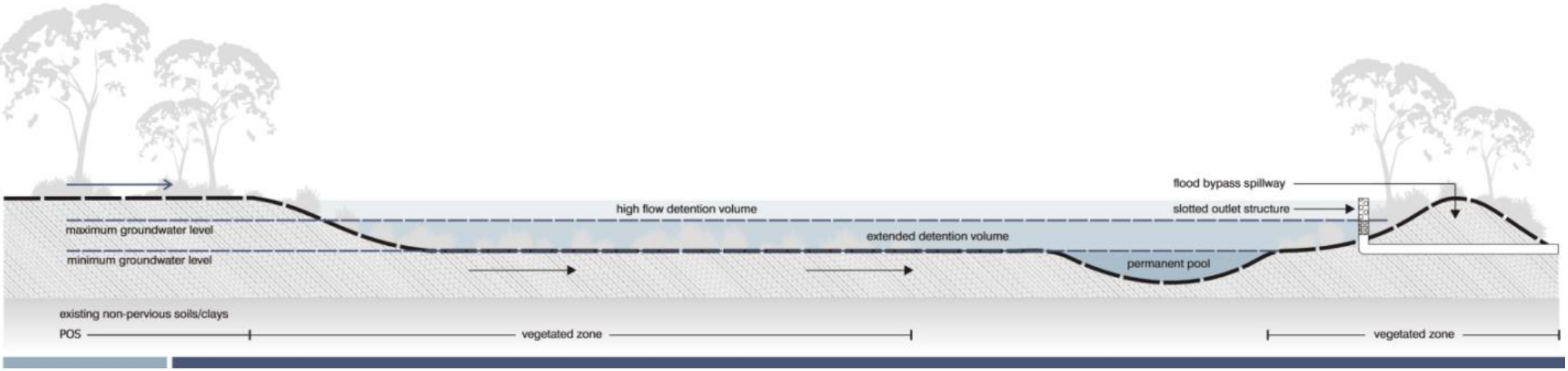
An ephemeral wetland may have significant amounts of water within it over winter and less water in summer . which have some if not all of the values of a Ephemeral wetlands may even dry out They provide habitats for animals such as (Water Facts 4: Water and Rivers Commission January 1994) important wildlife habitats and corridors. stormwater management as they help for people to enjoy. compensate very high flows.

Living streams and ephemeral wetlands have stable vegetated banks with many plant species. unattractive, part of its infrastructure.

Living streams and ephemeral wetlands provide a refuge for bush birds and other native animals and are an important part of our cultural and spiritual heritage. creek which runs only in winter or a

4. Ephemeral wetland design

example of wet/dry wetlands within the urban landscape context


flood bypass spillway
high flow detention volume
slotted outlet structure
maximum groundwater level
extended detention volume
minimum groundwater level
permanent pool
existing non-pervious soils/clays
POS
vegetated zone
vegetated zone

water sensitive urban design
example within the urban environment

The model below demonstrates the concept of a 'Treatment Train'

A series of Best Management Practices in pervious soils act like leaking cups throughout the entire drainage management scheme slowing and infiltrating stormwater. Transient floodwaters are conveyed through natural systems.

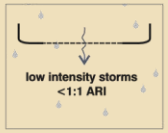
wsud principals

1. treat (infiltrate) at source ✓
2. use of a 'treatment train' ✓
3. convey in natural systems ✓

1. treat (infiltrate) at source

Water run-off to be retained within immediate area by:

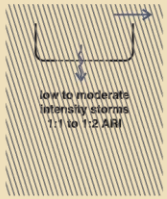
- maximising permeable surfaces
- using local soakwells
- planting trees with large canopies over impermeable surfaces



2. use of 'treatment train'

Water run-off to be retained within road reserves and lots by:

- use of flush kerbs or kerb breaks in carparks and along roadways
- creating permeable verges
- using vegetated and buffer filter strips (swales) along edges of roadways, and impermeable surfaces
- by using slotted pipes under pedestrian path or centre median strips to collect and infiltrate road runoff - useful to maintain narrow road reserve



3. convey in natural systems

Water run-off to be retained within large road reserves and public multiple use corridors by:

- retaining existing natural channels
- using riparian vegetation to improve water quality through bio-filtration
- creating riffles and pools to improve water quality and provide refuge for flora and fauna
- retaining seasonal wetlands and vegetation and avoiding
- conservation category wetlands should not become part of the proposed stormwater treatment system
- converting existing drains into constructed waterways or 'Living Streams' to cope with 1:1 year ARI with excess water to be accommodated within the designed mixed use area

4.< 1:20 high intensity storms

Water run-off to be accommodated within the flood plain and incorporated into:

- public open space and multiple use corridors as a natural drainage system
- all road reserves ie. create water weirs along swales to detain flows and allow infiltration closer to the source