

The image is a composite cover for a report. The background is a photograph of a creek. On the left, a paved path curves through a green golf course with several trees. The creek flows from the background towards the foreground. The right bank is heavily vegetated with tall grasses and trees. In the foreground, a large green frog is perched on a log in the water. Another smaller green frog is visible in the bottom right corner. The text is overlaid on the image in white with a black outline.

# **Yakamia Creek Living Stream Management Plan**

**Prepared for the  
Oyster Harbour Catchment Group Inc.  
By S and G Janicke**

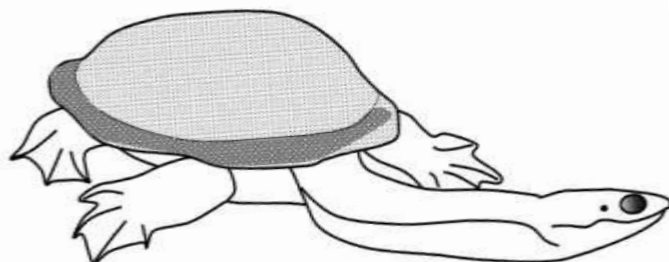
**February 2015**





## The origin of the name Yakamia Creek

The WA Department of Education Aboriginal Education website notes that; “Many local Aboriginal place names have the ending *"in"* (to the north) or *"up"* (to the south). These suffixes belong to different dialects of the Noongar language, and both mean "place of". The location of many important sites near natural sources of water has led to the common but incorrect belief that these suffixes mean the presence of water”.



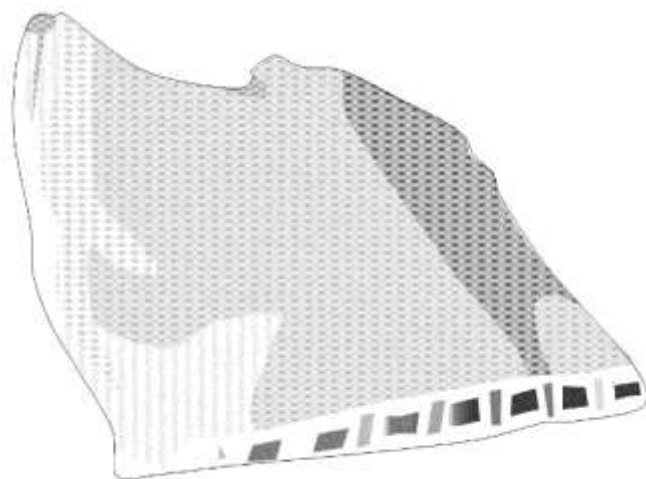
Local Albany historian Bob Howard (*A Noongar History of Albany*) noted that the lower Yakamia Creek locality was formerly known as *Yakinup* from *Yakin* – the long-necked tortoise. The locality can therefore be understood to mean, *the place of the long-necked tortoise*.

The name Yakamia is considered to be a combination of two words, *yaka* and *mia*.

The Aboriginal name for temporary shelters constructed at campsites is *mia* or *myah*. This suggests a subtle variation in meaning for *Yakamia*, perhaps originally referring to a campsite. Interestingly, the area around Duck Lake (now renamed *Weelara*) near the junction of Albany Highway and Hanrahan Road was a traditional campsite and it also lies on the Yakamia Creek watershed at the end of the granite ridge which descends from Mount Melville.

To complicate matters, the word *Yacka* refers to a wild dog. The iconic Dog Rock, which lies on the southern watershed of Yakamia Creek near the top of York Street, was known as *yaccan toort*.

A Wikipedia entry suggests that Yakamia is thought to mean ‘sister to a small creek’ in the Noongar language. The origin of this interpretation is unclear. Nevertheless it can be noted that the upper Yakamia Creek branches into several minor drainage lines. These small tributaries might easily be described as sisters, one of which is said to have been spring fed and of course, fresh water is a necessary feature of a favoured campsite.



## **YAKAMIA CREEK LIVING STREAM MANAGEMENT PLAN**

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The information presented in this report is based on sources believed to be reliable and on field observations and interpretation of available data. While due care has been taken in the preparation of this report, Steve & Geraldine Janicke give no warranty that the information or associated assessments are infallible. The authors do not accept any responsibility for how this report is interpreted and used and the subsequent results or outcomes of that use by other parties. Any views or opinions presented in this report are solely those of the authors and do not necessarily represent those of the Oyster Harbour Catchment Group Inc.

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Yakamia Creek Living Stream Management Plan

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## Please Note:

This is Part A of the Yakamia Creek Living Stream Management Plan. The document has been split into three parts and has been reduced in quality to enable it to be downloaded from the internet.

The three parts are:

YAKAMIA\_CK\_LSMP\_PartA\_without\_maps

YAKAMIA\_CK\_LSMP\_PartB\_without\_maps

YAKAMIA\_CK\_LSMP\_PartC\_Appendices and maps

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## Overview

This report provides a systematic overview of the nature of the main trunk of Yakamia Creek between the watershed at Anson Road and its confluence with Oyster Harbour. The overview also includes four tributaries, two in the Centennial Park precinct and two entering the creek from the western side of the catchment below North Road. Seven floodway zones were identified on the basis of their position in the catchment landscape. Within these zones, 108 discrete sections of the floodway were delineated, each with distinctive attributes. The sections cover 15.5 Kilometres of stream channel, 9.4 Kilometres of the main trunk and 6.1 Kilometres of tributary. The general management issues for each of the sections was assessed and rated in terms of constraints on environmental rehabilitation opportunities. Five key types of constraint were identified under the following headings; area of riparian space available, stormwater conveyance, land tenure (use) issues, public amenity and maintenance issues. A short list of sections suitable for Living Stream projects in the near future was distilled from the assessment in Table 6: Tier 1 Summary of opportunities, objectives and design considerations.

The section 'Recommendations to Oyster harbour Catchment Group' focuses more on the contribution the group can make to promoting a holistic approaching to the management of Yakamia Creek rather than offering prescriptive engineering solutions to specific technical problems, for example the poor water quality or how to deal with flooding in the lower catchment. The greatest hindrances to integrating an environmental plan with other management plans for the creek, are social in nature.

Management recommendations for landholders downstream of North Road are given as 'Best and better foreshore management practices for the lower Yakamia Creek' as appropriate to overall character of that part of the floodway environment. The authors consider this is an interim measure pending the acceptance by all stakeholders of the long term goal of creating a continuous riparian corridor along the lower catchment and associated tributaries.

The Oyster Harbour Catchment Group Inc. (OHCG) have more than twenty years collective on-ground experience in managing river and creek systems and are well positioned to contribute practically to projects, in collaboration with other stakeholders. An important strength of the OHCG is an understanding of and commitment to successful environmental outcomes for projects in the long term. Maintenance of Living Stream sites is crucial to achieving those outcomes and a failure in this area can undo a lot of good work. Recommendations to the OHCG for progressing Living Stream project opportunities and levels of involvement are provided in 'Recommendations to OHCG for Tier 1 sites' **Error! Reference source not found.** and 'Summary of General recommendations to OHCG FOR Tier 2 sections downstream of North Road.'

Two important supplementary documents are provided. Supplement 1 presents seven urban Living Stream projects from other regions. These have been chosen because they have issues in common with Yakamia Creek. These are not 'fill' for the report, but each case study provides useful

insight into the realities of Living Stream development in urban areas and the lessons learnt. This is after all a relatively new field of urban development and this report emphasizes that success depends on a significant change in community expectations regarding how the stream should be managed into the future. Supplement 2 is a geo-referenced photographic record of the target creek sections, here called a Photo-audit. This provides a visual overview of the status of the system in 2014 and highlights various management issues.

The Living Stream Management Plan emphasizes that stakeholder consultation is more than a 'hoop' to jump through in order to achieve an environmental goal. It is a critical ongoing component for sustainable management of the creek system.

## Introduction

The aims of this management plan are to:

- Provide recommendations on appropriate management of Yakamia Creek by private landholders, the City of Albany and State Government agencies.
- Identify, and propose solutions for key problem areas and issues.
- Inform environmental rehabilitation priorities for natural resource management stakeholders, the City of Albany and State Government agencies.
- Identify the next 2 to 5 rehabilitation sites for Yakamia Creek Living Stream Projects.

A Living Stream Management Plan presents opportunities for rehabilitation of fragmented urban waterways, opportunities that are both desirable and feasible with respect to their ecological health. It also considers the various social benefits.

It has been estimated<sup>1</sup> that by 2050 approximately 80% of the world population will be living in cities. The passage of water through these areas, its quality and function as an essential resource, requires a sophisticated management approach.

The aim of a holistic waterways management plan is to return continuity of riparian form and function to urbanised catchment streams. Without a significant consensus by the urban population this this can only be achieved in part. The defining characteristic of many urban streams is the fragmentation of their floodway form. There are abrupt changes at cadastral boundaries and a lack of continuity of riparian structure from the watershed to the lowest point in the catchment and from one reach to the next. The fragmentation of urban streams is not only created by division imposed by land tenure, but is compounded by differing expectations regarding the role that the waterways play in the environment. Developers have traditionally given little thought to the matter of riparian continuity. Nevertheless, urban streams are continuous in a hydrological sense, provided flows are not totally impounded. Neither is a stream simply defined by the main trunk, but it includes the branching network of tributaries and many minor swales and gullies that capture rainfall and steer it downhill. A water sensitive city manages its waterways and water resources in a holistic, rather than a piecemeal fashion. The City of Albany is well placed to becoming a water sensitive city.

The City of Albany's vision<sup>2</sup> for the next ten years is to be clean, green and sustainable. Within the objective to protect and enhance our natural environment, the City has endorsed actions that protect and enhance the health of our waterways including providing habitat for local flora and fauna.

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<sup>1</sup> Uniview, 2014, Vol 33/2

<sup>2</sup> City of Albany (2014) '*Community Strategic Plan Albany 2023: Our Vision*'



The expanding demands of urban development have tended to an acceptance of environmental projects, provided they fit into the vacant spaces that are of less interest to developers and provided they cause no disruption to existing drainage infrastructure. That perspective is changing. For example the CRC for Water Sensitive Cities based in Melbourne, has chosen the City of Geraldton in WA, to demonstrate how regional centres can become models of water sensitive urban design. It is suggested that the City of Albany is well suited to demonstrate a progressive approach to urban water management, one that goes beyond the disposal of inconvenient stormwater.

Notwithstanding the above aims of this management plan, it is not a flood management plan nor is it a stream restoration plan in the accepted sense. Typically, a stream restoration plan (also called a river action plan) is developed for relatively intact streams which have retained their essential natural features, but are experiencing degradation due to human activity. A restoration plan describes the pre-disturbance characteristics of a waterway and suggests how it might be defended against a range of pressures in order to limit and if possible reverse degradation. In a river action plan works that promotes protection and recovery are recommended. This usually involves protective measures such as fencing to exclude stock, re-vegetation with local riparian plant species in areas where they are disappearing, the provision of stable crossings and other infrastructure. A River Action Plan also provides guidelines for best management practices. In some cases restoration may involve intervention in the form of bed and bank stabilization works, but preferably using natural materials such as vegetation, loose rock and wood. This approach is referred to as *soft engineering*.

A Living Stream Management Plan (LSMP) starts with a degraded and fragmented urban waterway and considers ways to introduce ecosystem attributes that are compatible with the multiple constraints that urbanization has created. These attributes will not necessarily represent the original natural state of the waterway. For this reason, the term *retrofitting drains* has been attached to the Living Stream concept. Nevertheless, there are commonalities between restoration and Living Stream rehabilitation, particularly where there are pockets of remnant riparian vegetation. In those situations protection measures may be the main management tactic. Some sections of the lower Yakamia Creek tributaries appear to fit into this category. Two requirements for developing a Living Stream Management Plan for Yakamia Creek (LSMP) are first to understand the character of Yakamia Creek itself and secondly to identify the constraints on appropriate environmental management.

For these reasons a holistic ecosystem concept plan for Yakamia Creek, one that considers in detail both ecological and social amenity along its entire length from the watershed to Oyster Harbour, would prove useful. This report lays a foundation for such a plan and it will always be a work in progress. Short-term projects should therefore be undertaken with a long-term view in mind, a view that will span many decades.

### **Overarching city planning requirements**

The City of Albany's Community Strategic Plan 2023<sup>1</sup> presents the vision "To be Western Australia's most sought-after and unique Regional City to love, work and visit." Under the theme of being clean, green and sustainable, the Strategic Plan states that "our community loves the City's natural assets, coastline and green spaces within our municipality." The vision for a sustainable city includes environmental actions to "promote habitat protection and encourage development that incorporates or re-establishes ecologically sound vegetation and waterway corridors". The Planning objective is, "to preserve the natural ecological and drainage function of

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<sup>1</sup> City of Albany (2014) 'Community Strategic Plan Albany 2023: Our Vision'

water courses, drainage systems and floodplains and limit the potential for damage to buildings caused by flooding and/or inundation.” This is a challenging task.

A number of investigative reports and management plans for Yakamia Creek have been prepared for the City of Albany and are relevant to this document. These documents describe the factors that will support or constrain the development of environmentally focused projects along the creek.

Some key documents are;

- Yakamia Creek Arterial Drainage Plan (2014)<sup>1</sup>.
- Community Strategic Plan, Albany 2023
- Yakamia Structure Plan area – City of Albany Environmental Assessment – opportunities and constraints. (2013)<sup>2</sup>.
- City of Albany. Flood Management Plan, Yakamia B Catchment. Prepared by Opus International Consultants (2006).
- Yakamia Creek – Albany Floodplain management Strategy (2002). Prepared by the Water and Rivers Commission.
- City of Albany 2010 *Albany Local Planning Strategy*
- City of Albany Policy (2014) Yakamia/Lange Structure Plan
- Centennial Park Sporting Precinct Master Plan

## The characteristics of Yakamia Creek

Yakamia Creek is the smallest of three main catchment systems feeding water into Oyster Harbour, the other two being the Kalgan River and the King River. Another smaller catchment is Johnson Creek that enters Oyster Harbour between the mouths of the King and the Kalgan Rivers. The catchment area of Yakamia Creek is approximately 21 Km<sup>2</sup> (0.8% of the total Oyster Harbour catchment area) compared to the Kalgan River at 2562 Km<sup>2</sup> and the King at 375 Km<sup>2</sup>.

There are several short tributaries feeding into the main trunk of Yakamia Creek. Those in the upper urban catchment are ephemeral and many sections are piped underground. Two short drainage lines descending from the Mount Clarence ridge have been included in this report. There are also two tributaries, extending from the north west side of the catchment near Mason Road (Lange) and Callistemon View / Range Road and these have their confluence with the main trunk between North and Lower King Roads. These tributaries do not have official names and it would be helpful to promote community awareness of their existence their need of some level of protection, by naming them. For the purposes of this report, the tributaries will be referred to as Lange tributary and Callistemon View tributary.

**Recommendation: That names be given to the two larger tributaries, extending from Mason Road (Lange) and Callistemon View / Range Road that enter Yakamia Creek between North and Lower King Roads.**

## Divisions of the creek line

The historical allocation of land along the creek for urban development, has essentially divided the main trunk into two zones with different land tenure issues. The upper zone (35% of the main

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<sup>1</sup> Essential Environmental. (2014) ‘*Yakamia Creek Arterial Drainage Plan*’. Prepared for the City of Albany.

<sup>2</sup> Melanie Price (2013) ‘*Yakamia Structure Plan Area, City of Albany Environmental Assessment - Opportunities and Constraints*’, Report No. AA2012/020 by Aurora Environmental for the City of Albany.

channel) is predominantly City land with public amenity and the middle to lower zone (65% of the main channel) is mostly private land (see Figure 1).

In addition, the two short tributaries entering the floodway downstream of North Road have remnant vegetation areas that are still in reasonable condition and these are of environmental interest with respect to conservation. These two tributaries flow through privately owned land. The Mount Clarence/ Melville drainage lines service the Centennial Park precinct. Together these four zones suggest different priorities and focus for achieving desirable environmental outcomes for Yakamia Creek. The overarching management issues for the four zones are summarised in the Table 1 below.

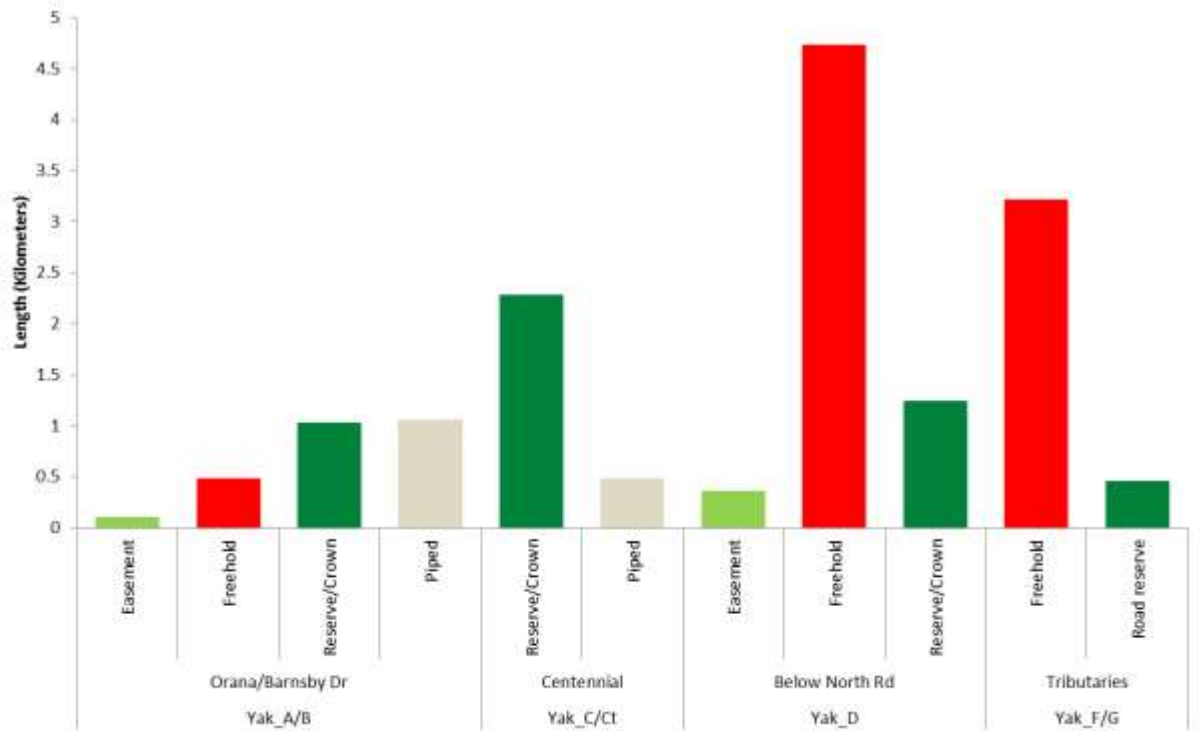


Figure 1: Tenure of Yakamia Creek and its tributaries.

Table 1: Overarching environmental management issues for the four zones of Yakamia Creek.

Zone	Strength	Weakness
Upper Yakamia	Primarily subject to City of Albany management and offering various public benefits.	Highly fragmented floodway form defined by diverse management demands and community interests.
Centennial Park recreation precinct	Predominantly public open space with opportunities to improve riparian continuity and function. The Centennial Park Sporting Precinct Development Plan	Physically fragmented drainage lines with current and expanding recreational facilities setting the precedent for area use.
North Road to Oyster Harbour.	Relatively consistent channel form and general management requirements. Technically these reaches lend themselves to significant reconstruction.	Subject to diverse landholder preferences and expectations. Private ownership.

Western tributaries (Callistemon View and Lange)	Potential for conservation of existing channel form with associated remnant scrubland and woodland in moderately good condition.	Subject to increasing pressures from high density urban development upstream and potential subdivision requirements. Severe threat from weed encroachment. Private ownership.
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### Channel geomorphology and hydrology

The longitudinal bed slope of the main trunk of Yakamia Creek, from the watershed to the mouth, provides a foundation for understanding the fluvial geomorphology of the floodway. Fluvial geomorphology refers to the connection between the underlying geological structure of the catchment and the way in which rainfall runoff and groundwater shapes the drainage system. Urban development modifies these ancient processes creating new pressures on the creek. The lengthways bed slope (Figure 2) reveals potential high and low energy sections with respect to water velocity (stream power), although bed slope is not the only factor controlling flow velocity. Steeper slopes indicate reaches that have a higher risk of erosion and low slopes indicate reaches prone to sediment deposition (where flow slows down). Bed and bank stability also determine the level of risk of degradation in erosion and sedimentation prone areas. In areas with low cohesive sandy soils, vegetation plays a critical role in bed and bank stabilisation.

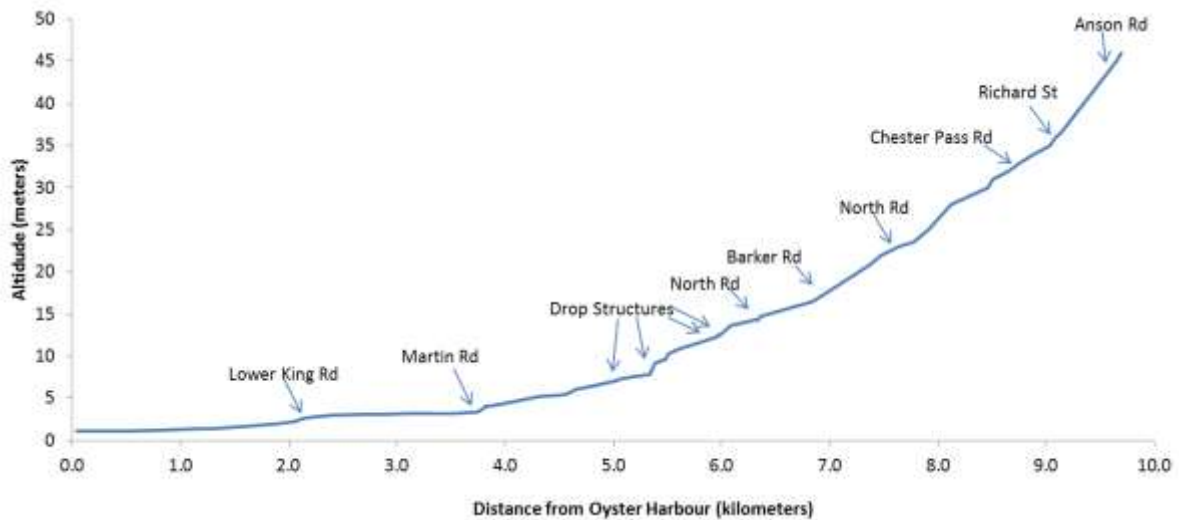


Figure 2: Longitudinal bed altitude profile of Yakamia Creek

The longitudinal bed profile matches well with the four management zones defined above. The profile, from the watershed above Anson Road to Oyster Harbour, has the relatively smooth concave-upward form of a graded stream channel. A graded stream is one for which a balance has been created over time between the amount of erosion and the transportation / deposition of sediment. There appear to be no major geological discontinuities along the profile, although a layer of subsurface coffee rock was observed in several sections and is responsible for local irregularities in the bed slope. An example of this is the head-cut (waterfall) a short distance downstream of the North Road and Sanford Road intersection (Figure 3).



**Figure 3: The waterfall and head-cut a short distance downstream of the North Road and Sanford Road intersection. The upstream progress of the head-cut has been slowed by a coffee rock layer.**

There are a number of artificial drop structures (Figure 11) along the lower reaches of the creek. These were installed to reduce the energy of flow when the creek line was straightened thus increasing the local bed slope and discharge velocity. A drop structure controls the water surface slope and is typically constructed on minor streams to move water to a lower elevation with the controlled dissipation of flow energy as it passes over. By removing energy from the flow, and hence reducing the water velocity, a drop structure may reduce the overall erosion risk further downstream. Nevertheless, if poorly designed, the section of channel immediately downstream may be at greater risk of erosion, typically, deepening and widening the channel. Drop structures, unlike dams, are not built for water impoundment, diversion or raising the water level. The drop structure can aid oxygenation of the water, but can also hinder ecological processes, for example the movement of fish upstream for spawning.

The drop structures along the lower Yakamia Creek were required to offset the removal of meanders when the channel was straightened. Meanders moderate the slope of the channel and hence the erosive power of the flow. The observed bank erosion along the channel is explained in part by the tendency of the stream discharge to recreate natural meander form. For this reason projects that favour reinstatement of sinuosity in the straightened channel are preferred for enhanced environmental and hydrological function. Sinuosity (channel curvature) also increases hydraulic and terrestrial habitat diversity.

Channel sinuosity is a desirable feature of Living Streams.



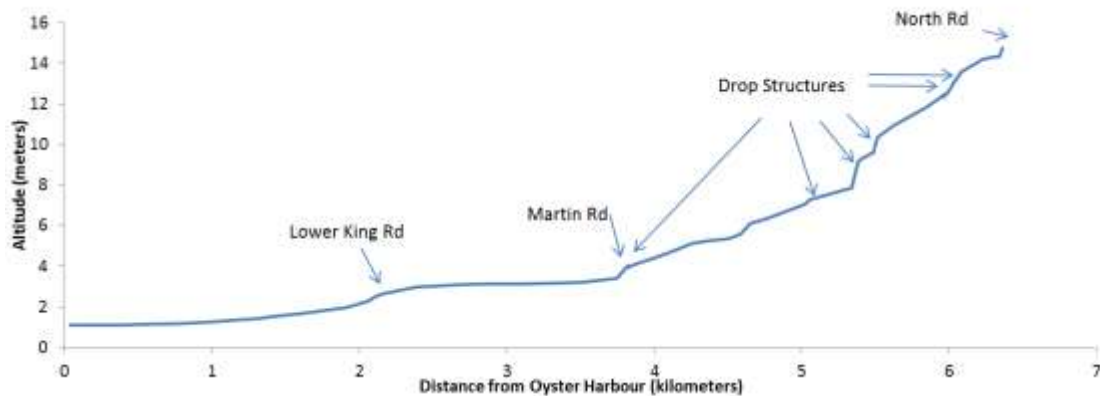
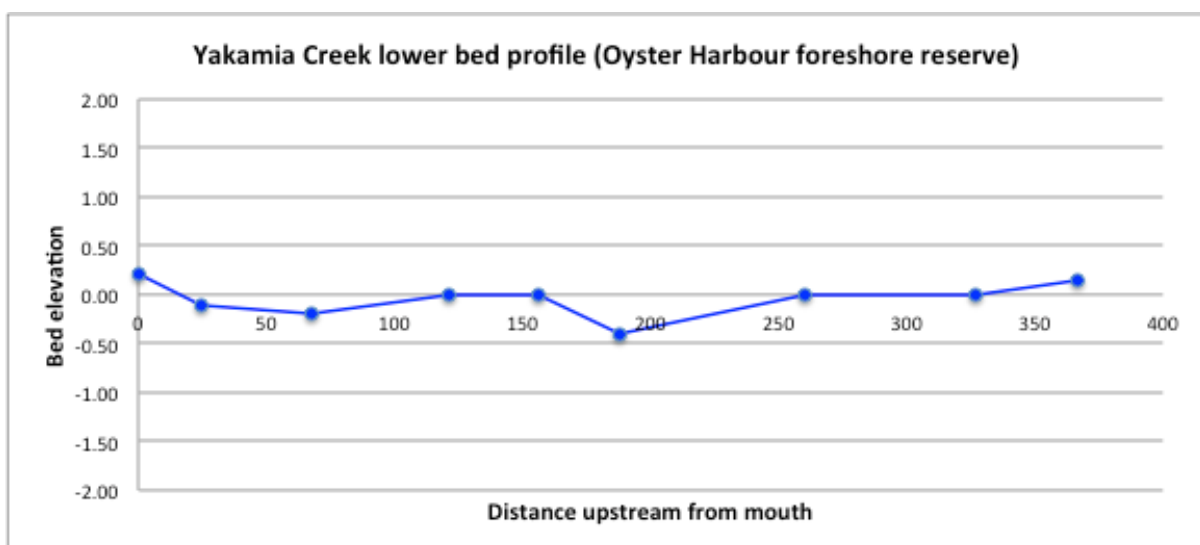


Figure 4: shows more detail of the bed slope downstream of North Road. Note how the slope quickly levels out.

The average channel bed gradient from the watershed to Oyster Harbour is moderate at approximately 0.005 (a 5 metre fall over 1000 metres). However, the upper part of the channel has a higher mean gradient of approximately 0.009 (9 metres per 1000 metres) compared to a very low gradient of approximately 0.0015 (1.5 metre fall over 1000 metres) in the lowest reaches of the creek (Figure 4). The very low slope in this zone is consistent with it being a natural sediment deposition area with a wide floodplain developed over thousands of years. This area would likely have been estuarine in character for some periods in the past. Yakamia Creek is still influenced by tides for approximately 2 Kilometres upstream of its outfall at Oyster Harbour. This would likewise tend to hinder stream discharge and promote sediment deposition.

A cursory examination of the channel through the foreshore reserve upstream of its entrance into Oyster Harbour provided some evidence of the amount of sediment deposition in the vicinity of the mouth of the creek. Figure 5 below shows the relatively flat bed profile of the 400 metre long reach upstream of the mouth. There is some evidence of a long sediment plume between 50 and 200 metres and an associated scour hole at the narrow outfall. There is also a slightly deeper pool between 150 and 250 metres upstream.

The foreshore area out from the mouth appears to have features characteristic of long-term deposition processes. No studies of sediment discharge into Oyster Harbour were located, but sediment cores may provide a clearer picture of the impacts of urban development over the past two hundred years. This investigation may provide a useful project for a university Honours student.



**Figure 5: The creek bed profile of the first 400 metre reach going upstream from the mouth of Yakamia Creek**

In addition to storm water runoff, groundwater discharge into Yakamia Creek is a significant hydrological feature and accounts for general stream flow when it is not raining. Seepages can be seen along the banks in all four zones but appear more significant between North Road and Lower King Road. A number of properties along the lower reaches have various lateral drains to direct groundwater seepage into the creek line. Much of the catchment area is underlain by acid sulphate soils (ASS) that if exposed to the atmosphere generates sulfuric acid that degrades water quality and impacts vegetation as well as deteriorating built infrastructure. The presence of acid sulphate soils at shallow depths imposes a natural constraint on both urban development and Living Stream project designs. Interestingly there is evidence of acidification of top soil in some areas and these bare areas have similar features to salt scalds. There has been some pressure to dig the channel deeper to improve drainage efficiency, however the high risks associated with exposing acid sulphate soils makes this option unwise.

Centennial Park is underlain by Spongeolite, a friable sedimentary rock partly composed of clay silts and the breakdown products of marine sponges from a time when the ocean covered the land. The impervious granite hills (plutons), Mt Clarence, Mt Melville and uplands of Spencer Park and Yakamia/ Lange feed groundwater flow to the creek. The groundwater system is therefore an important factor affecting water quality, Riparian management should include areas further from the dominant channel where groundwater seepage occurs and this is as important as managing the channel itself.

## The condition of Yakamia Creek downstream of North Road/ Sanford Road.

The condition of the riparian zone of Yakamia Creek along the lower reaches can be aptly described as a weed infested ditch. Interestingly, in places where there is a diversity of competing weeds, including larger woody species, this has promoted the creation of channel features that have a more natural form. These areas now form a complex, though non-natural ecosystem. Land use and the type of weed management used on a property are two factors that have a significant influence on riparian character and development.

### Flora

The authors have not been able to find any clear photographic records or detailed descriptions of the early-settlement vegetation in the Yakamia Creek area. Sandiford and Barrett (2010)<sup>1</sup> described the *Taxandria juniperina* (Swamp Cedar) Closed Forest vegetation unit as the most commonly found vegetation around swamps, freshwater lakes and along drainage lines that once formed extensive groves on the drained flats around Albany. Mature stands of Swamp Cedar can be seen along sections Yak\_C1, Yak\_D2.2 and Yak\_D5.7 (See maps 1, 5 and 8 respectively). Mature stands generally have fewer understory shrubs and were more open. However they are easily killed by fire and regenerate from seed forming very dense thickets. *Callystachys lanceolata* (Wonnich) occurs with Swamp Cedar and where local soaks or seepages occur on sandy to peaty soil. It is most likely that Swamp Cedar was the dominant vegetation, either as tall closed forest or dense thickets around the flats of North Road and the flats adjacent to Ulster Road. Other vegetation units along the Yakamia floodplain are *Homalospermum firmum*/*Callistemon glaucus* (Albany bottlebrush) (See Figure 6) Swamp Thicket, *Astartea scoparia* (Tea tree Swamp) Thicket, *Evandra aristata* Sedgeland *Melaleuca cuticularis*/*M. preissiana* (Paperbark) Open Woodland and *Baumea articulata* Closed Sedgeland.



Figure 6: *Homalospermum firmum* and *Callistemon glaucus* (Albany bottlebrush)

Sandiford and Barrett (2010) noted that these units were susceptible to weed invasion with Sydney Golden Wattle (*Acacia longifolia*) and Taylorina (*Psoralea pinnata*) commonly observed within them. There are many other weeds throughout the remnant vegetation of the floodplain including Pampas Grass (*Cortaderia selloana*) and Gorse (*Ulex europaeus*). Melanie Price (2013)<sup>2</sup> of Aurora

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<sup>1</sup> Sandiford, E.M. and Barrett, S. (2010). *Albany Regional Vegetation Survey, Extent Type and Status*, A project for the Department of Environment and Conservation. Unpublished report. Department of Environment and Conservation, Western Australia.

<sup>2</sup> Melanie Price (2013) *Yakamia Structure Plan Area, City of Albany Environmental Assessment - Opportunities and Constraints*, Report No. AA2012/020 by Aurora Environmental for the City of Albany

Environmental commented that much of the vegetation associated with Yakamia Creek does not constitute native vegetation due to almost complete invasion by weeds. Despite the proliferation of weeds, there are some moderately healthy vegetation remnants along parts of the short tributaries entering the main channel near Mason Road (Lange tributary) and Range Road (Callistemon View tributary).

Upslope, *Taxandria parviceps* (Tea Tree) transitional Shrubland occurs on grey sand or in pockets of poorly drained sand over laterite. This gives way to Jarrah/Marri/Sheoak Laterite Forest, Jarrah/Sheoak/Albany Blackbutt Sandy Woodland and Banksia coccinea Shrubland/ Albany Blackbutt /Sheoak Open Woodland. Melanie Price (2013) presents a detailed description and maps of the existing remnant vegetation communities within the Yakamia Lange localities including the priority flora and priority ecological communities present.

## **Fauna**

Yakamia Creek is named as the home of the long-necked tortoise (*Chelodina oblonga*). It has not been recorded in any studies; however one was accidentally excavated in 2013 during the construction phase of the Yakamia Creek Living Stream adjacent to Barnesby Drive (Mark Waud per comm.) A number of residents along Ulster Road have also commented on seeing the long-necked tortoise.

Melanie Price (2013) has listed vertebrate species<sup>1</sup> recorded from various recent and historical surveys in the region and outlined the number of species recorded and their status by group which is reproduced below (Figure 7). Her recommendation regarding fauna was: “Retention of vegetation suitable for Threatened Black Cockatoos, Western Ring-tail Possums and Priority Quenda are most likely to benefit other significant species which may occur in the area. These fauna habitat types comprise a combination of Jarrah/Sheoak/Albany Blackbutt Sandy Woodland and Wetland Mosaic vegetation. It will be most beneficial to retain elements of these vegetation types which enhance connectivity and coincide with other significant features (e.g. wetlands and watercourses).”

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<sup>1</sup> Appendix H in Melanie Price (2013) *Yakamia Structure Plan Area, City of Albany Environmental Assessment - Opportunities and Constraints*, Report No. AA2012/020 by Aurora Environmental for the City of Albany

#### FAUNA SPECIES BY GROUP

GROUP	NUMBER OF SPECIES	COMMENT
Frogs	Five of a possible 14 species found in the region.	No Threatened or Priority species recorded
Reptiles	Eighteen species of reptiles including 12 skinks, three elapids, one gecko, one pygopod and one varanid. An additional 16 species of reptiles are known to occur in the region but were not recorded in YSPA.	No Threatened or Priority species recorded
Birds	Fifty-nine bird species were recorded in YSPA. A total of 150 bird species are likely to be found in the Albany region. However, many are associated with marine habitats and are not likely to utilise or rely on the YSPA.	Carnaby's Black Cockatoo Baudin's Cockatoo Red-tailed Black Cockatoo
Mammals	Eleven native species of mammals were recorded in the YSPA including three bat species. Three introduced species were recorded (cat, fox and rabbit).	Western Ring-tail Possum Southern Brown Bandicoot

Figure 7: Numbers of vertebrate fauna species recorded from various recent and historical surveys in the Albany region (Source: Melanie Price (2013))

#### **Aquatic fauna**

There have been no systematic aquatic fauna studies done in the Yakamia catchment. Studies<sup>1</sup> in the adjacent and similarly fresh Marbellup Creek and King River show a high diversity of aquatic invertebrates and fish exists in the region and would likely have existed in Yakamia Creek. Fish and crayfish species present in the region and potentially present in Yakamia Creek are:

- Mud Minnow (*Galaxiella munda*),
- Nightfish (*Bostockia porosa*),
- Pouched Lamprey (*Geotria australis*)
- Western Minnow (*Galaxias occidentalis*),
- Western Pygmy Perch (*Nannoperca / Edelia vittata*),
- Gilgie (*Cherax quinquecarinatus*)

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<sup>1</sup> Barbara A Stewart (2011) An assessment of the impacts of timber plantations on water quality and biodiversity values of Marbellup Brook, Western Australia. Environmental Monitoring and Assessment (2011) 173:941–953  
 Cook, B. A., Janicke, G. & Maughan, J. 2008. Ecological values of waterways in the South Coast Region, Western Australia. Report No CENRM079, Centre of Excellence in Natural Resource Management, University of Western Australia. Report prepared for the Department of Water.  
 Janicke, G., Cook, B. A. & Maughan, J. 2008. Ecological values of the King River in relation to waterways in the South Coast Region, Western Australia. Report No CENRM098, Centre of Excellence in Natural Resource Management, University of Western Australia. Report prepared for the Department of Water.  
 Morgan, D. L., H. S. Gill and I. C. Potter (1998). "Distribution, identification and biology of freshwater fishes in southern-western Australia." Records of the Western Australian Museum (Supplement No. 56).



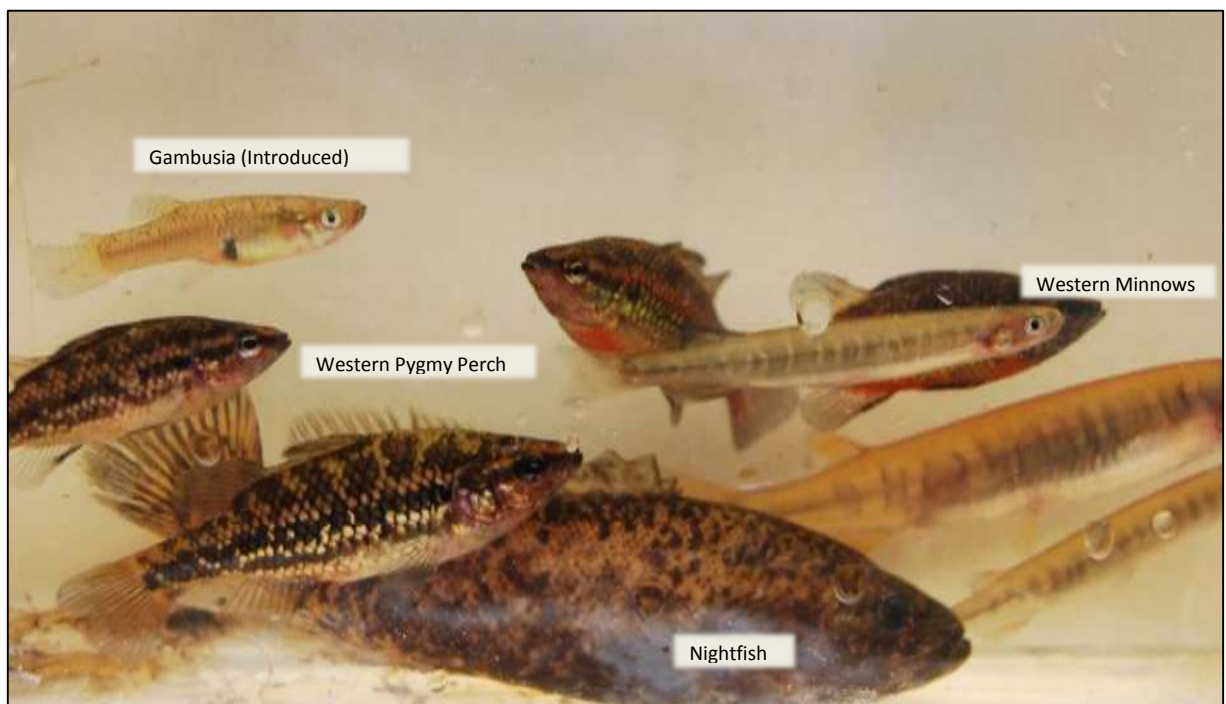
- Gilgie sp. (*Cherax crassimanus*)
- Koonac (*Cherax preisii*),
- Smooth Marron (*Cherax cainii*),

An opportunistic water sampling exercise for fish and macroinvertebrates was undertaken in the King River and Yakamia Creek by the authors, in collaboration with Department of Fisheries Community Education Officer Tahryn Thompson and University of Western Australia fish ecologist Dr Paul Close (CENRM) on 29<sup>th</sup> November 2014. In the King River three species of native fish, (Nightfish, Western Minnow and the Western Pygmy Perch), and two species of freshwater crayfish Smooth Marron and Koonac) were collected. The introduced Gambusia (*Gambusia holbrooki*), was also collected (See Figure 8.)

The site chosen for sampling in Yakamia Creek was Section Yak\_D2.4 (see map 5) which is between two drop structures. The only fish collected were the introduced Gambusia and the only freshwater crayfish was the introduced Yabby (*Cherax destructor*) (See Figure 9). There were also fewer aquatic macroinvertebrates present in the sample collected from Yakamia Creek. The drop structures are significant barriers to native fish movement. Sampling in the two tributaries, (Sections F and G on maps 6, 9 and 10) and lower down in Yakamia Creek would help to determine if any native fish still live in the Creek.

These observations suggest:

- Living Stream project success may be determined in part by monitoring fauna and flora diversity and numbers.
- The re-introduction of native aquatic species into re-engineered habitats is a possibility.
- Monitoring bird numbers and diversity is a good indicator of increased invertebrate diversity in rehabilitated sections (See Bannister Creek case study.)



**Figure 8: Fish netted from the King River that would once have lived in Yakamia Creek, except for the introduced Gambusia. (Photo by S. Janicke)**



Figure 9: The Yabby (*Cherax destructor*) has been introduced from the eastern states competes with our local endemic freshwater crayfish.

### Aboriginal Heritage

An Aboriginal heritage survey and consultation was undertaken for the Yakamia/Lange Structure Plan<sup>1</sup> area and this saw Yakamia Creek registered with the Department of Indigenous Affairs (DIA) as a site under Section 5(b) of the 'Aboriginal Heritage Act 1972' (Figure 10). The ten members of the Aboriginal Heritage Reference Group Aboriginal Corporation (AHRGAC) requested that provisions be made so that Yakamia Creek has a buffer zone (30m) where no urban development takes place and that the creek line be rehabilitated with local native plant species.

The continuous riparian buffer as recommended, is compatible with the preferred Living Stream ideal of riparian continuity along a stream and the 30 metre buffer is generally applicable upstream of North Road. However, a 30 metre buffer should be considered a minimum requirement downstream of North Road and in those reaches the riparian corridor width should be extended to amply accommodate the geo-morphological attributes of the broader floodway as well as the main channel.

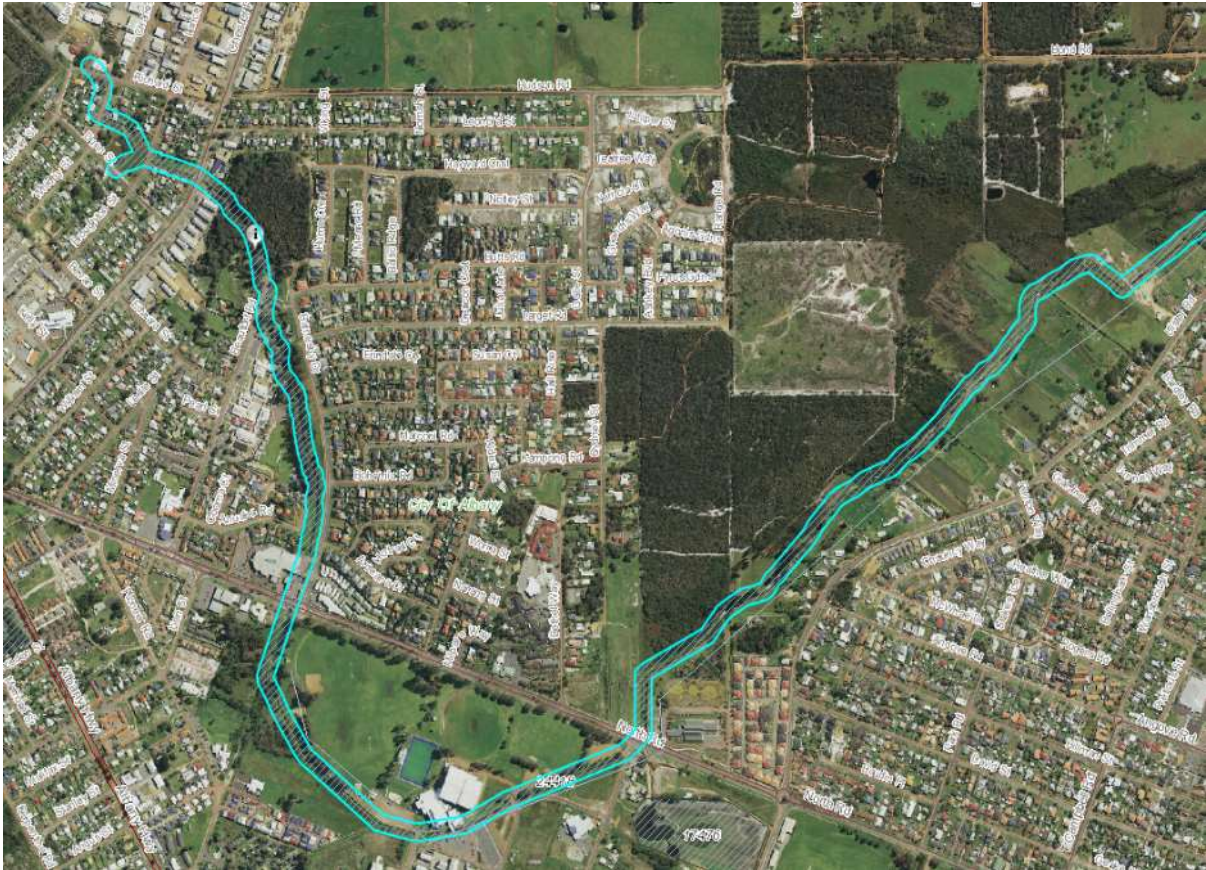
Any Living Stream rehabilitation planning for sections of Yakamia Creek registered with the Department of Indigenous Affairs should include Noongar consultation in the design phase. Rehabilitation activities that - *dig any hole or otherwise disturb the surface of the ground, or remove or disturb any stone, soil, sand, rock or gravel, or any other natural object* - will require consent according to Regulation 10 of the Aboriginal Heritage Regulations 1974. Further information on notification requirements can be found on the State Governments Department of Aboriginal Affairs website.<sup>2</sup>

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<sup>1</sup> City of Albany Policy (2014) Yakamia/Lange Structure Plan

<sup>2</sup> <http://www.daa.wa.gov.au/en/Heritage-and-Culture/Resources/Policies-and-procedures/Regulation-10/>





**Figure 10: Aboriginal Heritage Sites – showing the 30m buffer zone requested by AHRGAC. (Source Department of Aboriginal Affairs Aboriginal Heritage Inquiry System (<http://maps.dia.wa.gov.au/AHIS2/>) accessed 16<sup>th</sup> February 2015. <sup>1</sup>**

### **A Brief Management History of Yakamia Creek**

Yakamia Creek is an ecosystem that warrants more than the title – drain. A common misconception regarding the definition of a creek is that it only consists of the most obvious low flow channel. The extent of the floodplain contradicts this view. Yakamia Creek was and is, a composite of flow paths as it meanders toward the inlet and is connected to the groundwater recharge (source areas) and discharge (outflow) areas along the floodway. The riparian zone is the interface between the upland valley sides and the channel and it is influenced by groundwater flow, as well as the surface flows. Although most parts of the creek are now highly channelized to facilitate faster drainage of the riparian flats, the low flow dominant channel is only one part of the waterway system.

The dominant channel of Yakamia Creek would likely have slowly migrated back and forth across the floodplain areas over the centuries as a result of the meandering habit of natural streams. This process would have been strongly influenced by changing vegetation distribution, density and type. The build-up of woody material and the redistribution of sediment would also have promoted changing flow paths. The occasional severe storm event, drought or bushfire would also have affected the ongoing processes of erosion and sedimentation and hence channel location. Secondary channels and backwaters may have developed within the broader flood prone areas reflecting various flood events and changing vegetation conditions.

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<sup>1</sup> Topographic maps and data copyright © Commonwealth of Australia, Geoscience Australia (2015). Aerial Photos, Cadastre, Local Government Authority, Native Title boundary, Roads data copyright © Western Australian Land Information Authority trading as Landgate (2015)

In 1959 the Public Works Department and the Albany Town and Shire planned the construction of a steep sided linear drain and excavation works were undertaken in 1961. In the steeper upstream reaches, ditches, armoured banks and culverts have been relatively effective in confining storm water flowing from the slopes and transporting it to the lower catchment. A number of landowners along the floodway of the lower catchment consider that subsequent to the construction of the drain, maintenance works have been inconsistent and inadequate to address flooding issues.

The excavation and straightening of the channel reinvigorated erosion and depositional processes and this accounts for the undermining of banks, flood scours and deposition of sediment plumes. The clearing of native vegetation and disturbance of topsoil along the channels also facilitated the establishment of dense infestations of assorted weeds.

The extensive drainage works undertaken in the early 1960's did not address the flooding issue as expected and did not produce a particularly stable floodway. However, it did raise landowner expectations about local government custodianship of the channel and bequeathed an expensive maintenance demand on the City of Albany and by association, ratepayers.

The highly modified nature of the creek floodway plainly demonstrates that the conservation of natural waterway features and the associated riparian vegetation was of little interest to landholders in the historical management of this waterway.

Since the earlier works, studies regarding the management of Yakamia Creek have been dominated by concerns about the mitigation of flooding and local waterlogging. The occasional large floods have caused some problems and damage to infrastructure.

In the upper reaches of the creek, drainage works have focused on protecting roads and other infrastructure by moving storm water quickly downstream. In some sections flows have been piped underground and in others the channel has been lined with rock or concrete. However, sophisticated ways of managing the ecosystem in these areas have not eventuated, although some detention basin works have been constructed and two localised Living Stream projects have been undertaken in recent years.

The upper reaches of the creek pass through land set aside for public purposes, namely parkland, sports fields, and for passive recreation. Because of the public amenity profile of these areas there are reservations about undertaking rehabilitation works that may restrict the area available for the expansion of these facilities. The possible increased risk of local flooding is also of concern. Works to control storm water flooding in Dunn Park in the upper catchment have been criticised for taking up public open space. This highlights how different community interests can create conflicts and slow the planning and design process.

A 1981 Flood Investigation by the Public Works Department<sup>1</sup> estimated that some 12,000 cubic metres of sediment had been deposited in a 2.5 Kilometre section of the channel upstream of the Lower King Road during the twenty years since the initial channel modifications. This resulted in reduced discharge carrying capacity and where levees were in place the bed was raised above the floodplain further inhibiting efficient drainage. Steep bank batters in sandy soils also facilitated erosion. The exact origin of the sediment was uncertain, but was attributed to either bed and bank erosion in the steeper upper catchment or to various development works being undertaken immediately upstream of North Road. The Public Works Department estimated the cost for the drain maintenance at \$109,000 for the Town and \$113,000 for the Shire (1981 costs).

Following this, the Town and Shire Councils, Public Works Department, Minister for Water Resources, Crown Law Department and the Local Government Department held discussions on

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<sup>1</sup> "Yakamia Creek Flood Investigation Report" PWD Design branch, May 1981

the problem of who, if anybody had legal responsibility for the status of Yakamia Creek and who should carry out the work – if anybody, and meet the costs. The Shire resolved in 1982:

“That the Yakamia Drain is considered to be a natural water course and that, as a result, whilst Council acknowledges its present condition, it takes the view that it has no obligation to expend the considerable amount of public funds requested to rectify the present situation.”<sup>1</sup>

The City of Albany maintains this stance, although mutually agreeable solutions to drainage issues continue to be sought.

In 1989 the Water Authority commissioned Binnie and Partners Pty Ltd to undertake a further flood management study.<sup>2</sup> The emphasis once again, was on flood mitigation in the middle to lower reaches of the catchment and it was stated that over the previous 50 years the problem had gradually worsened (this was 28 years since the previous large scale drainage works). The causative factors were;

- Heavy siltation of the creek caused by sediments eroded from the steeper upper reaches of the catchment being deposited in the flatter lower reaches.
- Urbanisation in the upper reaches which had significantly increased the rate of runoff and the magnitude of flood peaks.
- Catchment clearing for farming which also increased the runoff rate and flood magnitude although not as significantly as urbanisation, and
- Lack of maintenance that had reduced the flow capacity of the creek.

The study recommended a number of actions and these included;

- Retention of a portion of the vegetated flood prone area as a ‘bio-filter’.
- Flood protection provided by means of levees for rural lands situated outside the area set aside for the purpose of a bio-filter.
- Adequate flood-gated drainage outlets through levees designed for existing town drainage outlets between Martin Road and Lower King Road

The Water Authority had derived a design flow of 15 Cumecs<sup>3</sup> (approximately the volume of a VW Kombi van every second) with a conservative return period of 10 years (ARI)<sup>4</sup> and 25% of the catchment urbanised. The subsequent hydrologic modelling by Binnie and Partners produced a comparable value of 14.4 Cumecs at Martin Road. At that time flood modelling was based on the estimation that 25% of the catchment was urbanised and 25% was un-cleared, leaving 50% cleared or semi-cleared, but essentially rural. It should be noted that the 1989 study had no gauging data against which to calibrate their flood discharge model.

It was recognised that increasing urbanization would further alter the catchment discharge characteristics by increasing the area of hard surfaces and hence the rapidity of storm water runoff. This would mean more water, more often, moving more quickly along the creek line. As a result further studies would be required to confirm or modify the calculations. It should be noted that that the detention/ bio-filter was never constructed since the Council resolved to support the

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<sup>1</sup> Town of Albany File Notes: Report to Councillors from Director of Works and Technical Services. May 1990

<sup>2</sup> Yakamia Creek Management Study (1989) Report by Binnie and Partners Pty Ltd for Water Authority of WA.

<sup>3</sup> 1 Cumec = 1 cubic metre per second (1 m<sup>3</sup>/s).

<sup>4</sup> A 10 year ARI flood means that in any particular year there is a 1 in 10 chance of it occurring.



concept on the premise that it would not be responsible for the maintenance of the filter.<sup>1</sup> Thus the search for a cheap solution to an expensive problem continued.

In 2000, Green Skills undertook a survey of the condition of the channel and riparian vegetation along Yakamia Creek for the City of Albany and the then, Albany Waterways Management Authority. This represented a first holistic environmental assessment of the condition of the riparian areas of the modified creek. The recommendations of the assessment advocated adopting a more 'natural' stream form with vegetated foreshore buffer zones up to 60 metres wide. The weed management issue was also identified as a critical factor for the health of the system. However, no clear definition of what constituted a 'natural form' was specified

In 2001 the Department of Water (Water and Rivers Commission)<sup>2</sup> undertook a further flood study to refine design flood flow estimates for Yakamia Creek. Two stream flow gauging stations had been constructed in the early 1990's to provide real data that could be used to calibrate the URBS-CM hydrologic model. The two gauging sites were located at North Road and the Lower King Road. The North Road site (now destroyed by stream flows) provided 8 years of data, but this was not sufficient to provide a flood frequency analysis.

It was noted that during the 8 year period from 1993 to 2001 the largest flood flow recorded was 4.8 cubic meters per second and that was recorded on 29 August 1998. The Lower King Road gauging site yielded intermittent data with a continuous record only available for the period 1998 to 2000.

The hydrologic model yielded some estimates of the way in which the creek responds to various storm events. Flood discharge was estimated for 2, 5, 10, 25, 50 and 100 year average recurrence interval storm events.

Analysis of the likely duration of the ARI events indicated a period of 72 hours with a lower secondary peak flow at around 36 hours. For all model simulations the critical duration of the flood at the Lower King Road was around 36 hours. The duration figure of 72 hours was adopted as the critical duration.

During April 2005 the catchment experienced two major storm events within a twenty-four hour period. These caused widespread flooding and were initially estimated to represent a 1 in 100 year ARI rainfall event. In 2006 Opus International Consultants Pty Ltd, undertook a flood analysis of this event for the City of Albany. This enabled flood management maps to be produced for 10 and 100 year design storm events and a Flood Management Plan (2007)<sup>3</sup> was developed to guide future urban expansion. A number of significant deficiencies in the existing storm water drainage system were also identified.

Some landholders have expressed frustration that these hydrological studies seem repetitious and were avoiding the need for on ground actions. In reality the studies represent improvements in methods to assess the flood runoff characteristics of the creek system. One problem is that the catchment characteristics are continuously changing with urban development. This means that flood studies gradually become out dated. Flood runoff modelling does not offer solutions to flooding problems, but is essential to provide sufficiently accurate data for designing proposed drainage solutions.

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<sup>1</sup> Town of Albany File Notes: Report to Councillors from Director of Works and Technical Services. May 1990.

<sup>2</sup> Department of Water (2001) "Yakamia Creek Flood Study" Unpublished report Hydrological and Water Resources Series HY 06 2001.

<sup>3</sup> Opus International Consultants (A. Vanceva) 2007, *City of Albany Flood Management Plan: Yakamia B Catchment* Report for City of Albany.

The bottom line message for Living Stream projects, as for traditional drain design, is that works in the floodway need to be robust enough to easily handle flood discharges that tend to occur at 2 to 5 year intervals and be able to recover from larger storm events. In addition, Living Stream works should be designed to ensure they pose no more of a problem than standard drains. The 100 ARI peak discharge thus represents a conservative design parameter.

These requirements imply that qualified engineering design input will be mandatory for all project proposals along the creek, as they were for the Barnesby Drive stream rehabilitation site.

The Oyster Harbour Catchment Group was formed in 1992 and became an incorporated body in 1994. Its primary focus has been natural resource and it has been very successful in attracting significant funding for waterways protection measures, but it was only in 2012 that more attention was focused on the King River and Yakamia Creek catchments.

The City of Albany and various other stakeholders have in more recent times considered the role of the creek system in providing other community services. These services include, improved water quality, visual amenity, passive recreation, city ambience and ecological function through the protection and where possible, reinstatement of local flora and fauna species and the provision of suitable habitat for their maintenance. The potential impacts of the discharge from Yakamia Creek, on water quality in Oyster Harbour, is also becoming an important issue. However, such innovations are currently minimal. Some rehabilitation was undertaken adjacent to the Yakamia Primary School in the 1990's, although this involved re-vegetation using non-local trees. A benefit of this work is that it showed how re-vegetation could affect the creek environment favourably. The Barnesby Drive and Sanford Road Living Stream projects have introduced the community to the concept of Living Stream development based on careful design for integrating storm water management and ecosystem function. Community events to assist with weed management at the Barnesby Drive Living Stream site have been encouraging, with people showing an interest in the project.

### **Community management concerns**

Storm water flooding, traffic movement and public amenity appear to be the main community concerns along the upper catchment floodway. In the middle reaches flooding is of some concern along with weeds and waterlogging. The primary desire of landholders along the lower reaches of the creek, given the semi-rural nature of the larger properties, is to have adequate drainage to alleviate flooding and waterlogging. This issue dominates discussions on the management of the creek in these areas.

Following the initial restructuring of the creek line from a natural floodway to a linear drain in 1961, management efforts have tended to be reactive and sporadic and hindered by a preoccupation with localized problems and arguments about who is responsible for what.

The 'fix-all' solution generally offered is the enlargement and regular 'cleaning out' of the existing channel, preferably at the expense of the City. This suggests some community appreciation that a holistic rather than a piecemeal management approach is needed. While excavation can improve flood flow it should be noted that a larger and supposedly more efficient channel was the goal of the 1961 drainage works. It begs the question, why didn't those works deal with the problem of flooding, erosion and excessive sedimentation? The lower reaches of Yakamia creek are a broad, natural flood zone and have a very low slope as well as coming under the influence of tides in the lower reach. These factors place physical limitations on the discharge conveyance efficiency of any excavated channel.

The goal of more consistent and efficient management of the middle to lower floodway that passes through many private properties is achievable, but will require a compromise regarding land

development. This is the finding of Melanie Price (2013)<sup>1</sup> in the urban development plan for the Yakamia/Lange precincts. It will in turn require the creation of a more detailed foreshore concept plan for the floodway from North Road to Oyster Harbour, including the associated tributaries. This should be based firmly on catchment hydrology and proper functioning condition of the floodway, in an ecological sense. In that case, landholder consensus and commitment with a durable memorandum of understanding between all stakeholders will be essential for the best management of the creek environs. Unfortunately this is currently lacking.

### **Community consultation – clear messages**

A community meeting was undertaken on the 14<sup>th</sup> of October 2014. The focus was the catchment downstream of North Road. The meeting was attended by 22 landholders after 63 invitations were sent out. The meeting was chaired by Louise Duxbury and presentations were given by Steve Janicke (on the geomorphology of the creek), Karen McKeough (from DOW, on the water quality of the creek) and Jonathon Bilton (from Oceans Foods, on the importance of water quality for the aquaculture industry).

The primary concern and frustration of the attending landholders was that they wanted to know why their houses and sheds flood ‘all the time’ and why ‘someone’ wasn’t doing something about it. Weed control was also considered important for various reasons, mainly the vegetation encroachment into the drain thus reducing its efficiency.

Attending landholders from the broad low-lying areas were generally of the opinion that “There is no need to call it a creek anymore: it is now the Yakamia Drain.” Their reasoning was, “when the drain was dug in 1959 it did not follow the creek so it is no longer a creek. Thus having created a drain it is the Councils responsibility to maintain it.” The question of who was responsible for the creek was answered in part by Austin Rogerson (drainage engineer, CoA) that since the creek runs through private property, it is the responsibility of the landholders. It is not vested as a reserve or an easement with the CoA. In this respect it is different to Robinson Drain which is a Water Corporation drain with an easement over the land and comes under a drainage Act. This issue has been on-going since the late 1970’s with the Town of Albany Council resolution, made in December 1983, stating “that the Yakamia drain is considered to be a natural water course and that, as a result, whilst Council acknowledges its present condition, it takes the view that it has no obligation to expend the considerable amount of public funds requested to rectify the present situation.”

### **Yakamia Creek as a Living Stream**

*“Yakamia Creek and its tributaries provide a significant district ecological connection to Oyster Harbour and beyond. Connectivity associated with these features should be retained and strengthened through provision of adequate buffers and rehabilitation of degraded areas”.* (Melanie Price (2013)<sup>2</sup> Aurora Environmental)

In practice, stream rehabilitation projects that are suited to Yakamia Creek will vary in nature and degree from section to section. At the high end, the Living Stream model reinstates many of the features of natural stream form and at the low end, limited enhancement is undertaken in order

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<sup>1</sup> Melanie Price (2013) *Yakamia Structure Plan Area, City of Albany Environmental Assessment - Opportunities and Constraints*, Report No. AA2012/020 by Aurora Environmental for the City of Albany

<sup>2</sup> Melanie Price (2013) *Yakamia Structure Plan Area, City of Albany Environmental Assessment - Opportunities and Constraints*, Report No. AA2012/020 by Aurora Environmental for the City of Albany

to achieve one or two specific outcomes. Some of the potential outcomes of projects are as follows;

**Rehabilitation providing and sustaining ecosystem function includes;**

- The maintenance of native flora and fauna species.
- Nutrient and bacterial bio-filtering to improve water quality
- Increased rainfall infiltration into the groundwater system
- The provision of shade to reduce algal growth.
- The provision of shade to control certain weed species.
- Improved air quality.

**Rehabilitation providing community services includes;**

- Provision of passive recreation opportunities.
- Enhanced visitor and tourist experience.
- Improved quality of life and mental health of residents.<sup>1</sup>
- Improved property values.
- Enhancement of sporting environs.
- Engagement of the community in effective urban water management
- Provision of an educational resource for students
- Suppression of ambient traffic noise.
- Demonstration of progressive urban water management.
- Increase capacity for urban water harvesting in the future.
- Reduced need for parkland irrigation and mowing.

The conveyance of water through the urban landscape along Yakamia Creek offers social and environmental benefits besides the mitigation of the occasional inconvenient flood or local waterlogging. These benefits have valid economic, social and ecological implications providing so-called, *ecosystem services*. People, it must be said, are also included in the living ecosystem. In addition, Yakamia Creek flows into Oyster Harbour and this is a recognised and well-used natural asset to the Albany community and should be maintained in good condition. Although Yakamia Creek represents less than 1% of the total catchment area draining into Oyster Harbour its influence is not insignificant with respect to water quality and the consequences of pollution.

Most streams support living organisms to a greater or lesser extent and the chief aim of a Living Stream development, unlike a drain, is to increase the diversity of plants and animals, including a host of less obvious organisms such as fungi and microorganisms that underpin ecological processes. The degree of biodiversity is ultimately dependent on the physical structure of the floodway and the quality of the water flowing through it. Increased biodiversity can also provide a check on the proliferation of unwanted animal and plant species.

Nevertheless, it would be unrealistic to set the goal for Living Stream projects along Yakamia Creek to: *reinstate the original natural stream form*. In the Albany urban environment, human activity has fundamentally altered the pre-settlement ecosystem. By covering the catchment with impervious surfaces such as roads, buildings and paving, the storm and groundwater runoff pattern for the entire catchment has been dramatically changed and many of the changes are effectively irreversible. The original floodway form would no longer match the new runoff characteristics.

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<sup>1</sup> Findlay S.J. and Taylor M.P (2006) *Why rehabilitate urban river systems?* Area: 38.3 312-325 Royal Geographical Society (with The Institute of British Geographers)

Drain characteristics can be simply described and measured, but ‘natural’ streams, by virtue of their complex channel geometry and riparian vegetation characteristics, are much harder to describe and therefore to reconstruct and manage. This management plan does not attempt to define an ideal channel form or natural stream environment for reaches of Yakamia Creek. Rather it considers what waterway attributes may help enhance the ecological function of the drainage system, within the constraints imposed by urban development. The durability of these enhancements will, in turn, define what a successful stream rehabilitation project means in the context of the urbanised catchment. There will be an element of experimentation required and the monitoring of projects outcomes over time should attempt to answer the questions, “What worked, what didn’t work and why?”

### **Principles of Living Stream design**

The concept of Living Streams rests on the premise that a linear drain in an urban environment may be restructured and enhanced with natural features without compromising its stormwater conveyance role. Drain design has generally been dictated by ease of construction and upfront cost. Properly engineered for both low flow and floodwater conveyance, the floodway can be managed in a way that minimises erosion and sedimentation (hence ongoing maintenance costs) by adopting a natural cross-section, enhancing sinuosity and using native vegetation to stabilise the channel (soft engineering). That is what nature does.

Living Stream design goes beyond urban stormwater conveyance, to create riparian and aquatic habitat for living things, both plants and animals and by association, people. Done well, Living Streams achieve multiple outcomes, including the fostering of a healthier urban ecosystem, improved water quality, effectively conveying floodwaters and creating attractive landscape features for the residential community and visitors (Water and Rivers Commission, 1998<sup>1</sup>).

The term ‘stream restoration’ is often used for projects aimed at preserving a natural environment, but restoration implies returning a system to its original condition. The urban Living Stream concept is better described by the phrase *stream rehabilitation* or *ecosystem enhancement* (Findlay and Taylor. 2006<sup>2</sup>). This suggests the possibility of reinstating some aspects of the original stream ecosystem, but predominantly it means improving stream attributes and controlling adverse degrading processes.

The aims of Living Stream rehabilitation are therefore;

- To reintroduce some critical attributes of natural stream function (not necessarily the original) in selected reaches, if not over the entire length of the stream, for ecological and social benefits.
- To create attributes that are compatible with existing and likely future urban development.
- To influence other development plans to incorporate environmental values.
- To protect any remaining natural attributes of the drainage system where possible.

Living Stream retrofitting is designed to achieve desirable environmental outcomes as well as allowing for community interests such as sport, passive recreation and pedestrian thoroughfare, without compromising the essential urban stormwater drainage function of the creek.

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<sup>1</sup> Water and Rivers Commission 1998b, *Living Streams*, Water Facts 4, Water and Rivers Commission, Perth, Western Australia.

<sup>2</sup> Findlay S.J. and Taylor M.P (2006) *Why rehabilitate urban river systems?* Area: 38.3 312-325 Royal Geographical Society (with The Institute of British Geographers)



In order to gain insight into the nature of urban constraints and to evaluate the potential for Living Stream development along Yakamia Creek, it will be helpful to begin by reviewing the physical attributes of a simple engineered open drain.

## Drains

The function of most drains is simply to convey water from point A to point B as quickly, efficiently and cheaply, as possible. Other stream functions are not generally considered a priority. The usual reasons for designing such a drain are; first to control damaging floods and secondly to reduce waterlogging in developed areas or in land earmarked for development. A hydraulically efficient drain is designed to have a simple geometric cross-section constant along its length with relatively 'smooth' bed and bank surfaces and a uniform lengthwise slope. A common drain profile is trapezoidal, having a flat base and straight, steeply sloping banks. Any hindrance to the uniform flow of water reduces the efficiency of the drain and these are avoided in designs. Nevertheless, in urban environments such impediments are common and include road crossings, culvert pipes, sediment deposits, sudden drops in bed level (drop structures, Figure 11), encroaching vegetation (often weeds), effluent discharge points, changes in drain cross-section and accumulated detritus and rubbish.



Figure 11: Drop structure on Yakamia Creek in section D2.5

Drains are designed to limit the inherent physical characteristics of moving water, by fixing the geometry of the channel. This type of control is illustrated by the armoured section of Yakamia Creek adjacent to the Cricket grounds at the western end of Centennial Park Sporting Precinct (Figure 12). However; in natural streams water flow acts to construct and shape the channel.



**Figure 12: The armoured section of Yakamia Creek at the western end of Centennial Park Sporting Precinct, July 2011.**

### **Natural streams**

In contrast to a simple engineered open drain, natural streams exhibit complex curvature of the dominant channel, the floodway and the extended floodplain. The cross-sectional area and shape reflects the diversity of storm flows and groundwater discharging from the catchment. This results in highly variable cross-sectional geometry. There are a number of common features of the cross-section of a stream, although not all need be present depending on the overall valley shape. These features include the dominant channel, fluvial terraces or benches, the floodplain and riparian verge. Figure 13 shows an idealised cross-section with these features. The bed slope is also variable, a result of geological formations and water alternatively speeding up and slowing down along its path. The bed and bank surfaces vary in 'roughness' depending on the soil type, the diversity and density of vegetation and assorted subsurface features including the geological foundation of the landscape.

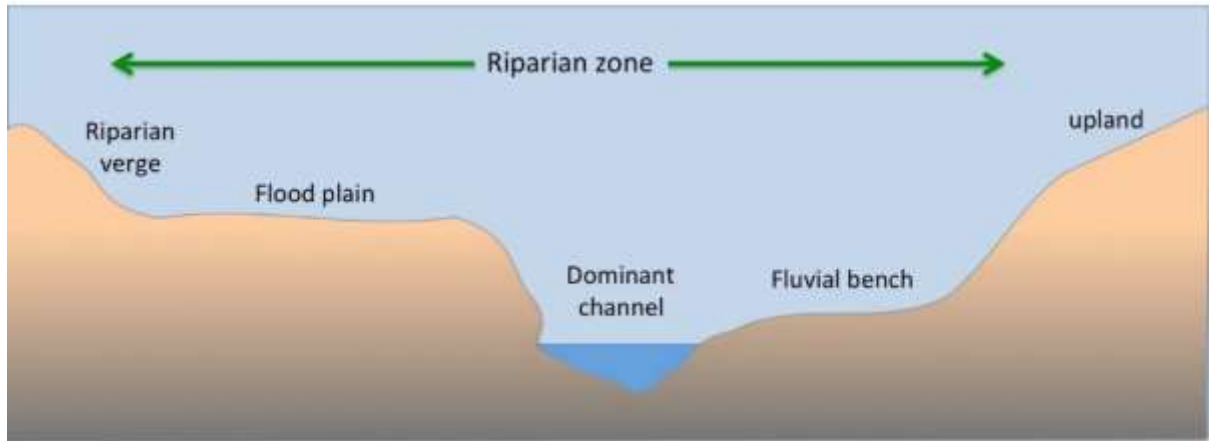


Figure 13: Common features of an idealised cross-section of a stream.

Living Streams are constructed channels designed to mimic natural streams, with high flows accommodated along the vegetated streamline and its floodway (Department of Environment and Swan River Trust 2006<sup>1</sup>). Low flows are also functional in an ecological sense, serving to create and maintain habitat diversity. Healthy fringing vegetation provides shade, wildlife habitat, ecological corridors, erosion control, recycling and bio-filtration of pollutants.

Stream energy is dissipated unevenly along the channel and this equates to the development of many localised channel features such as pools, riffles, knickpoints<sup>2</sup>, waterfalls, bank scours, bends, point-bars, sediment plumes, fluvial terraces or benches, bank undercuts, accumulations of bed material, deadwood, silt, sand and rocks. Natural streams generally take up more space than drains and this partly explains the pressure to straighten them or to pipe them underground. The most critical attribute of a stream section, from the point of view of designing rehabilitation works, is having enough space to carry them out. This is often described as providing an adequate foreshore 'buffer'.

A question often asked is how wide should a foreshore buffer be to be adequate? Unfortunately, arbitrary foreshore buffer widths rarely match the varying morphological attributes of the riparian areas. It is suggested that the word buffer be replaced by the less defensive words, riparian zone. In order to achieve a realistic outcome, an appropriate foreshore riparian width must be determined locally, by considering the spatial dimensions of the floodway zone on a section-by-section basis. Important factors include the valley profile, whether it is V shaped with confined flow or shallow with a broader floodplain, as well as the likely extent of various floods and the subsurface and groundwater sources.

### Hydraulic attributes of channels (the key to management)

Channel attributes of bed-slope, cross-sectional area, surface roughness and water velocity are the key factors that help define the overall hydraulic character of both natural streams and engineered drains. In all streams, these basic attributes are interdependent and influence each other to form the distinct features we associate with rivers and creeks, large and small, worldwide. In other words, if one attribute is modified, others will tend to readjust according to the frequency

<sup>1</sup> Department of Environment and Swan River Trust 2006, *Retrofitting, Storm water Management Manual for Western Australia*, Department of Environment and Swan River Trust, Perth, Western Australia.

<sup>2</sup> A **knick point** is a term in geomorphology to describe a location of a river or channel where there is a sharp change in channel slope, such as a waterfall or lake.

and intensity of rainfall runoff events from the catchment. Thus weather patterns play a crucial role in determining long term stream form.

**Water flowing along an unarmoured drain will act to reconstruct natural channel features.**

Considerations on what constitutes appropriate management should take all of the catchment into account. This is chiefly achieved through undertaking hydrological studies to determine how much water is falling on the catchment and how much is flowing through it, as well as how often and how strongly. The various flood studies undertaken for Yakamia Creek were done in order to understand the pattern of catchment runoff, not to specify a solution to flooding problems, although the information is essential for solutions to be found. Sediment eroded from the tributaries as well as the bed and banks of the main channel, is transported to the lower reaches and deposited in the low gradient parts of the channel and on the flood plain.

In summary, the geometrical attributes of a natural stream reflect the intrinsic interaction between a wide range of rainfall runoff events and the soils that compose the floodway. Many features that are considered a problem for engineered drains are acceptable attributes of natural channel form. A simple drain is often constructed largely to try and handle major floods; and this sums up the current status of much of Yakamia Creek.

### **Water Sensitive Urban Design**

Water Sensitive Urban Design (WSUD) is the integrated design of the urban water cycle, incorporating water supply, wastewater, stormwater and groundwater management and environmental protection. The aim of WSUD is for all streams of water to be managed as a resource, as they have quantitative and qualitative impacts on land, water and biodiversity, and the community's aesthetic and recreational enjoyment of waterways<sup>1</sup>. There are various stormwater management techniques available that integrate public open space, water quality and environmental enhancement objectives which are described in detail in state and national publications. Supplement 1 of this report presents a number of case studies that are very pertinent to future Living Stream projects along Yakamia Creek.

### **Retention and Detention basins and Bio-filters**

This report suggests the use of detention basins with bio-filters (constructed wetlands) that are compatible with the objectives of Living Stream projects. These built structures help retain the function of floodplains wherever the former extent must of necessity be restricted.

The two urban storm water structures that can be integrated into Living Stream projects in the Yakamia Creek catchment are retention and detention basins. A *detention* basin is an area of low lying ground adjacent to or associated with the path of stormwater and is designed to intercept and slow storm runoff to lessen the impact on downstream areas. A *retention* basin traps water in a pond, lake or wetland associated with a stream and the water eventually seeps (infiltrates) into the ground or is lost to evaporation and evapotranspiration. The groundwater system naturally acts to both detain and retain rainfall.

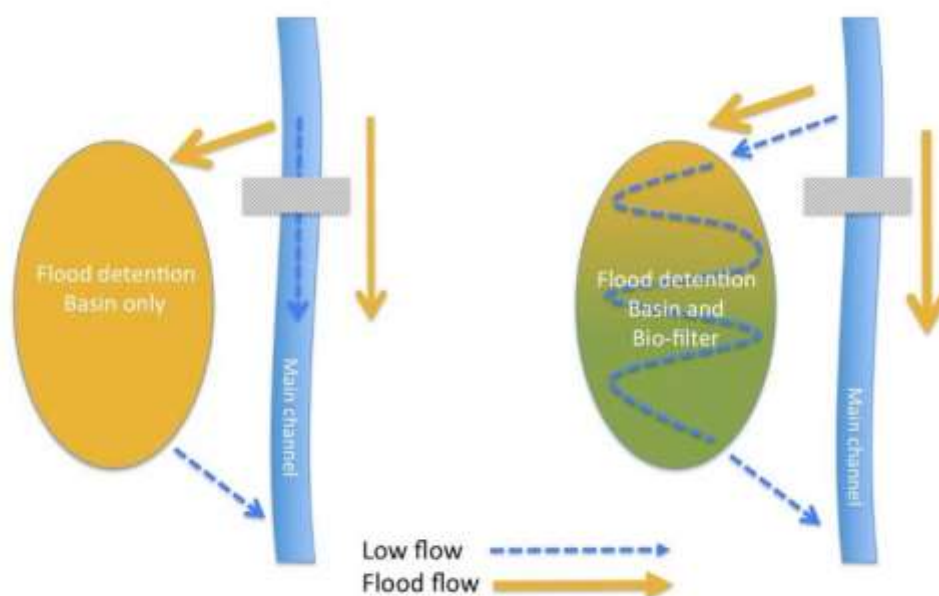
These two types of basin emulate the wetlands, backwaters and groundwater we associate with natural stream systems. They function to strip nutrients and other contaminants from stormwater

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<sup>11</sup> BMT WBM Pty Ltd (2009) *Evaluating Options for Water Sensitive Urban Design (WSUD) – A National Guide*. Guidelines developed in accordance with National Water Initiative Clause 92 (ii) for the Joint Steering Committee for Water Sensitive Cities

and therefore improve the water quality. For this reason they are increasingly used in urban environments. Along a Living Stream, retention and detention basins become *constructed wetlands*. Traditionally, wetlands have been viewed as a liability, only suitable for landfill in the same way as creeks have been viewed simplistically as drains.

Since vegetation is used to do the nutrient stripping both retention and detention basins can act as *bio-filters* however the bio-filter function is most efficient at processing low flows. A simple detention area is designed to divert flood flows into a basin and release the water slowly, while low flows and excess flood flows pass down the main channel. A detention basin with bio-filter function diverts low flow and the initial flood flow into the basin while excess flood flows pass down the main channel. Figure 14 below illustrates the two potential functions of a detention basin. The hydraulic operation of each with respect to low and high flows in the stream is fundamentally different. Placing a detention basin in the main stream channel is a possibility, but the risk of flood damage to any bio-filtration features is increased.



**Figure 14: Comparison of the conceptual flow paths for floods and low flows using a detention basin and a detention basin plus bio-filtration function.**

Constructed wetlands can also provide a diverse habitat for supporting plants and animals as well as be designed to provide a pleasant park environment with various social amenities. Case Study 7: Toowoomba West in Supplement 1 illustrates a flood detention and bio-filter basin. Constructed wetland design for Yakamia Creek is discussed a little more under the heading, 'Benefits of Living Stream development for selected Tier 1 targets'.

Water quality monitoring at a number of locations in Yakamia Creek indicates that levels of nutrients, minerals and bacteria exceed recommended levels for a healthy stream environment. For this reason it is suggested that provision of both floodwater detention and bio-filtration of low flow stream discharge along Yakamia Creek needs to be considered wherever it is feasible to do so, even if this means modifying the existing channel infrastructure.

Drains that are designed to move stormwater along the channel as quickly as possible offer no opportunity for improving water quality via vegetative bio-filtration.

Three areas in the upper catchment are considered as offering significant opportunity for constructed wetlands, Dunn Park, Bevan Road and the western end of Centennial Park Sporting Precinct (downstream of the intersection of North Road and Barnesby Drive). Other sections also



qualify, and are discussed in this management plan. There is also opportunity for the provision of small-scale bio-filtration and infiltration installations at domestic and industrial sites. These are especially appropriate if they can be placed as near to the source of stormwater as is feasible. By re-directing localised rainfall runoff into areas where it can infiltrate into the ground, the risk of flooding downslope can be significantly reduced. These WSUD options are not developed in this management plan.

### **Living Stream maintenance**

The successful rehabilitation of a waterway to create a Living Stream is a long-term process and requires a maintenance plan to contribute to the success of a project. Maintenance activities may be needed more frequently during the initial establishment phase<sup>1</sup>.

Common maintenance issues include:

- ease of access to sites,
- repair of minor damage to the in-stream restoration features following bigger floods (e.g. rock displacement from riffle, riprap and chute, bed and banks erosion, sediment accumulation, damage to the existing banks vegetation),
- growth of weeds, inadequate plant establishment or excessive establishment,
- regular maintenance of pre-treatment features (such as filter strips or litter and sediments traps etc.),
- if a project is undertaken by a contractor or developer, the maintenance responsibilities can change after the agreed warranty period ends,
- changing pressures and impacts from nearby developments, e.g. revised zoning, change of land ownership, changes in business.

Some maintenance observations from the Department of Water<sup>2</sup>:

- Bed and banks stabilising structures such as riffles, chutes, riprap, large woody debris etc. should be inspected at least annually and if possible after each heavy flood. If problems appear, maintenance should be performed promptly to prevent potential costly damage.
- During the initial stage when the vegetation has not fully established, there may be a high risks of banks erosion or slumping. Such erosion can extend rapidly, so should be controlled as soon as possible. However, it is important to investigate the reason for the erosion so that appropriate measures can be implemented.
- A visual inspection of flow patterns (during low and high flows) on waterways, vegetation establishments, vandalism (to infrastructure or vegetation) etc. can assist with promoting better understanding of problems.
- Regular or long term maintenance issues may be litter collection, sediment or debris removal and weed control.
- If the site experiences high sediment deposition and/or high litter problem, an in-stream sediment trap (e.g. a riffle or a pool) and/or a gross pollutant trap at the upstream of the Living Stream site can be installed.
- Community ownership to the project can play an important role in the short and long term maintenance, especially when the area has public access for recreational purposes.
- A newly vegetated site should be checked every two weeks for the first six months to allow early detection of germinating weed species and assessment of the success of plantings; supplementary planting may be required.

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<sup>1</sup> Department of Water (April, 2011), *An overview of living stream project: initiation to implementation*.

<sup>2</sup> Department of Water (April, 2011), *An overview of living stream project: initiation to implementation*.



- A concentrated focus is required on the weed control in the first two to three years unless the native vegetation is fully established.
- Some selective thinning of vegetation may be required to restore the flood conveyance capacity of the channel. Clearing of significant debris dams, disoriented woody debris, culvert blockages etc. should be undertaken to maintain the capacity of the channel.
- Additional introduction of habitats (including introducing aquatic animals) may be required if habitat improvement is not satisfactory.
- Depending upon the nature and location of the site, the responsibilities of inspection and maintenance can be shared with the local communities and/or any other relevant stakeholders.

We have observed too frequently, money, effort and volunteer hours being negated by overspray and indiscriminate use of herbicides to control weeds. One aspect of the failure of the Paterson St. "Living Stream: project (see Case Study 6 in Supplement 1) is that native seedling regeneration could not occur, being sprayed out whereas annual grasses reoccurred each year. It is important for the longer term success of a Living Stream project that regeneration of riparian plants through germination and seedling growth be allowed to occur. Preference should be for 'Friends' groups to weed by hand. Training of staff operating spray units tends to focus on health and safety considerations for the operator. Maintenance operators also need training in discerning and valuing native vegetation and their seedlings.

## **Please Note:**

This is Part A of the Yakamia Creek Living Stream Management Plan. The document has been split into three parts and has been reduced in quality to enable it to be downloaded from the internet.

The three parts are:

YAKAMIA\_CK\_LSMP\_PartA\_without\_maps

YAKAMIA\_CK\_LSMP\_PartB\_without\_maps

YAKAMIA\_CK\_LSMP\_PartC\_Appendices and maps