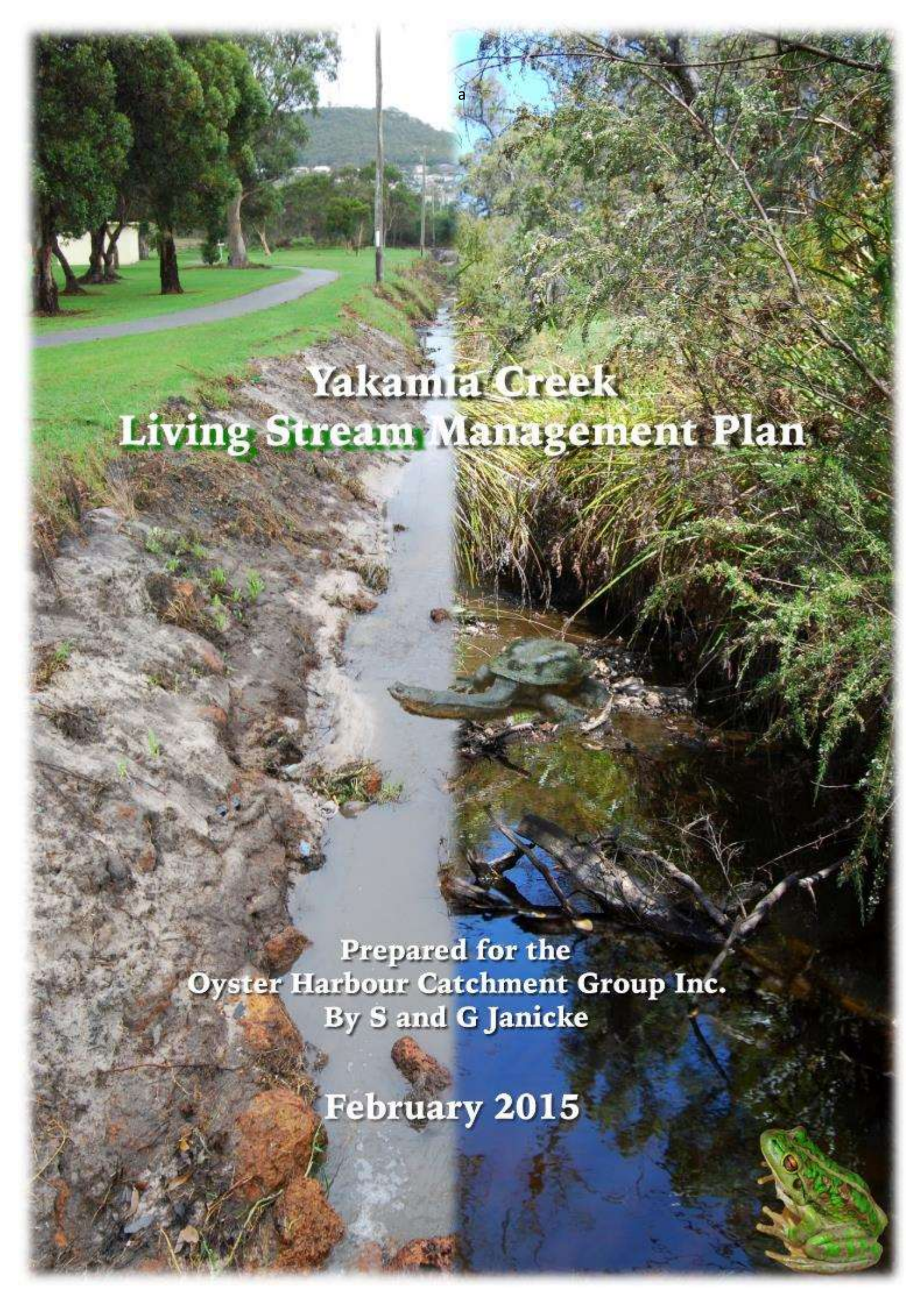


The background image is a photograph of a creek. On the left, a paved path curves through a grassy area with trees. The creek itself is in the center, with a sandy and rocky bank on the left and a more vegetated bank on the right. A large green frog is perched on a log in the water. In the bottom right corner, there is a small, detailed illustration of a green tree frog.

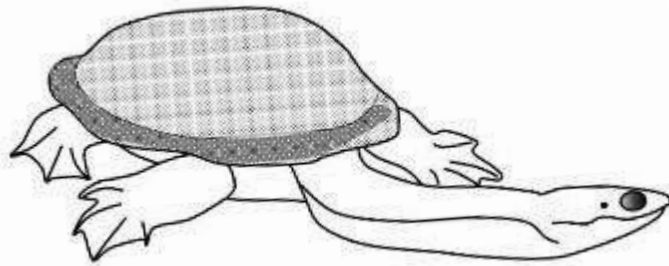
Yakamia Creek Living Stream Management Plan

**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”.



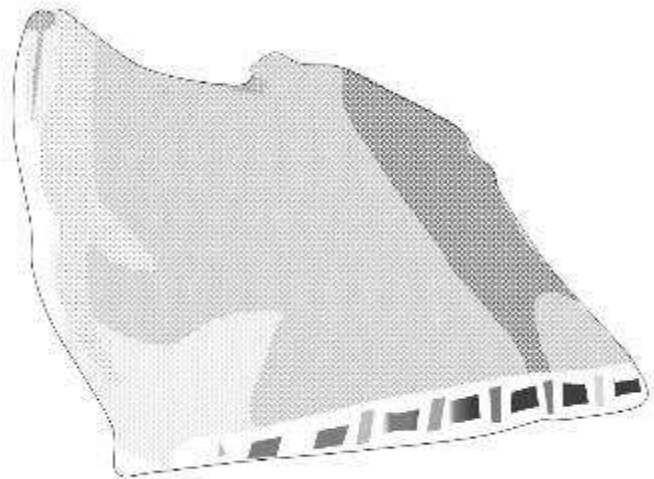
Local Albany historian Bob Howard (*A Noongar History of Albany*) noted that the lower Yakamia Creek locality was formerly known as *Yakinup* from *Yakin* – the long-necked tortoise. The locality can therefore be understood to mean, *the place of the long-necked tortoise*.

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.

Cover image by: Steve Janicke

Yakamia Creek Living Stream Management Plan

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SOUTHCOAST
NATURAL RESOURCE MANAGEMENT INC.



Steve & Geraldine Janicke

Please Note:

This is Part B 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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Yakamia Creek Living Stream opportunities – assessment methodology

Two overarching factors underpinned the method for determining what sections of the Yakamia Creek system offer opportunities for Living Stream development. These were;

- Existing section attributes.
- Constraints on potential section modifications.

Existing section attributes defined the nature of the local riparian ecosystem and constraints here mean; limitations imposed on any proposed floodway enhancements. Each of the overarching factors was qualified by a number of criteria. The measure for each criterion consisted of a number of features for which presence or absence could be established at each stream section. The approach was not to create a 'scientific' formula that would choose likely project sites, but to ensure that constraints were systematically examined for each section and the implications for rehabilitation options evaluated. The final score of features was used as a justification for rehabilitation feasibility. Various levels of rehabilitation are possible and what could be applied to a particular section will depend, not only on constraints, but also on other management objectives that may be identified.



Assessment of current channel form, issues and Living Stream opportunities

The purpose of the channel assessment was fourfold as follows;

- To identify the physical and vegetative characteristics of discrete sections of the main stream channel and selected tributaries.
- To determine what constraints would apply to any attempted modifications.
- To determine where opportunities might exist for stream enhancement projects.
- To determine what those opportunities are.

In addition geo-referenced photo points were established to assist with tracking changes to sections over time. The photo point audit is included as Supplement 2 to the Yakamia Living Stream Management Plan.

The study sections

The parts of Yakamia Creek that were of primary focus in this report consist of 15.5 Kilometres of channel, divided as follows;

- 9.4 Kilometres of the main channel of Yakamia Creek between Anson Road and Oyster Harbour,
- 6.1 Kilometres of tributary.

The channels were divided into seven zones each reflecting their position in the catchment. Zones were then divided into sections. Typically, section ends have been determined by road crossings, a change in land tenure, different land uses, necessary drain function or other noticeable change in channel form. 108 sections were identified, a number that indicates to some extent the level of fragmentation of the creek. The zones are described in Table 1 and shown on the map in Figure 1.

Maps 1 to 11 in the Appendices define contiguous sections of the main channel of Yakamia Creek (86 sections) and 4 key tributaries (22 sections).

Table 1: Division of the channels of Yakamia Creek.

Zones	Length (kms)	Description
Yak _A	1.6	Between Anson Road and Chester Pass Road
Yak _B	1.1	Between Chester Pass Road and North Road and adjacent to Barnesby Drive.
Yak _C	2.8	North Road around Centennial Park Sporting Precinct and including the tributaries from Albert Street and Knight Street.
Yak _D	4.3	North Road / Sandford Road to Lower King Road
Yak _E	2.1	Lower King Road to Oyster Harbour
Yak _F	0.9	Callistemon View tributary
Yak _G	2.8	Lange tributary

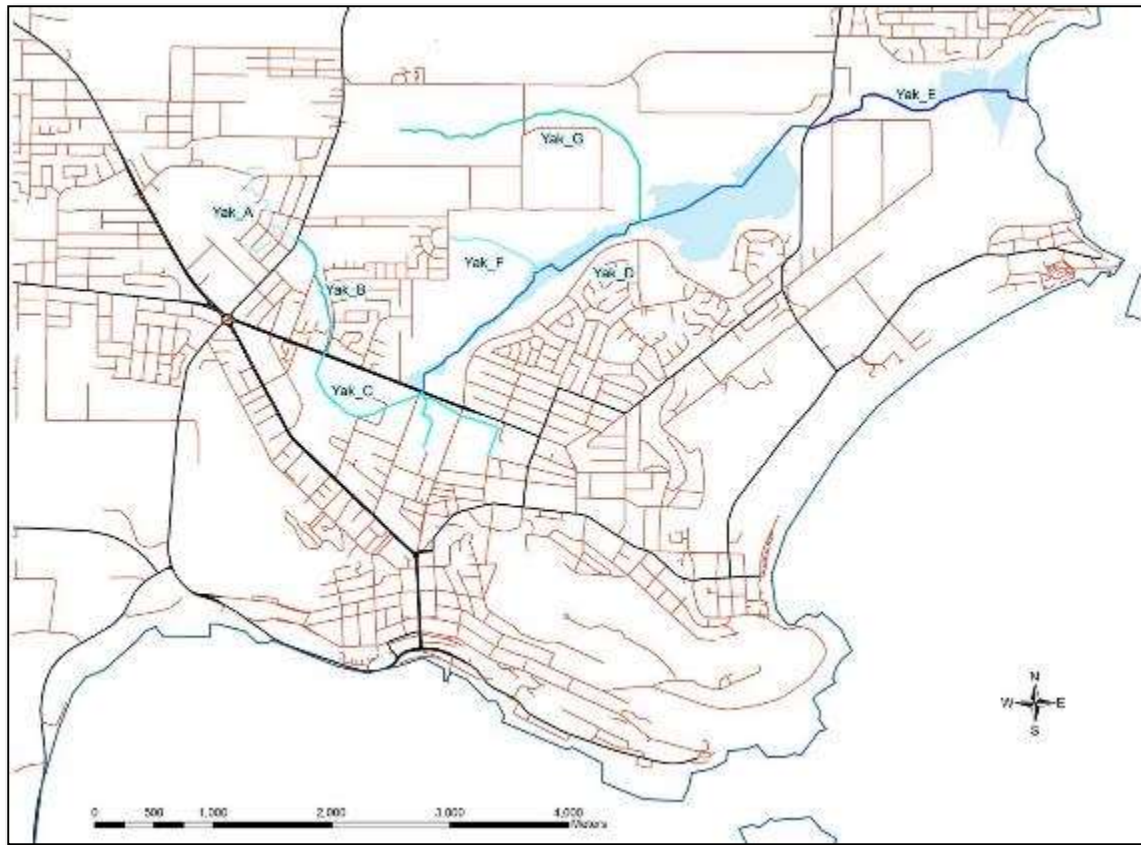


Figure 1: Study zones of Yakamia Creek.

Determining project opportunities along Yakamia Creek

Opportunities for Living Stream projects are subject to qualification and three primary levels of intervention are suggested;

- A.** Reconstruction of the floodway and riparian attributes at the section scale. For example;
 - ◇ Redesigning channel cross-sectional form and bed slope features.
 - ◇ Recreating channel sinuosity.
 - ◇ Creating wetland zones (including ponds, retention and detention basins).
 - ◇ Re-vegetating an entire section with an adequate foreshore riparian buffer.
- B.** General enhancement or protection of existing riparian attributes. For example through;
 - ◇ Weed management.
 - ◇ Re-vegetation of degraded areas with native species.
 - ◇ Localised bank and bed stabilization.
 - ◇ Introduction of rock or logs to increase habitat diversity.
- C.** The introduction of basic ecosystem features for specific, but limited reasons. For example;
 - ◇ Construction of riffle zones for aeration of water.
 - ◇ Patch re-vegetation for shading.
 - ◇ Creating nutrient stripping areas to improve water quality.
 - ◇ Intercepting water near rainfall source to promote soil infiltration.
 - ◇ Adding some visual amenity, e.g. planting a few trees.
 - ◇ Limited weed control.
 - ◇ Repairing aging infrastructure.
 - ◇ Relocating stormwater drains.
- D.** No modification (do nothing).

Constraints on environmental rehabilitation were rated according to the criteria defined in Table 3 and Table 4 below. The rating provided a justification for why a section may or may not be suitable for Living Stream development and if so, to what extent. The fewer constraints there are the greater the opportunity to undertake more significant levels of rehabilitation. The section ratings are meant as a guide only since other external factors may favour or exclude one or more sections. For example several connected sections may warrant priority attention over isolated sections with fewer constraints. The final decision about which section(s) offer the best opportunities should be a joint decision between the key stakeholders. It may be noted that minor impediments such as the location of a fence or a path were not considered to be valid impediments to sound environmental management of the creek system in the medium to long term.

Public lands and particularly undeveloped or partly developed areas tended to score lower in terms of constraints, and sections constrained by infrastructure and private tenure tended to score the higher.

The minimum constraint score across all nine criteria was zero and the maximum was 27. In order to short list sections for further consideration, the scores were grouped into one of four tiers of potential intervention. These are outlined in Table 2.

Table 2: The four tiers of potential Living Stream project opportunities.

Tier	Constraints rating	Action
1	0 - 5	Initial, feasible targets for Living Stream rehabilitation
2	6 - 10	Future potential, but with one or two significant issues to take into account.
3	11 - 20	Problematic, with multiple development issues to consider
4	> 20	Highly constrained (do nothing)

For details on how sections were scored see Appendix 1. Table 5 below is a grouping of these results into the initial preferred and feasible targets (Tier 1 sections) and summarises opportunities, objectives and design considerations for retrofitting. The isolated sections in Tier 1 provide smaller project opportunities, but rehabilitating a group of connected sections offers larger scale ecological and social outcomes and these reaches are favoured opportunities for medium term (2 – 5 years) projects. It is also suggested that when developing rehabilitation projects in target sections, due consideration should be given to the way in which the works may connect to upstream and downstream sections and whether there are ways constraints can be removed or lessened in the future. The approach should be to review the importance of any Tier 2 sections immediately upstream and downstream of proposed project areas.

Table 3: Constraints on Living Stream development in an urban environment

Constraint	Interpretation	Assessment criteria
Area of riparian space available	The lateral and longitudinal extent of the stream channel determines the scope of designed works that is possible. Insufficient space will limit development or render it inappropriate.	Section length. Width available for riparian vegetation.
	Lateral confinement, typically found along linear urban drains, provides less opportunity for introducing natural stream sinuosity and associated habitat for increasing biodiversity, both aquatic and terrestrial.	Opportunity to add channel sinuosity.
	The character of the channel immediately upstream and/or downstream of a target section may also limit ecological connectivity and development. Nevertheless, short sections or patches are not necessarily excluded and can contribute to the overall condition and health of the waterway.	Section connectivity with reaches upstream and downstream.
Optimum Stormwater conveyance	Urban stormwater management requires that Yakamia Creek channel adequately accommodates peak discharges that typically recur at 5 year (Moderate flood) and 100 year (Major flood) intervals.	Capacity to alter channel cross-section.
	Stormwater conveyance may be the only allowed function for a section of urban stream channel. For example some sections are piped underground with no feasible alternative.	Conveyance stormwater infrastructure.
Land tenure issues	The willingness of the landowner to participate in Living Stream rehabilitation is crucial to whether the project even gets started. Land titles confer rights to landowners and custodians to use and modify waterways without detriment to upstream or downstream users. However, the diversity of values, aspirations and opinions generally hinders a consistent approach to management along an entire stream reach. Living Stream project aspirations may be (and often are) thwarted by lack of agreement between stakeholders, even to the extent of making the 'do nothing' option, the only option.	Land Tenure
Public Amenity	Streams contribute to the quality of an environment and the quality of resident and visitor lifestyle. They can also improve local economic values through tourism and real estate valuations. Drains may pose public safety and health risks while providing their basic service.	Public Amenity.
Maintenance Issues	The presence of infrastructure such as power poles, other drains, adjacent buildings and crossings will not only constrain what works can be undertaken, but the ease of ongoing maintenance of a section. This constraint relates strongly to the need for adequate riparian space to construct and maintain stream ecosystem characteristics. Low maintenance attributes of Living Stream projects are desirable factors to be included where possible in the design phases of projects. Hindrances to channel maintenance limit Living Stream proposals and works.	Equipment/ machinery/ personnel access.



Table 4: Constraint criteria

Scoring for constraints to Living Stream development	0 = No constraints	1 = Some constraints	2 = Moderately constrained	3 = Highly constrained
Section length score	Greater than 100 metres	50 -100 metres	30 - 50 metres	Less than 30 metres
Riparian connectivity up and down stream	Continuous up and down	Crossing culvert one end	Crossing culvert two ends	Piped either end or both ends
Capacity to add channel sinuosity.	Full meander plus	Full meander	Half meander	None
Width available for riparian veg.	Full flood way	Dominant channel bed and bank plus 2 - 30 m either side. Fluvial terraces	Dominant channel bed and bank plus up to 2m either side	None
Capacity to alter cross-section	Unrestricted cross-section modification	Slope and fluvial terraces	Reduce bank slope	none
Stormwater conveyance infrastructure	None	Lateral pipe inputs and /or drop structures mid-section	Armoured bank/bed mid-section	Fully piped/culvert
Land tenure score	Reserve or Public open space	Road reserve / easement	Other public vested interest	Private/piped/culvert
Public amenity	Public thoroughfare, visual amenity and area ambience	Thoroughfare	Access but no thoroughfare	No public access
Maintenance (personnel, equipment access, scale of works)	Fully accessible	Easement access	Easement/Reserve, access through private property	Private ownership - constrained access/Culvert



Table 5: Tier 1 Summary of opportunities, objectives and design considerations.

Note: these sections are ordered in sequence downstream from the headwaters, not in order of priority.

(Grouped sections) Tier 1	General location	Rehabilitation opportunities/ Management objectives	Project design considerations
1 A05.1, A05.2, A05.3, A11	Dunn Park bounded by Dunn, Whidby and Broughton Streets	Opportunity exists to create a constructed ephemeral wetland as a vegetated bio-filter detention area designed to remove pollutants from stormwater and attenuate larger storm events in a modified detention area. Management objectives are: • reduce sediment, nutrient and other pollutant export, • improve visual and recreational amenity, • increase shading to limit weeds and algal growth, • erosion control through soft engineering, • reconnection of existing remnant bush patch to streamline revegetation, • increase terrestrial and aquatic habitat and biodiversity values, • stormwater and low flow detention control, • gross pollutant trapping at lower end (Broughton St).	The area offers a demonstration site for water sensitive urban design in a highly visible location. Install an ephemeral detention and bio-filter wetland for both channels. Ensure low flows are directed through bio-filters. Note; this will require the Bevan Street tributary flood flows to be detain more effectively at Bevan Street. (See Tier 2, Point 2 in Table 7) Improve connectivity and visual amenity regarding public access to the light industrial area as well as the High School. Utilise pathways to separate lawn grass from native revegetated areas. Improve public walkway alongside the channel between Whidby and Broughton Streets. Recover sufficient flat area for residents to be able to ‘kick a ball’ around. Protect the remnant native bush patch which currently is in moderate condition and representative of the original bush cover. Connect remnant bush to stream revegetation. Use block sedge plantings along water’s edge and on fluvial terraces to reduce weed incursion and protect from erosion. Plant shade trees strategically alongside the creek and wetland Adequate visibility across the parkland should be maintained for security (i.e. medium height trees,



(Grouped sections) Tier 1	General location	Rehabilitation opportunities/ Management objectives	Project design considerations
			ground cover and channel fringe species with less emphasis on middle story shrubs). Install a sign with an artist's impression of the final outcome before the proposed works.
2 B06.1, B06.2, B07, B08	Adjacent to Barnesby Drive and Yakamia Primary School	Build on current Living Stream works through weed management and re-vegetation guided by the development of a holistic plan for these sections. Management objectives: • reduce bank slope of high eroding steep banks, • improve visual amenity, • erosion control and bed and bank stability through soft engineering, • improved connecting pathways, • removal of the eastern states swamp mahogany eucalypts using a staged approach, • reduce flow velocity of stormwater conveyance, • increase channel shading to improve water temperatures, • increase terrestrial and aquatic habitat and biodiversity values, • weed control, • gross pollutant trapping at lower end (North Road).	Produce a detailed landscape map of the whole precinct to promote aesthetic, community and environmental aspects and to guide future projects. High eroding steep banks occur in some sections (e.g. lower part of sections B07. These bank slopes need to be reduced for public safety reasons as well as remove a source of sediment. Use block sedge plantings along water's edge and on fluvial terraces to reduce weed incursion and protect from erosion. Use the bridges and walk paths on both sides to develop an exercise circuit with outdoor exercise equipment. Utilise pathways to separate lawn grass from native revegetated areas. Replace the crossing between Sections 6.1 and 6.2 with one that is more visually pleasing and with less interference with the channel cross-section. Install several rocky riffles to back flood head cut prone areas and reduce flow velocity (and hence bed incision) and increase aquatic habitat diversity. Implement a staged approach to the replacement of the eastern states swamp mahogany eucalypts with less invasive native trees and ground covers.



(Grouped sections) Tier 1	General location	Rehabilitation opportunities/ Management objectives	Project design considerations
3 C1, C2, C3, C4	Western end of Centennial Park Sporting Precinct.	Note: Plans for this area will need to incorporate the Centennial Park Sporting Precinct redevelopment plans. This area offers an opportunity for creating a complex urban waterway ecosystem involving a constructed wetland and bio-filter detention area that is also a public amenity. Management objectives: • gross pollutant trapping at top end to catch rubbish from North Road, • improve visual amenity, • reduce sediment, nutrient and other pollutant export, • dense planting to shade out weeds, • erosion control through soft engineering and adding sinuosity to channel, • reconnection of existing remnant bush patch to the streamline, • increase channel and wetland shading to improve water temperatures, • increase terrestrial and aquatic habitat and biodiversity values, • stormwater and low flow detention control.	Well-designed, a Living Stream can improve the visual amenity of this area. The area offers a demonstration site for water sensitive urban design in a highly visible location. Note: An environmental design for the Centennial Park Sporting Precinct has been drawn up by Syrinx Environmental to treat ground water and surface nutrient export from the sporting fields. It is not known what scope was in the brief to modify Yakamia Creek, however some concept plans have been submitted to the council. Details of their designs have not been available for viewing during the preparation of this document. There is room to add sinuosity into the channel to limit erosion and to develop a constructed wetland bio-filter and detention basin. Consider the use of block sedge plantings along water's edge and on fluvial terraces to reduce undercutting and bank erosion. The channel can be re-routed to enhance bio-filtration options. Ensure low flows are directed through bio-filters. The function of the two current culvert stormwater 'chokes' and the bunding needs to be reassessed in terms of future wetland and bio-filter detention. Section C1 contains a range of rocks, concrete and other structures that can be removed. The channel cross-section appears to be too small as evidenced by the extensive bank erosion on both sides of the channel. The wetland blocks to the west of sections C1 and C2 are owned by the City of Albany and it is recommended



(Grouped sections) Tier 1	General location	Rehabilitation opportunities/ Management objectives	Project design considerations
			these to be rezoned from residential to park. This would increase the land available for significant wetland features and improve bio-filtration efficiency. Assess what vegetation features need protection e.g. older wetland trees including their root zone. Ground water levels and acid sulphate soil assessment will be required during the planning phase. Public thoroughfare connections between Pioneer, North and Barker Roads can be enhanced. Utilise pathways to separate lawn grass from native revegetated areas and to link revegetated areas with the bike path to improve passive recreation. Consider installing a raised walkway through the wetland with viewing platforms and interpretive signage. Consider installing a sign with an artist's impression of the completed works to advertise the plan and to increase public awareness of Living Stream benefits. Liaise with Western Power regarding location of power poles. These should not dictate the design of drainage works appropriate to the area. Engage the local Noongar community in the design of the wetland precincts.
4 C9.1, C9.2	Centennial Park Athletics Precinct Sanford and North Roads	Note: Plans for this area will need to incorporate the Centennial Park Sporting Precinct redevelopment plans. The opportunity exists to restructure the channel form (cross-section and sinuosity), and improve the area ambience and visual amenity to complement rehabilitation works across the road.	There is room to add sinuosity to the channel and to modify its cross-sectional shape to include fluvial terraces. Utilise block sedge plantings along the water's edge and on fluvial terraces to reduce undercutting and bank erosion. Bio-filtration of groundwater between the



(Grouped sections) Tier 1	General location	Rehabilitation opportunities/ Management objectives	Project design considerations
		Management objectives: • improve visual amenity, • tall tree planting to shade out weeds, • increase channel shading to improve water temperatures, • erosion control through soft engineering, • increase terrestrial and aquatic habitat and biodiversity values, • reduce flow velocity of stormwater conveyance, • gross pollutant trapping at lower end.	creek and the PCYC can be improved through appropriate sedge and shrub planting. Maintain adequate foreshore buffer between channel and built infrastructure (at least 30 meters as initially requested by the Aboriginal Heritage Reference Group Aboriginal Corporation). The visual amenity of the creek can be greatly enhanced. Utilise pathways to separate lawn grass from native revegetated areas. Install a gross pollutant trap downstream of North and Sanford Roads to prevent rubbish from being washed down Yakamia Creek (PET bottles, snack wrappers and other rubbish have been observed and complained about, 3 kilometres downstream).
5 Ct3, Ct4	Centennial Park Central Precinct, Community parkland North Road and Lockyer Avenue	Note: Plans for this area will need to incorporate the Centennial Park Sporting Precinct redevelopment plans. An opportunity exists to develop a detailed landscape plan for the whole precinct within which these sections are a part. An opportunity exists to extend the existing riparian enhancement works as a shaded avenue along the eastern drainage line parallel to North Road. Management objectives: • improve visual amenity, • reduce sediment, nutrient and other pollutant export, • increase channel shading to improve water temperatures and limit weed growth, • erosion control through soft engineering,	Consider a comprehensive landscape design approach to incorporate aesthetic, community and environmental aspects of the precinct for the two tributary branches and the lakes (sections Ct3, Ct4, Ct6, Ct7 and Ct8). There is room to add sinuosity to the channel and to modify its cross-sectional shape to include fluvial terraces. Utilise block sedge plantings along water's edge and on fluvial terraces to reduce erosion and increase bio-filtration. The visual amenity and passive recreation along the creek can be greatly enhanced. Provide an attractive pedestrian crossover between the two sections. Utilise pathways to separate lawn grass from native revegetated areas.



(Grouped sections) Tier 1	General location	Rehabilitation opportunities/ Management objectives	Project design considerations
		• reduce flow velocity of stormwater conveyance, • increase terrestrial and aquatic habitat and biodiversity values, • stormwater conveyance.	The invasive aquatic weed <i>Sagittaria</i> has been found in these sections. It is a Weed of National Significance (WONS) and these sections need regular monitoring. Control of this weed is important to prevent it invading further downstream of North Road.
7 Ct 6, Ct7	Centennial Park Central Precinct, Community parkland The lakes and the recent rehabilitation site by Sanford Road	Note: Plans for this area will need to incorporate the Centennial Park Sporting Precinct redevelopment plans. The opportunity exists to build on the existing works through the creation of a landscape plan for the whole precinct within which these sections are a part. Management objectives: • improve visual amenity, • reduce sediment, nutrient and other pollutant export, • increase channel shading to improve water temperatures, • bank protection through soft engineering, • increase terrestrial and aquatic habitat and biodiversity values, • reduce flow velocity of stormwater conveyance, • gross pollutant trapping at lower end.	Consider a landscape design approach to incorporate aesthetic, community and environmental aspects of the precinct for the two tributary branches and the lakes (sections Ct3, Ct4, Ct6, Ct7 and Ct8). All works should be part of a greater landscape design for the precinct. Consider introducing bio filtration along section Ct5 and enhancing the little dam at the very top of section Ct6 to treat the water from the light industrial and shopping areas before it enters the lakes. Provision for interception and efficient removal of trash and sediment (pre-bay) before entry into the lake should also be considered.
6 E4, E5	Oyster Harbour foreshore reserve	No specific physical intervention is required here. Management objectives: • Protection from further disturbance due to drain maintenance.	Limit maintenance access to the southern bank. Minimise disturbance to native vegetation during maintenance works. Note: The delta at the mouth of the creek supports a range of wading bird species.



Yakamia Creek Living Stream Management Plan

(Grouped sections) Tier 1	General location	Rehabilitation opportunities/ Management objectives	Project design considerations
		Develop protocols for maintenance works.	

(Isolated sections) Tier 1	General location	Rehabilitation opportunities/ Management objectives	Project design considerations
8 Ct1	Downstream of the corner of Symers and Knight Streets, adjacent to the soccer fields.	Opportunity exists to restructure the channel form (cross-section and sinuosity), and improve the area ambience and visual amenity. Management objectives: - improve visual amenity, - increase channel shading to improve water temperatures, - erosion control through soft engineering, - increase terrestrial and aquatic habitat and biodiversity values, - reduce flow velocity of stormwater conveyance, - gross pollutant trapping at lower end.	The natural stream form and function should be allowed for in any landscape plan. Maintain adequate foreshore buffer between channel and built infrastructure (at least 10 metres here). Room can be made to add sinuosity to the channel and to modify its cross-sectional shape to include fluvial terraces. Utilise block sedge plantings along water's edge and on fluvial terraces to reduce erosion and add habitat and biodiversity values. Utilise pathways to separate lawn grass from native re-vegetated areas and provide bridge cross overs. Provision for interception and efficient removal of trash.
9 D1.2 (consider including D1.1 from Tier 2)	Adjacent to City of Albany Offices and RAAFA retirement village.	These two sections have been eroding with channel deepening due to a head cut that has travelled up to and exposed a coffee rock layer forming a 'water fall'. Before any stream rehabilitation works can be undertaken here, a full topographic survey needs to be undertaken.	Enhance ecological connectivity with adjacent artificial wetlands behind the City of Albany buildings. Provision of public parkland and thoroughfare from North Road and RAAFA Amity retirement village. Consider creating parkland and access easements in the case of sub-division of adjacent lands across the creek to the north.



(Isolated sections) Tier 1	General location	Rehabilitation opportunities/ Management objectives	Project design considerations
		This area offers an opportunity to connect future sub-divisions to the north with North Road, via public parkland with a strong environmental theme. Management objectives: • improve visual amenity, • reduce flow velocity of stormwater conveyance, • erosion control determined through survey, • increase terrestrial and aquatic habitat and biodiversity values, • weed control, • gross pollutant trapping just below the North Road culvert.	The unstable and steeply incised channel lends itself to demonstrating better channel cross-section design that accommodates natural stream features including diversity of habitat (designed fluvial terraces and increased sinuosity). Improved bed and bank stability and weed management may provide a template for Best Management Practices for downstream landholders and future system modifications, without detracting from the channels flood water conveyance capacity. Note that the proposed plan for the Range Road intersection opposite Sanford Road within the Yakamia/Lange Structure Plan implies that the road cuts across the bend of Yakamia Creek. Any further designing of the Range Road, North Road intersection should include a plan for rehabilitating this section of Yakamia Creek with a Living Stream emphasis. (See further notes in Tier 2 table). The proposed Range Road intersection ignores proper stream form and function in this area. A minimum foreshore buffer of not less than 10m wide from the top of both banks should allow for access to downstream sections. Note that the Aboriginal Heritage Reference Group Aboriginal Corporation have requested at least a 30 metre buffer.



Recommendations to OHCG for Tier 1 sites

The Barnesby Drive Living Stream project highlighted the fact urban Living Stream development deals with numerous and diverse community expectations to a greater extent than many rural river restoration projects. This is reflected in the multiple roles that streams play in this environment. Environmental Problem solvers should recognise that the social aspects of waterways management are as important as the implementation of an on-ground environmental ideal. A Living Stream project is not simply about putting up a fence to limit stock (or people) access and re-vegetation of the riparian zone. It has to be integrated with the requirements of residential and industrial infrastructure. For this reason the OHCG will only ever be one of a number of stakeholders all with differing demands on the outcomes of foreshore project proposals.

One of the aims of this Living Stream Management Plan was to identify the next 2 – 5 sites for Living Stream projects. The opportunities assessment identified nine potential sites as listed in Table 5. The suggested priority sites at this stage are:

- Dunn Park (including Bevan Street)
- Upper Barnesby Drive
- The western end of the Centennial Park Sporting Precinct
- Downstream of North/Sanford Road

For all parts of the target areas of the creek, key stakeholders are the City of Albany, the local Noongar community, Water Corporation, Department of Water, Department of Aboriginal Affairs, South Coast NRM, and the Health Department. Other stakeholders concerned with specific reaches of the creek are; residents, assorted sporting groups, other community interest and 'Friends of' groups, Centennial Park Sporting Precinct committee, businesses including land developers, Main Roads Department, Department of Planning, Fisheries WA and others. The following recommendations for OHCG outline project opportunities and engagement in this social context.

Some general recommendations for the OHCG

- Determine what proportion of the OHCG's time and effort can realistically be allocated to Yakamia Creek over a specific time frame, for example 2015 to 2025.
- Ensure that project officers have a mandate in their contracts to routinely liaise with stakeholders regarding project developments and needed resources along Yakamia Creek.
- Develop a support model for weed management along the creek, with SCNRM, Friends of Yakamia Creek, the Noongar community, Bushcarers and other relevant groups. The current model for funding NRM projects has the disadvantage of creating a competitive or isolated outlook amongst groups who often have common aims.
- Provide basic training for project officers in the area of Water Sensitive Urban Design (WSUD).
- Develop a framework (not parts of individual projects) to facilitate periodic monitoring of the environmental outcomes of riparian management projects after they have been completed. Often this aspect of environmental management is not factored into many plans and is soon displaced by other projects and neglected.
- Seek and support a local champion(s) who can be an advocate for better environmental management in the Yakamia Creek catchment.



Table 6: Recommendations to OHCG for Tier 1 sections

(Grouped sections) Tier 1	General location	Key stakeholders	Recommended project focus for the OHCG
1 A05.1, A05.2, A05.3, A11	Dunn Park bounded by Dunn, Whidby and Broughton Streets	City of Albany (CoA), residents, Water Corporation, Health Department, Noongar Community.	Liaise with the CoA regarding a constructed wetland/ bio-filter design to improve the water quality and social amenity of the park area. Consult with the local Noongar community regarding ideas and proposals for the area.
2 B06.1, B06.2, B07, B08	Adjacent Barnesby Drive and Yakamia Primary School	CoA, residents, Friends of Yakamia Creek, Yakamia Primary School, Noongar Community.	Consult with the Yakamia Primary School regarding educational opportunities for these sections of the creek. Work with the Friends of Yakamia Creek to incrementally replace the exotic eucalypts with less invasive native trees. Liaise with private landholders of the Tier 2 sections upstream (as far as Chester Pass Road) to control Sydney Wattles and other weed infestations along the creek. Consider projects to redesign and upgrade the pedestrian culvert crossings along these sections
3, 4, 5, 7 C1, C2, C3, C4, C09.1, C09.2, Ct3, Ct4, Ct 6, Ct7	Centennial Park Sporting Precinct.	CoA, Centennial Park Sporting Precinct Committee, Noongar Community	Consult with the City of Albany and the Centennial Park Sporting Precinct Committee to determine how the proposed nutrient bio-filtration design (designed by Syrinx Environmental and before council) fits in with a constructed wetland/ bio-filter function and maintenance. Future projects may involve modifications to the initial installation to improve ecological outcomes in the long term. Ongoing maintenance will be an important issue.
6 E4, E5	Oyster Harbour foreshore reserve		Be an advocate for the conservation of the foreshore areas at the mouth of Yakamia Creek to prevent further excavation and unnecessary damage to riparian vegetation. Develop specific protocols to govern sediment removal if this is needed to improve the drainage efficiency of the channel. Currently this natural asset is out of sight and out of mind (apart from UWA interest in water quality).

(Grouped sections) Tier 1	General location	Key stakeholders	Recommended project focus for the OHCG
(Isolated sections) Tier 1	General location	Key stakeholders	Recommended project focus for the OHCG
8 Ct1	Downstream of the corner of Symers and Knight Streets, adjacent to the soccer fields.	CoA, Centennial Park Sporting Precinct Committee and the Agricultural Show committee.	Liaise with the CoA regarding appropriate channel and riparian design with improved nutrient and contaminant stripping capacity.
9 D1.2 (and D1.1 from Tier 2)	Adjacent City of Albany Offices and RAAFA retirement village.	CoA	Liaise with the CoA to provide sufficient (WSUD) riparian buffer width at the North Road intersection in the proposed Range Road intersection plans. Consult with the CoA to consider riparian and channel modifications to create a Living Stream floodway as the lead in for future concept plans for any proposed riparian corridor through the downstream sections. <u>Note</u> that this section offers one of the few opportunities for OHCG to be the principal project proponent in collaboration with the City of Albany.



Benefits of Living Stream development for selected Tier 1 targets

An environmental design for the Centennial Park Sporting Precinct has been drawn up by Syrinx Environmental to treat ground water and surface nutrient export from the sporting fields. It is not known what scope they had in their brief to modify Yakamia Creek however concept plans have been submitted to the council.

In this report stream function factors are discussed for several Tier 1 targets. There are many considerations that are beyond the scope of this report with respect to site development plans. The Department of Water (WA) and Melbourne Water have excellent publications outlining design guidelines for constructed wetlands.

Constructed wetlands are vegetated detention areas which are designed to remove fine particulate matter and dissolved pollutants from low flows with a high flow by-pass which comes into effect once the wetland has been filled to capacity (detention basin function). The effectiveness of constructed wetlands is dependent on reducing flow velocity and promoting biological transformations of pollutants by passing the flow through a series of pools and biofilms in vegetation bands. See Figure 2 for a schematic representation of a typical constructed wetland. Secondary benefits of constructed wetlands are landscape amenity, and habitat creation. Connecting a constructed wetland to existing bushland vegetation will enhance both the bushland and the wetland.

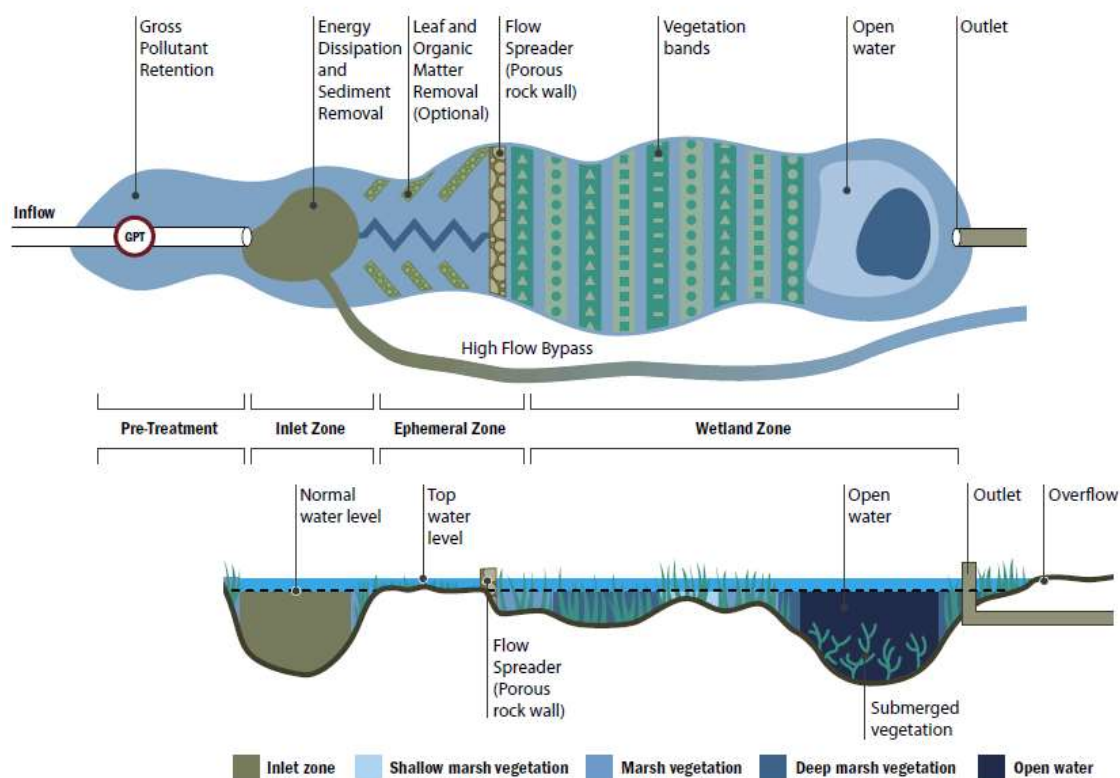


Figure 2: Schematic representation of a typical constructed wetland in plan view and longitudinal view. (from Melbourne Water (2005)¹)

¹ "Constructed Wetland System Design Guidelines for Developers" Version 3 (2005) Melbourne Water.

An observation on the limited success of various revegetation projects is the frequent skimping on the density of planting. It was noted on the Bannister Creek rehabilitation project that blocks of sedges were planted along the water's edge, forming mats of vegetation that were pinned in place. Although they were more expensive, they gave a better result¹.

Costs for constructing wetlands vary depending on many factors. The Department of Water (in "Stormwater Management Manual" ²) cite 2002 eastern states examples as ranging from approximately \$500 000 to \$700 000 per wetland hectare with earthworks and vegetation being the dominant costs. They also cite maintenance costs as approximately 2% of construction costs.

The **New Water Ways** brochure on the Liege Street Wetland gives their costs for both development and maintenance. This wetland is about one hectare within a four hectare site.

Development Costs

Conceptual design and construction/ revegetation specifications	\$63,000
Construction ¹	\$726,000
Planting and restoration activities ²	\$74,000
Total (ex GST) ^{3,4,5,6}	\$863,000

1. Approximate figure, includes in-kind funding.
2. Includes supervision time but does not account for volunteer time (not tracked but significant).
3. Construction/revegetation costs only relate to wetland design and implementation and not landscape elements (e.g. signage, boardwalks, paths, seating, etc.).
4. Costs in 2004-05.
5. SRT, Water Corporation, City of Canning staff time for planning not quantified.
6. Costs relate to implementation of both the ~1ha wetland and the entire ~4ha site in which the wetland is located.

Maintenance Costs ^{1,2}

• 2005/2006	\$30,200
• 2006/2007	\$30,300
• 2007/2008	\$20,200
• 2008/2009	\$24,600
• 2009/2010	\$24,100
• 2010/2011	\$21,100

1. All figures are an approximation of costs which includes supervision time but does not account for volunteer time and excludes GST. Planning and management for staff at Swan River Trust, Water Corporation, and City of Canning have not been quantified
2. Costs relate to maintenance of both the ~1 ha wetland and the entire ~4ha site in which the wetland is located

¹ Per. com. Julie Roberts, CEO of South East Regional Centre for Urban Landcare.

² "Storm water Management Manual for Western Australia: Structural Controls" Department of Water (2004–2007), accessed from the internet 1/4/2014 at;
[http://portal.water.wa.gov.au/portal/page/portal/WaterManagement/Storm water/Storm waterMgtManual](http://portal.water.wa.gov.au/portal/page/portal/WaterManagement/Storm%20water/Storm%20waterMgtManual)



The following sites, consisting of one or more stream sections, provide good opportunities to ensure that Living stream function is represented along the Yakamia Creek floodway. Of particular importance are the functions of bio-filtration, water cleaning, diversity of riparian and in-stream habitat features, environmental appreciation and trash interception. The monitoring of the outcome of any proposed development for these sites will be important for ensuring that they become and remain more than simply, decorated ditches.

Dunn Park Living Stream benefits opportunities (sections A05.1, A05.2, A05.3, A11)

An opportunity exists to value add to the existing detention pond at Dunn park by improving vegetated bio-filter detention area to remove pollutants from stormwater and attenuate larger storm events in the existing detention area. The area offers a demonstration site for water sensitive urban design in a highly visible location. Figure 3 shows the area.

Two stream sources meet at the lower end of the park. The catchments for both of these channels include paved industrial areas which can produce rapid high flows. The Bevan Street tributary flood flows will need to be detained more effectively than the current detention basin. There is some opportunity to further enhance the Bevan Street area (Sections A07, A08 and A09) to improve bio-filter detention to 'clean' the water flowing from this industrial area as well as to detain flood flows. This is discussed further under Tier 2 sites.

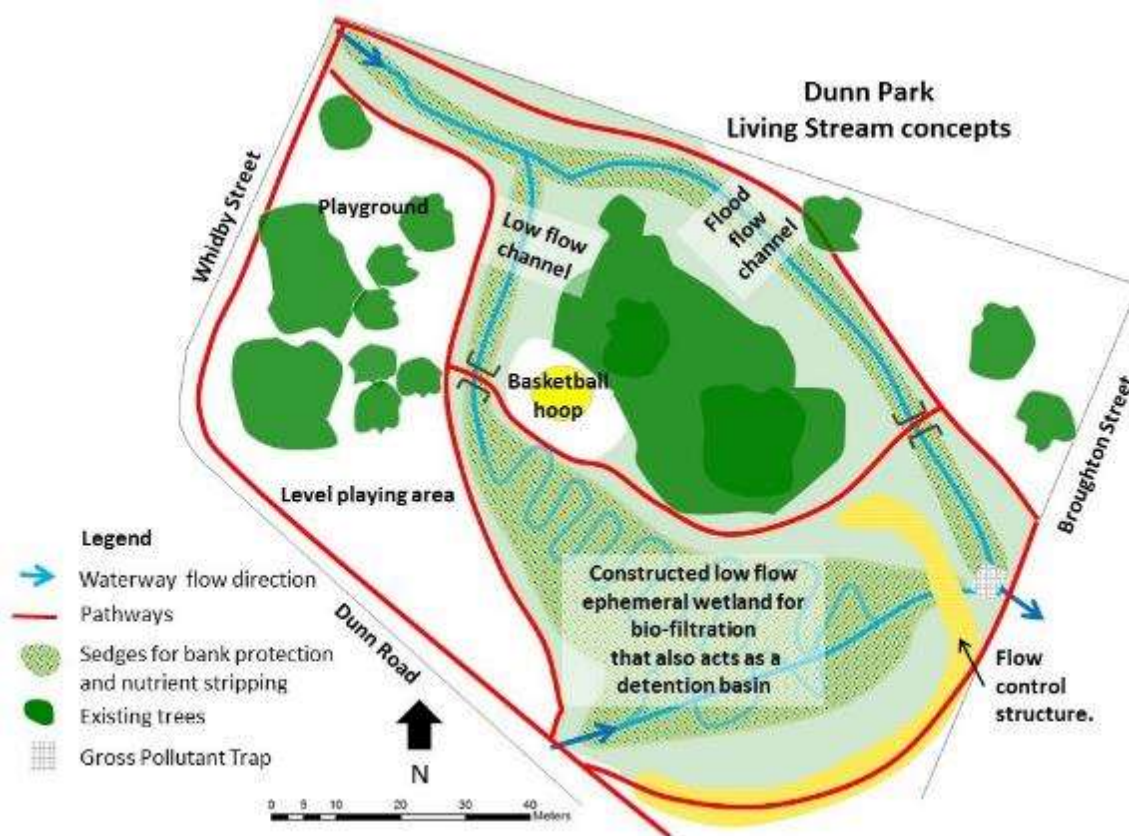


Figure 3: Concept design for constructed ephemeral wetland and bio-filter detention area for Dunn Park.

The remnant native bush patch in the centre of the park is currently in moderate condition and is representative of the original bush cover and would be a value to preserve with some weed control. There are threats to its integrity due to the abutting grassed areas. The remnant patch can be protected by linking it with revegetation around the channel and wetland. Block sedge plantings along the water's edge and on fluvial terraces are recommended as they establish quickly, provide a sufficient density to reduce weed incursion and protect the bank from erosion.

The current detention basin in Dunn Park tends to remain soggy for much of the year and has reduced the open space area for residents to 'kick a ball around'. Extension of a flat 'play' area should be considered (See Figure 4).

The redesigned basin area is at the confluence of section A5.3 (the current detention basin) with section A11 that receives flows from the Bevan Street stormwater sump. The primary design issue is ensuring that high storm discharge from both sources can be adequately accommodated. Opportunity exists to improve bio-filtration at the Broughton St end of the park as well as along the main channel on the northern side.



Figure 4: The detention basin at Dunn Park after receiving flow from a storm event. The initial flow enters the basin via the diversion channel at the left. A good quality patch of remnant vegetation (rare along Yakamia Creek) can be seen in the background.

Western End of Centennial Park Sporting Precinct -- Sections C1, C2, C3 & C4

This area offers perhaps the most diverse opportunity for demonstrating Living Stream functionality along Yakamia Creek, involving constructed wetlands and a bio-filter detention area and public amenity.

Note: The City of Albany development plans for this area incorporate Water Sensitive Urban Design to complement the development of the sporting precinct.

Arguments in favour of using this site as a demonstration site include:

- It is in a highly visible location.
- It increases the public amenity of the sporting precinct.
- It is within sight of the Barnesby Drive Living Stream works.
- The broad space available offers an excellent opportunity to create a complex riparian system incorporating the flood plain with the stream channel.
- It was historically an important wetland and floodplain area.

Any works along these sections of Yakamia Creek should include the following living stream functionality:

- Channel form that emulates a natural form,
 - sinuosity
 - low and high flow cross-sections
 - lateral terraces and
 - ease of access.

There is room to add sinuosity into the channel to limit erosion and to develop a constructed wetland bio-filter and detention basin. The wetland blocks to the west of sections C1 and C2 and owned by the City of Albany would increase the land available for significant wetland features and improve bio-filtration efficiency.

Discussions with the City suggest that re-routing the main channel to the southern side of the area could provide more space for a constructed wetland. There is opportunity for Public thoroughfare

connections between Pioneer, North and Barker Roads to be enhanced with linkages through the revegetated areas and the existing bike paths to improve passive recreation. Community awareness of environmental issues can be addressed with a raised walkway through the wetland, viewing platforms and interpretive signage. The local Noongar community should be engaged in the implementation of the wetland precinct and interpretive signage.



Figure 5: Aggressive channel excavation along section C3 below North Road tends to promote weed growth and encourage bank erosion.

Centennial Park Athletics Precinct - C09.1, C09.2

There is opportunity to provide some bio-filtration function along this section as well as improve the area ambience and visual amenity to complement rehabilitation works across Sanford Road

There is room to add sinuosity to the channel and to modify its cross-sectional shape to include fluvial terraces. Utilise block sedge plantings along water's edge and on fluvial terraces to reduce undercutting and bank erosion. Bio-filtration of groundwater between the creek and the PCYC can be improved through appropriate sedge and shrub planting (See Figure 6).



Figure 6: Drainage from Graham Street enters Yakamia Creek from behind the PCYC. There is opportunity to provide some bio-filtration function and improved visual amenity here.

PET bottles, snack wrappers and other rubbish have been observed and complained about, 3 kilometres downstream in Yakamia Creek. A Gross Pollutant Traps (GPT) above North would help to reduce rubbish being washed down Yakamia Creek below North Road.

Centennial Park Central Precinct, Community parkland - Ct3, Ct4 and Ct 6, Ct7

Opportunity exists here to incorporate the existing riparian enhancement works into a broader landscape plan. Possibilities includes a shaded avenue along the eastern drainage line parallel to North Road. Any landscape design should incorporate aesthetic, community and environmental aspects of the precinct for the two tributary branches and the lakes.

Added sinuosity to the channels and modified cross-sectional shape to include fluvial benches would be appropriate for Living Stream functionality (See Figure 7). Block sedge plantings within the channel and along water's edge and on fluvial terraces reduce erosion, increase bio-filtration and reduce weeds. The two small swales entering the eastern branch should be incorporated into the bio-filtration design.

Opportunity exists to introduce bio filtration along section Ct5 and to enhance the small dam at the very top of section Ct6 to treat water from the light industrial and shopping areas, before it enters the lakes. Provision for interception and efficient removal of trash and sediment (pre-bay) before entry into the lake is also recommended.



Figure 7: Section Ct3 receives drainage from the Campbell Road and Cull Park. Added sinuosity and bio-filtration would enhance the existing riparian works downstream.



Figure 8: In Section CT1 there is plenty of room to consider enhancing the drain with living stream attributes to improve visual amenity.

Centennial Park Soccer Precinct – Ct1

Living stream attributes along this section would include restructuring the channel form to add slight sinuosity and modified low and flood flow cross-sectional shape. The utilization of block sedge plantings along water's edge and on fluvial terraces can reduce erosion and add habitat and biodiversity values. Pathways can be used to separate lawn grass from native revegetated areas and provide access to bridge cross overs.

Table 7: Tier 2 Summary of opportunities, objectives and design considerations.

Note: these sections are ordered in sequence downstream from the headwaters, not in order of priority. It is suggested it would be premature to design Living Stream projects for Tier 2 sections downstream of North Road until landholder agreement to basic concept plans is secured or sufficient riparian foreshore has been excised through the subdivision process.

(Grouped sections) Tier 2	General location	Rehabilitation opportunities/ Management objectives	Project design considerations
1 A1.1, A1.2	Urban drain upstream of Anson Road	A shallow linear drain runs through private property at a boundary and currently serves light industrial blocks including the green waste facility. Possibilities exist to detain and retain storm discharge, but particularly to improve bio-filtration capacity for nutrient and contaminant stripping. Management objectives are: • reduce sediment, nutrient and other pollutant export, • stormwater and low flow detention control.	Further development of the land should require installation of stormwater retention and infiltration systems on the properties and adjacent to the drain.
2 A7, A8, A9	Bevan Street to existing stormwater detention basin	A short section of open stream line connects the light industrial areas via Bevan Street, to an existing fenced detention basin. The opportunity exists to create an ephemeral constructed wetland detention basin and bio-filter within the road reserve and adjacent Lot 109 Whidby Road and the existing fenced detention basin. Part of this section is a deep open ditch and part is piped underground. Management objectives are: • reduce sediment, nutrient and other pollutant export, • stormwater and low flow detention control, • improve visual amenity,	The area has a backyard, out-of-sight-out-of-mind appearance (i.e. unsightly), but it is a public thoroughfare. Rehabilitation would improve the interface between residential land and business premises and improve land values. Procuring Lot 109 Whidby Street and the road reserve would provide a larger connected area for the design of an ephemeral constructed wetland and enhance its storm water capacity and bio-filtration function. Any re-vegetation design should take into account visibility as an important consideration for area security. Currently water quality, particularly pathogen and petrochemical levels are a concern. Detaining and bio-



(Grouped sections) Tier 2	General location	Rehabilitation opportunities/ Management objectives	Project design considerations
		• increase terrestrial and aquatic habitat and biodiversity values, • improved connecting pathways.	filtering more stormwater in this area would help relieve pressure on the bio-filter and detention area at Dunn Park. Involve the local residents and the Noongar community in the planning phase to improve a sense of ownership of the area.
3 B2, B3, B4, B5	Between Chester Pass Road and Barnesby Drive	This group of sections links the rehabilitation works downstream along Barnesby Road with Chester pass Road and therefore offers an opportunity to improve connectivity and consistency of management. Management objectives are: • stormwater conveyance, • reduce sediment, nutrient and other pollutant export, • improve visual amenity, • increase terrestrial and aquatic habitat and biodiversity values, • erosion control and bed and bank stability through soft engineering, • weed control.	Improving stream connectivity by ‘defragmenting’ these sections is an important design consideration. Maximise the channel foreshore riparian buffer width in the design. (at least 30 metres as requested by the Aboriginal Heritage Reference Group Aboriginal Corporation) Utilise block sedge plantings along water’s edge and on fluvial terraces to reduce bank erosion. Improved public thoroughfare would strengthen the connection to the CBD, improve area ambience and therefore land values. Provision of a walkway and bicycle path. The adjacent bush is Jarrah, Marri, Sheoak laterite forest with parts in moderate condition. Ensure connection of retained remnant vegetation to foreshore riparian buffer.
4 C5, C6	Upstream of the Albany Leisure and Aquatic Centre at the end of Barker	The current bank armoured is slowly collapsing in places. The eventual replacement of the current drain structure with Living Stream meandering channel and modified	Any significant environmental rehabilitation along these sections would require replacement of the straight armoured ditch with a slightly meandering channel and modified cross sectional shape to include



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(Grouped sections) Tier 2	General location	Rehabilitation opportunities/ Management objectives	Project design considerations
	Road and adjacent to the western parking area	cross-section needs to be included in the current planning of the area. Management objectives are: • stormwater conveyance, • improve visual amenity, • increase terrestrial and aquatic habitat and biodiversity values, • erosion control and bed and bank stability through soft engineering, • reduce flow velocity of stormwater conveyance by adding sinuosity to channel.	fluvial terraces. Utilise block sedge plantings along water's edge and on fluvial terraces to reduce undercutting and bank erosion. There is a short trapezoidal drain entering on the western bank that comes from Albany Highway via Pioneer Road. This was restructured in 2014 pending the construction of units on the adjacent private land. Maintain adequate foreshore buffer between channel and built infrastructure (at least 30 metres as requested by the Aboriginal Heritage Reference Group Aboriginal Corporation).
5 D2.1 to D5.9	North Road to Lower King Road	It is suggested that OHCG involvement in the foreshore management of these lower reaches would be premature and limited with respect to initiating any substantial on-ground works. The principle management need here is to achieve consensus between landholders and the City regarding the future of the waterway. In that respect it is suggested that the OHCG should not consider committing to Living Stream projects at this time. However, support for more consistent floodway maintenance actions would likely be accepted by a number of residents. The general recommendations are that the OHCG; • Be an active advocate for the Yakamia/ Lange riparian corridor plan.	Living Stream project activity will need to be guided by the City of Albany development plans that unfold over the coming decade as defined in the Yakamia/Lange Structure Plan.¹ Three flood zones may be designated according to the 100 year ARI boundary. (See Figure 11) These sections form the longest reach of Yakamia Creek with the greatest potential for a continuous, integrated and multi-functional riparian corridor. Current landholder expectations limit Living Stream development along these sections to weed management and localised bank stabilization works.

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



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(Grouped sections) Tier 2	General location	Rehabilitation opportunities/ Management objectives	Project design considerations
		- Promote better riparian management practices through information and media products. - Support weed management projects. A more detailed discussion can be found under the heading 'Summary of General recommendations to OHCG for Tier 2 sections downstream of North Road.' and 'Best and better foreshore management practices for the lower Yakamia Creek.' Management objectives are: - develop an ecological and hydrological detailed plan for the whole length, - constrain development within the foreshore riparian zone defined by CoA Yakamia/Lange Structure Plan¹, - increase terrestrial and aquatic habitat and biodiversity values, - weed control - erosion control and bed and bank stability through soft engineering, - reduce flow velocity of stormwater conveyance by adding sinuosity to channel.	Environmental considerations conflict with landholder expectations for land use and for excavating a large enough channel to remove the risk of flooding. The flood plain should be retained as a floodplain with no substantial infrastructure development permitted. A detailed model of the floodplain, identifying and incorporating ecological as well as hydrological processes is required. Current concept models are an insufficient foundation on which to build the desired holistic plan for best management of Yakamia Creek between North Road and Oyster Harbour. Such a plan would ideally be supported by obtaining a Digital Elevation Model (DEM) of the entire floodway, to an accuracy of at most +/- 10 cm, to clearly delineate the many drainage features. The case study of Bannister Creek shows what can be achieved when retrofitting a dug drain into a Living Stream in similar sandy soils.
6 E1, E2, E3	Between Lower King Road and the Oyster Harbour foreshore reserve	Opportunities for environmental rehabilitation are uncertain at this stage. The discussion under the heading 'Summary of General recommendations to OHCG for Tier 2 sections downstream of North Road.' and 'Best and	Consultation with the landholder to determine how the creek is functioning, is a prerequisite. Woody weeds are a significant issue, but appear to be serving a channel stabilization role in some sections.

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



(Grouped sections) Tier 2	General location	Rehabilitation opportunities/ Management objectives	Project design considerations
		better foreshore management practices for the lower Yakamia Creek' It is suggested that OHCG involvement in the foreshore management of these lower reaches would be premature and limited with respect to any substantial on-ground works. The preliminary management is to achieve consensus between landholders and the City regarding the future of the waterway. In that respect it is suggested that the OHCG should not consider committing to Living Stream projects at this time. However, support for more consistent floodway maintenance actions would likely be accepted by a number of residents. The general recommendations are that the OHCG; • Be an active advocate for the extension of the Yakamia/ Lange riparian corridor concept to link with Oyster Harbour. • Promote better riparian management practices through information and media products. • Support weed management projects. Management objectives are: • develop an ecological and hydrological concept plan for the whole length of these sections, • increase terrestrial and aquatic habitat and biodiversity values, • weed control, with replacement by comparable native plant species, • erosion control and bed and bank stability through soft engineering where appropriate,	



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(Grouped sections) Tier 2	General location	Rehabilitation opportunities/ Management objectives	Project design considerations
		Accommodate the natural tendency of the channel to adopt a sinuous form.	
7 Zone F	Tributary flowing downstream from Callistemon View (0.9 Km)	An opportunity exists to ensure an adequate foreshore riparian buffer zone is incorporated in the development of the area. This should include the damp scrubland of the valley floor and elements of the fringing woodland. See the discussion under the heading 'Summary of General recommendations to OHCG for Tier 2 sections downstream of North Road.' and 'Best and better foreshore management practices for the lower Yakamia Creek' It is suggested that OHCG involvement in the foreshore management of these lower reaches would be premature and limited with respect to on-ground works. The preliminary management is to achieve consensus between landholders and the City regarding the future of the waterway. In that respect it is suggested that the OHCG should not consider committing to Living Stream projects at this time. However, support for more consistent floodway maintenance actions would likely be accepted by a number of residents. The general recommendations are that the OHCG; - Support weed management projects. - Be an active advocate for the Yakamia/ Lange riparian corridor plan.	Until a detailed sub-division plan has been decided, project activity in these areas is limited to landholder engagement to undertake weed control. Nevertheless, pre-emptive weed management action is a critical need to ensure future developments can protect and maintain existing vegetation values. Later, specific Living Stream projects will be dependent on the recommendations of the by CoA Yakamia/Lange Structure Plan¹.

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



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(Grouped sections) Tier 2	General location	Rehabilitation opportunities/ Management objectives	Project design considerations
		- Promote better riparian management practices through information and media products. Management objectives are: - give the creek a name to establish its identity and ecological place in the community, - develop an ecological and hydrological detailed plan for the whole length, - constrain development within the foreshore riparian zone defined by CoA Yakamia/Lange Structure Plan¹, - increase terrestrial and aquatic habitat and biodiversity values, - weed control - erosion control and bed and bank stability through soft engineering, - reduce flow velocity of stormwater conveyance by adding sinuosity to channel.	
8 Zone G	Lange tributary, between Mercer, Catalina and Mason Roads (2.7 Km)	The opportunity exists to ensure an adequate foreshore riparian buffer zone is incorporated in the development of the area. This is to include the damp scrubland of the valley floor and elements of the fringing woodland. See the discussion under the heading 'Summary of General	Until a detailed sub-division plan has been decided, project activity in these areas is limited to landholder engagement to undertake weed control.

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



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(Grouped sections) Tier 2	General location	Rehabilitation opportunities/ Management objectives	Project design considerations
		recommendations to OHCG for Tier 2 sections downstream of North Road.’ and ‘Best and better foreshore management practices for the lower Yakamia Creek’ It is suggested that OHCG involvement in the foreshore management of these lower reaches would be premature and limited with respect to substantial on-ground works. The preliminary management is to achieve consensus between landholders and the City regarding the future of the waterway. In that respect it is suggested that the OHCG should not consider committing to substantial Living Stream projects at this time. However, support for more consistent floodway maintenance actions would likely be accepted by a number of residents. The general recommendations are that the OHCG; • Support weed management projects. • Be an active advocate for the Yakamia/ Lange riparian corridor plan. • Promote better riparian management practices through information and media products. Management objectives are: • give the creek a name to establish its identity and ecological place in the community, • develop an ecological and hydrological detailed plan for the whole length,	Later, specific Living Stream projects will be dependent on the recommendations of the by CoA Yakamia/Lange Structure Plan¹.

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



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(Grouped sections) Tier 2	General location	Rehabilitation opportunities/ Management objectives	Project design considerations
		- constrain development within the foreshore riparian zone defined by CoA Yakamia/Lange Structure Plan, - increase terrestrial and aquatic habitat and biodiversity values, - weed control - erosion control and bed and bank stability through soft engineering, - reduce flow velocity of stormwater conveyance by adding sinuosity to channel.	

Tier 2 (Isolated sections)	General location	Rehabilitation opportunities/ Management objectives	Project design considerations
9 C8	Immediately downstream of the Albany Leisure and Aquatic Centre	This section has been channelised and armoured; however future planning should consider creating a more natural transitional zone into the Living Stream rehabilitation proposed for the following two downstream sections. Management objectives are: - stormwater conveyance, - improve visual amenity, - increase terrestrial and aquatic habitat and biodiversity values, - erosion control and bed and bank stability through soft engineering,	Any significant environmental rehabilitation along these sections would require replacement of the straight armoured ditch with a slightly meandering channel and modified cross sectional shape to include fluvial terraces. Utilise block sedge plantings along water's edge and on fluvial terraces to reduce undercutting and bank erosion. Maintain adequate foreshore buffer between channel and built infrastructure (at least 30 metres as requested by the Aboriginal Heritage Reference Group Aboriginal Corporation).



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Tier 2 (Isolated sections)	General location	Rehabilitation opportunities/ Management objectives	Project design considerations
		• reduce flow velocity of stormwater conveyance by adding sinuosity to channel.	
10 Ct 5	At western boundary of the Sanford Road football ground	There is room for improved bed and bank stabilization without compromising the drainage function. Management objectives are: • stormwater conveyance, • improve visual amenity, • increase terrestrial and aquatic habitat and biodiversity values, • erosion control and bed and bank stability through soft engineering, • reduce flow velocity of stormwater conveyance by adding sinuosity to channel.	A 'filter' at the lower end of this section would serve to improve water quality and intercept rubbish and sediment before it can enter the ornamental lakes .It should be designed to easily facilitate removal of accumulated material. There is little room to add sinuosity to the channel, but there is some scope to modify its cross-sectional shape to include fluvial terraces. The current flows are tending to form these at present. Utilise block sedge plantings along water's edge and on fluvial terraces to reduce erosion and increase bio-filtration.



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11 D1.1	Immediately downstream of North Road and adjacent to the Water Corporation Sewerage pump station	This section is constrained for space, nevertheless it acts to connect the upper catchment to a broadening riparian area downstream. The comments for Section D1.2 in 'Table 5: Tier 1 Summary of opportunities, objectives and design considerations. are applicable here. Management objectives: • improve visual amenity, • reduce flow velocity of stormwater conveyance, • erosion control determined through survey, • increase terrestrial and aquatic habitat and biodiversity values, • weed control, • gross pollutant trapping just below the North Road culvert.	The current channel is highly incised with steep (potentially dangerous) banks. Head-cutting proceeded upstream after excavation and is now limited by an exposed lateritic shelf that has created a waterfall approximately 1.5 meters high. This feature may lend itself to enhancement if the downstream section is developed as an environmental park and better pedestrian access is provided. Proposed road works to connect North Road to the Lange urban development should allow for a sufficient vegetated buffer (> 10 m either side) along this short section to ensure that access to the sections downstream is not compromised. Adequate access will be important for future public amenity and maintenance of the lower reaches of the creek. Note that the Aboriginal Heritage Reference Group Aboriginal Corporation have requested at least a 30 metre buffer.
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Summary of General recommendations to OHCG for Tier 2 sections downstream of North Road.

OHCG involvement in the foreshore management of these lower reaches is currently limited with respect to on-ground works. The principle management need here is to achieve consensus between landholders and the City regarding the future of the waterway. In that respect it is suggested that the OHCG should not consider committing to Living Stream projects at this time. However, support for more consistent floodway maintenance actions would likely be accepted by a number of residents. The general recommendations are therefore that the OHCG;

- Be an active advocate for the Yakamia/ Lange riparian corridor plan.
- Promote better riparian management practices and protection through information and media products.
- Support weed management projects.

Best and better foreshore management practices for the lower Yakamia Creek

The sections of Yakamia Creek between North Road and the Lower King Road have been rated as Tier 2 in terms of constraints on Living Stream development. The long-standing controversy about who should maintain the modified channel between North Road and Lower King Road and the resulting inaction, has promoted an inconsistent approach to both floodway improvement and maintenance. The continued controversy is the overarching constraint along these lower sections. It has also hindered the implementation of best management practices and thwarted attempts to create a detailed foreshore management plan that would be acceptable to landholders as well as the City of Albany.

The City of Albany's Yakamia/Lange Structure Plan¹ has an ultimate vision for the area that includes protection of the foreshore areas adjacent to waterways that feed into Oyster Harbour. The overarching objective of the plan is the creation of a broad, connected riparian corridor for the creek system between North Road and Martin Road including the two western tributaries (See Figure 9). This buffer along the main channel encompasses the flood prone areas and wetlands.

The allocation of land for the foreshore reserve will be a requirement of subdivision and future urban development. This is likely to occur gradually over a long period of time if the riparian zone is not to be resumed by the City. For this reason there are no reliable short-term opportunities to implement a holistic foreshore plan. Nevertheless, a detailed pre-emptive plan can be developed and this should constrain and steer future development in these flood plain areas. Thus best management practice (BMP) should be defined in terms of a holistic reconstruction of the floodway along the 6.4 Kilometre reach between North Road and Oyster Harbour.

It is beyond the scope of the Living Stream management plan to present a detailed riparian corridor design with sufficient detail to support the type of micro-management of the waterway needed to achieve the desired environmental outcomes. However, suggestions for what key elements should be covered in the working plan are presented.

The riparian area described in the Yakamia/Lange Structure Plan was based on the known flood extent and associated ecological values of the area. It represents an optimum design balancing the need for urban expansion with protection of water assets. The text boxes in Figure 9 suggests some interim management objectives. Since these actions concern private land holdings, ongoing community consultation will be essential to promote the concept plan.

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



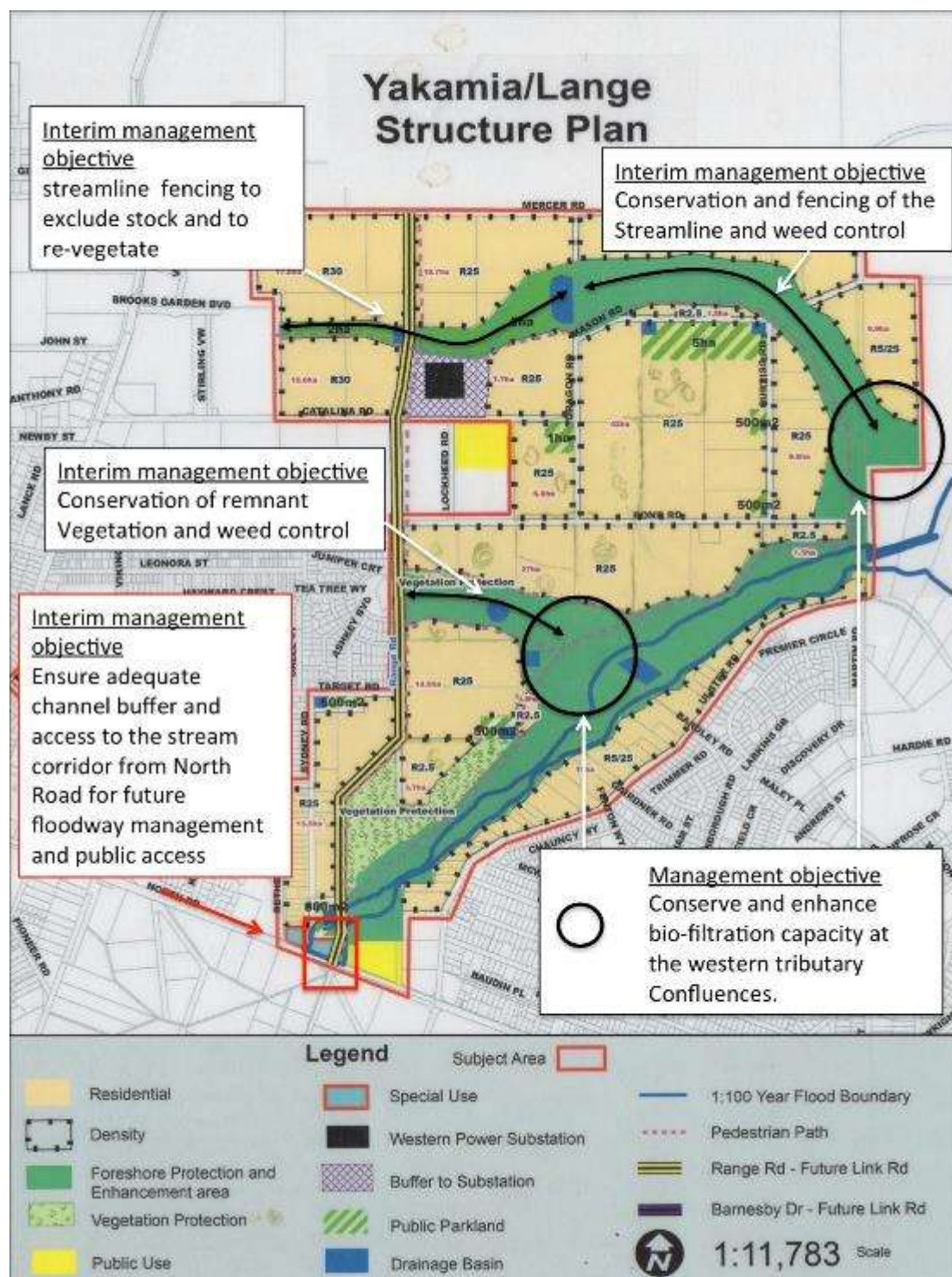


Figure 9: Yakamia / Lange Structure Plan with added interim management objectives in text boxes.

It is also recommended that more detail be obtained regarding the confluences of the western tributaries (to be named) for the purpose of determining existing and potential bio-filtration function in the waterways. The circles areas in Figure 9 are critical surface and subsurface water treatment sites.

Interim better management practices are suggested for the maintenance of the existing floodway of the creek. These can be promoted to landholders and are also applicable to ongoing foreshore management. These practices are discussed as principles and assertions in the following sections.

Channel and foreshore management practices

It may seem obvious, but floodplains are called floodplains for that simple reason.

In the effort to turn floodplains into something else landholders and local government agencies often find themselves fighting an age old battle with nature that is usually expensive, time consuming and often counter-productive. Sometimes works are of marginal benefit to the wider community though important to individual landholders or specific vested interests.



Figure 10: Extent of the 2005 flood. (Photo courtesy of Wilhelm Ficko).

The lower reaches of Yakamia Creek include broad floodplain and wetland zones where sediment is naturally deposited from turbid storm water. These reaches have a shallow gradient and flood waters are able to spread out (Figure 10).

Infrastructure (fences, sheds, buildings, tracks, crossings) built on the floodplain will always incur some risk of flood damage.

Since the Yakamia/Lange Structure Plan¹ is aimed at securing a riparian corridor through the subdivision process this will mean that many properties that currently span the floodplain will need dividing. Figure 11 below shows the approximate extent of 1 in 100 year flood levels. Three relatively distinct stream reaches based on flood extent, can be seen. While flooding may be of some inconvenience in the upper reach, it is of greater concern to owners of small properties in the middle reach and the larger properties along the lower reach.

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



Figure 11: Distinct 1 in 100 year flood reaches along the middle to lower Yakamia Creek

The Yakamia/ Lange Structure Plan largely concerns the upper and middle reaches shown in Figure 11 and the proposed corridor is relatively confined. However, an adequate corridor along the lower reach that allows the system to act as a natural floodplain, is considered problematic due to the natural floodplain width. One compromise may be to direct and confine floodwaters towards the less developed northern side of the floodplain by enhancing detention and retention of water in those areas. These works would preferably be in the form of constructed wetlands providing bio-filtration of urban stormwater runoff and maintenance of fauna and flora habitat.

Landholders have argued that the City of Albany should be responsible to create and maintain a much larger channel. The claim that the City (i.e. rate payers) should bear the burden because the Town and Shire constructed the drain in the first place (1960) and that urbanization has subsequently increased catchment discharge, is only based on the premise that floodplains serve no useful purpose and should be dried out.

There is no guarantee that enlarging the main channel will achieve the desired result of 'drying out' the floodplain, given the hydrologic and geomorphologic characteristics of the area. Nevertheless from a Living Stream perspective, an enlarged channel may be hydraulically advantageous, given ongoing land development in the catchment. Such modifications should be based on reinstating appropriate natural stream form. In that case channel maintenance would be reduced to vegetation management within the floodway and floodplain areas. These assertions must be tested by hydrological modelling rather than by guesswork since the bed gradient is slight along lower reaches of the creek the (approximately 1 metre fall per Kilometre).

Better management practice

Plan and design infrastructure to cope with the inevitable extreme flood event

Detention basins can act like constricted floodplains while alleviating the impact of flooding further afield. They should also be allowed to serve multiple functions wherever possible. For example as vegetative bio-filters to improve water quality, create of bird and animal habitat, protect of remnant bush areas and improve social amenity of the area.



Figure 12: Sediment deposition in Yakamia Creek showing natural channel bank reconfiguration. Photo taken November 2014.

Sediment deposited from frequent moderate sized floods acts to fill in over widened or deepened channels (Figure 12) and the channel is generally reshaped to suit the annual pattern of flood discharge. Straightening and continual excavation of the channel generates an ongoing maintenance war. Over narrowing of the channel leads to increased bed and bank erosion as flows speed up and act to enlarge the cross-sectional area by scouring and undermining banks (Figure 13).

Best management practice

Channel dimensions (cross-sectional area and shape) should be determined on the basis of the hydrology of the catchment and the specific hydraulic conditions for each stream reach.



Figure 13: Neridup Creek near Esperance showing lateral enlargement of the creek channel as a consequence of the absence of stabilizing bank vegetation. Photo by Steve Janicke

Large floods created flood terraces or benches along this channel. Although these are a natural feature of many rivers and streams, removing vegetation accelerates the process considerably. If stabilised with vegetation the naturally enlarged areas can resist further erosion during subsequent floods. Aggressive excavation of the channel also destabilises the friable sandy soil of the bed and banks and sets the scene for further erosion.

A channel enlarged above its natural form may mitigate flooding up to a point, but is not likely to prevent it occurring in low lying areas during the occasional, but inevitable extreme storm events.

Levee banks retain flood waters in the dominant channel, they also retain sediment raising the bed level and decreasing the drainage efficiency of the channel and increasing the risk of flood waters breaching the banks.

Best management practice

Floodway vegetation is managed without unnecessarily disturbing the bed and bank soils.



Figure 14: Yakamia Creek rebuilding channel sinuosity. Photo taken November 2014.

Stream flows will act on a straightened channel to rebuild sinuosity (curvature) and this is characteristic of a more stable channel form (Figure 14).

Armouring the bed and banks may give some longevity to the drain, but poor armouring will eventually be damaged and can aggravate bed and bank erosion.

Better management practice

Where there are signs that the flow is tending to create bends in a channel these should be allowed to form and not be tampered with. Some stabilization of the steeper outside bends may be necessary and the bend can be controlled by removing part of the point bar if excess sedimentation is a problem.



Figure 15: Armoured section of Yakamia channel upstream of the Aquatic Centre (2007).

The sediment plumes evident in Figure 15 show that erosion was still active in the upstream catchment at the time the photo was taken. Mobile sediment is naturally deposited in a way that promotes the creation of meanders into a stream channel.



Figure 16: Erosion on the bank of Yakamia Creek caused by stock accessing the water. Photo taken November 2014.

Stock, like you and I, will choose the easiest access point to a stream. Stock pugging destabilises floodway top-soils and create erosion prone pockets that are easily exploited by the next significant flood flow (Figure 16).

Stock defecating directly into Yakamia Creek is an unacceptable source of water contamination, affecting the health of the stream and Oyster Harbour, as well as that of the stock themselves.

Best management practice

Stock should be kept off the banks and out of the stream channel. If they are allowed access for grass control this should only be for a fixed period of time, sufficient to achieve the aim and it should preferably be done when the ground is dry and firm.



Figure 17: Bank collapse under kikuyu grass after the 2008 flood, Photo courtesy of Wilhelm Ficko

Kikuyu provides reasonable armouring of top soils, but is not as effective at stabilizing the toe of high, steep channel banks and preventing bank collapse (Figure 17). Native plants, such as sedges that can grow in this zone and they do a better job.



Figure 18: The water's edge (toe of the bank) of Yakamia Creek where the banks are steep and collapsing (Section D2.4)

The toe of a stream bank is where stream erosive power is strongly expressed. Less consolidated (soil) banks if undermined, collapse under their own weight. This is a common occurrence along the deeper incised sections of Yakamia Creek where bank height may be two or more metres and the soils are weakly consolidated (Figure 18).

Groundwater seepage from upslope of the channel can promote bank slumping in steeply incised gullies.

Ad hoc dumping of rocks in the channel to deal with erosion hotspots can actually aggravate bank erosion in these situations, by increasing local water turbulence.

Better management practice

Soft engineering is using a variety of plants in appropriate zones of the floodway to create a stable channel without compromising drainage efficiency.

In-stream vegetation slows water flow and raises the water level thereby increasing the risk of flows overtopping the bank however fringing vegetation stabilises the banks and broader floodway by reducing the flow velocity.

Well vegetated streams tend to be narrower, deeper and faster flowing than channels lacking stabilizing vegetation (Figure 19). Streams flowing through poorly consolidated soils will tend to widen and become shallow (Figure 20).

Best management practice

The channel cross-sectional area beneath a crossing should match the average cross-sectional area upstream and downstream. Bridges with an adequate span are favoured over narrow culvert crossings. For this reason the stable cross-sectional area for a stream channel should not be reduced by more than 10% at a crossing.

Along Yakamia Creek, the larger woody weeds currently act to stabilise the floodway adjacent to the dominant channel, in lieu of the original native vegetation (Figure 19).



Figure 19: A well vegetated section of Yakamia Creek, albeit predominantly with weeds. (Photo courtesy of Sheryn Prior).

Better management practice

Replacement of weed species with native plants and any reconfiguration of the floodway cross-section, will be better supported with block sedges. Although more expensive, these have been shown to be effective. (See the Bannister Creek Case Study in Supplement 1)

Erosion control is synonymous with water velocity control. Therefore the layout and physical structure (density, story composition) of riparian buffering vegetation should be designed to accommodate floodwater that moves out of the dominant channel. Care should be taken to avoid concentrating flood flow paths, thereby increasing flow velocities and creating unwanted erosion hotspots.

Aggressive colonizing weeds that produce long lasting seeds (for example Gorse) must be consistently treated for many years if adequate control and eventual eradication is the goal.

Better management practice

Engage a local 'Friends of' group to assist with weed control.



Figure 20: Yakamia Creek, looking upstream at the crossing and widened channel downstream created by turbulence. (2005 flood photo courtesy of Wilhelm Ficko).

Narrowing the channel at crossings decreases construction costs, but it also increases the local flow velocity, creating a turbulent, highly erosive zone immediately downstream of the crossing outlet. In the situation shown in Figure 20, back eddies acting on unstable banks have widened the channel. In the worst case scenario the crossing itself would eventually collapse.

Better management practice

Channel modifications and maintenance works should be subject to the requirements of a ‘whole of stream’ development and maintenance plan.

Landholders who provide gates at property boundaries can help facilitate easy access for more efficient maintenance of the floodway. If a holistic management plan is to be implemented along Yakamia Creek easy access for channel maintenance and weed control is important to reduce maintenance costs (Figure 21).



Figure 21: Boundary gate between two properties adjacent to Yakamia Creek. Photo taken November 2014.

The Western tributaries (Tier 2)

The two short western tributaries of Yakamia Creek currently retain significant areas of remnant bushland although this is being degraded through uncontrolled vehicle use and weed invasion. The public currently access the private land downstream of the constructed wetland bounded by Range Road and Callistemon View (tributary F). The most obvious public use of the area is as a dumping ground for rubbish. However, the tracks are also used as an informal walk trail and the recreational use of motorbikes and 4WD's.

Water flow appears to become noticeably channelized approximately 350 meters downstream of Range Road, however the vegetation is very dense and the channel is narrow and shallow as a result. The riparian zone is broad encompassing wetlands with tracks along the interface between the wet areas and the woodland on the fringing slopes.

The upper reach of tributary G is cleared farmland, but further downstream there are areas of fragmented remnant vegetation. The recommended initial action in these areas will be to fence and re-vegetate the streamline to restore continuity of riparian vegetation. Stock watering points are also recommended.

Recommendation

The Oyster Harbour Catchment Group could consider consultation with landholders regarding weed management and the protection of remnant native vegetation as the immediate priority. As mentioned, the implementation of significant on-ground floodway development projects is premature.



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Please Note:

This is Part B 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

