Possible ecological futures for Merri and Darebin creeks

Christopher J Walsh[1], Nick Bond[2], and Tim D Fletcher[1]

Melbourne Waterway Science-Practice Partnership
[1]Department of Resource Management and Geography, The University of Melbourne
[2]Australian Rivers Institute, Griffith University

Walsh, C.J., Bond, N., and Fletcher, T.D. (2013) *Possible ecological futures for Merri and Darebin creeks.* Melbourne Waterway Science-Practice Partnership, The University of Melbourne. September 2013.

Summary

The expansion of urban development in the northern growth corridor will urbanize most of the catchments of Merri and Darebin creeks, presenting challenges for stream protection. The challenges also present opportunities for effective integrated water management that can address human needs and protect the ecological values of the corridors stream ecosystems.

We used existing distribution models for macroinvertebrate families and fish species, built from the extensive long-term biological monitoring data held by Melbourne Water, to characterize the current condition, and ecological values of the waterways of the corridor. We also used the models to assess the likely changes in those values under a range of management scenarios following the full development of the corridor.

The rural sections of the creeks retain substantial ecological values: while moderately degraded, they comply or nearly comply with State Environmental Protection Policy objectives. The metropolitan reaches of the creeks are severely degraded, and do not comply.

Development of the northern growth corridor using standard urban stormwater management practices (as routinely applied to meet clause 56 of the Sustainable Neighbourhoods Code) will certainly result in the loss of multiple existing values in the Merri and Darebin Creeks, and in Melbourne Water failing to meet its environmental protection obligations, and the objectives of Melbourne Water's Healthy Waterway Strategy.

The currently proposed integrated water management strategy for the corridor greatly increases the risk that urban stormwater will not be able to be adequately retained, treated or released in a flow regime adequate to protect the receiving streams. The risk of loss of values in the creeks under the currently proposed strategy is very high. It also increases the cost and decreases the likelihood of any future restoration of values to the lower Merri and Darebin creeks.

To reduce the risk of loss of values in Merri and Darebin creeks, alternative strategies for urban stormwater management are required in the developing catchments. Standards that have been tested by Melbourne Water and others in the east of Melbourne could be applied in these catchments: application in the Merri and Darebin catchments is technically easier because of the lower rainfall. However, such standards will be substantially more challenging to meet without large demands for harvested water. Adequate infiltration and evapotranspiration losses in the absence of harvesting, will require planning of developments to incorporate very large areas of open space, ideally along drainage lines.

Applying such new standards to a small number of tributaries, to protect those tributaries identified as highest value, will not be adequate to prevent the degradation of the mainstem Merri Creek, which is the primary habitat for valuable frog, fish and macroinvertebrate populations. Attempts to mitigate the catchment-scale impacts through manipulation of channels or the provision of riparian vegetation, are very unlikely to result in any measurable response in stream-dependent values, or in ecosystem services such as nutrient retention, if catchment-scale stormwater management has not been adequately provided.

A review of the economic, hydrologic and ecological analyses that led to the currently proposed, high-risk strategy is recommended.

Introduction

Melbourne Water, in planning for the development of the northern growth corridor of the Melbourne Metropolitan area, is seeking to implement Integrated Water Management (IWM) to deliver multiple benefits, including the protection of the aquatic ecosystems of the corridor. The primary waterways of the corridor are Merri and Darebin creeks.

Melbourne Water's Healthy Waterway Strategy (HWS: Melbourne Water 2012a) seeks to prioritize investment to a) first protect the waterways that are in the best condition; b) restore waterway condition where it can be achieved most efficiently; c) prevent further degradation; d) maintain long-term potential of ecosystem health and; e) address hotspots where current condition poses unacceptable risks to public health, safety or waterway values.

Strongly complementary multiple benefits can be derived from the dispersed retention, harvesting and infiltration of urban stormwater: management activities that are necessary for protection of streams in urban catchments that can also provide benefits of water supply augmentation, urban cooling, and flood mitigation (Walsh, Fletcher & Burns 2012). These multiple benefits have been identified in Melbourne Water's Stormwater Strategy (Melbourne Water 2012b), and point to urban stormwater management as a primary activity that bears upon the objectives of both the Healthy Waterways Strategy and Melbourne Water's strategic goals for IWM.

Melbourne Water, as custodian for Melbourne's waterways, has obligations under the State Environment Protection Policy (SEPP) to meet biological and water quality objectives for the streams and rivers that it manages. Merri and Darebin creeks fall under the Yarra Catchment variation of the policy (Government of Victoria 1999). The SEPP biological objectives equate to two of the waterway values identified by the HWS (macroinvertebrates and fish). Macroinvertebrate assemblage composition, in particular, is a useful indicator of stream condition that provides a strong indication of the likelihood of streams being able to support other stream-dependent values identified by the HWS (platypus and some frog species). In turn, riparian vegetation, which is identified as a separate value by the HWS, is a strong determinant of in-stream condition, including the composition of macroinvertebrate, fish, and frog assemblages, and platypus distributions.

An assessment of possible Melbourne Water investment strategies in these catchments requires first an assessment of the current condition of their waterways to assess a) the extent of current compliance with the SEPP, and b) which of the investment priorities of the HWS the streams of the catchment are likely to fall under. Secondly, predictions are required of how stream condition (including the stream-dependent values of the HWS) and compliance with the SEPP are likely to change under different stream and urban water management scenarios once the corridor is developed.

Melbourne Water has an extensive, long-term dataset of macroinvertebrate and fish records for waterways of the Melbourne Region, including the Merri and Darebin catchments. These datasets provide an important resource with which to make predictions about the consequences of various water and stream management scenarios. Recent research, building on this important dataset, has permitted strong, quantitative predictions of response of stream fauna, including macroinvertebrates (Walsh & Webb 2013), fish (Bond, Walsh & Baggiano 2013), frogs (Canessa & Parris 2013), and platypus (Martin *et al.* 2013), across the Melbourne region to a range of potential management actions. In this report, we use the predictions of these studies to assess current condition of the waterways of the Merri and Darebin catchments, and their compliance with SEPP objectives. We then use the models to predict likely changes to stream condition and compliance under a range of potential management actions.

Methods

State Environment Protection Policy Objectives and their interpretation

The Yarra Catchment variation to the SEPP (Government of Victoria 1999) identifies the following objectives for tributaries of the Yarra River (for Merri and Darebin creeks, as "Western waterways", the objectives for rural and urban streams are identical, except where identified):

- a minimum SIGNAL index score of 5.5;
- a minimum of 20 macroinvertebrate families;
- a minimum 10 (in rural streams) or 12 (in urban streams) families identified as "key";
- presence of blackfish (*Gadopsis marmoratus*), Tupong (*Pseudaphritis urvilli*), Grayling (*Prototroctes maraena*), spotted galaxias (*Galaxias truttaceous*), and common galaxias (*G. maculatus*)

SIGNAL score has been demonstrated to be a strong indicator of human disturbance in the streams of Melbourne (Walsh 2006; Walsh & Webb 2013). However the maximum value of SIGNAL score that is observed in streams unaffected by human impacts varies strongly across the region, with the maximum predicted SIGNAL score for streams of the Merri and Darebin creeks being ~5.8, compared to scores approaching 7 in the higher discharge streams of the east (Walsh & Webb 2013).

This variability is in part controlled for in the SEPP by setting different objectives for eastern and western streams. However, as Darebin and Merri are the two driest subcatchments in the Yarra catchment, achievement of the target SIGNAL score will be more difficult for streams of these catchments than other western catchments. Thus, a small degree of latitude could arguably be given in assessing SIGNAL scores in these catchments.

Walsh & Webb (2013) developed a new index, MELMIF (based on Melbourne Water's macroinvertebrate dataset[1]) which is as strong a predictor of human impact as SIGNAL score, but is formulated so that the maximum score under no human impact is invariant across the region (a maximum value of 1). Arguably, this index could serve as a superior indicator of stream condition across the region. We present MELMIF scores in addition to SIGNAL scores, and discuss an appropriate MELMIF score for compliance.

The models of Walsh & Webb (2013) permit prediction of the number of families at each reach of the region (accounting for climatic and physiographic variation). They classified families as sensitive (i.e. showed a negative response to at least one of urban stormwater runoff or land clearance) or weedy (i.e. showed a positive response to human disturbance), with the sensitive families corresponding closely to those listed as "key" by the SEPP. We thus use the predictions of Walsh & Webb (2013) to estimate compliance with SIGNAL score and number of families (total and key).

[1] For further details on Melbourne Water's macroinvertebrate database, and the reliability of the models derived from it that are used in this report, see Walsh & Webb (2013)

We use the models developed by Bond *et al*. (2013) to predict the presence of fish species identified as objectives by the SEPP.

We do not make formal quantitative predictions of frog and platypus distributions, but use the conclusions of Canessa & Parris (2013) and Martin *et al*. (2013) in combination with conclusions from the fish and macroinvertebrate models to infer likely responses.

Prediction of response under alternative management scenarios

We concentrate on the likely effect of two primary potential management actions. Firstly we simulate the application of new stormwater management standards proposed by Walsh *et al*. (2012) across the region by setting attenuated imperviousness (AI: Walsh & Kunapo 2009) to zero. AI is an estimate of the proportion of a catchment covered by impervious surfaces with direct drainage connection to the receiving stream. To reduce the AI of an impervious surface to zero requires reduction of days of direct runoff from the surface to a small number of days per year, and the restoration of high quality filtered baseflows delivered in an appropriate flow regime to the stream. *The achievement of these objectives is likely to be extremely difficult without harvesting a large proportion of the impervious runoff in catchments* (Walsh *et al*. 2013).

Current urban stormwater practice, including common practices that meet the best practice environmental management guidelines (Victoria Stormwater Committee 1999), are not considered to alter AI. The most common current practices are guided by the guideline's loads objectives, which do not adequately alter the changes to untreated high-flow frequency (i.e. the frequency of disturbance events which combine hydraulic stress and increased pollutant concentrations), or reduced dry-weather quantity and quality (Burns *et al.* 2012). Furthermore, there is no evidence that the common approaches taken to reduction of pollutant loads to meet the objectives of these guidelines has resulted in any positive stream response across the region (Walsh 2004; Webb & King 2009).

Secondly, we model the effect of riparian forestation as a management activity to protect or restore stream ecosystems. The models of Walsh & Webb (2013) and Bond *et al*. (2013) use a measure of forest cover that weights forest by its distance upslope from and along the stream, so that almost all of the effect of catchment cover is explained by forest within 100 m of the stream, and 2-3 km upstream. While much of the Merri and Darebin catchments were likely to be grassland historically, the riparian zones of the streams were likely to be river red gum (*Eucalyptus camaldulensis*) woodland, which we believe would be adequately modeled by the attenuated forest cover measure of our source studies.

We modeled the effect of planting of riparian woodland along the catchment's streams in 20-, 40- and 100-m-wide buffers, by drawing hypothesized riparian buffers and recalculating attenuated forest cover. Note that these simulations assume continuous riparian cover upstream, and do not simulate revegetation projects that cover a limited length of stream.

We do not model the effect of local-scale channel works for provision of habitat. Walsh & Webb (2013) showed that the effect of addition of riffles made little-to-no difference to the predictions of macroinvertebrate response. This conclusion was consistent with the growing number of studies that have demonstrated little or no change in ecological structure or function resulting from channel restoration, particularly in circumstances where larger scale impacts (such as urban stormwater runoff) limit the potential for response (Bernhardt & Palmer 2011; Sudduth *et al.* 2011; Violin *et al.* 2011; Webb *et al.* in review).

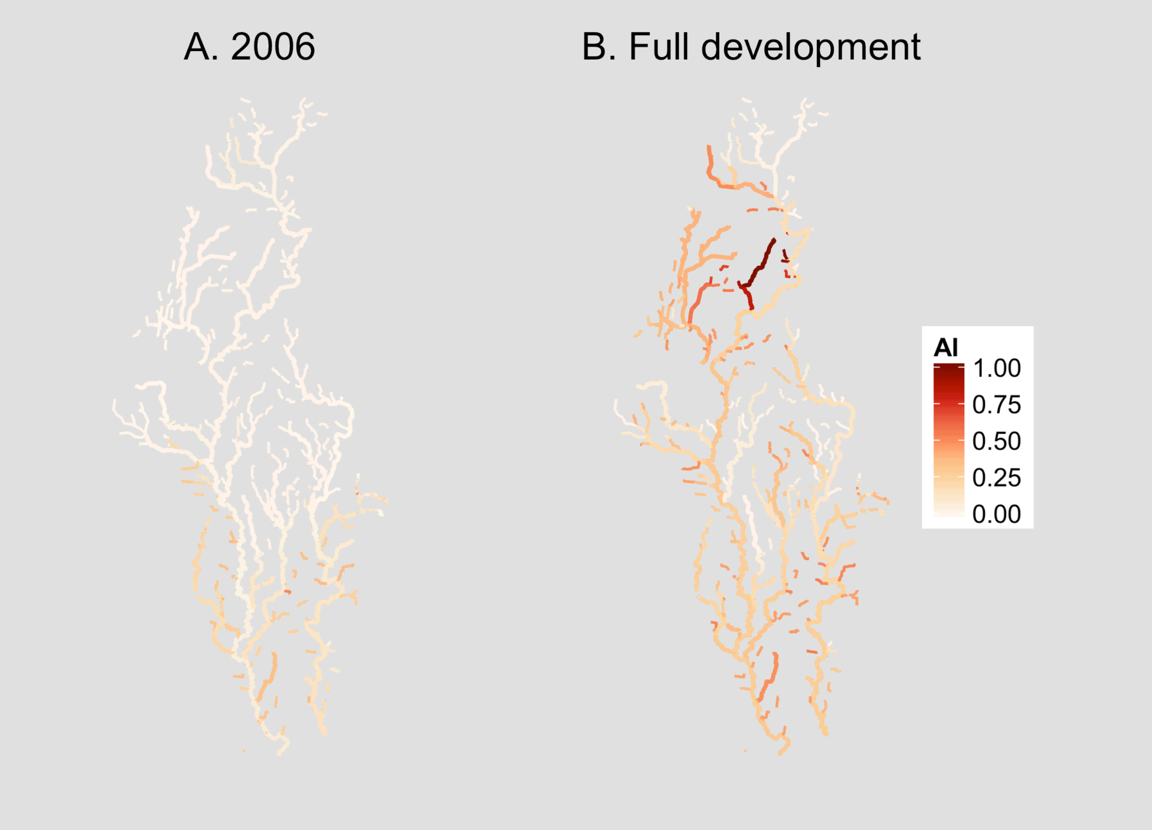

Fig. 1. Attenuated imperviousness A. calculated from 2006 aerial imagery (source: Grace Detailed-GIS Services 2012), and B. calculated using infill and urban expansion projections, assuming that all new impervious surfaces will be connected to streams. The thinner dashed lines are drainage lines with catchment areas of 1-5 km^2, which are excluded from subsequent maps in this report.

Future land use change

The predicted change resulting from urban expansion and infill under existing stormwater management practices was simulated by using Melbourne Water's projections for increases in total impervious area in existing urban areas, and areas zoned for future development under the urban growth boundary designated in 2012 (Fig. 1). Our estimates of future impervious coverage might differ from those being used by Melbourne Water currently. We could re-run the scenarios with revised coverage estimates, if required.

Under the assumption of current stormwater management practices, all new increases to impervious area were assumed to equal increases in AI. Under the assumption of the application of new standards all new on existing AI was set to zero. Although existing developments will not meet such objectives immediately, the application of standards for redevelopment could see the gradual removal of all AI over coming decades. Melbourne Water (Rossrakesh *et al.* 2012) undertook testing of the feasibility and cost of applying such standards to new developments and building extensions. Even in the high-rainfall eastern suburbs that are wetter, with soils of very low infiltration capacity, making the retention of stormwater in catchments more challenging than in the Merri and Darebin catchments, they found that the flow and water quality regime could be returned to that similar to a zero AI state at reasonable costs.

The stream network

To portray our predictions, we use the stream network associated with the directly connected imperviousness layer used by Melbourne Water (Grace Detailed-GIS Services 2012). This network includes all drainage lines with catchment areas >1 km^2. In the Merri and Darebin catchments, such small drainage lines are unlikely to be too small to be adequately modeled by the source studies, and are not illustrated, other than in Fig. 1. In the metropolitan area, such drainage lines have been converted to buried stormwater drains. In as yet undeveloped areas the implementation of stormwater management standards for stream protection (as described above) would almost certainly require such drainage lines to be reserved as public open space to permit adequate evapotranspiration and infiltration. The mapping and classification of such small drainage lines is the subject of a proposed MW Science-Practice partnership project, as is the question of their hydrologic and ecological importance across the Melbourne Water region.

Results

2006 conditions

In 2006, the stream network outside the metropolitan area largely complied with SEPP objective for macroinvertebrate assemblage composition. The number of sensitive families predicted in samples from all reaches upstream of the metropolitan area was ≥20 (Fig. 2A), suggesting consistent compliance with the objectives for both total number of families (20) and "key" families (10 or 12: these families dominate the list of families classed as sensitive by Walsh & Webb (2013)). SIGNAL score was predicted to be >5.4 in most reaches upstream of the metropolitan area, with the exception of reaches of Merri Creek between Kalkallo Creek and Wallan, where SIGNAL score was more typically 5.3 (Fig 2B). Given the dry nature of these catchments, and the coarse nature of the SEPP objectives for SIGNAL, it could be argued that these reaches adequately comply with SEPP objectives.

MELMIF scores suggested a more uniform condition among rural reaches of the streams, except for the upper reaches of Taylors Creek, west of Wallan, which are predicted to be

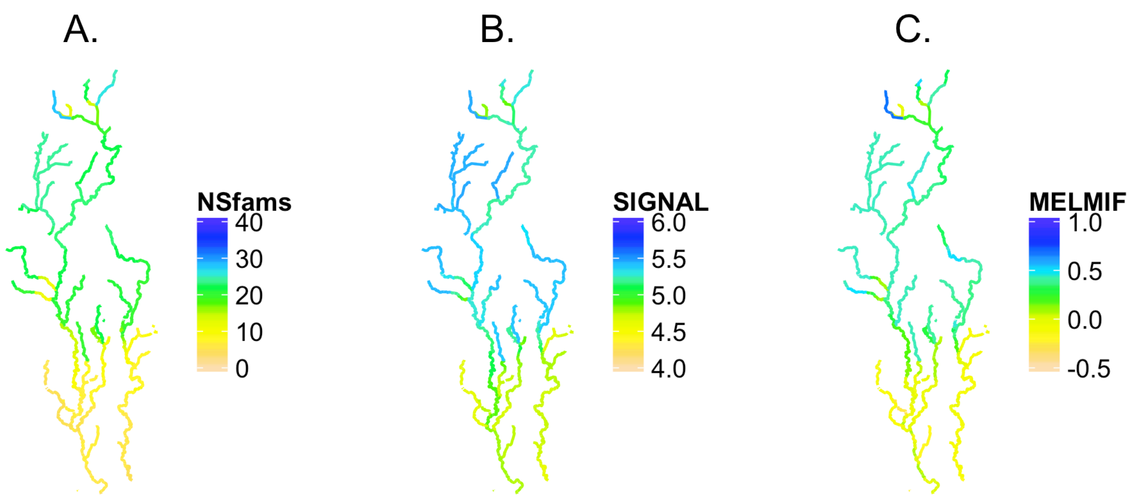

Fig. 2. Predicted measures of macroinvertebrate assemblage composition under 2006 conditions. A. Number of sensitive families (in a pair of standard samples); B. SIGNAL score; C. MELMIF score.

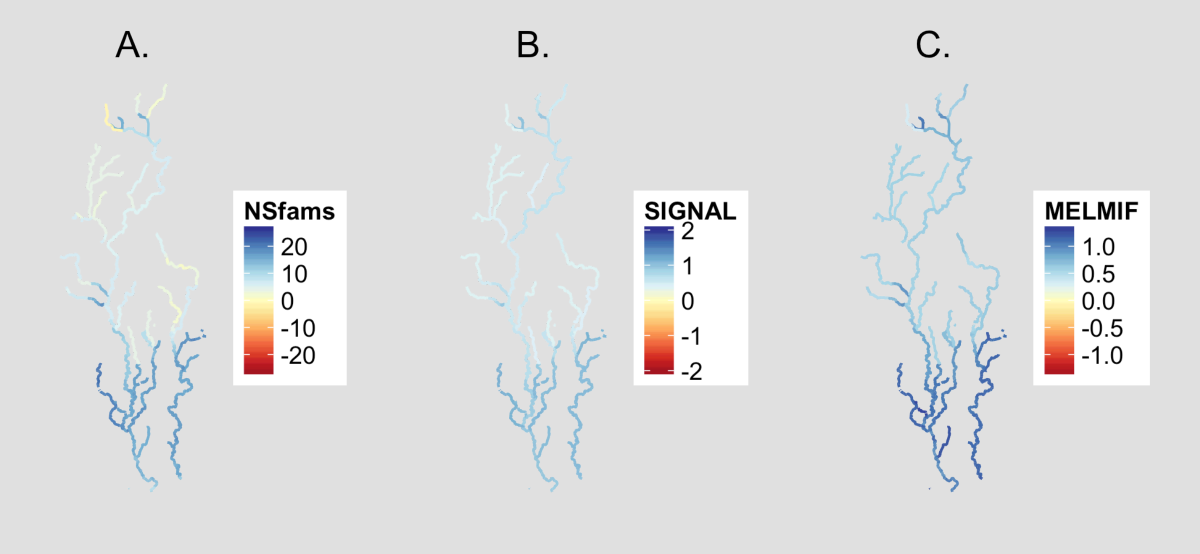

Fig. 3. Difference in predicted measures of macroinvertebrate assemblage composition in the absence of human impacts compared to 2006 conditions. A. Number of sensitive families (in a pair of standard samples); B. SIGNAL score; C. MELMIF score. Deeper blue shades signify that more families are predicted to occur in the absence of human impacts than are collected under 2006 conditions.

in substantially better condition than other reaches in the catchments (Fig. 2C). The distribution of MELMIF scores among the rural segments of the catchment suggests a MELMIF score of 0.4 is an appropriate target (met by most rural reaches) to comply with SEPP objectives.

Despite meeting SEPP objectives, the rural reaches of the catchments supported fewer sensitive families than are predicted to have occurred in the Merri and Darebin systems in the absence of human impacts (Fig. 3). The number of families absent from these reaches that would be expected in the absence of human impacts is relatively small (<10, Fig. 3A), and this is reflected in the small differences predicted in SIGNAL scores between 2006 and no-human-impact predictions (Fig. 3B).

In contrast, predicted MELMIF scores in 2006 were substantially lower than those predicted in the absence of human impacts (Fig. 3C). This is because of the weighting scheme applied by MELMIF, which gives greater weight to families rarely collected under current conditions, but predicted to inhabit these streams in the absence of human impacts.

For instance, the difference in MELMIF scores in the reaches of Merri Creek from Kalkallo to the Lockerbie North drain between 2006 (~0.44) and in the absence of human impacts (1.0) is explained by the rarity under current conditions of a number of families (Gripopterygidae stoneflies, Leptophlebiidae mayflies, Hydrobiosidae and Calamoceratidae caddis-flies, Podonominae and Tanypodinae midges, Ceratopogonidae and Tipulidae flies, Elmidae beetles) that are predicted to have occurred commonly in these streams in the absence of human impacts. The common occurrence of the invasive snail, *Physa acuta*, also contributes to the difference in MELMIF, as unexpected weedy families, such as Physidae, are weighted negatively in its formulation.

Thus, although the rural reaches of Merri and Darebin Creeks retain macroinvertebrate assemblages of value that require protection, they are demonstrably moderately degraded.

Reaches within the metropolitan area were substantially more degraded again, consistently failing to meet any of the SEPP objectives for macroinvertebrates. The very low scores for MELMIF scores in these reaches (Fig. 2C, 3C) were driven by the absence of most sensitive families and the common occurrence of several weedy families.

Of the five fish species identified as objectives for Yarra tributaries in the SEPP, four (spotted galaxias, blackfish, tupong, and grayling) occur rarely in the Melbourne Water data. Tupong were too rare to allow a predictive model at all, while the models for spotted galaxias, blackfish and grayling predict low probabilities of occurrence in Merri and Darebin creeks under both current and possible future scenarios. However, blackfish were collected in 2001 and 2009 in the upper reaches of Merri Creek, suggesting a small, vulnerable extant population of this species isolated from other blackfish populations by the degraded reaches of the lowland Merri Creek.

Common galaxias is commonly collected in the lowland metropolitan reaches of both Merri and Darebin Creeks, and is less commonly collected in the rural reaches of the streams (Fig. 4A). Its more common occurrence in degraded metropolitan streams suggests that it is not an appropriate indicator species for the SEPP.

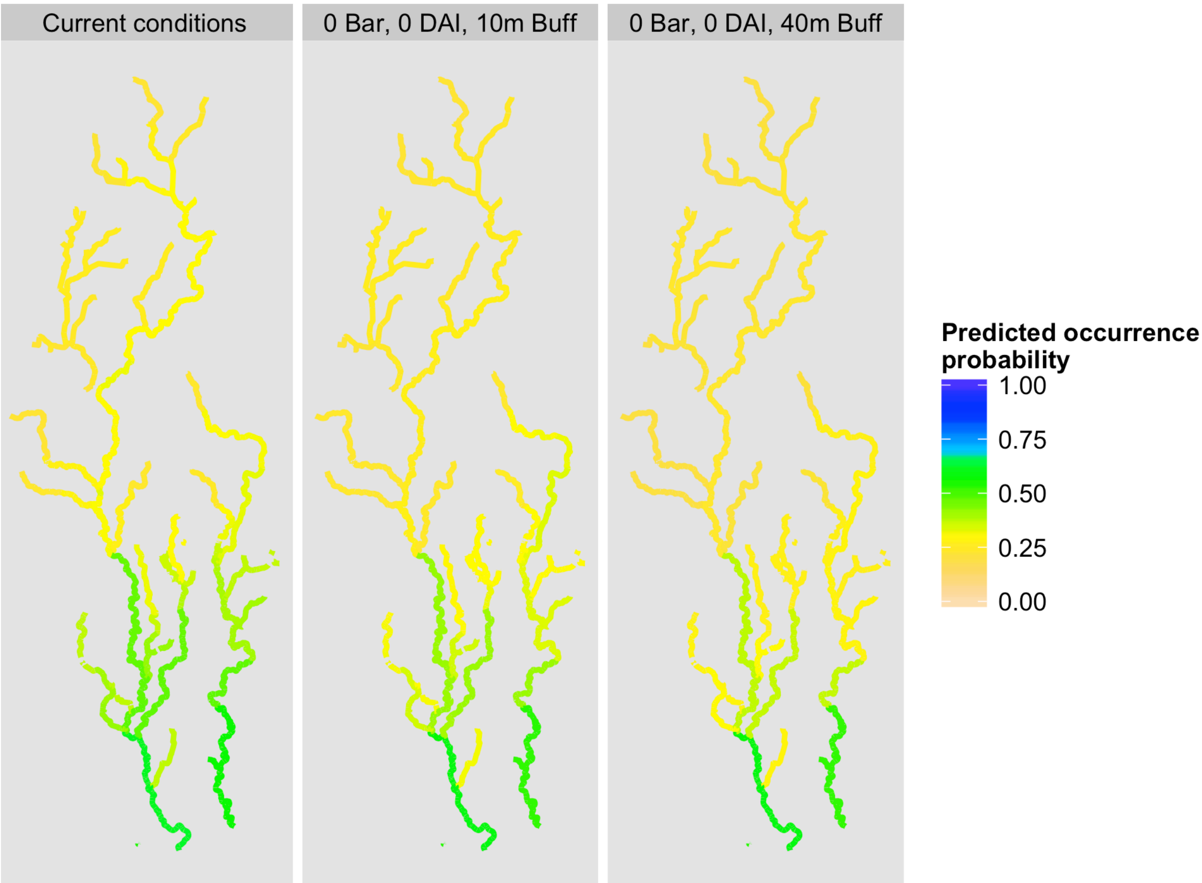

Fig. 4. Predicted probability of occurrence of common galaxias, *Galaxias maculatus*, under 2006 conditions (current conditions), and assuming no barriers to migration (0 Bar), no stormwater impacts (0 DAI) and with vegetated riparian zones of 10-m width (10m Buff) and 20-m (20m Buff).

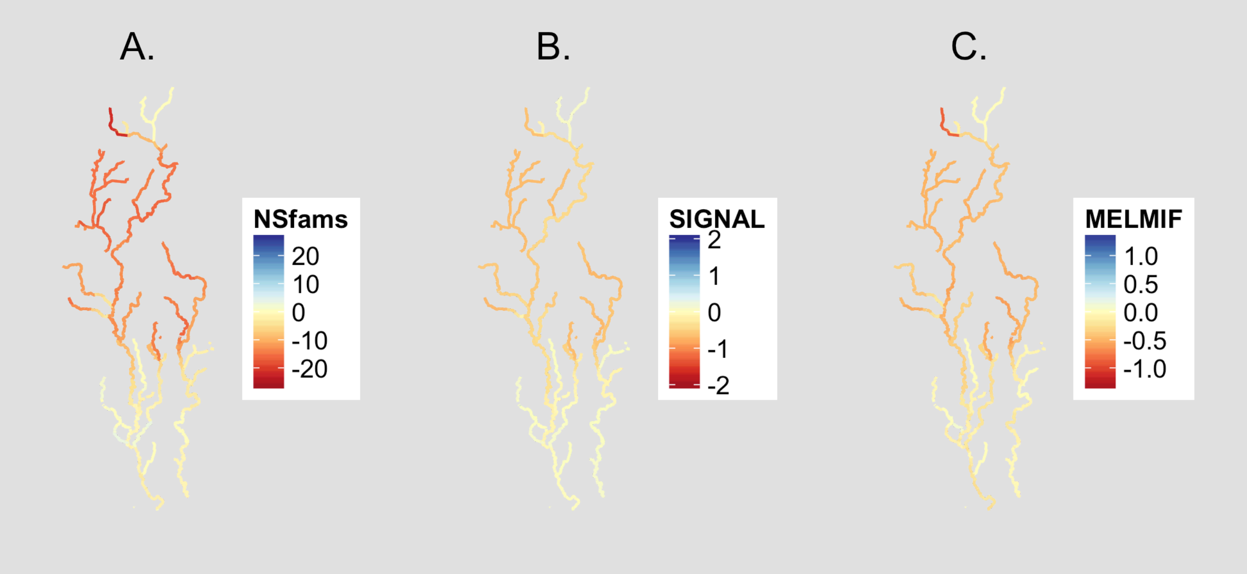

Fig. 5. Difference in predicted measures of macroinvertebrate assemblage composition following development of the northern growth corridor, assuming current stormwater management practices, compared to 2006 conditions. A. Number of sensitive families (in a pair of standard samples); B. SIGNAL score; C. MELMIF score. Deeper red shades signify that more families that occurred commonly in 2006 are predicted to be absent after development.

Future scenarios

If the northern growth corridor is developed using standard stormwater management practices, the currently rural reaches of the Merri and Darebin creeks will be severely degraded, to a similar level of degradation that is observed in metropolitan reaches of the creeks today (Fig. 5). Typically, this will result in the loss of 10–20 sensitive families, and an increase in the occurrence of weedy families.

Families currently collected commonly in these reaches that will certainly be lost or become substantially rarer under such a scenario include Baetidae and Caenidae mayflies, Hydropsychidae, Hydroptilidae, Ecnomidae and Leptoceridae caddis-flies, Gyrinidae and Hydrophilidae beetles, Corydalidae dobsonflies, Simuliidae blackflies, Aeshnidae dragonflies, Planorbidae snails, Chiltonidae amphipods, Atyidae shrimp. Such a scenario would also likely see the increased occurrence of weedy families such as Glossiphonidae leeches and Notonectidae (true) bugs.

Such a significant degradation of macroinvertebrate assemblage composition would certainly ensure the loss of any remaining blackfish population in Merri Creek.

With this dramatic loss of biodiversity, no reaches in either catchment would continue to meet SEPP objectives under such a scenario.

The severe impacts of urban stormwater runoff on the waterways of the Darebin and Merri catchments would not be significantly mitigated by local-scale remediation. The predicted loss of families following development of the catchment with standard stormwater management but with woodland riparian buffers of 40 m width along all drainage lines of the catchments is very similar to the predicted loss without such a large streamside intervention (Fig. 6).

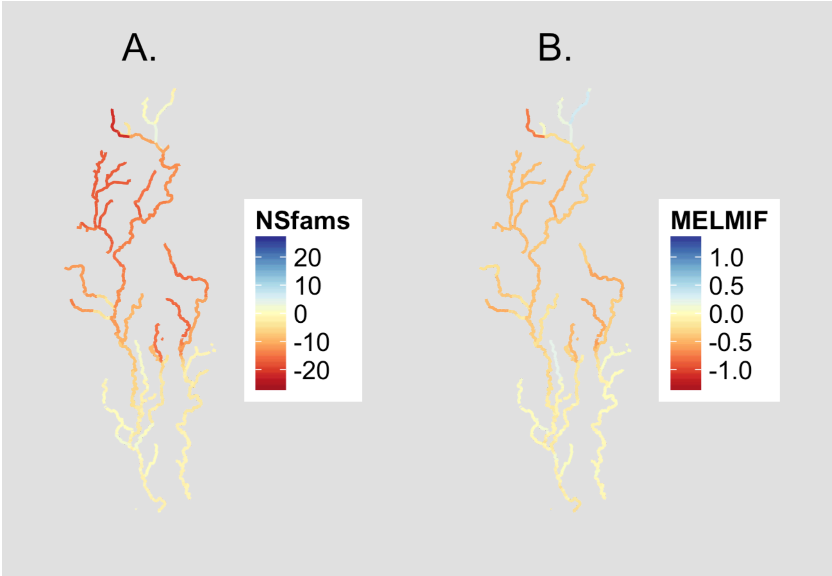

Fig. 6. Difference in predicted measures of macroinvertebrate assemblage composition following development of the northern growth corridor, assuming current stormwater management practices, but with 40-m wide vegetated buffers along all streams, compared to 2006 conditions. A. Number of sensitive families (in a pair of standard samples); B. MELMIF score.

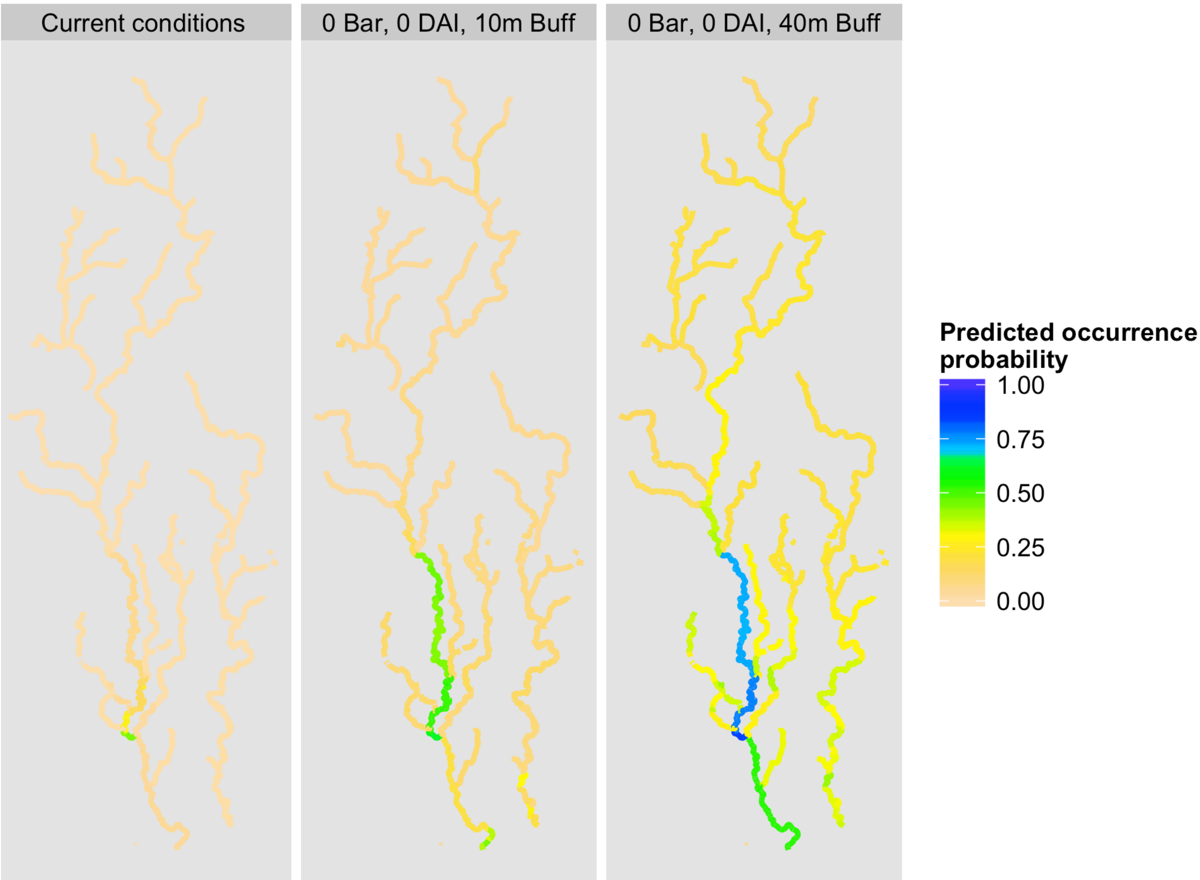

Fig. 7. Predicted probability of occurrence of broad-finned galaxias, *Galaxias brevipennis*, under 2006 conditions (current conditions), and assuming no barriers to migration (0 Bar), no stormwater impacts (0 DAI) and with vegetated riparian zones of 10-m width (10m Buff) and 20-m (20m Buff).

However, the combination of adequate stormwater retention applied throughout the catchment, combined with provision of woodland buffers is likely to result in a substantial improvement in macroinvertebrate richness (potentially a response as portrayed in Fig. 3). Such a future is also likely to encourage the recovery of native fish species such as broad-finned galaxias (Fig. 7) and Australian smelt (Fig. 8).

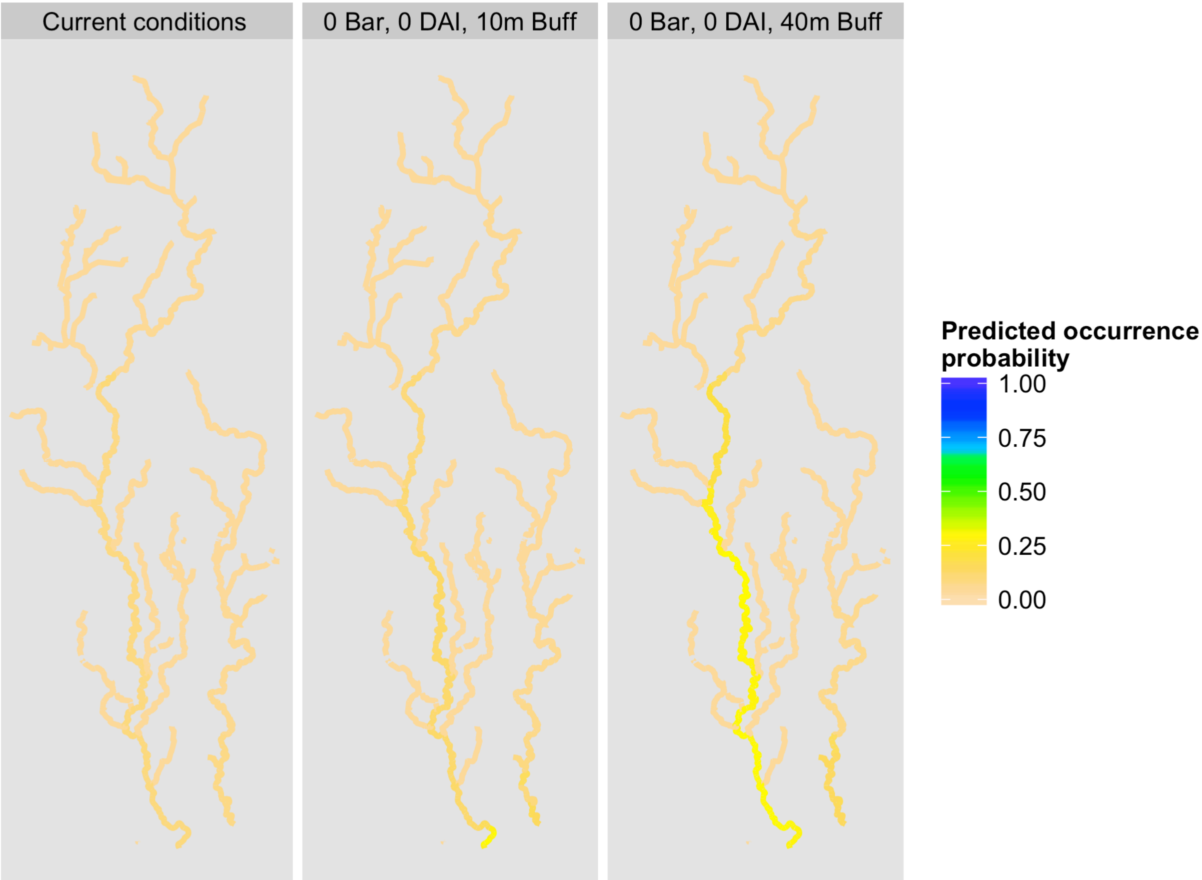

Fig. 8. Predicted probability of occurrence of Australian smelt, *Retropinna semoni*, under 2006 conditions (current conditions), and assuming no barriers to migration (0 Bar), no stormwater impacts (0 DAI) and with vegetated riparian zones of 10-m width (10m Buff) and 20-m (20m Buff).

Discussion

Ecological values of Merri and Darebin creeks

None of the reaches of the Merri or Darebin creeks is in excellent ecological condition, indicating that these streams do not fall under the highest 'protect the best' priority for investment identified by the HWS (Melbourne Water 2012a). However, the compliance or near-compliance of rural segments of the Merri and Darebin Creeks suggests they currently retain ecological values worthy of protection. Certainly, in addition to obligations under the SEPP, the investment priority to 'prevent further degradation' is relevant, in light of the clear and serious threat posed by standard stormwater practices being applied in the new developments of the catchment. The protection of these reaches would also be consistent with the strong community support for protection of biodiversity as a priority for Melbourne Water (The Klein Partnership 2012).

The large number of families predicted to be lost if the corridor is developed with standard stormwater practices equates to tens of species, and represents a fundamental shift in ecological structure and function that has already been observed in streams subject to urban stormwater impacts, both in the downstream reaches of the study streams and in streams worldwide (Walsh *et al.* 2005). Such a shift would certainly entrain the loss of other values and services provided by the rural reaches of these creeks in their current condition.

The responses of large, mobile species such as fish and platypus to catchment impacts are more challenging to model (Martin *et al.* 2013), making them less easy-to-interpret indicators of stream condition. The absence of species such as platypus, grayling, and spotted galaxias from less degraded upland reaches of Merri and Darebin creeks is likely at least in part a result of the isolation of these relatively small areas of potentially suitable stream habitat from their source populations by degraded metropolitan reaches. For this reason, any remaining small population of river blackfish in the upper Merri is vulnerable as a result of isolation, and seriously threatened by the likely degradation of the upper reaches of the creek. Their complete absence from sites subject to even small amounts of conventional urban stormwater drainage (Danger & Walsh 2008) suggests a very high risk of the loss of this species if the catchment is developed with current stormwater management practice.

In addition to the evidence presented here for the ecological values of the creeks, indicated by their macroinvertebrate and fish assemblages, Canessa & Parris (2013) demonstrated high stream-dependent frog diversity along the rural reaches of Merri Creek, with declining species richness in metropolitan reaches. Their models suggested that the driver of the loss of frog species was degradation of the aquatic vegetation community along the stream, which they found was driven primarily by urban stormwater runoff. This decline in frog diversity driven by urban stormwater runoff is of even greater concern because the frog assemblage of Merri Creek includes the endangered growling grass frog of national significance (Hale *et al.* 2013).

Platypus are no longer resident in Merri or Darebin creek, despite large populations having once inhabited both creeks (Serena & Williams 2008). The large Merri and Darebin platypus populations were extirpated during the 20th century, likely in large part as a result of degradation of the lowland reaches of the creeks resulting from urban stormwater runoff (Martin *et al.* 2013).

Our models show a strong relationship between multiple elements of stream ecosystems and attenuated imperviousness, but a consistently less strong relationship with total imperviousness, suggesting that catchment urbanization per se is not the factor limiting the condition of streams such as Merri and Darebin creeks, but urban stormwater run-off is. Thus a long-term goal of protecting the upper, currently rural reaches of these creeks, and of restoring ecological structure and function to currently degraded reaches is possible, with a universal shift in urban stormwater management as the urban fabric is renewed over future decades, and with careful management of riparian zones.

Such a long-term restoration vision, consistent with current concepts of ecologically successful restoration (Palmer *et al.* 2005), and with the investment priority of the HWS *to maintain long-term potential of ecosystem health* (Melbourne Water 2012a), could conceivably include the return of platypus to these streams, as they, too, are likely limited by urban stormwater runoff more than by catchment urbanization (Martin *et al.* 2013).

However, such potential for long-term protection and restoration will certainly be lost without universal application of new standards for urban stormwater runoff for stream protection, such as those implemented recently in a new planning scheme by the Yarra Ranges Council (Rossrakesh *et al.* 2012).

The loss of ecological values in rural reaches of both catchments resulting from urban stormwater impacts can be predicted with a high degree of certainty (on the basis of models used in this study, and the extensive global literature that has shown degradattion fesulting form urban stormwater runoff in cities around the world: Walsh *et al.* 2005; Wenger *et al.* 2009). However, the extent to which urban stormwater needs to be retained and treated, and stormwater flow and water quality regimes need to resemble pre-urban flow and water regimes, to achieve protection of stream values, is less certain.

Wilson *et al*. (2013) speculated that stream health in the northern growth corridor could be protected by dispersed bioretention systems alone, without the need for harvesting. This conclusion is very unlikely to be correct, for a number of reasons.

Firstly, they used an analysis of the Surrey River catchment in southwest Victoria to determine the natural pre-development *surface runoff frequency* of the catchment, concluding that surface runoff would likely have occurred on ~35 days/year. It is almost certain that this analysis is flawed, because it used the frequency of *hydrological response* (which primarily represents subsurface processes such as throughflow), rather than the *frequency of pervious area surface runoff,* which provides a suitable target for *impervious runoff frequency* (Walsh, Fletcher & Ladson 2005; Walsh, Fletcher & Ladson 2009; Burns *et al.* 2013). Most rises in stream flow in streams such as the Surrey River in response to rainfall result from subsurface flows through catchment soils, which provides substantial attenuation and infiltration. Such subsurface flows do not result in significant disturbance to streams. In contrast, impervious runoff delivered through sealed stormwater drainage systems results in much larger peak flows, much faster rise and decline of flow in each event, and the delivery of manifold pollutants to the stream. Their conflation of streamflow response following rainfall with surface runoff led them to infer a target reduction for impervious runoff frequency that is likely to be inadequate to protect the condition of these streams: such a frequency of disturbance is an order of magnitude greater than the frequency of surface runoff events that the streams currently experience (Hill, Mein & Siriwardena 1998). The likelihood of effective protection of stream ecosystems will be greatest if the frequency of runoff from catchment impervious surfaces can be reduced to the lowest possible level.

Secondly, effective stormwater management for stream protection requires consideration not only of runoff frequency, but also the restoration of appropriate pattern and quality of filtered flows to streams (Walsh, Fletcher & Burns 2012). In highly seasonal and ephemeral streams, such of those of the Merri and Darebin catchments, reliance on infiltration systems without reducing the large increase in total runoff, will likely result in increased perenniality, which will change the nature of the streams, particularly for fauna such as frogs that rely on the lotic nature of many of the creek's pools.

Thirdly, Wilson *et al*. (2013) hypothesise that evapotranspiration from biofiltration systems as a means of adequately reducing runoff volume, having identified that infiltration rates in the northern urban growth area are very low. However, extensive field measurement of the relative contributions of infiltration and evapotranspiration in impermeable has been undertaken by Hamel and others (Hamel *et al.* 2012; Hamel & Fletcher 2013; Hamel *et al.* in press), with evapotranspiration being shown to play only a very minor role in the water balance. For example, a biofiltration system making up 3% of its impervious area (considerably bigger than typical current practice) would likely lose no more than 3% of inflow to evapotranspiration, even taking into account exfiltration and subsequent evapotranspiration by surrounding vegetation.

Fourthly, as Wilson *et al*. (2013) identify, the soils of the northern growth corridor make infiltration difficult, increasing the likelihood that meeting appropriate hydrological targets to protect streams will require harvesting.

Lastly, all peer-reviewed studies that have assessed the feasibility of strategies for meeting pre-development flow frequencies and water quality have identified that such targets cannot be achieved without significant rainwater or stormwater harvesting (Mitchell *et al.* 2006; Burns *et al.* 2012; Poelsma, Fletcher & Burns 2013; Burns *et al.* in review). In short, the suggestion by Wilson *et al.* (2013) that significant rainwater or stormwater harvesting is not necessary to protect waterway health is flawed both conceptually and in its modeling approach.

There is thus an urgent need to critically assess the risk of potential IWM strategies to the receiving streams of these catchments. The current proposed IWM strategy for the northern growth corridor, by minimizing the potential for reducing the volume of urban stormwater runoff—the primary degrader of Melbourne's stream ecosystems—in preference to augmentation of the water supply through wastewater recycling, greatly increases the difficulty of adequately retaining, treating and releasing urban stormwater in an appropriate flow regime to protect stream ecosystems.

The current strategy, by not having adequately assessed the threat posed by urban stormwater runoff, increases the risk of losing multiple existing values in the Merri and Darebin Creeks, and of Melbourne Water failing to meet environmental protection obligations, to almost certain. It also defers, increases the cost, and decreases the likelihood of any future restoration of values to the lower Merri and Darebin creeks.

Applying new standards, as we propose in this report, to a small number of tributaries to protect those tributaries identified as highest value will not be adequate to prevent the degradation of the mainstem Merri Creek, which is the primary habitat for valuable frog, fish and macroinvertebrate populations. Attempts to mitigate the catchment-scale impacts through manipulation of channels or the provision of riparian vegetation, are unlikely to result in any measurable response in the values considered in this report, or in ecosystem services such as nutrient retention if catchment-scale stormwater management has not been adequately provided (Bernhardt & Palmer 2011; Sudduth *et al.* 2011; Violin *et al.* 2011; Palmer, Filoso & Fanelli 2013; Webb *et al.* in review).

To reduce the risk of loss of values in Merri and Darebin creeks, new strategies for urban stormwater management are required in the developing catchments. The standards applied in the east of Melbourne (Rossrakesh et al., 2013) could be applied (quite likely more easily from a technical point of view because of the lower rainfall), but will be substantially more challenging without large demands for harvested water. Adequate infiltration and evapotranspiration losses, in the absence of harvesting, will require planning of developments to incorporate very large areas of open space, ideally along drainage lines.

However, we urge a review of the economic, social, hydrologic and ecological analyses that led to the currently proposed, high-risk strategy.

References

Bernhardt, E.S. & Palmer, M.A. (2011) River restoration: the fuzzy logic of repairing reaches to reverse catchment scale degradation. *Ecological Applications,* **21,** 1926–1931.

Bond, N., Walsh, C.J. & Baggiano, O. (2013) Modelling fish distributions across an urban gradient to inform natural resource management. Griffith University, Brisbane, and the University of Melbourne, Melbourne.

Burns, M.J., Fletcher, T.D., Ladson, A.R. & Walsh, C.J. (in review) Flow-regime management at the urban land-parcel scale: a test of feasibility. *Journal of Hydrological Engineering*.

Burns, M.J., Fletcher, T.D., Walsh, C.J., Ladson, A.R. & Hatt, B. (2013) Setting objectives for hydrologic restoration: from site-scale to catchment-scale *(Objectifs de restauration hydrologique : de l'échelle de la parcelle à celle du bassin versant)*. *Novatech* (eds J.-L. Bertrand-Krajewski & T. Fletcher). GRAIE, Lyon, France.

Burns, M.J., Fletcher, T.D., Walsh, C.J., Ladson, A.R. & Hatt, B.E. (2012) Hydrologic shortcomings of conventional urban stormwater management and opportunities for reform. *Landscape and Urban Planning,* **105,** 230–240.

Canessa, S. & Parris, K.M. (2013) Multi-Scale, Direct and Indirect Effects of the Urban Stream Syndrome on Amphibian Communities in Streams. *PLoS ONE,* **8,** e70262.

Danger, A. & Walsh, C.J. (2008) Management options for conserving and restoring fauna and other ecological values of urban streams in the Melbourne Water region. Department of Resource Management and Geography, The University of Melbourne, Melbourne.

Government of Victoria (1999) Variation to state environment protection policy (Waters of Victoria): insertion of Schedule F7, Waters of the Yarra Catchment. The Craftsman Press, Melbourne, Australia.

Grace Detailed-GIS Services (2012) Directly connected imperviousness compilation for Melbourne Water selected catchments.

Hale, J.M., Heard, G.W., Smith, K.L., Parris, K.M., Austin, J.J., Kearney, M. & Melville, J. (2013) Structure and fragmentation of growling grass frog metapopulations. *Conservation Genetics***,** in press.

Hamel, P. & Fletcher, T.D. (2013) The impact of stormwater source-control strategies on the (low) flow regime of urban catchments *Novatech* (eds J.-L. Bertrand-Krajewski & T. Fletcher). GRAIE, Lyon, France.

Hamel, P., Fletcher, T.D., Daly, E. & Beringer, J. (2012) Water retention by raingardens: implications for local-scale soil moisture and water fluxes. *7th International Conference on Water Sensitive Urban Design* (eds T.H.F. Wong & D.T. McCarthy). Engineeers Australia, Melbourne Australia.

Hamel, P., Fletcher, T.D., Walsh, C.J., Beringer, J. & Plessis, E. (in press) Water balance of infiltration systems in relation to their operating environment. *Water Science and Technology*.

Hill, P., Mein, R. & Siriwardena, L. (1998) How much rainfall becomes runoff? Loss modelling for flood estimation. Cooperative Research Centre for Catchment Hydrology, Melbourne, Australia.

Martin, E.H., Walsh, C.J., Serena, M. & Webb, J.A. (2013) Urban stormwater runoff limits distribution of platypus. *Austral Ecology,* **38,** DOI: 10.1111/aec.12083.

Melbourne Water (2012a) Draft Healthy Waterways Strategy. A Melbourne Water strategy for managing rivers, estuaries and wetlands. Melbourne Water, Melbourne.

Melbourne Water (2012b) Draft Stormwater Strategy. A Melbourne Water strategy for managing urban and rural runoff. Melbourne Water, Melbourne.

Mitchell, V.G., Hatt, B.E., Deletic, A., Fletcher, T.D., McCarthy, D.T. & Magyar, M. (2006) Integrated stormwater treatment and harvesting: technical guidance report. Institute for Sustainable Water Resources, Monash University, Melbourne.

Palmer, M.A., Bernhardt, E.S., Allan, J.D., Lake, P.S., Alexander, G., Brooks, S., Carr, J., Clayton, S., Dahm, C.N., Follstad Shah, J., Galat, D.L., Loss, S.G., Goodwin, P., Hart, D.D., Hassett, B., Jenkinson, R., Kondolf, G.M., Lave, R., Meyer, J.L., O'Donnell, T.K., Pagano, L. & Sudduth, E. (2005) Standards for ecologically successful river restoration. *Journal of Applied Ecology,* **42,** 208–217.

Palmer, M.A., Filoso, S. & Fanelli, R.M. (2013) From ecosystems to ecosystem services: Stream restoration as ecological engineering. *Ecological Engineering***,** in press.

Poelsma, P.J., Fletcher, T.D. & Burns, M.J. (2013) Restoring natural flow regimes: the importance of multiple scales *(La restauration d'un régime d'écoulement naturel : la mise en oeuvre à plusieurs échelles)*. *Novatech* (eds J.-L. Bertrand-Krajewski & T. Fletcher). GRAIE, Lyon, France.

Rossrakesh, S., Walsh, C.J., Fletcher, T.D., Matic, V., Bos, D. & Burns, M.J. (2012) Ensuring protection of Little Stringybark Creek: evidence for a proposed design standard for new developments. Melbourne Waterway Protection and Restoration Science-Practice Partnership, The University of Melbourne, Melbourne.

Serena, M. & Williams, G.A. (2008) Distribution and management of platypus in the greater Melbourne region. Australian Platypus Conservancy, Melbourne.

Sudduth, E.B., Hassett, B.A., Cada, P. & Bernhardt, E.S. (2011) Testing the Field of Dreams Hypothesis: functional responses to urbanization and restoration in stream ecosystems. *Ecological Applications,* **21,** 1972–1988.

The Klein Partnership (2012) Community perceptions: 2012 headlines presentation. Melbourne.

Victoria Stormwater Committee (1999) *Urban stormwater: best practice environmental management guidelines*. CSIRO, Melbourne.

Violin, C.R., Cada, P., Sudduth, E.B., Hassett, B.A., Penrose, D.L. & Bernhardt, E.S. (2011) Effects of urbanization and urban stream restoration on the physical and biological structure of stream ecosystems. *Ecological Applications,* **21,** 1932–1949.

Walsh, C.J. (2004) Impacts of stormwater treatment wetlands on stream macroinvertebrates: a study of four wetlands constructed by Melbourne Water on streams in eastern Melbourne. Water Studies Centre, Monash University, Melbourne.

Walsh, C.J. (2006) Biological indicators of stream health using macroinvertebrate assemblage composition: a comparison of sensitivity to an urban gradient. *Marine and Freshwater Research,* **57,** 37–47.

Walsh, C.J., Fletcher, T.D. & Burns, M.J. (2012) Urban stormwater runoff: a new class of environmental flow problem. *PLoS ONE,* **7(9),** e45814. doi:45810.41371/journal.pone.0045814.

Walsh, C.J., Fletcher, T.D. & Ladson, A.R. (2005) Stream restoration in urban catchments through re-designing stormwater systems: looking to the catchment to save the stream. *Journal of the North American Benthological Society,* **24,** 690–705.

Walsh, C.J., Fletcher, T.D. & Ladson, A.R. (2009) Retention capacity: a metric to link stream ecology and storm-water management. *Journal of Hydrologic Engineering,* **14,** 399–406.

Walsh, C.J. & Kunapo, J. (2009) The importance of upland flow paths in determining urban effects on stream ecosystems *Journal of the North American Benthological Society,* **28,** 977–990.

Walsh, C.J., Roy, A.H., Feminella, J.W., Cottingham, P.D., Groffman, P.M. & Morgan, R.P. (2005) The urban stream syndrome: current knowledge and the search for a cure. *Journal of the North American Benthological Society,* **24,** 706–723.

Walsh, C.J. & Webb, J.A. (2013) Predicting stream macroinvertebrate assemblage composition as a function of land use, physiography and climate: a guide for strategic planning for river and water management in the Melbourne Water region. Department of Resource Management and Geography, The University of Melbourne, Melbourne.

Webb, J.A. & King, E.L. (2009) A Bayesian hierarchical trend analysis finds strong evidence for large-scale temporal declines in stream ecological condition around Melbourne, Australia. *Ecography,* **32,** 215–225.

Webb, J.A., Walsh, C.J., Rice, P. & Breen, P.F. (in review) Local habitat restoration improves urban macroinvertebrate assemblages, but only in streams with lower imperviousness. *Ecological Applications*.

Wenger, S.J., Roy, A.H., Jackson, C.R., Bernhardt, E.S., Carter, T.L., Filoso, S., Gibson, C.A., Hession, W.C., Kaushal, S.S., Martí, E., Meyer, J.L., Palmer, M.A., Paul, M.J., Purcell, A.H., Ramirez, A., Rosemond, A.D., Schofield, K.A., Sudduth, E.B. & Walsh, C.J. (2009) Twenty-six key research questions in urban stream ecology: an assessment of the state of the science. *Journal of the North American Benthological Society,* **28,** 1080–1098.

Wilson, G., Edwards, P., McGrath, J. & Baumann, J. (2013) Integrated water managment planning in Melbourne's north: maximizing the achievement of environmental outcomes. *Water,* **April 2013,** 1–5.