TECHNICAL REPORT

ENVIRONMENTALLY SUSTAINABLE EXTRACTION LIMITS FOR THE WESTERN MOUNT LOFTY RANGES PRESCRIBED WATER RESOURCES AREA

2010/01

Government of South Australia
Department for Water

ENVIRONMENTALLY SUSTAINABLE EXTRACTION LIMITS FOR THE WESTERN MOUNT LOFTY RANGES PRESCRIBED WATER RESOURCES AREA

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FOREWORD

South Australia's Department for Water leads the management of our most valuable resource—water.

Water is fundamental to our health, our way of life and our environment. It underpins growth in population and our economy—and these are critical to South Australia's future prosperity.

High quality science and monitoring of our State's natural water resources is central to the work that we do. This will ensure we have a better understanding of our surface and groundwater resources so that there is sustainable allocation of water between communities, industry and the environment.

Department for Water scientific and technical staff continue to expand their knowledge of our water resources through undertaking investigations, technical reviews and resource modelling.

Scott Ashby
CHIEF EXECUTIVE
DEPARTMENT FOR WATER

ACKNOWLEDGEMENTS

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CONTENTS

FIGURES

TABLES

SUMMARY

This report aims to provide a framework to inform the environmentally sustainable development of water resources in the Western Mount Lofty Ranges Prescribed Water Resources Area. It recommends extraction limits that aim to keep aquatic ecosystems at an ‘acceptable’ level of risk through meeting the objective of *maintaining self-sustaining populations that are resilient to times of drought*. While this report makes no explicit reference to social or economic needs for water, as is required in the development of an environmental water provision, environmentally sustainable extraction limits are presented that have regard for these competing needs for the water.

This ‘acceptable’ level of risk was determined through correlating the success of environmental water requirement measures with the condition of aquatic ecosystems in the Mount Lofty Ranges that is expected to be sustainable (VanLaarhoven and van der Wielen 2009). The resulting level of risk correlated to an environmentally sustainable extraction limit of <5% of upstream runoff. While expected to be environmentally sustainable, this extraction limit is unlikely to be socially or economically acceptable.

Further investigations targeted alternative methods of water resource development that are expected to maintain environmental sustainability, and increase extraction limits to more socially and economically viable levels. The flow regime is most impacted in the Low Flow Season, as are environmental water requirements relating to low flows, so investigations were made into the influence of providing flows around, or from, existing licensed onstream dams.

This alteration in when and how water is taken from the system has a significant influence on the success of environmental water requirement measures, increasing the environmentally sustainable extraction limit from 5% to 25% of upstream runoff.

The Fleurieu Peninsula, at the southern end of the western Mount Lofty Ranges, supports significantly more wetlands than other areas of the region. These wetlands support many animal and plant species, many of which have conservation status at the regional, state or national level. The presence of these species and prevalence of peat substrates means that these wetlands are very sensitive to drying out. Thus they warrant being maintained at a lower level of risk than other regions of the Mount Lofty Ranges. The recommended sustainable extraction limit above wetlands on the Fleurieu Peninsula is 10% of upstream runoff.

The watercourse environments in the Gawler, Torrens and Onkaparinga rivers across the plains have changed significantly due to modification of the flow regime by large upstream reservoirs. Complete ecological functioning is no longer possible in these ecosystems, and often not desired (e.g. overbank flows in urbanised areas). However, some environmental values remain. Environmentally sustainable extraction limits for these systems are recommended that combine releases of additional flows from reservoirs, and the introduction of a threshold flow rate below which water cannot be extracted.

The water resource management options outlined in this report must be considered as the first stage of an adaptive management regime. A robust monitoring program should be implemented to test the hypothesised relationships between flow and ecological condition or processes, and to ensure that the stated environmentally sustainable extraction limits with the objective of *maintaining self-sustaining populations that are resilient to times of drought* is achieved.

1. INTRODUCTION

Environmental water requirements (EWRs) are defined as 'the water regime needed to sustain the ecological values of ecosystems, including their processes and biological biodiversity, at a low level of risk' (DWLBC 2006).

Environmental water provisions (EWPs) are defined as 'those parts of environmental water requirements that can be met at any given time. This is what can be provided at that time with consideration of existing users' rights, social and economic impacts' (DWLBC 2006).

An understanding of EWRs for the Mount Lofty Ranges (MLR), outlined by VanLaarhoven and van der Wielen (2009), is a key aspect of water allocation planning and licensing. The findings of that report show that no sites tested in the Western Mount Lofty Ranges (WMLR) Prescribed Water Resources Area provided all EWRs under current water resource development levels. Current extraction levels would need to be significantly reduced to meet all EWRs, and it is unlikely that the necessary extraction reduction would be socially or economically acceptable.

To inform EWPs, extraction limits need to be determined that will sustain water-dependent ecosystems at a higher, but still acceptable, level of risk, while considering and recognising existing and future social and economic water needs (e.g. stock and domestic, irrigation).

This study recommends environmentally sustainable extraction limits on the basis of a minimum ecological condition that still has an acceptable likelihood of achieving the goal of self-sustaining aquatic populations resilient to times of drought. This goal was developed to be consistent with the objectives of the State NRM Plan (DWLBC 2006) and South Australia's Strategic Plan (Government of South Australia 2006). A minimum ecological condition was identified by expert interpretation of monitoring data on ecosystem condition.

This report details the process employed to inform the environmental component of environmental water provisions and recommends environmentally sustainable extraction limits for the WMLR Prescribed Water Resources Area.

1.1. STUDY AREA

The WMLR Prescribed Water Resources Area study area comprises the area from the South Para catchment in the north, to the catchments of the Fleurieu Peninsula draining directly into Gulf St Vincent, and Backstairs Passage and the Southern Ocean in the south. The 56 catchments in the study area drain 6479 km of mostly seasonal watercourses (Figure 1).

1.2. WATER RESOURCE MANAGEMENT IN THE MLR

The water resources of the WMLR, including surface water, watercourse water and groundwater, were prescribed on 20 October 2005. Under prescription, the local natural resources management (NRM) board is required to prepare a water allocation plan (WAP) for the prescribed resources. The Adelaide and Mount Lofty Ranges (AMLR) NRM Board is responsible for developing the WMLR WAP, assisted by the then Department of Water, Land and Biodiversity Conservation (now Department for Water). The Department for Water is also responsible for the overall water licensing process, as well as allocating water to existing users at the time the prescription process started.

Figure 1: Western Mount Lofty Ranges Prescribed Water Resources Area

Western Mount Lofty Ranges PWRA
Catchments
Major Watercourse
Road

N

0 7.5 15 22.5
Kilometres

Government of South Australia
Department for Water

Produced by: DFW Science, Monitoring and Information
Map Projection: MGA Zone 54
Map Datum: Geocentric Datum of Australia 1994
Date: September 2010

M:\Projects_SW\Mt_Lofty_Ranges\EWR_Project\ReportMaps\mxds\EWP Figure 01 - GeneralDescriptionMap.mxd LewisM01

A key component of the water allocation planning process is identification of the quantity, quality and regime of water required to sustain water-dependent ecosystems. This, and other information on the water resources and social demands, is used to set sustainable extraction limits and other water management policies. These extraction limits and management policies need to recognise the legitimate right of the environment to water, and provide an equitable balance between social, economic and environmental water requirements.

Both surface water (including flows in watercourses) and groundwater play important roles in meeting EWRs in the MLR. Groundwater may contribute to surface flows by discharging to the surface as springs or baseflow. Organisms may use groundwater while still below the surface, including stygofauna (fauna that live in groundwater systems, including caves and aquifers) and phreatophytic vegetation (plants that draw water from the groundwater table to maintain vigour and function). Information on presence, distribution and water requirements of stygofauna and phreatophytic vegetation in the MLR is currently very limited and insufficient for assessing their EWRs at this point. Therefore, in this report, extraction recommendations will be made only for surface waters, relating to direct extractions and extraction from dams, where processes for protecting groundwater-dependent ecosystems will be developed in a separate process based on the findings of Costar et al (2008).

1.3. ENVIRONMENTAL WATER REQUIREMENTS

Aquatic and riparian biota have evolved life-history strategies based on the spatial and temporal presence of habitat (Poff et al. 1997; Bunn and Arthington 2002). Water regime is a major determinant of the presence, quality and availability of habitat. In such a regime a number of key flow components support evolved biological responses, such as:

- providing in-channel habitat
- stimulating fish spawning
- flushing excess sediment from the stream bed
- entraining organic material from the floodplain
- maintaining channel forms.

Changes to important elements of the water regime are likely to lead to changes in the presence and condition of aquatic habitats and functioning of biotic processes, and consequently the condition and composition of water-dependent ecosystems (e.g. Lloyd et al. 2004).

Existing EWR investigations for the MLR (e.g. SKM 2003 for the Onkaparinga) do not detail information in a way that allows for illustrating or testing the implications of different water resource management options. They state EWRs in absolute terms which are site specific and difficult to apply at the catchment scale. Allocation policies must be able to be trialled against a resulting ecosystem response/risk to inform environmentally sustainable diversion limits and EWPs. The approach used in these investigations are however useful in developing flow rules for managing regulated watercourses, such as downstream of major reservoirs.

EWRs for the WMLR have been determined and a tool developed that allows water allocation plan policies to be tested against an aquatic ecosystem response (see VanLaarhoven and van der Wielen (2009) and Section 1.4 below).

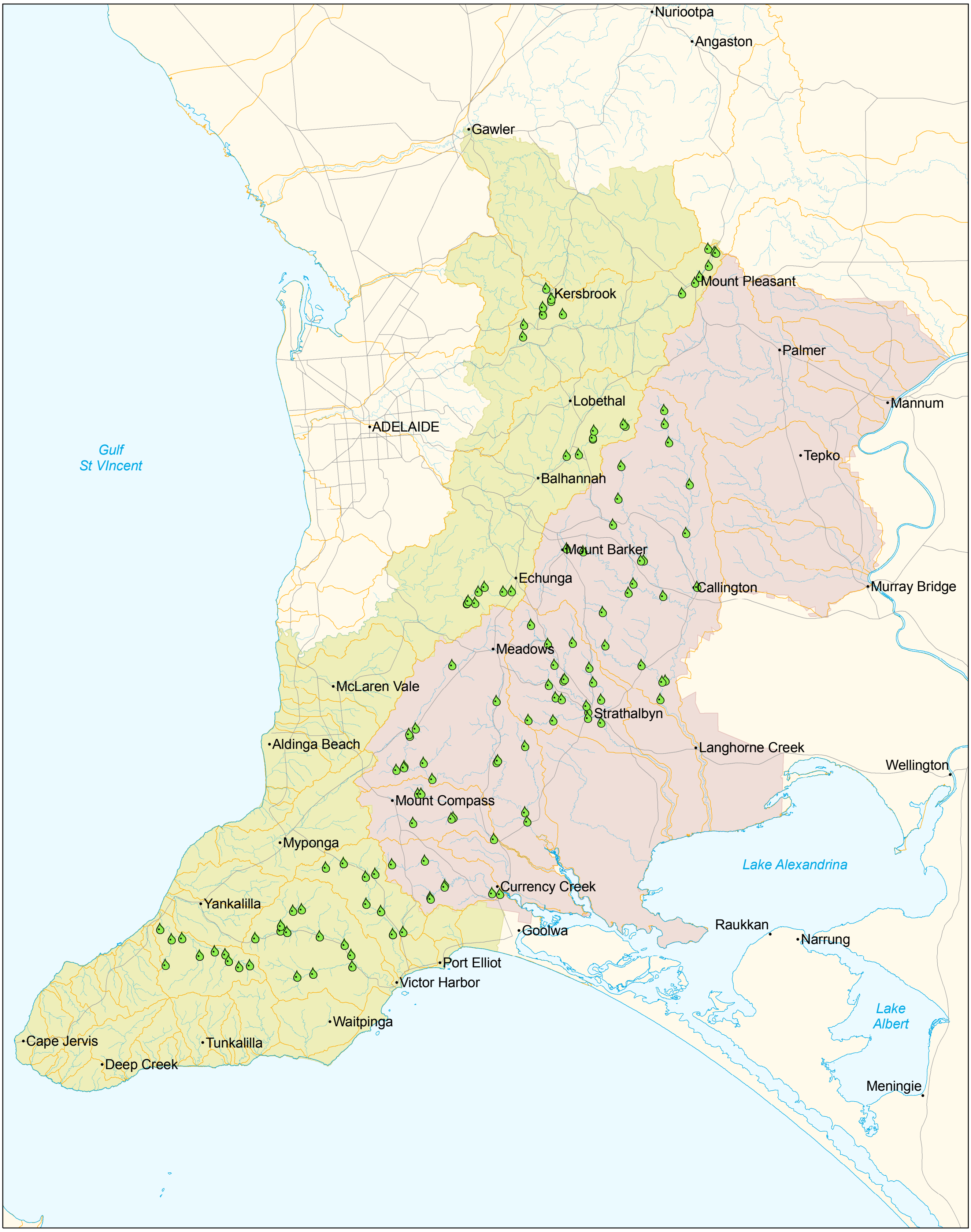
1.4. CURRENT STATE OF EWRS IN THE WMLR – A SUMMARY

EWRs for the WMLR have been described using a series of flow statistics or 'metrics' that represent various components of the flow regime (VanLaarhoven and van der Wielen 2009). The metrics cover a range of ecologically significant components of the flow regime such as low flows, freshes and bankfull flows, and are accounted for separately for different seasons of the year. An example of a metric is the duration (in days) of no flow during the Low Flow Season (generally summer to mid autumn).

Based on expert opinion, limits were set for each of the metrics: how far they can deviate from its value under a natural regime (impacts of dams removed) while still maintaining, at low risk, the ecological processes they support (VanLaarhoven and van der Wielen 2009). A metric that remains within these limits is considered to 'pass'; a metric that exceeds these limits 'fails' to adequately provide that particular EWR.

It is considered that passing all metrics will maintain water-dependent ecosystems at a low level of risk.
EWRs were tested by this method at 65 sites in the WMLR Prescribed Water Resources Area (Figure 2) which had adequate flow data. No test site was found to pass all metrics, and 50% of sites passed less than 75% of metrics (Figure 3), suggesting that water-dependent ecosystems at all test sites are at an elevated risk of degradation (VanLaarhoven and van der Wielen 2009).

Figure 2: EWR test sites in the Mount Lofty Ranges



Prescribed Water Resources Areas

Eastern Mount Lofty Ranges PWRA

Western Mount Lofty Ranges PWRA

Catchment

Major Watercourse

Road

EWR test site

N

0 10 20 30

Kilometres

Government of South Australia
Department for Water

Produced by: DFW Science, Monitoring and Information
Map Projection: MGA Zone 54
Map Datum: Geocentric Datum of Australia 1994
Date: September 2010

M:\Projects_SW\Mt_Lofty_Ranges\EWR_Project\ReportMaps\mxds\EWP Figure 02 - EWRTestSites.mxd LewitM01

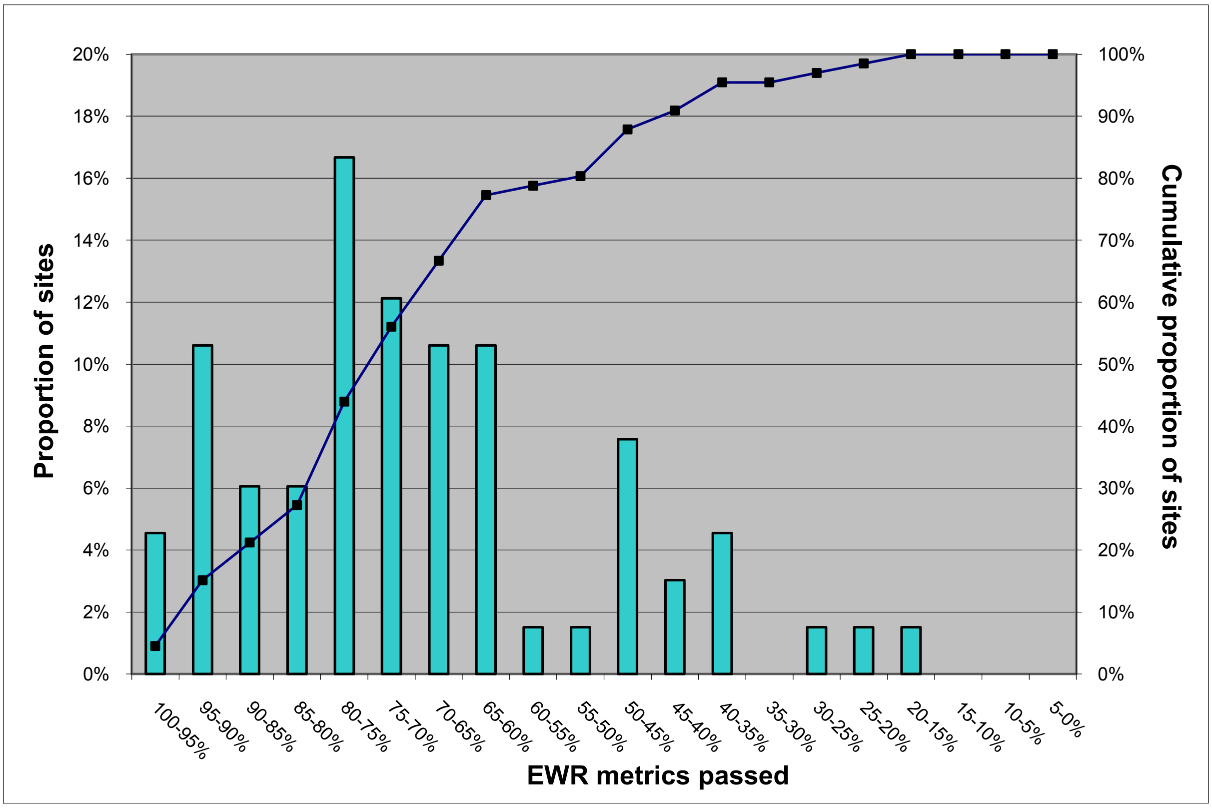


Figure 3. Proportion of WMLR sites passing EWR metrics (from VanLaarhoven and van der Wielen 2009)

2. PROJECT AIM

Environmental water requirements determined by VanLaarhoven and van der Wielen (2009) for the Mount Lofty Ranges can be used to inform the development of EWPs for the WMLR by establishing environmentally sustainable extraction limits. Recommendations in this report aim to maintain water-dependent ecosystems at an acceptable level of risk, while recognising the needs of existing domestic users and industries that rely on water resources in the Prescribed Area.

A number of guidelines in Appendix B of the State NRM Plan (DWLBC 2006) support this process.

Principle 16
Water allocation and management decisions must take a precautionary approach by first ensuring environmental benefit outcomes, including natural ecological processes and biodiversity of water dependent ecosystems, are maintained. It follows that further allocation of water for new consumptive uses, and any other new water resource developments, must ensure ecological values are protected.

Principle 17
In systems where there are existing consumptive extraction volumes, environmental water provisions must be as close as possible to the required environmental water requirements while recognising the rights of those existing users.

The goal of the defined EWRs is to promote self-sustaining populations of aquatic and riparian flora and fauna that are resilient in times of drought (VanLaarhoven and van der Wielen 2009). To this end the project focuses on conserving biota and ecosystems currently present in the region by establishing suitable hydrological conditions that promote resilience by maintaining or increasing species population numbers and spatial extent. Any flow regime that does not meet these standards is unlikely to be sustainable in the long term.

Environmentally sustainable extraction limits are determined from EWRs by assessing relative risk. Resilient to drought does not mean aquatic ecosystems and their components are impervious to it, as any population of aquatic animals and plants exist with some level of risk that they will become locally extinct (or regionally extinct in extreme circumstances) due to variations in the local climate. Therefore, to meet the above principles, the goal of environmentally sustainable extraction limits will be the same as the goal of EWRs, but a higher level of risk will be accepted that water-dependent ecosystems will be degraded due to the combined effects of water resource development and climatic variability.

This report recommends environmentally sustainable extraction limits to that can be used to inform EWPs for the Prescribed Water Resources Area, and water resource development options that influence these extraction limits.

3. METHODOLOGY

3.1. OVERVIEW OF THE PROCESS

VanLaarhoven and van der Wielen (2009) developed a method that informs the likely incremental changes in risk to water-dependent ecosystems resulting from changes in the level of water resource development. This method, outlined below, can be used to test various water resource management scenarios against the likely consequential impact on water-dependent ecosystems.

3.1.1. CORRELATION BETWEEN EWR METRICS AND WATER-DEPENDENT ECOSYSTEM CONDITION

The water-dependent ecosystems of the MLR support a diverse range of fauna and flora. From this diversity, two biotic groups (fish and macroinvertebrates) have sufficient monitoring data to develop a relationship between hydrological conditions and an ecological response.

VanLaarhoven and van der Wielen (2009) show a relationship between the success of EWR metrics and the ‘condition’ of fish and macroinvertebrate populations as measured by recruitment success for fish and population condition for macroinvertebrates (Section 4.1). This relationship can be used to define an acceptable level of fish recruitment success or macroinvertebrate population condition. These levels of risk can then be related back to the success of the EWR metrics.

This level of risk is considered to be as far as we can deviate from the natural flow regime and still maintain an acceptable probability of meeting the ecological objective of having self-sustaining populations of aquatic ecosystems and biota that are resilient to times of drought.

3.1.2. CORRELATION BETWEEN EWR METRICS AND EXTRACTION VOLUMES

VanLaarhoven and van der Wielen (2009) report a correlation between the success of EWR metrics and level of extraction. This, along with the correlation between EWR metrics and water-dependent ecosystem condition identified in Section 3.1.1, can be used to inform the level of extraction that will lead to an acceptable level of water-dependent ecosystem ‘health’ (Section 5.2).

3.1.3. INVESTIGATE THE INFLUENCE OF INTRODUCING A THRESHOLD FLOW RATE

In the MLR, the largest impacts on the flow regime appear to be on low flows and freshes in the Low Flow and both Transitional (high to low, and low to high) Flow seasons. If a threshold flow rate is introduced to the scenario, below which water cannot be captured, then the impacts of water resource development on these lower flows could be minimised. The likely result will be larger extraction limits that are not expected to significantly compromise aquatic ecosystems. The benefit of providing flows from licensed onstream dams will be investigated to improve the success of EWR metrics, along with the corresponding influence on extraction limits.

Hydrological water balance models were used to simulate the dynamics of providing threshold flows through dams as outlined in Teoh (in prep). The resulting changes in the flow regime were used in the metric calculations of VanLaarhoven and van der Wielen (2009).

3.2. PROCESS SUMMARY

1. Develop an acceptable ecological ‘condition’ of fish and macroinvertebrates (Section 4) able to meet the ecological objectives (Section 2).
    a. Use expert advice to determine the threshold for an acceptable level of ecological ‘condition’.
    b. Use the correlation between ecological condition and EWR metric success to determine the corresponding acceptable level of EWR metric success.
2. Determine environmentally sustainable extraction limits (Section 5).
    a. Use the correlation between EWR metric success (1b) and extraction volumes to determine environmentally sustainable extraction limits.
3. Investigate the influence of providing flows from licensed onstream dams on environmentally sustainable extraction limits.
    a. Determine an ecologically significant threshold flow bypass rate (Section 5.3.1).
    b. Determine the influence of providing these flows on the success of EWR metrics, and resulting changes in environmentally sustainable extraction limits (Section 5.3.2).
4. Monitoring recommendations (Section 6).

4. DEFINING AN ECOLOGICALLY ACCEPTABLE TARGET

EWRs identify the flow regime required to maintain the aquatic ecosystems, biota and processes in the MLR at a low level of risk of degradation (VanLaarhoven and van der Wielen 2009). The goal of environmentally sustainable extraction limits in this process is to maintain aquatic ecosystems, biota and processes in the WMLR at an *acceptable* level of risk, while recognising the needs of existing users, as well as associated social and economic impacts. State NRM Plan (DWLBC 2006) guidelines support this process (Section 2).

4.1. ACCEPTABLE LEVEL OF RISK

An EWP that will meet the goal of 'ensuring environmental benefit outcomes, including natural ecological processes and biodiversity of water-dependent ecosystems, are maintained' (Appendix B, Principle 16 of the State NRM Plan (DWLBC 2006)), depends on defining a relationship between aquatic ecosystem condition and the level of water resource development.

A relationship between breeding and survivorship success of two fish species, macroinvertebrate population condition, and the success of EWRs is reported in VanLaarhoven and van der Wielen (2009). Based on the ecological objective of 'self-sustaining populations, resilient to times of drought', these relationships can be used as a decision point beyond which the risks to meeting the objective are considered to be too great. Once a decision point has been reached (i.e. % of years successful recruitment events for fish, or a given macroinvertebrate population condition), a corresponding level of metric success is noted (Section 4.1.1 and 4.1.2) and compared to the corresponding level of extraction (Section 5) to develop an ecologically sustainable diversion limit.

For the purposes of this report, only the expected risks with regard to ecological condition and processes are assessed. Risks with regard to the methodology (e.g. uncertainty around metric deviation limits, flow as the major driver of condition, future flow) are not explicitly assessed, but are acknowledged and are expected to be addressed through the implementation of the recommended monitoring and evaluation program.

4.1.1. FISH

The abundance and size distribution of southern pygmy perch and mountain galaxias populations have been monitored annually in autumn for 3–7 years at a range of sites in the eastern and western MLR. Given the close proximity and similarities in hydrology and physical watercourse form, it is reasonable to assume that fish species will have similar responses to flow across both Prescribed Water Resources Areas. Therefore they can be used to develop the hydro-ecological relationships required to inform environmentally sustainable extraction limits and EWPs for both areas.

Recruitment was considered to be the most flow-sensitive process, and one of the most important processes in promoting population resilience. Therefore, recruitment data was examined to identify the percentage of time that recruitment was marginal or poor (i.e. number of years with marginal or poor recruitment out of the number of years monitoring data was collected). The proportion of years with marginal or poor recruitment at a monitoring site was compared to the proportion of flow metrics passed for that site for mountain galaxias (Figure 5) and southern pygmy perch (Figure 6). Poorer ecological condition (i.e. a higher proportion of time when recruitment is marginal or poor) was found to correlate with fewer metrics passing at a site.

A range of other processes will also affect ecological condition, including habitat quality (e.g. degradation by stock access, clearance of vegetation), water quality and predation by feral fish. These other aspects may account for some of the scatter apparent in Figure 5 and Figure 6. However, as flow pattern is a key driver in the structure and function of ecological communities, it is assumed that the observed relationship between fish recruitment and changes to flow regime can be attributed to changes to flow regime.

4.1.1.1. Acceptable ecological target – fish

Mountain galaxias and southern pygmy perch are relatively short lived (~3 years) species. Suitable breeding conditions are needed often enough to build population numbers and promote resilience to withstand poorer flow years and ensure the survival of these species.

Consecutive years of poor to marginal breeding events occur under natural conditions and native fish species have developed strategies to persist through these periods. Enough recruitment is expected in the marginal years to maintain sufficient population numbers for these species to recover in subsequent years once improved hydrological conditions prevail.

Expert opinion suggests better-than-marginal recruitment events are needed in at least 7 years out of every 10 (M Hammer, AquaSave Consultants, pers. comm. 2009; D McNeil, SARDI, pers. comm. 2009) to maintain sufficient population numbers of these species, but that 3 marginal recruitment events should not occur sequentially. Under stable climatic conditions, the probability of a run of 3 consecutive years of poor to marginal fish breeding is once in 37 years (Figure 4), potentially leading to population crashes for fish species with relatively short life-cycles. More conservative targets (i.e. a requirement for more frequent better-than-marginal recruitment events) would reduce the probability of such crashes.

The ecological target of 7 out of 10 years having better than marginal recruitment, equates approximately to an EWR metric success rate of 85% (i.e. 85% of the 45 metrics listed in Table 3 are passed) (Figure 5 and Figure 6).

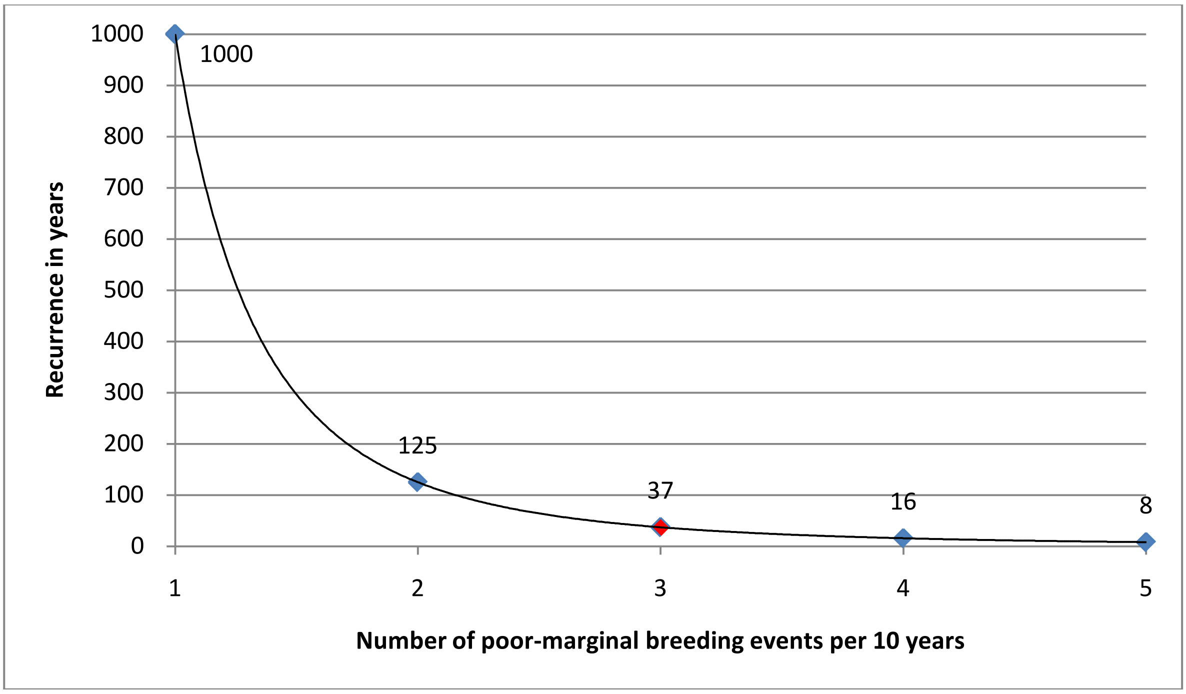


Figure 4. **Return period (in years) for 3 sequential years not meeting the acceptable number of poor–marginal breeding events per 10 years target (as shown on the X-axis). (e.g. the probability of 3 successive years not meeting a 1 year in 10 'better than marginal breeding' target is 1 in 1000 years; the probability for 3 successive years not meeting a 2 in 10 target is 1 in 125 years)**

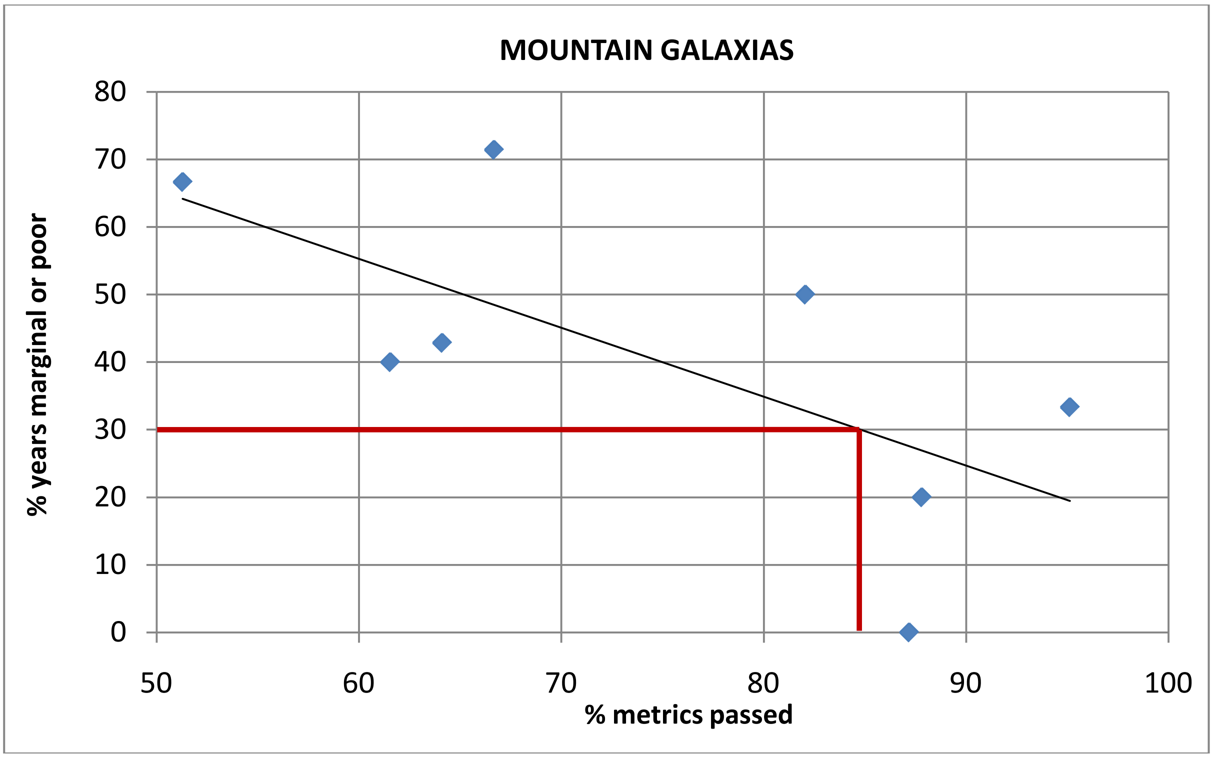


Figure 5. **Relationship of mountain galaxias recruitment to percentage of metrics passed at each site; each point represents a single fish monitoring site (adjusted r^2=0.37; F=5.078 (P=0.0651))**

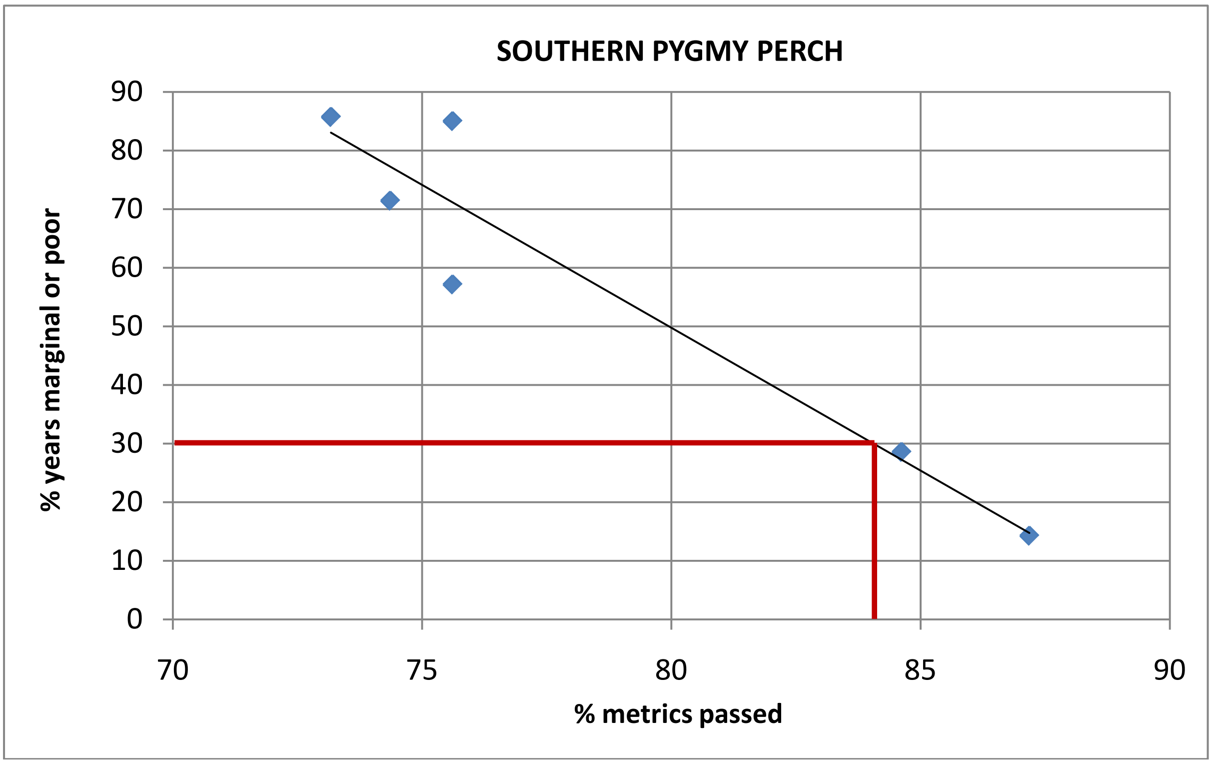


Figure 6. **Relationship of southern pygmy perch recruitment to percentage of metrics passed for; each point represents a single fish monitoring site (adjusted r^2 =0.90; F=53.83 (P=0.0007))**

4.1.2. MACROINVERTEBRATES

Macroinvertebrate monitoring data has been collected at a range of sites throughout the MLR, primarily under the auspices of the AusRivAS (Australian River Assessment System) protocol on behalf of organisations such as the Environment Protection Authority and NRM boards. Twelve sites were selected for analysis based on representativeness, length of record and access to adequate flow data.

The average percentage of metrics passed for sites in each of the macroinvertebrate condition rating groups is shown in Figure 7. Poorer condition is correlated with a lower percentage of metrics passing at a site.

As for fish, a range of other processes will also affect condition of the macroinvertebrate community, including habitat quality (e.g. degradation by stock access, clearance of vegetation), water quality and predation. However, as flow pattern is a key driver in the structure and function of ecological communities, it is assumed that the observed relationship between macroinvertebrate population condition and changes to flow regime can be attributed to changes to flow regime.

4.1.2.1. Acceptable ecological target – macroinvertebrates

Expert opinion recommends that a target of macroinvertebrate population condition between moderate and good is likely to promote resilience and allow populations to be sustainable in the long term (P McEvoy, Australian Water Quality Centre, pers. comm.). This ecological target equates to an EWR metric success rate of between 80-90% (i.e. 80-90% of the 45 metrics listed in Table 3 are passed) (Figure 7).

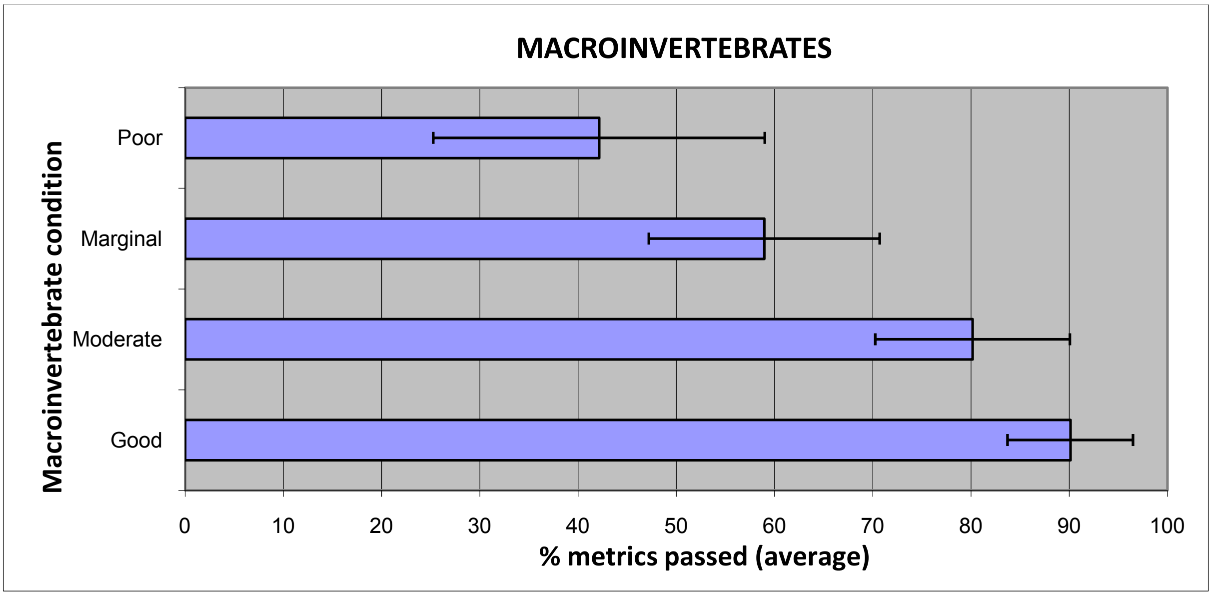


Figure 7. Metrics passed for monitoring sites in each condition rating group for long-term condition of the macroinvertebrate community; error bars: standard deviation (Spearman's Rank: rho=0.87, P=0.0003)

4.1.3. SUMMARY

The success of EWR metrics in the MLR will vary according to upstream water extraction volumes, and provides an indication on relative levels of risk to the aquatic environment. A 100% metric pass rate indicates a high probability that the aquatic environment will be sustainable in the long term. Under current development conditions, none of the 65 test sites were found to pass all metrics.

If the goal of EWPs is to meet EWRs (i.e. meeting 100% of metrics), there will be a need to significantly cut current water extraction volumes, which is unlikely to be economically sustainable or socially acceptable. Therefore, there is a need to define an alternative, ecologically acceptable target other than meeting 100% of metrics. The target would involve accepting a higher risk of degradation that still has an acceptable probability of maintaining aquatic ecosystems in a sustainable state in the long term.

The correlations of proportion of EWR metrics passed at a site with the recruitment success of mountain galaxias and southern pygmy perch; and with macroinvertebrate population condition, can be used to define an alternative, acceptable level of metric success.

Expert opinion based on fish life-history and macroinvertebrate population composition was used to define an acceptable level of fish recruitment success (better than marginal in no less than 7 years in 10) and macroinvertebrate population condition (good–moderate health), that will maintain an acceptable probability that these populations will be sustainable in the long term.

Based on the correlations (Figure 5, 6 and 7), a site that passes 85% of EWR metrics will meet this level of risk.

5. ENVIRONMENTALLY SUSTAINABLE EXTRACTION LIMITS

The State NRM Plan (DWLBC 2006) definition of EWPs (see Section 1) and Principles 16 and 17 (see Section 4) provide the framework for how environmentally sustainable extraction limits are developed for the WMLR Prescribed Water Resources Area.

Recommended environmentally sustainable extraction limits will inform the development of EWPs, which, like EWRs, are more than just a volume of water that must be set aside for the environment. Aquatic and riparian biota have evolved life-history strategies based on the spatial and temporal presence of habitat (Poff et al. 1997; Bunn and Arthington 2002), of which the water regime is a major determinant. Therefore changes to components of the water regime are likely to lead to changes in the presence and condition of aquatic habitats, and subsequently the condition and composition of water-dependent ecosystems (e.g. Lloyd et al. 2004).

5.1. SPATIAL SCALE

Water resource development has a proportionally greater impact on the flow regime, and therefore EWRs, immediately downstream of the point of development. The level of impact decreases further downstream as other sources contribute to flow.

This has consequences for the scale at which extraction limits are applied to developments to meet environmentally sustainable extraction limits (Table 1).

Surface water management zones (the scale at which metrics passed is illustrated in Figure 11) have been developed on the basis of *reach types* (VanLaarhoven and van der Wielen 2009), each of which represents a length of river with similar ecosystems, habitats, processes and biota. Therefore, each reach type will have a different EWR driven by differences in the presence of varying biota, ecosystems and processes. As a general rule, the confluence of reach types (not including headwaters which are not considered to have significant EWRs in most cases) has been used to differentiate each surface water management zone. This ensures that each stretch of watercourse will have its water needs met without being compromised by development in adjacent watercourses.

The application of extraction limits at the scale of surface water management zone will minimise the risk of forming environmentally unsustainable ‘hotspots’ of water resource development. A level of water resource development expected to be environmentally sustainable is spread evenly across each catchment. Water allocated at this scale will have the greatest potential of being environmentally sustainable across the whole of the Prescribed Water Resources Area.

Table 1. Environmental implications for application for extraction limits

Scale of extraction limit application	Testing point	Distribution of water resource development	Extent of environmental impact
Catchment	End of catchment	• Likely to be an uneven distribution of water resource development throughout catchment, with some areas heavily developed and other areas with less development	• Some areas of the catchment likely to have higher risks of environmental degradation where localised extraction is higher than environmentally sustainable extraction limit; other areas of the catchment likely to have less development, and a consequential lower risk of environmental degradation
Surface water management zone (SWMZ)	End of SWMZ	• More even distribution of water resource development throughout catchment	• Even level of environmental risk across catchment; some localised areas of higher risk possible at the upstream end of SWMZs

5.2. *WATER EXTRACTION AND EWRS*

The delivery of EWRs, through the use of metrics, have been tested at 65 representative sites across the WMLR, chosen because they have adequate flow data (Figure 2). They show varying levels of stress on the environment and corresponding varying risk of environmental degradation. The correlation between level of extraction (extraction volume from dams) at each test site and the corresponding success of EWR metrics is shown in Figure 8.

Work on an alternative, ecologically acceptable level of risk (Section 4) indicates that passing 85% of EWR metrics does increase the risk of ecological degradation but is considered to be within acceptable limits. A success rate of 85% for EWR metrics equates to an environmentally sustainable diversion limit of 3–4% of upstream runoff (Figure 8).

A more detailed discussion of the relationship between extractions from dams and EWR metric success can be found in VanLaarhoven and van der Wielen (2009).

The correlation developed from these 65 test sites has been used to infer the likely success of EWR metrics and hence the level of risk to water-dependent ecosystems in other areas of the MLR where extraction volumes are known or have been estimated (Figure 11). It shows that a significant number of management zones pass less than the 85% of metrics required to meet the environmentally sustainable extraction limit. Extraction volumes in these largely ungauged MLR areas has been estimated by using flow data generated through hydrological modelling using dam locations and estimated volumes mapped from 2005 aerial photography, and assuming 50% extraction from dams >5 ML, 30% from dams <5 ML, and 85% runoff reduction from land under forestry compared to pasture. These extraction volumes are only an estimate and may differ from more accurate extraction data, which will be determined through the prescription process.

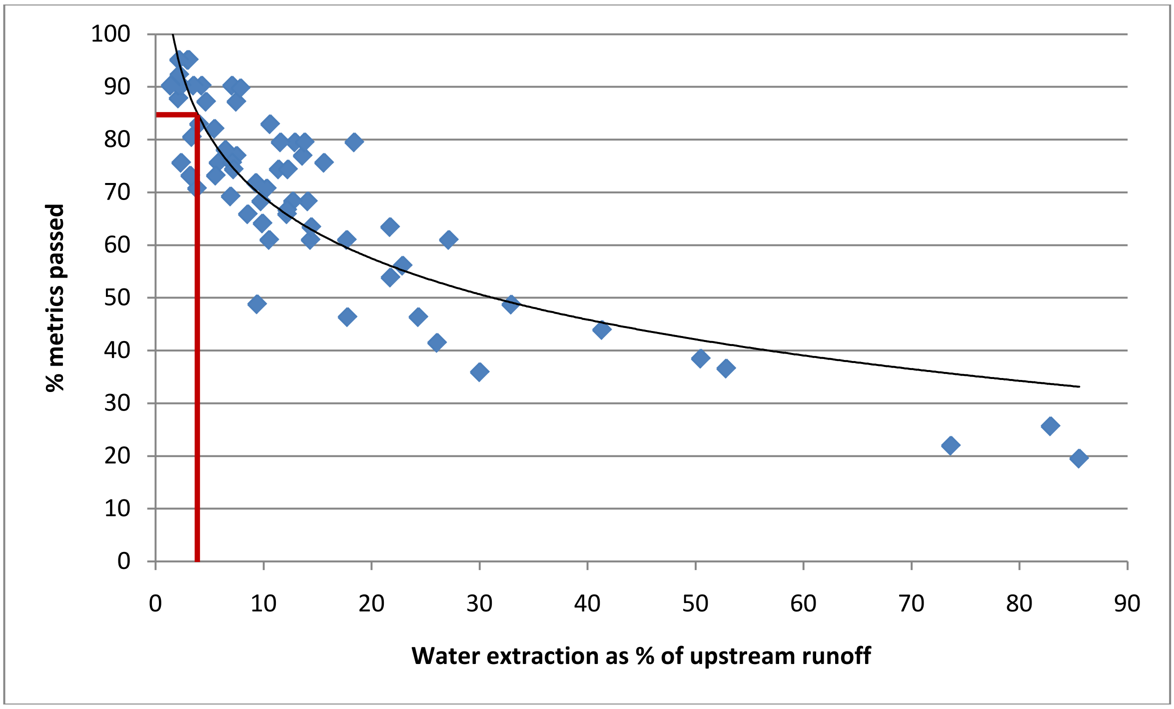


Figure 8. **Relationship of water extraction at 65 sites across the WMLR to percentage of metrics passed (r^2=0.75; F=168.0 (P<0.0001)) (adapted from VanLaarhoven & van der Wielen 2009)**

5.2.1. METRIC SUCCESS RATE

The range of scatter evident in the correlation between the success of EWR metrics and water extraction levels (Figure 8) is likely due to dam positioning and size, and the proportion of unlicensed dams (see glossary) present. Therefore, when a 5% extraction limit is applied to all test sites, a proportion will fail the success criteria of passing 85% of metrics. Table 2 shows the success rate of metrics for different extraction bands for each of the 65 test sites, and indicates that a significant proportion of sites pass less than 85% of metrics, even at very low extraction levels.

Table 2. **Proportion of sites meeting the ecologically acceptable target (pass 85% of metrics) for different extraction volumes (as % of upstream runoff) bands**

Extraction as % of upstream runoff	# sites in this extraction band	# sites passing >85% of metrics	% of sites passing >85% of metrics
0–5	16	11	68.8
5–10	16	3	18.8
10–15	15	0	0
15–20	4	0	0
20–25	4	0	0
>25	10	0	0

5.2.2. SUMMARY

The target of passing 85% of EWR metrics relates to an increased, but acceptable, level of risk of degradation to fish and macroinvertebrate populations.

VanLaarhoven and van der Wielen (2009) report a correlation between extraction volumes and the success of EWR metrics, indicating that an extraction limit of less than 5% of upstream runoff is required to meet the ecological target of passing 85% of EWR metrics.

Without controls on how and when water is captured, the environmentally sustainable extraction limit is 5% of upstream runoff. This is expected to maintain the water-dependent ecosystems of the Western Mount Lofty Ranges at an acceptable level of risk.

An extraction limit of 5% in the WMLR Prescribed Water Resources Area is unlikely to be socially or economically acceptable. The following sections investigate options for increasing the extraction limit while maintaining an acceptable level of risk to water-dependent ecosystems.

5.3. INFLUENCE OF RESTORING THRESHOLD FLOWS

Dams change the flow regime by both reducing total volume of flow and delaying flow events by holding back flows until they fill and begin to spill. The delay in flows is most noticeable when dams are not at capacity, for example during the irrigation period (October to March). Figure 9 shows that while the percentage of annual flow captured during the drier months is minimal, the percentage of flow captured in each of these months is very large. For example, the proportion of annual flow captured in February is ~1% but over 80% of the flow for that month is captured. Smaller flows are proportionally more impacted than higher flows, as larger flows will cause dams to fill and spill much quicker.

This pattern of impact on the flow regime from dams is well reflected in the performance of EWR metrics (Table 3). Measures of low flow had very low pass rates in each of the flow seasons; larger bankfull flows were only marginally impacted. Fresh flows that fall between these two extremes also fall between them in the proportion of EWR metrics met.

Metrics in the Low Flow Season generally performed worse than metrics in Transitional Flow seasons, which in turn performed worse than the High Flow Season. This is well reflected in the proportion of sites that pass the low flow metric (80th percent exceedence non-zero flow), which passed at only 6.1% of sites in the Low Flow Season and 28.8% of sites in the High Flow Season. Similar patterns can be seen in other metrics, including average duration of zero-flow spells (68.2% vs 78.8%) and average number of fresh flows (30.3% vs 81.8%).

If these lower flows were allowed to bypass dams or not be captured, it may be possible to allocate larger volumes, while maintaining a sustainable level of risk to water-dependent ecosystems.

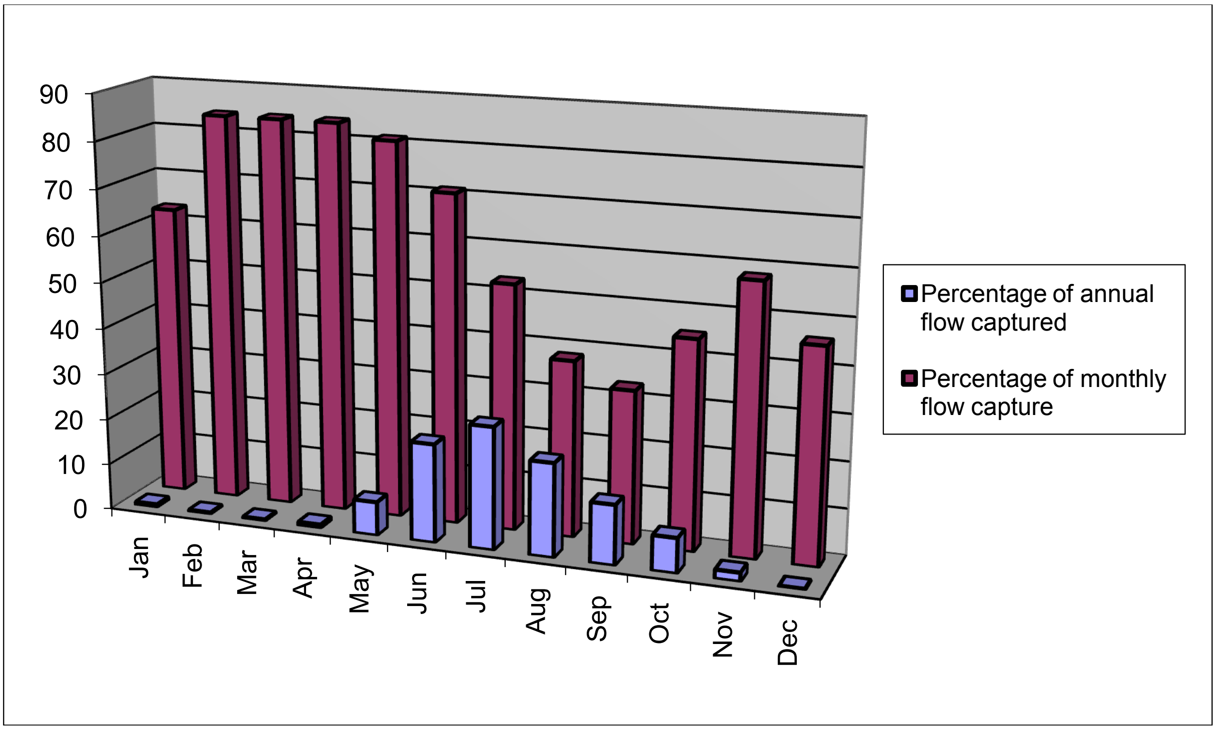


Figure 9. Generic impact of dams on annual and monthly flow in a single year

5.3.1. THRESHOLD FLOW RATE

The use of threshold flow rates is a method by which water can be shared between consumptive users and the environment. Under this management approach, only flows at or above a given threshold flow rate may be captured, while those below are not captured or are otherwise allowed to flow into the downstream watercourse.

Freshes in the two transitional flow seasons are the largest of the flow components that have been significantly impacted by surface water resource development, and therefore have been used as the basis for setting the threshold flow rate. By using freshes to determine a threshold flow, the impact to low flows will also be minimised. Flow exceedence percentiles (i.e. the percentage of time that a particular flow rate is exceeded) were used to determine a consistent and easily calculated way of setting a threshold flow rate that would encompass these flow levels.

The 34 sites selected across the Mount Lofty Ranges for analysis were selected as being representative of different climate conditions and reach types. The daily flow rates (in ML/day) considered to represent a fresh in each of the two transitional flow seasons (2 times the median non-zero flow in the flow season of interest; as defined in VanLaarhoven and van der Wielen 2009), were determined for each site. The higher of these fresh flow rates at a site was then expressed as a percent exceedence value for the flowing period using natural flows for 1974–2006. For example, at a given site:

1. Calculate the flowing period.
    a. Example: Flows occur on 8000 out of the total of 12,053 days between 1974 and 2006.
2. Determine the natural fresh flow rate.
    a. Example: 2 ML/day.

3. Determine the number of days that the fresh flow rate (2a) is exceeded.
   a. Example: 2400 days.
4. Determine the number of days that the fresh flow rate is exceeded (3a) as a percentage of the total flowing period (1a).
   a. 2400 days/8000 days = 30%.
5. In this scenario, a flow rate of 2 ML/day is equivalent to the 30th percent exceedence non-zero flow, as daily flows are higher than this flow rate in 30% of days with flow.

Calculations for the threshold flow rate were also performed using the whole period, not just the flowing period. However, results were much more variable and showed no consistent trend by which a single threshold flow rate could be determined.

Using the flowing period only, the majority of test sites showed that the fresh flow rate was exceeded in 15–25% of days. As such the threshold flow rate has been defined as the 20th percent exceedence non-zero flow (i.e. flows that occur for 20% of the flowing period can be captured – note that these are higher flow events and generally account for 80–95% of the total annual flow volume). The application of this threshold flow rate is considered to improve the flows most affected by water resource development for the majority of sites.

The recommended, ecologically significant threshold flow rate is the 20th percent exceedence non-zero flow.

5.3.2. INFLUENCE OF THRESHOLD FLOWS ON EWR METRICS

Providing threshold flows from licensed dams (see glossary) has a significant influence on the success of EWR metrics. Improvements are seen in every flow season (Table 3) with the greatest improvements in those most impacted under current development levels (i.e. low flows important for maintaining critical refugia habitat during the Low Flow Season and times of drought).

The most significant improvements are observed in the Low Flow Season, followed by improvements in the low–high (T1) and high–low (T2) Transitional Flow seasons. Metrics relating to flows below the threshold flow rate will still fail at a proportion of sites due to the impacts of unlicensed dams which do not bypass threshold flows.

The increased success rate is lower in the High Flow Season, and some metrics relating to higher flows in the other flow seasons are negatively impacted due to the influence of providing low flows back to the system. Dams that provide threshold flows to the system, through bypassing or pumping, have a lower water capture rate. The corresponding delay in dam fill time delays dam spill which is a significant contributor to larger flow rate events. It may cause a failure in some metrics relating to higher flow rates but most of these metrics retain very high pass rates in excess of 80%.

Table 3. Proportion of test sites passing EWR metrics under current conditions and threshold flows

Metric	% sites passing without provision of threshold flows	% sites passing with provision of threshold flows	Influence of providing threshold flows (% improvement)
Annual: can occur at any time of the year			
Number of years with 1 or more bankfull flows	90.9	87.9	-3
Average duration of bankfull flow spells	98.5	95.5	-3
Average total duration of bankfull flow per year	90.9	83.3	-7.6
Low flow season			
Average daily LFS flow	75.8	98.5	+22.7
80^{th} percent exceedence non-zero flow	6.1	75.8	+69.7
Number of years with LFS zero flow spells	86.4	95.5	+9.1
Average number of LFS zero flow spells per year	92.4	100	+7.6
Average duration of LFS zero flow spells	68.2	97	+28.8
Number of years with one or more LFS freshes	43.9	98.5	+54.6
Average number of LFS freshes per year	30.3	86.4	+56.1
Average total duration of LFS freshes per year	6.1	98.5	+92.4
Transition 1: Low to high flow season			
Average daily T1 flow	69.7	80.3	+10.6
80^{th} percent exceedence non-zero flow	16.7	90.9	+74.2
Current month reaching median flow of natural T1 median (delay)	40.4	100	+59.6
Number of years with T1 zero flow spells	86.4	98.5	+12.1
Average number of T1 zero flow spells per year	98.5	100	+1.5
Average duration of T1 zero flow spells	77.3	100	+22.7
Number of years with one or more T1 freshes	69.7	95.5	+25.8
Average number of T1 freshes per year	50	93.9	+43.9
Average total duration of T1 freshes per year	40.9	95.5	+54.6
Number of years with 2 or more T1 freshes	56.7	93.3	+36.6
Frequency of spells higher than LFS fresh level	50	100	+50
High flow season			
Average daily HFS flow	93.9	93.9	0
80^{th} percent exceedence non-zero flow	28.8	98.5	+69.7
Number of years with HFS zero flow spells	75.8	100	+24.2
Average number of HFS zero flow spells per year	98.5	100	+1.5
Average duration of HFS zero flow spells	78.8	93.9	+15.1
Number of years with one or more HFS freshes	87.9	87.9	0
Average number of HFS freshes per year	81.8	87.9	+6.1
Average total duration of HFS freshes per year	86.4	84.8	-1.6
Number of years with 1 or more spell greater than the annual 5th percentile flow in HFS	92.7	85.4	-7.3
Number of years with 2 or more freshes early in the season (Jul, Aug)	94.7	94.7	0
Transition 2: High to low flow season			
Average daily T2 flow	90.9	97	+6.1
Median non-zero daily T2 flow	25	100	+75
80^{th} percent exceedence non-zero flow	7.6	93.9	+86.3
Current month reaching median flow of natural T2 median (early onset)	43.9	100	+56.1
Number of years with T2 zero flow spells	69.7	93.9	+24.2
Average number of T2 zero flow spells per year	100	100	0

Average duration of T2 zero flow spells	72.7	100	+27.3
Number of years with one or more T2 freshes	66.7	77.3	+10.6
Average number of T2 freshes per year	72.7	77.3	+4.6
Average total duration of T2 freshes per year	50	78.8	+28.8
Frequency of spells higher than LFS fresh level	50	100	+50
Number of years with 1 or more spell greater than the annual 5th percentile flow	78.7	59.6	-19.1
Number of consecutive years with no T2 fresh	33.3	33.3	0

5.3.3. RELATIONSHIP BETWEEN WATER EXTRACTION VOLUMES AND EWR METRICS WITH THRESHOLD FLOWS

Extraction volumes (as % of upstream runoff) at 65 sites (Figure 2) in the WMLR can be correlated to the success of EWR metrics. The ecologically acceptable level of risk discussed in Section 4 suggests that passing 85% of EWR metrics is within acceptable limits even though it increases the risk of ecological degradation. A success rate of 85% for EWR metrics equates to a dam extraction volume of 25% of upstream runoff if threshold flows are provided from licensed dams (Figure 10).

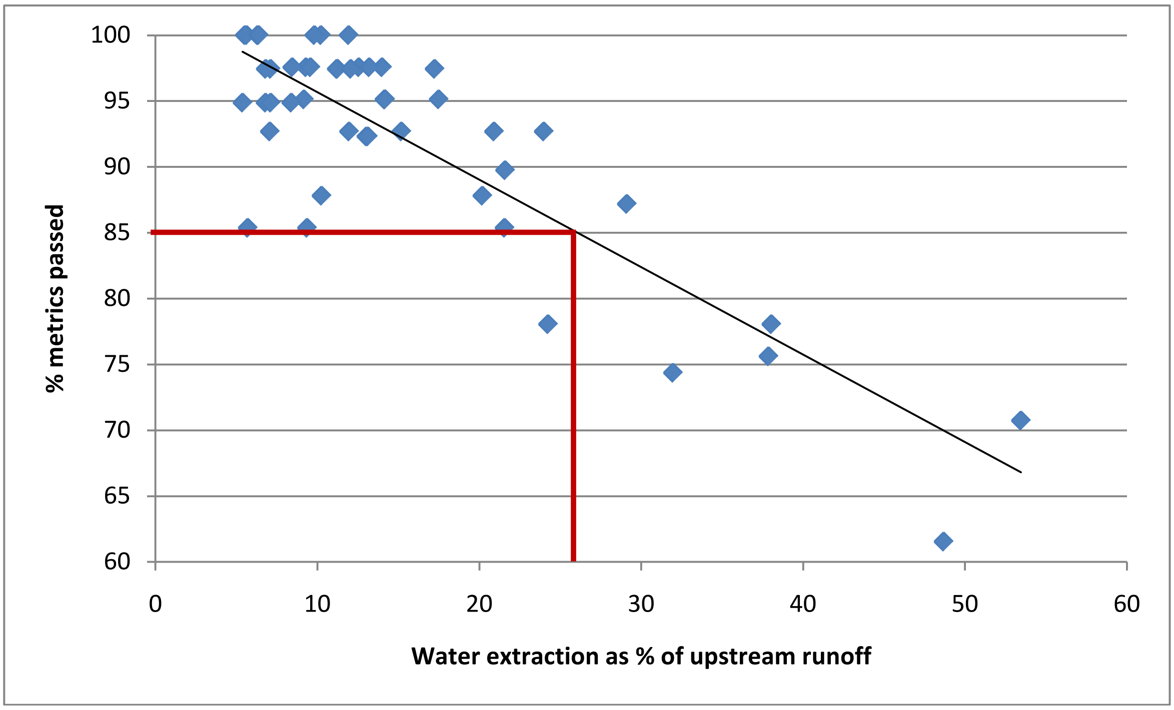


Figure 10. Comparison of percentage of metrics passed against water extraction across the WMLR assuming the provision of threshold flows (r^2=0.73; F=120.3 (P<0.0001))

This level of extraction, and its relationship with a metric success limit expected to be sustainable, is based on monitoring data collected for fish recruitment success (Section 4.1.1) and macroinvertebrate population condition (Section 4.1.2). Table 4 links these three variables together through correlations found in the data. Note that the numbers in the table are indicative only and may not truly represent the real world situation. They represent the relationships between ecological condition, extraction level and metric success variables through reported correlations, and do not reflect the variability (scatter) in the data that has been used to generate them.

Table 4. Modelled relationship between extraction limit, metric success and ecological condition with the provision of threshold flows

Modelled extraction*	% Metrics passed	% years with better than marginal breeding events	
		Mountain galaxias	Southern pygmy perch
5	99	84	100
15	92	78	100
25	86	71	78
35	79	64	46
45	72	57	13

* as percentage of upstream runoff

The correlation developed from these 65 test sites has been used to infer the likely success of EWR metrics at the surface water management zone scale (Section 5.1) and hence the level of risk to water-dependent ecosystems in other areas of the MLR where the extraction volume is known or has been estimated (Figure 12). Extraction volumes in these remaining, largely ungauged, areas has been estimated by hydrological modelling using dam locations and estimated volumes mapped from 2005 aerial photography, and assuming 50% extraction from dams >5 ML, 30% from dams <5 ML, and 85% runoff reduction from land under forestry compared to pasture. These extraction volumes are only an estimate and may differ from more accurate extraction data, which will be determined through the prescription process. Given current extraction volumes, a significantly higher proportion of zones are found to meet the target of passing 85% of metrics than without the provision of threshold flows.

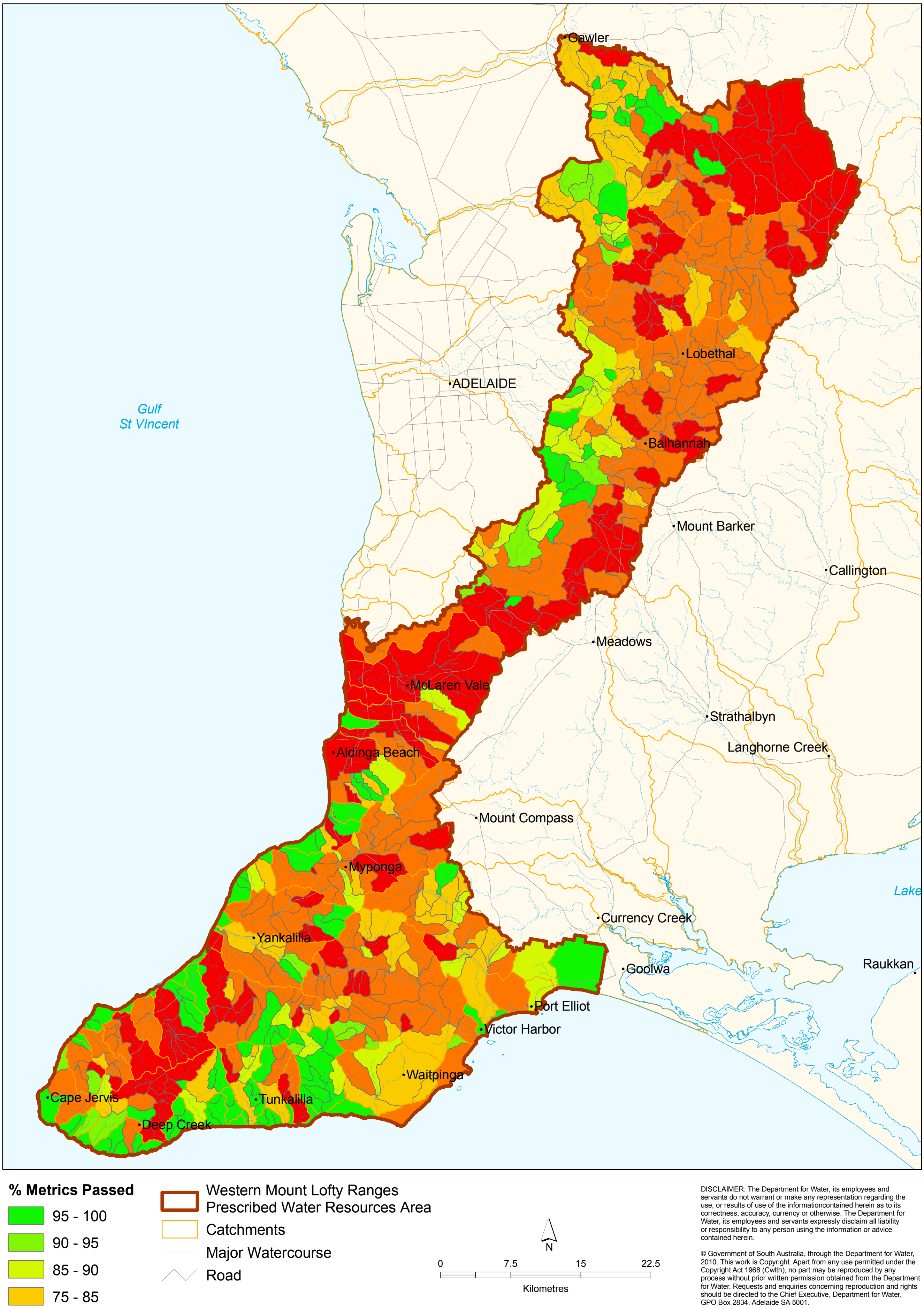
5.3.3.1. Metric success rate

The range of scatter evident in the correlation of the success of EWR metrics and extraction levels (Figure 10) is likely due to a number of variables, including dam positioning and size, and proportion of unlicensed dams present. Therefore, a 25% extraction limit applied to all test sites will see a proportion fail the success criteria of passing 85% of metrics due to site specific factors. Table 5 shows the success rate of metrics for different extraction bands. With the provision of threshold flows, no test site fails more than 85% of metrics until extraction reaches 20%. At 25% extraction, a significant proportion of sites still pass more than 85% of metrics. It is expected that the objective of drought resilience is consistent with this outcome, as sites where 85% (or better) of metrics are passed will experience acceptable levels of risk in maintaining permanent aquatic habitat that act as refugia during dry periods."

Table 5. Proportion of sites meeting the ecologically acceptable target for different extraction bands with the provision of threshold flows

Extraction as % of upstream runoff	# sites in this extraction band	# sites passing >85% of metrics	% of sites passing >85% of metrics
0–5	16	16	100
5–10	14	14	100
10–15	13	13	100
15–20	4	4	100
20–25	6	5	83.3
>25	8	1	12.5

Figure 11: Proportion of Environmental Water Requirement metrics passed in the Mount Lofty Ranges without the provision of threshold flows
(estimated using deemed current water use as % of upstream runoff)



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Department for Water

Produced by:	DFW Science, Monitoring and Information
Map Projection:	MGA Zone 54
Map Datum:	Geocentric Datum of Australia 1994
Date:	September 2010

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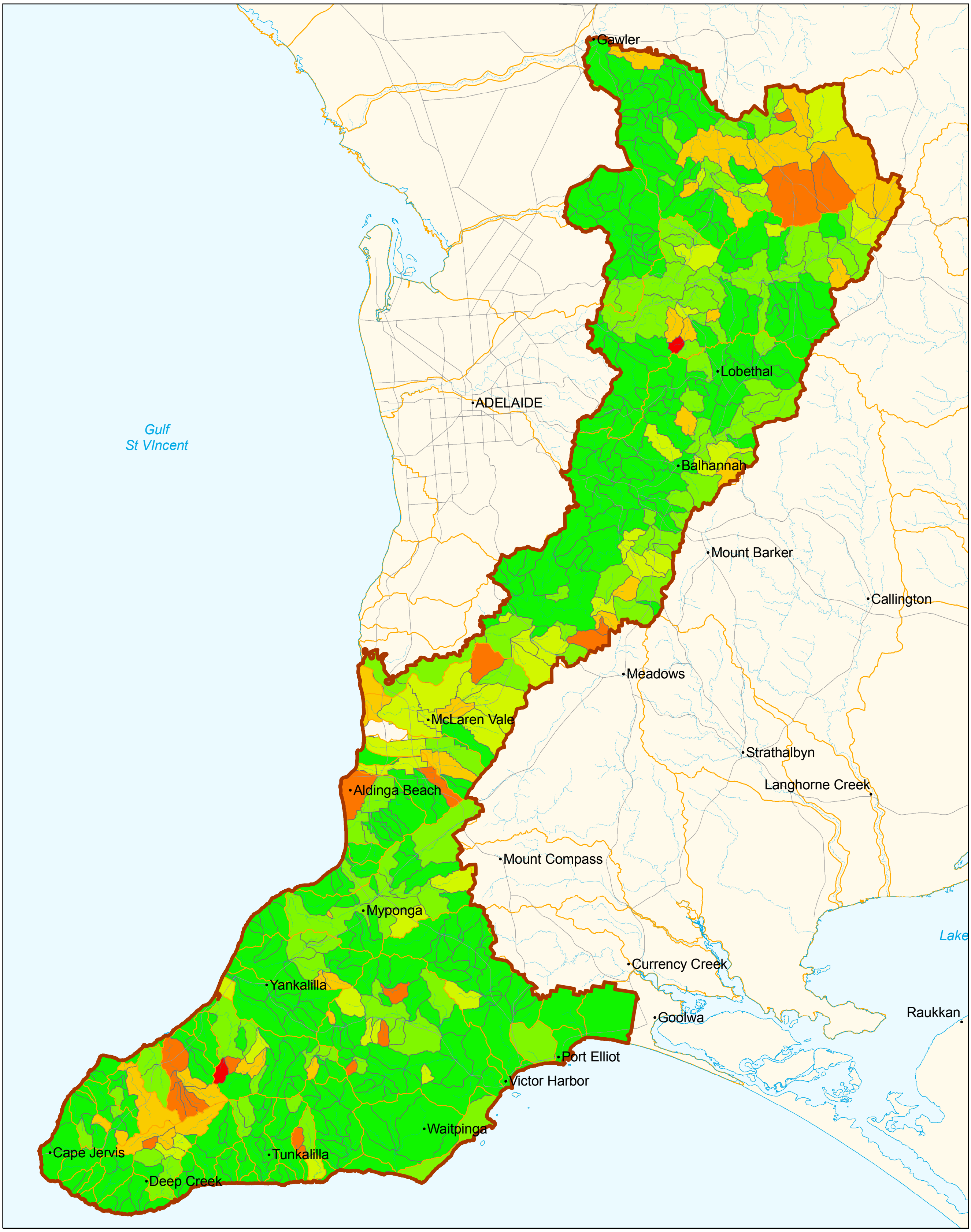
Figure 12: Proportion of Environmental Water Requirement metrics passed in the Mount Lofty Ranges with the provision of threshold flows (estimated using deemed current water use as % of upstream runoff)



% Metrics Passed

- 95 - 100
- 90 - 95
- 85 - 90
- 75 - 85
- 60 - 75
- <60

- Western Mount Lofty Ranges Prescribed Water Resources Area
- Catchments
- Major Watercourse
- Road

N

0 7.5 15 22.5

Kilometres

Government of South Australia
Department for Water

Produced by: DFW Science, Monitoring and Information
Map Projection: MGA Zone 54
Map Datum: Geocentric Datum of Australia 1994
Date: September 2010

M:\Projects_SWMt_Lofty_Ranges\EWR_Project\ReportMaps\mxds\EWP Figure 12 - % EWR metrics met WithLFB.mxd LewitM01

While an extraction limit of 25% results in the majority of test sites passing greater than the recommended 85% of metrics, it is also important to consider which metrics are failing. Passing 85% of metrics is deemed to result in an acceptable level of risk to the environment, however it is necessary to consider whether specific ecologically critical metrics are consistently failing. The loss of functions represented by these metrics will lead to proportionally higher environmental risk, due to the critical EWRs they represent (e.g. flows required to maintain permanent aquatic refugia).

Six test sites have a current extraction level of 20-25% which were used to determine the success rate of metrics. Table 6 shows that nine metrics were found to have a pass rate of less than 2 in 3, but only one metric had a pass rate of less than 50%. The T2 metric *"number of years with 1 or more spell greater than the annual 5th percent exceedence flow"* represents an EWR that promotes large-scale fish movement. Consequences for this metric failing are that fish species may move either less often, or move less distance (due to lower magnitudes). The reduction in this metric means that fish may be restricted to move over shorter distances in the majority of years, leading to a slight reduction in resilience as more remote habitats may not be repopulated as often if they suffer local extinctions. This risk is further reduced if core refugia are maintained, lowering the potential for localised extinctions.

Table 6. Metrics passing at less than 2/3 of sites at 20-25% extraction levels

Metric*	# Sites tested	# Sites passed	% passed
T2: Number of years with 1 or more spell greater than the annual 5th p.e. flow	6	2	33.3
T1: Average daily T1 flow	6	3	50.0
T2: Average total duration of T2 freshes per year	6	3	50.0
HFS: Number of years with 1 or more spell greater than the annual 5th p.e. flow in HFS	5	3	60.0
HFS: Number of years with one or more HFS freshes	6	4	66.7
HFS: Average total duration of HFS freshes per year	6	4	66.7
Annual: Average total duration of bankfull flow per year	6	4	66.7
T2: Number of years with one or more T2 freshes	6	4	66.7
T2: Average number of T2 freshes per year	6	4	66.7

*T1: Transition 1, T2: Transition 2, HFS: High Flow Season, Annual: Can occur at any time of year

5.3.4. PROPORTION OF FLOW BYPASSED

Flow bypasses allowing water to flow through the system, slightly reduce the proportion of the resource capacity able to be captured, but significantly increase the quantity able to be captured and used when considering environmental sustainability. Hydrological modelling using the WaterCRESS platform indicates that bypassing a threshold flow rate equivalent to the 20th percent exceedence non-zero flow equates to a minimal volume returned to the system of approximately 1–3% of total runoff volume given existing development levels (K. Teoh, DWLBC, pers. comm. 2009).

5.3.5. RELIABILITY OF SUPPLY

The impacts of bypassing threshold flows on the reliability of supply is an important economic and social consideration when returning flows to the system, and has been tested and reported by Alcorn (2009). Findings show that 54% of dams tested showed that reliability of supply was reduced by less than 10% (i.e. dams reaching supply level in 10% fewer years), and 84% showed a reduction of less than 20% (supply was considered to be met when dams filled to 85% of capacity, a possible overestimation in many areas).

5.3.6. SUMMARY

Passing 85% of EWR metrics is an alternative ecological target that relates to an increased, but acceptable, level of risk of degradation to the aquatic environment in the western Mount Lofty Ranges.

Water resource development through the construction of onstream dams has resulted in a change in the flow regime for which endemic biota and ecosystems have evolved life-history strategies. The largest impacts are observed in the Low Flow season and in metrics which relate to low flows due to dam capture. The introduction of a threshold flow rate below which water cannot be captured or diverted was found to ameliorate many of the water regime impacts caused by onstream dam construction. An ecologically significant threshold flow rate of the 20th percent exceedence non-zero flow was developed based on being equivalent to the most impacted components of the flow regime.

VanLaarhoven and van der Wielen (2009) report a correlation between extraction volumes and the success of EWR metrics. Exploration of this correlation indicates that with the provision of threshold flows, an extraction limit of 25% or less of upstream runoff will meet the alternative ecological target of passing 85% of EWR metrics. The application of extraction limits at the surface water management zone scale (Section 5.1) will minimise the risk of forming environmentally unsustainable ‘hotspots’ of water resource development. Water allocated at this scale will have the greatest potential of being environmentally sustainable across the Prescribed Water Resources Area.

With provision of threshold flows, the environmentally sustainable extraction limit is 25% of upstream runoff. This is expected to maintain the water-dependent ecosystems of the Western Mount Lofty Ranges at an acceptable level of risk.

5.4. WETLANDS OF THE FLEURIEU PENINSULA

The Fleurieu Peninsula, at the southern extent of the Mount Lofty Ranges, extends south and west from, and includes, the Myponga and Hindmarsh catchments. The Fleurieu Peninsula supports significantly more wetlands, aquatic animals and plants of conservation significance than other areas in the region and as such warrants further consideration in the development of water resources.

Wetlands on the Fleurieu Peninsula (Figure 13) are known to support over 700 plant species, of which over 30% have conservation status at the regional, state or national level. They also support over 180 vertebrate species, 25 of which have conservation significance at the regional or national level, and 3 are protected under international treaties.

A subset of wetlands in the region, classified as ‘Swamps of the Fleurieu Peninsula’, has been recognised as a matter of national environmental significance. These wetlands are protected under the Australian

Government *Environment Protection and Biodiversity Conservation Act 1999* as a Critically Endangered Ecological Community. They occur in valley flats, as perched systems, in the often deeply incised drainage lines of higher lands and surrounding creeks and rivers. The underlying substrates in a large proportion of wetlands are highly organic or 'peaty' in nature, ranging from fibrous peat to loams maintaining an organic-rich upper layer (A Stevens, MLR Southern Emu-Wren and Fleurieu Peninsula Swamp Recover Team Scientific Officer, pers. comm. 2009).

These organic and peaty substrates are very sensitive to water stress, to the point that they can be irreversibly impacted if excessively dried. Ecosystems and species that depend on the conditions in these organic substrates can be lost and the risk of erosion, which can potentially impact upon extensive lengths of watercourse, is increased (Charman 2002).

The sensitivity and conservation significance of these ecosystems and the organisms they support, and the risk of irreversible damage from excessive drying, warrants wetlands on the Fleurieu Peninsula, as mapped by Harding (2005), being maintained at a lower acceptable level of risk than other regions of the Mount Lofty Ranges.

Environmentally sustainable extraction limits for watercourses in the WMLR have been developed using fish and macroinvertebrate population condition as a surrogate for environmental sustainability. Fish and macroinvertebrate populations use the habitats supplied by wetlands but may not be the most sensitive aspect of the environment in these ecosystems as they have permanent refuge pools to which they can retreat during dry periods. The goal for wetlands is to ensure the range of flows is delivered to maintain their (sensitive) substrates, and ensure adequate watering for the endangered aquatic vegetation that characterises the wetlands on the Fleurieu, and in turn supports the diversity of endangered vertebrates.

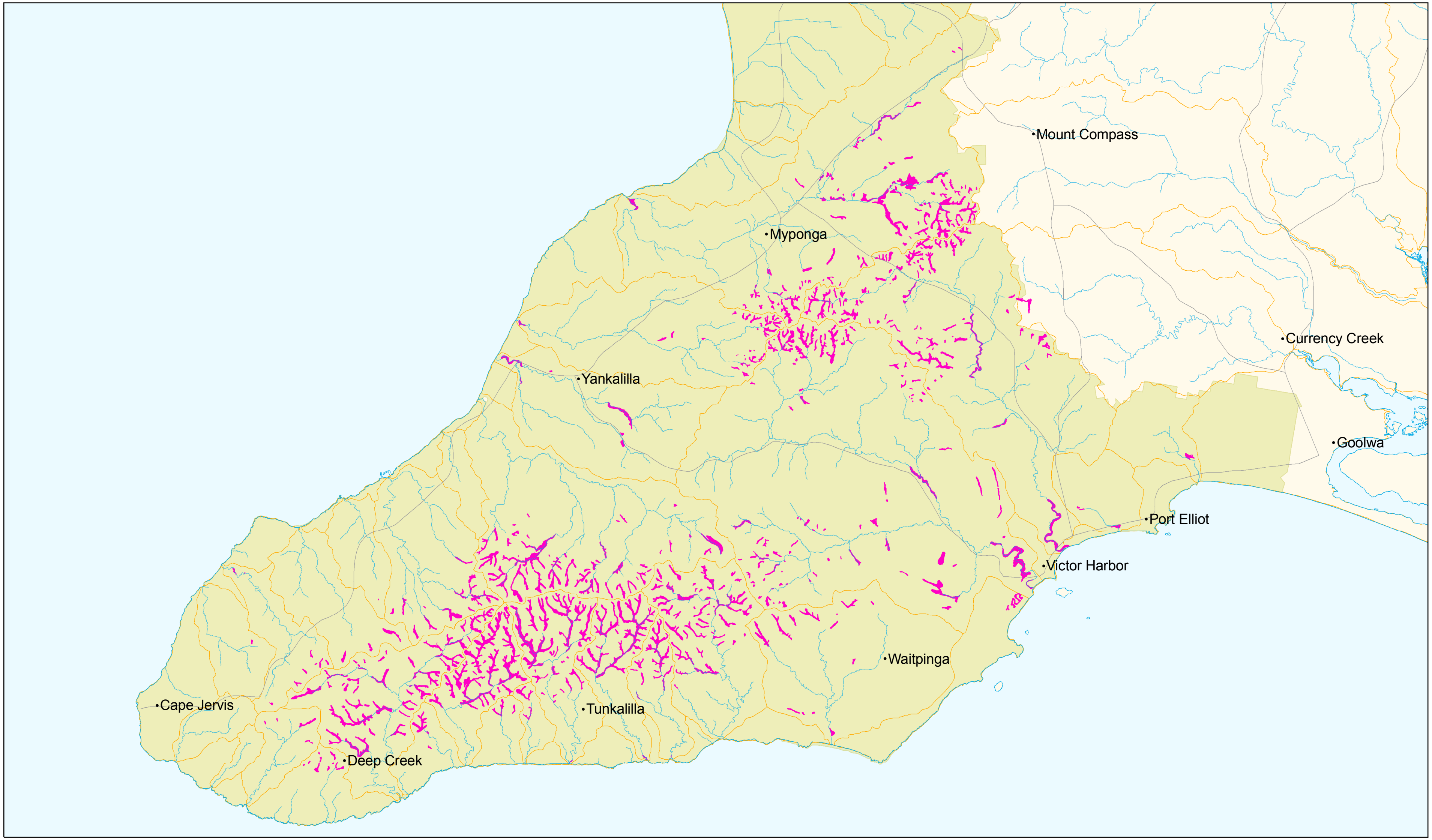
To reflect the conservation status of these wetlands, the biota they support and the sensitivity of the peat substrates, a metric pass rate of 95% is recommended upstream of wetlands on the Fleurieu Peninsula, rather than 85% as for the rest of the WMLR. It is recognised that the selection of this metric pass rate is based upon a qualitative assessment of risk and that there is a need for further data collection and assessment to quantitatively justify this recommendation.

Using the relationship between extraction volumes and metric success (Figure 10), a metric pass rate of 95% equates to an environmentally sustainable extraction limit of 10% of upstream runoff with provision of threshold flows. This level of extraction equated to 31% of sites passing all metrics, and 81% of sites meeting the criteria of passing 95% of metrics.

This recommended level of extraction is consistent with the findings of Deane and Shrestha (in prep) who report a relationship between plant functional group distributions and hydrology. They suggest that water extraction levels of up to ~10% of upstream runoff have little impact on wetland vegetation on the Fleurieu Peninsula, and that increasing levels of water extraction have a proportionally greater influence on the presence of vegetation functional groups.

With provision of threshold flows, the recommended environmentally sustainable extraction limit above wetlands on the Fleurieu Peninsula is 10% of upstream runoff. This is expected to maintain wetlands on the Fleurieu Peninsula at an acceptable level of risk.

Figure 13: Wetlands on the Fleurieu Peninsula



Wetland
Western Mount Lofty Ranges PWRA
Catchment
Major Watercourse
Road

N

0 4 8 12
Kilometres

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5.5. RIVERS ACROSS THE PLAINS

The main channels of the Gawler, Torrens, and Onkaparinga rivers across the Adelaide Plains are within the WMLR Prescribed Water Resources Area. All three main river channels are below large storages: South Para reservoir for the Gawler River, Kangaroo Creek reservoir for the River Torrens, and Mount Bold Reservoir for the Onkaparinga River. They thus have a more highly modified water flow regime than the remainder of the Prescribed Water Resources Area. Aquatic environments in these rivers are largely disconnected from the areas upstream of the reservoirs, and are therefore maintained through local runoff, groundwater contributions and reservoir spills (e.g. Philpott et al. 1999 for the Gawler River).

The aquatic environments downstream of the reservoirs have changed significantly due to hydrological modification and urbanisation, and complete ecological functioning is no longer possible or desired (e.g. overbank flow risk flooding in urbanised areas). However environmental values remain, including intact macroinvertebrate communities, and native fish and aquatic vegetation species (eFlows Working Group 2006). The recommended flows for the rivers across the plains will be based on the objective of maintaining and rehabilitating these remaining aquatic ecosystem values.

The aquatic ecosystems in the rivers across the plains retain the same vulnerabilities as areas upstream of the reservoirs, such as needing to be maintained during prolonged periods of zero flow, and requiring sufficient opportunities for the movement and breeding of biota. The water requirements of these aquatic ecosystems have been determined through previous studies (Philpott et al. 1999; SKM 2003), which have been used to recommend environmental water provisions that can be provided through a combination of strategically timed water releases from reservoirs (eFlows Working Group 2006), and the introduction of a threshold flow rate below which water cannot be extracted. Reservoir releases aim to provide identified flow requirements (SKM 2003; eFlows Working Group 2006) to maintain aquatic animal and plant species at an acceptable level of risk, while the threshold flow rate protects ecologically important flows generated from inputs below the reservoir.

The threshold flow rate will use the flow depth required to effectively allow fish movement, migration and breeding (10-20 cm (M Hammer, AquaSave Consultants, pers. comm. 2009)) as a surrogate measure that assumes suitable conditions for maintaining aquatic macroinvertebrate populations and aquatic vegetation species. Hammer indicates that this flow depth range is an initial estimation and needs to be verified. Details of the quantities of water required to meet these objectives are discussed in reports prepared by the eFlows Working Group (2006), and Teoh (in prep).

6. MONITORING NEEDS

A structured approach to monitoring and evaluation is critical to achieving continual improvement and effective adaptive management. Within the context of the recommendations within this report for the WMLR Water Allocation Plan it is critical to evaluate and report on whether interventions (WAP policies); 1) produce the predicted outcomes with regard to surface water flows; 2) meet stated environmental objectives; and 3) are based on sound scientific assumptions.

It is not in the scope of this report to develop a monitoring, evaluation, reporting and improvement plan for the required monitoring. However, the broad monitoring needed to report upon and evaluate the WAP, and allow policy improvement in future iterations, should include the following.

Monitoring should be integrated to allow the development of linkages between driving (hydrological, hydrogeological) and responding (ecological, physical) processes. This could be achieved by co-locating ecological monitoring and hydrological and hydrogeological monitoring sites.

Hydrological monitoring must be suitable to show whether WAP policies have resulted in the predicted surface water flows. A monitoring review held by relevant experts in hydrology would inform this need.

The stated environmental objective of the environmentally sustainable diversion limits outlined in this report is to ‘maintain self-supporting populations that are resilient to times of drought’. The quantitative measure of this objective has been that fish breeding events need to be better than marginal in 7 years out of 10, and that macroinvertebrate population health needs to be maintained in moderate–good condition as measured through the AusRivAS protocol. Collecting data on fish breeding events and macroinvertebrate populations as a time-series is required to evaluate the success of these outcomes, and will enable the testing/refinement of the hydro-ecological relationships between these environmental measures and the flow regime.

Integrated monitoring sites will contribute information to all of the above requirements through measuring surface water flows, monitoring ecosystem responses, and testing assumptions regarding ecological responses to flow.

7. CONCLUSIONS AND RECOMMENDATIONS

The natural flow paradigm states that the endemic biota within an ecosystem are evolved to fill the ecosystem niches created through the dynamics of the natural flow regime and its relationship with the spatial and temporal distribution of habitat (Poff et al. 1997; Bunn and Arthington 2002). Changes in the natural flow regime can create conditions to which native biota are poorly adapted, resulting in ecosystem degradation. However, given the natural variation (seasonal, annual and inter-annual) in the flow regime, aquatic biota evolve tolerances to some level of deviation (Jowett and Biggs 2008).

EWRs for the MLR have been determined based on the needs of three priority biotic groups: fish, macroinvertebrates and plants (VanLaarhoven and van der Wielen 2009), which cover all of the physical habitats of riverine systems of the MLR from instream to overbank. Rules and environmentally sustainable extraction limits able to inform EWPs, and presented in this report, are developed based on those needs.

The level of deviation likely to maintain water-dependent ecosystems in the WMLR Prescribed Water Resources Area at a low level of risk has been determined through the use of an expert panel, which has determined the success of EWRs by measurable metrics (see VanLaarhoven and van der Wielen 2009). Across the Prescribed Water Resources Area, 65 sites were tested using the EWRs; none passed 100% of metrics, indicating an elevated level of risk to the environment due to water resource development. Reducing allocation limits to meet EWRs is unlikely to be socially or economically acceptable.

To determine an alternative, ecologically acceptable target, a relationship was measured between ecological condition (fish recruitment and macroinvertebrate population condition) and the success of EWR metrics. Using expert advice on those conditions, it was found that passing 85% of EWR metrics is likely to lead to a sustainable level of risk to the fish and macroinvertebrate populations in the Prescribed Water Resources Area. These surrogate groups have been used on the assumption that if the EWRs for them are met, then the EWRs for the remaining water-dependent biota and ecosystems are also likely to be met.

A correlation between extraction volumes and EWR metrics indicates an environmentally sustainable extraction limit of less than 5%, which is unlikely to be economically or socially sustainable.

Most EWR impacts appear to occur in the Low Flow Season, on metrics that relate to lower flow rates. The influence of restoring threshold flows from all dams greater than 5 ML in volume to the system was investigated and found to cause a significant improvement to the success of most EWR metrics, particularly on flows maintaining critical aquatic refugia in the Low Flow Season. Lesser improvements were found in the Transitional and High Flow seasons.

This revised extraction/metric success correlation indicates that an environmentally sustainable extraction limit of 25% will meet the 85% metric success target in at least 75% of sites. This level of extraction, dependent on the presence of providing threshold flows back to the system, has a higher likelihood of being ecologically, socially and economically sustainable.

Wetlands on the Fleurieu Peninsula are known to support many animal and plant species with conservation status, and include a subset (Swamps of the Fleurieu Peninsula) protected under the *Environment Protection and Biodiversity Conservation Act 1999.* The highly organic substrates of many of these wetlands can be irreversibly damaged if excessively dried. An environmentally sustainable extraction limit promoting a lower level of risk is thus warranted, and a lower extraction limit of 10% of upstream runoff is recommended for catchment areas upstream of these ecosystems.

In the absence of returning threshold flows to the system, the environmentally sustainable extraction limit is <5% of upstream runoff.

If threshold flows are returned to the system from existing and new licensed dams, the environmentally sustainable extraction limit is 25% of upstream runoff.

Above wetlands on the Fleurieu Peninsula, if threshold flows are returned to the system from existing and new licensed dams, the recommended environmentally sustainable extraction limit is 10% of upstream runoff.

The watercourse environments in the Gawler, Torrens and Onkaparinga rivers across the plains have changed significantly due to the large impacts on the flow regime caused by large upstream reservoirs. Complete ecological functioning is no longer possible in these ecosystems, and often not desired (e.g. overbank flows in urbanised areas). However, environmental values do remain and include intact macroinvertebrate communities, and native fish and aquatic vegetation species. The flows required to maintain suitable aquatic habitats for these aquatic ecosystems will mimic the natural flow regime as much as is possible in the changed environment. Flow releases from the reservoirs will be strategically timed and a threshold flow rate introduced.

By implementing the recommendations in this report, and in the absence of other limiting factors (e.g. poor water quality, lack of habitat, presence of exotic species), areas with significant (>5% extraction as a percentage of runoff) water resource development can expect improvements in the components of the flow regime that support aquatic ecosystems and processes. The expected outcomes are an increased frequency of fish breeding events and larger fish population numbers, increased health of macroinvertebrate populations, and increased health and spatial extent of aquatic vegetation species.

Other aquatic animals and plants that are not part of the focus of this study are also expected to benefit, and geomorphic processes relating to maintaining a diversity of physical habitats are also expected to be maintained or improved.

The recommendations of this report should be considered to be the first step in an adaptive management program. A monitoring program should be implemented to evaluate whether impacts to the flow regime and the resulting ecological responses occur as hypothesised. The monitoring results need to be able to be used to refine the hydro–ecological relationships outlined in this report. Subsequently, the recommended environmentally sustainable extraction limits can be refined with consequential implications for EWPs.

UNITS OF MEASUREMENT

Units of measurement commonly used (SI and non-SI Australian legal)

Name of unit	Symbol	Definition in terms of other metric units	Quantity
day	d	24 h	time interval
gigalitre	GL	10^{6} m^{3}	volume
gram	g	10^{-3} kg	mass
hectare	ha	10^{4} m^{2}	area
hour	h	60 min	time interval
kilogram	kg	base unit	mass
kilolitre	kL	1 m^{3}	volume
kilometre	km	10^{3} m	length
litre	L	10^{-3} m^{3}	volume
megalitre	ML	10^{3} m^{3}	volume
metre	m	base unit	length
microgram	µg	10^{-6} g	mass
microlitre	µL	10^{-9} m^{3}	volume
milligram	mg	10^{-3} g	mass
millilitre	mL	10^{-6} m^{3}	volume
millimetre	mm	10^{-3} m	length
minute	min	60 s	time interval
second	s	base unit	time interval
tonne	t	1000 kg	mass
year	y	365 or 366 days	time interval

GLOSSARY

Adjusted flow — Calculated volume of water that flows over land with the presence of dams removed

Aquatic macroinvertebrates — Animals without backbones that spend all or part of their life-cycle in water. They are large enough to be seen with the naked eye and include insects, crustaceans, snails, worms, mites and sponges. The insects include the larvae of flying insects (e.g. midges, two-winged flies, dragonflies, mayflies, stoneflies and caddisflies) as well as the adults of some groups (e.g. waterbugs, beetles, springtails).

Aquifer — An underground layer of rock or sediment that holds water and allows water to percolate through

Baseflow — The water in a stream that results from groundwater discharge to the stream; often maintains flows during seasonal dry periods and has important ecological functions

Catchment — That area of land determined by topographic features within which rainfall will contribute to run-off at a particular point

Current flow — Gauged or modelled flow using 2005 dam development levels

Ecosystem — Any system in which there is an interdependence upon, and interaction between, living organisms and their immediate physical, chemical and biological environment

Endemic — A plant or animal restricted to a certain locality or region

Entitlement flows — Minimum monthly River Murray flows to South Australia agreed in to the Murray-Darling Basin Agreement 1992

Environmentally sustainable extraction limit — For the purposes of this report: the quantity of water that can be used from dams as a percentage of upstream runoff that is expected to provide an adequate downstream flow regime able to maintain self-sustaining populations of aquatic biota, that are resilient to times of drought.

Environmental water provision — That part of environmental water requirements that can be met; what can be provided at a particular time after consideration of existing users' rights, and social and economic impacts

Environmental water requirements — The water regimes needed to sustain the ecological values of aquatic ecosystems, including their processes and biological diversity, at a low level of risk

Floodplain — Of a watercourse means: (1) floodplain (if any) of the watercourse identified in a catchment water management plan or a local water management plan; adopted under the Act; or (2) where (1) does not apply — the floodplain (if any) of the watercourse identified in a development plan under the *Development Act 1993* (SA); or (3) where neither (1) nor (2) applies — the land adjoining the watercourse that is periodically subject to flooding from the watercourse

Flow regime — The character of the timing and amount of flow in a stream

Flow seasons — Seasons defined by the natural flow distribution, rather than the traditional seasons of summer, autumn, winter or spring. Flow seasons are: Low Flow Season, Transitional Flow Season 1 (low–high), High flow season, Transitional Flow Season 2 (high–low).

Fresh — A short duration, small volume pulse of streamflow generated by a rainfall event that temporarily, but noticeably, increases stream discharge above ambient levels

Fresh flow — Range from relatively small and short duration high flow events that last for one to several days as a result of localised rainfall during the Low Flow Season, to long, sustained increases in flow during Transitional and High Flow seasons as a result of heavy rainfall events; may last for a number of weeks but are still contained in the channel.

Licensed dam — Dam from which a licensed extraction is taken. In the Western Mount Lofty Ranges this includes stock and domestic dams with a volume greater than 5 ML, and all irrigation dams.

Metric — Hydrological terms used to quantify the environmental water requirements of water-dependent ecosystems (e.g. 80th per cent exceedence non-zero flow is a metric that represents low flows).

Natural flow — For the purposes of this project, the flow with the impacts of the 2005 level of dam development removed as modelled using the WaterCress platform (e.g. Alcorn et al. 2008; Teoh in prep) but accepting that some irreversible changes from pre-European flows have occurred due to land clearance and other water resource developments. It is more accurately termed the 'adjusted' flow, as there is little scope to determine or model the natural pre-European flow regime due to the confounding interactions between land-use change and water resource development on both the surface and groundwater systems, and the relationships/connections between the two.

Onstream dam — A dam, wall or other structure that is primarily used to store water and that takes an amount of surface water from the catchment above the dam in excess of 5% of its total volume

Phreatophytic vegetation — Vegetation that exists in a climate more arid than its normal range by virtue of its access to groundwater

Prescribed area, surface water — Part of the state declared to be a surface water prescribed area under the Act. The Western Mount Lofty Ranges Prescribed Water Resources Area is shown in Figure 1.

Reach type — The area of land from which water from the surface (e.g. rainfall, streamflow, irrigation) infiltrates into an aquifer

Seasonal watercourses or wetlands — Those watercourses or wetlands that contain water on a seasonal basis, usually over the winter–spring period, although there may be some flow or standing water at other times

Stygofauna — Animals that live within groundwater systems, including caves and aquifers

Swamps of the Fleurieu Peninsula — Wetlands on the Fleurieu Peninsula listed as critically endangered threatened ecological communities under the Australian *Environment Protection and Biodiversity Conservation Act 1999*

Unlicensed dam — Dam from which no licensed extraction is taken

Watercourse — A river, creek or other natural watercourse (whether modified or not) and includes: a dam or reservoir that collects water flowing in a watercourse; a lake through which water flows; a channel (but not a channel declared by regulation to be excluded from the this definition) into which the water of a watercourse has been diverted; and part of a watercourse

WaterCRESS — A computer based hydrological modelling program.

Water-dependent ecosystems — Those parts of the environment, the species composition and natural ecological processes, that are determined by the permanent or temporary presence of flowing or standing water, above or below ground; the in-stream areas of rivers, riparian vegetation, springs, wetlands, floodplains, estuaries and lakes are all water-dependent ecosystems

Water resource — a watercourse or lake, surface water, underground water, stormwater (to the extent that it is not within a preceding item) and effluent; an opening in the ground excavated for some other purpose but that gives access to underground water; a natural opening in the ground that gives access to underground water

Wetland — Defined by the Act as a swamp or marsh and includes any land that is seasonally inundated with water. This definition encompasses a number of concepts that are more specifically described in the definition used in the Ramsar Convention on Wetlands of International Importance. This describes wetlands as areas of permanent or periodic to intermittent inundation, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tides does not exceed six metres. For the purposes of this report, dams and well-defined, channelised watercourses are exempt from this definition.

ABBREVIATIONS

AMLR NRM Board	Adelaide and Mount Lofty Ranges Natural Resources Management Board
AusRivAS	Australian River Assessment System
DWLBC	Department of Water, Land and Biodiversity Conservation
DfW	Department for Water
MLR	Mount Lofty Ranges
EWP	environmental water provision
EWR	environmental water requirement
WAP	water allocation plan
WMLR	Western Mount Lofty Ranges

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