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Commonwealth Environmental Water Office
Monitoring, Evaluation and Research Program

MER Plan - Goulburn

Prepared for the Commonwealth Environmental Water Office

30 June 2019

Citation: This report should be attributed as:

Title: Lower Goulburn River Selected Area Monitoring, Evaluation and Research Plan (2019-2022). Prepared for the Commonwealth Environmental Water Office

Date: June, 2019

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Publisher: Commonwealth of Australia

This monitoring design project was commissioned and funded by Commonwealth Environmental Water Office.

The authors of this report as well as the Commonwealth Environmental Water Office respectfully acknowledge the traditional owners, their Elders past and present, their Nations of the Murray-Darling Basin, and their cultural, social, environmental, spiritual and economic connection to their lands and waters; in particular the Taungurung Clans and Yorta Yorta and Bangerang nations, traditional owners of the Goulburn River catchment

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1. Introduction

The Commonwealth Environmental Water Holder (CEWH) is responsible under the *Water Act 2007* (Cth) for managing Commonwealth environmental water holdings. The holdings must be managed to protect or restore the environmental assets of the Murray-Darling Basin, and other areas where the Commonwealth holds water, so as to give effect to relevant international agreements. The Basin Plan (2012) further requires that the holdings must be managed in a way that is consistent with the Basin Plan's Environmental Watering Plan. The *Water Act 2007* (Cth) and the Basin Plan also impose obligations to report on the contribution of Commonwealth environmental water to the environmental objectives of the Basin Plan.

Monitoring and evaluation are critical for supporting effective and efficient use of Commonwealth environmental water. Monitoring and evaluation will also provide important information to support the CEWH to meet reporting obligations. The Monitoring Evaluation and Research (MER) Program is the primary means by which the Commonwealth Environmental Water Office (CEWO) will undertake monitoring and evaluation of the ecological outcomes of Commonwealth environmental watering. The MER Program is a 3-year continuation of the Long-Term Intervention Monitoring (LTIM) Project with one significant enhancement – the inclusion of additional funding for research activities at the Selected Area scale. The MER Program will be implemented at seven Selected Areas over a three-year period from 2019-20 to 2021-22 to deliver five high-level outcomes (in order of priority):

1. Evaluate the contribution of Commonwealth environmental watering to the objectives of the Murray-Darling Basin Authority's (MDBA) Environmental Watering Plan
2. Evaluate the ecological outcomes of Commonwealth environmental watering at each of the seven Selected Areas
3. Infer ecological outcomes of Commonwealth environmental watering in areas of the Murray-Darling Basin not monitored
4. Support the adaptive management of Commonwealth environmental water
5. Monitor the ecological response to Commonwealth environmental watering at each of the seven Selected Areas.

This Monitoring Evaluation and Research Plan (MER Plan) details the monitoring, evaluation and research activities that will be implemented under the MER Program for the Lower Goulburn River Selected Area. This MER Plan includes:

- A description of the Selected Area, including details of Commonwealth environmental water to be delivered
- Evaluation questions relevant to the Selected Area
- Priority monitoring and research activities
- Monitoring indicator methods and protocols
- A monitoring schedule
- Evaluation methods and protocols
- A preliminary communication and engagement plan
- A project management plan, including project governance; risk assessment; quality planning; and health, safety and environmental planning.

2. Lower Goulburn River Selected Area Description

The Goulburn River extends from the northern slopes of the Great Dividing Range north to the Murray River near Echuca (Figure 1). The upper catchment lies within the lands of the Taungurung Nation and the lower reaches, across the northern plains, lies within the lands of the Yorta Yorta and Bangerang Nations. Mean annual flow for the catchment is approximately 3,200 GL (CSIRO 2008), and approximately half of that is on average diverted to meet agricultural, stock and domestic demand.

The Lower Goulburn River Selected Area includes the main river channel between Goulburn Weir and the Murray River (235 km), along with any low-lying riparian or wetland/floodplain assets that are connected to the river by in-channel flows up to bankfull. Environmental flows in the lower Goulburn River are not used to deliver overbank flows or to water the floodplain. Therefore, for the purposes of the LTIM Project, the lower Goulburn River Selected Area is considered a Riverine System under the Australian National Aquatic Ecosystem (ANAE) classification (Brooks et al. 2013).

The Goulburn MER Program divides its monitoring locations by *zones* (Figure 1). These are equivalent to the *reaches* used in previous environmental flow assessments (e.g. Cottingham and SKM 2011):

- Zone 1 – Main channel of the Goulburn River and associated wetlands and backwaters that are connected to the main channel at flows less than bankfull between Goulburn Weir and the confluence of the Broken River near Shepparton (i.e. Environmental Flow Reach 4).
- Zone 2 – Main channel of the Goulburn River and associated wetlands and backwaters that are connected to the main channel at flows less than bankfull between the confluence of the Broken River and the Murray River (i.e. Environmental Flow Reach 5).
- There are several sites outside these zones: the control site for macroinvertebrate monitoring in the lower Broken River, and several acoustic monitoring stations (for tracking fish movement) in the Murray River near the Goulburn confluence that may be monitored as part of contingency monitoring activities.

Zone 1 and Zone 2 are physically similar, have similar hydrology and are not separated by significant barriers. Moreover, they are equally affected by Commonwealth environmental water, which is controlled by the regulator at Goulburn Weir. With this in mind, the LTIM team (Webb et al. 2018) decided to invest effort in many monitoring activities in a single zone, rather than a small number of monitoring activities in both zones. For the MER Program, we continue to focus our activities on responses to environmental flows in Zone 2.

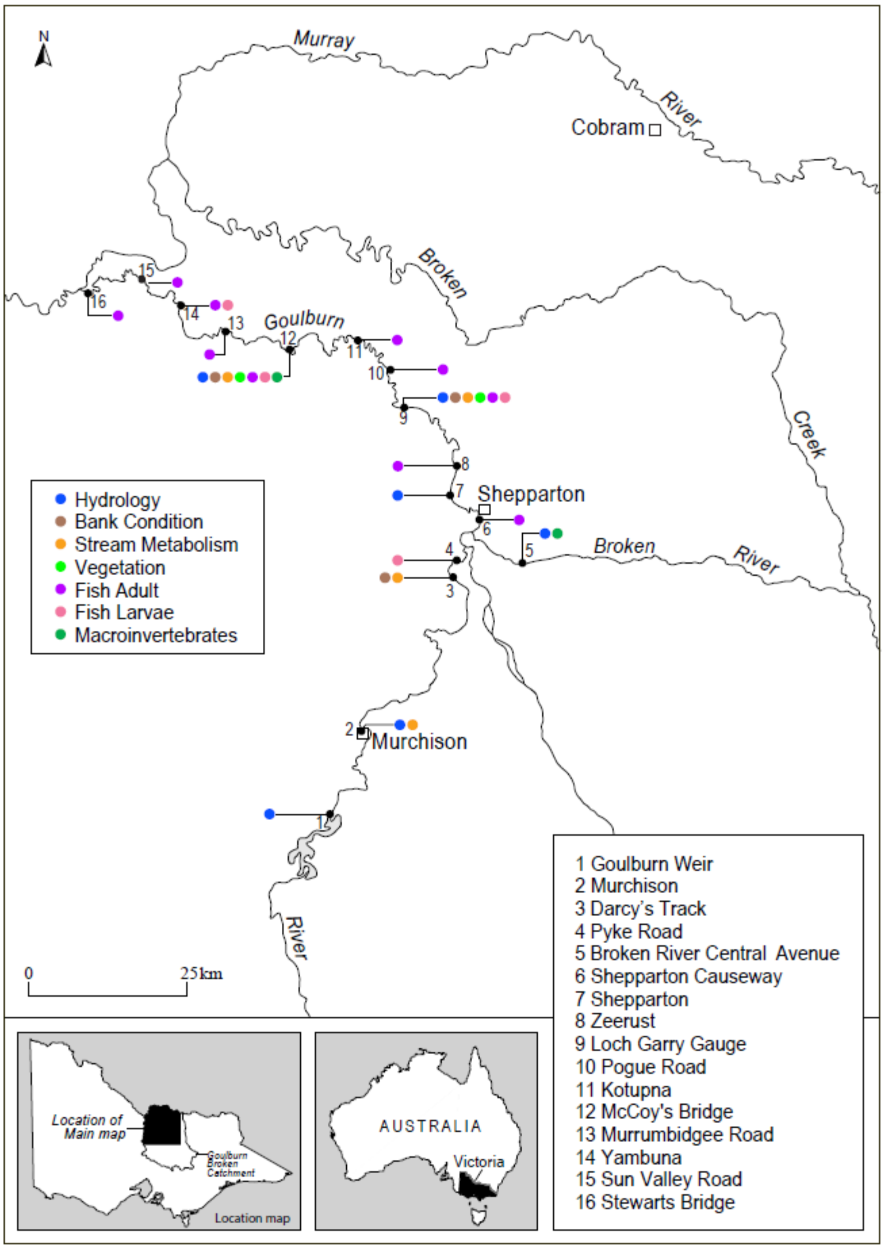

Figure 1 Map of the lower Goulburn River, with all monitoring sites marked, along with flow gauges used to generate flow data to be used in the MER Program. Some sites extend into the Broken River. Colours denote different monitoring activities, with some sites being used for multiple activities. Sites are indicated with site numbers, with the key providing the site name. Monitoring Zone 1 runs from Goulburn Weir to the confluence of the Broken River near Shepparton, with Zone 2 downstream from this point to the confluence with the Murray River.

Ecological Matters being investigated are: physical habitat - hydraulic (river flow and depth characteristics) and bank condition (erosion and sediment deposition); stream metabolism (photosynthesis and respiration as a potential source of food for macroinvertebrates and fish); macroinvertebrates (focusing on the biomass of large bugs such as insects and shrimps); bank vegetation (abundance and diversity of plant cover); and native fish spawning and populations (composition and abundance). Most monitoring activities undertaken in LTIM will continue under the MER Program.

The Goulburn Broken Waterway Strategy 2014–2022 (GBCMA 2014) identifies the Goulburn River as a priority waterway due to its significant environmental, social, cultural and economic values. The river and its associated floodplain and wetland habitats support intact River Red Gum forest and numerous threatened species such as Murray cod, trout cod, Australasian painted snipe and superb parrot. Natural river flows would have been high in the winter and low over the summer months.

Two major flow regulating structures are located on the Goulburn River; Lake Eildon and Goulburn Weir. The reach from Lake Eildon to Goulburn Weir is referred to as the mid Goulburn and the reach from Goulburn Weir to the Murray River is the lower Goulburn. Flows in the mid-Goulburn River are now lower than natural in winter and spring (flow is stored in Lake Eildon) and higher than natural in summer and early autumn (flow is released from Lake Eildon and then mostly diverted from the river at Goulburn Weir to supply irrigation and consumptive needs).

Downstream of Goulburn Weir the overall flow volume is decreased compared to natural but inflows from tributaries such as the Broken River and Seven Creeks have helped to retain the natural seasonal flow patterns (i.e. high winter flows and low summer flows). However, more recently, there has been an increase in summer and autumn flows through the lower Goulburn River as a result of Inter-Valley Transfer (IVT) flows from Lake Eildon to supply users further downstream in the Murray River. The timing and volume of IVT delivery is at the discretion of river operators, but environmental water managers provide advice to minimise ecological impacts of these releases.

The lower Goulburn River was heavily affected by the Millennium Drought and the subsequent floods in 2010–11 and 2012, which resulted in bare river banks susceptible to erosion. Vegetation has begun to re-establish over recent years, but the effects of recent IVT flows are still being evaluated. Also, golden perch, a flow-cued spawner, did not spawn during the Millennium Drought (Koster et al. 2012), making spawning and survival a priority to rebuild populations and age classes.

3. Commonwealth Environmental Watering

3.1 Overview of environmental water holding and watering options for the catchment

As of 28 February 2019, the Commonwealth held 328.2 GL of environmental water entitlements in the Goulburn and Broken rivers (Table 1). The Goulburn River receives other environmental flows including from the Victorian Environmental Water Holder and The Living Murray program, but the Commonwealth environmental water entitlement provides the vast majority of environmental water used to meet specific environmental flow objectives in the lower Goulburn River channel. Inter-Valley Transfers are also used to meet environmental flow targets when possible Gawne et al. (2013).

Table 1. Commonwealth environmental water entitlements as at 28 February 2019

(Volumes are regularly updated at http://www.environment.gov.au/water/cewo/about/water-holdings).

Location	Security	Registered entitlements (ML)	Long Term Average Annual Yield (ML)
Vic	High (Goulburn)	285,205	270,240
	Low (Goulburn)	42,467	19,265
	High (Broken)	534	507
	Low (Broken)	4	3
	Total	**328,210**	**290,016**

To maximise the efficient and effective use of Commonwealth environmental water, where possible, return flows from the Goulburn River are traded for use downstream, providing environmental benefits at multiple sites including Gunbower Forest, Hattah Lakes, the lower River Murray channel and floodplain wetlands, Lower Lakes, Coorong and Murray Mouth (CEWO 2017).

3.2 Expected outcome for Lower Goulburn River

High priority watering actions for the Goulburn River have typically been continuous baseflows throughout the year to maintain access to habitat, winter and spring freshes for vegetation and spring/summer freshes to stimulate golden perch spawning. In recent years, autumn freshes have also been delivered to attract young of year fish from the Murray River into the Goulburn River. To provide an example of this, the following section provides an overview of the priority flow components and expected outcomes for the Goulburn River for the most recent flow year (2017–18).

High-priority watering actions for 2017–18 in Reaches 4 and 5 included: continuous baseflows throughout the year for habitat; winter, spring and autumn freshes for bank vegetation; a spring/summer fresh to stimulate golden perch spawning; and a summer/autumn fresh to attract young of year fish migrating up the Murray River into the Goulburn River (CoA 2017, GBCMA 2017)_ENREF_3 (Figure 2).

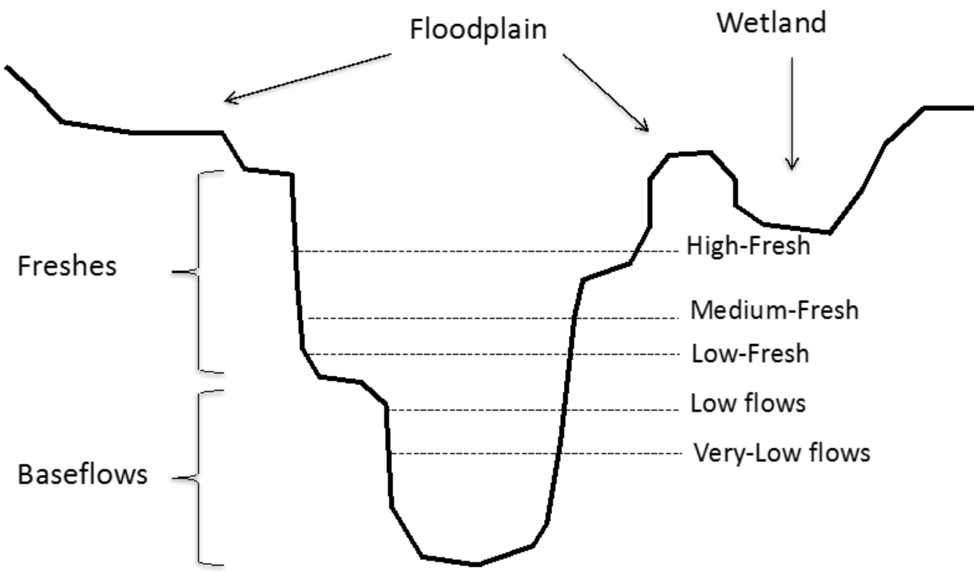

Figure 2 Flow stages defined by Stewardson and Guarino (2018).

During 2017–18 around 350 GL of environmental water was released into the lower Goulburn River. In addition, there were IVT flows of 258 GL, a substantial increase on previous years. The high IVTs reduced the opportunity to deliver environmental water over the summer and autumn period.

The planned delivery for environmental water in 2017–18 is summarised in Table 2, which also outlines the actual delivery and the conditions that influenced use decisions during the year

Table 2. Summary of planned and actual environmental flows for the lower Goulburn River 2017–18. Information on planned delivery and expected outcomes is from CoA (2017) and GBCMA (2017). Information on actual delivery provided by CEWO (unpubl. data).

Flow component type and planned magnitude, duration, timing	Expected outcomes (primary and secondary as at delivery)	Actual delivery details and any operational issues that may have affected expected outcomes Comments
Winter fresh (Jun-Jul) of up to 15,000* ML/day at Murchison/McCoys with 14 days above 6,600 ML/day	Contribute to a winter fresh to provide vegetation and maintain macroinvertebrate habitat. Also provides benefits to downstream ecological targets including lamprey migration.	This was the ramp-down of the winter fresh which commenced on 22 June 2017. Due to drying conditions across the catchment the planned duration and peak of the flow was slightly reduced. At Murchison the flow remained above 6,600 ML/day for 12 days and the peak flow reached just under 9,000 ML/day for 2 days on the 1st and 2nd July 2017.

Flow component type and planned magnitude, duration, timing	Expected outcomes (primary and secondary as at delivery)	Actual delivery details and any operational issues that may have affected expected outcomes Comments
Baseflow (July-Sep) 500–940 ML/day at Murchison/McCoys	Contribute to baseflows to maintain water quality and provide suitable habitat and food resources for native fish and macroinvertebrates and to water bank vegetation.	As planned, baseflow releases from Murchison provided 6 weeks of low flows between freshes, as recommended by LTIM researchers. The average baseflow for this period at Murchison was 845 ML/day, at the higher end of the range. Natural flows and tributary inflows downstream of Murchison between 9 Aug and 3 Sept 2017 provided a double peak of increased flow at McCoys Bridge.
Winter/early spring fresh (Aug) of up to 5,000 ML/day at Murchison/McCoys for 2 days	Contribute to a late winter fresh to achieve pre-spawning migration and increase food availability and fish condition prior to the Nov/Dec fish spawning flow.	Not Delivered. This action was included in CEWO and VEWH plans for the first time based on LTIM findings. Due to potential for low water availability later in the year, it was decided to give preference to delivering the two other planned spring freshes. As it happened natural in-flows upstream of McCoys provided additional flows in the lower Goulburn.
Spring fresh (Sept-Oct) of up to 10,000 ML/day at Murchison/McCoys Bridge with 14 days above 5,600 ML/day	Contribute to long-duration freshes in spring to water bank vegetation, provide soil moisture to banks and benches, distribute seed and allow plants to flower and seed for later germination and distribution.	Due to continued drying conditions across the catchment, the planned duration and peak of the first spring fresh was slightly reduced. At Murchison the spring fresh peaked at 7,685 ML/day and remained above 5,600 Ml/day for 9 days. At McCoys the peak was slightly lower and the days above 5,600 ML/day slightly fewer.
Baseflow (Oct-Nov) 500–940 ML/day at Murchison/McCoys	Contribute to baseflows to maintain water quality and provide suitable habitat and food resources for native fish and macroinvertebrate and to water bank vegetation.	As planned, baseflows were delivered to allow a maximum time between freshes for vegetation outcomes. This action was at the lower end of the range, with an average flow at Murchison of 559 ML/day and at McCoys Bridge of 745 ML/day.
Spring/summer fresh (Nov-Dec) of up to 10,000 ML/day at Murchison/McCoys with 2 days above 6,600 ML/day	Contribute to short-duration freshes during Nov-Dec to stimulate breeding of native fish (flow cued spawners), particularly golden perch.	As with earlier freshes in 2017–18, a revised lower peak of 5,500 ML/day was agreed for the second spring fresh. The actual peak was 5,190 ML/day on 20 Nov 2017 at Murchison and slightly less at McCoys. Channel constraints prevented the revised peak being achieved.
Baseflow (Nov-Dec) 500–940 ML/day at Murchison/McCoys	Contribute to baseflows to maintain water quality and provide suitable habitat and food resources for native fish and macroinvertebrate and to water bank vegetation.	The planned return to baseflows of 500–940 ML/day after the second spring fresh lasted 5 days before rainfall fell across the catchment (see entry below).
Baseflow (Dec-Jan) 500–940 ML/day at Murchison/McCoys	Contribute to baseflows to maintain water quality and provide suitable habitat and food resources for native fish and macroinvertebrate and to water bank vegetation.	The river flow returned to lower levels during this period and environmental water and IVT was delivered so that baseflows at the higher end of the planned range were achieved. Environmental water delivery at Murchison ceased on 31 Dec 2017 and IVT flows commenced on 1 Jan 2018.
Summer/autumn fresh (Feb to April) of 5,600 ML/day at Murchison/McCoys	Contribute to a fresh to maintain existing vegetation and encourage germination of new seeds and when	For the first four months of 2018 the planned flows were unable to be implemented. Instead, a high IVT balance dominated the volume and timing of water delivered and despite the best

Flow component type and planned magnitude, duration, timing	Expected outcomes (primary and secondary as at delivery)	Actual delivery details and any operational issues that may have affected expected outcomes Comments
for 2 days or 4,600 ML/day for 10 days **Baseflow (Feb-Apr) 500–940 ML/day at Murchison/McCoys**	coordinated with flows in the Murray River, facilitate fish migration. Contribute to baseflows to maintain water quality and provide suitable habitat and food resources for native fish and macroinvertebrate and to water bank vegetation.	intentions of environmental water holders, catchment managers and river operators the planned baseflows and summer/autumn fresh were not achieved.
Baseflow (May-Jun) 500–940 ML/day at Murchison/McCoys	Contribute to baseflows to maintain water quality and provide suitable habitat and food resources for native fish and macroinvertebrate and to water bank vegetation.	Baseflows were maintained as planned for 30 of the 41 days during this period. For 9 days from 25 May to 4 June 2018 there was a late-season increase in IVT demand. As a result of this flows increased to an average of 1,350 ML/day.
Winter fresh (Jun-Jul) of up to 15,000* ML/day at Murchison/McCoys with 14 days over 6,600 ML/day	Contribute to a winter fresh to provide vegetation and maintain macroinvertebrate habitat. Also provides benefits to downstream ecological targets including lamprey migration.	Cognizant of the need to maximise carryover into 2018–19 for early season environmental water, the peak for the winter fresh was revised down to 9,000 ML/day. The actual peak was 8,986 ML achieved at Murchison on 30 June 2018. The target of 14 days over 6,600 ML/day was achieved.

* This volume is recommended by scientists to achieve maximum ecological outcomes, but is unable to be achieved due to operational constraints that limit release from Goulburn Weir to around 10,000 ML/day.

3.3 Practicalities of monitoring

After the five years of monitoring in the lower Goulburn River under the LTIM Project, and with the increasing incorporation of data collected prior to the start of the LTIM Project, our understanding of the system has increased considerably. The conceptual model linking flow actions and ecological outcomes that we proposed prior to the start of the LTIM Project (Webb et al. 2018), has been largely confirmed. The current version of the model (Figure 3) includes new causal pathways compared to the original, and most of these pathways, as well as the original hypothesised pathways, while not proven, are being at least strongly suggested by the monitoring data collected. The notes below concentrate on changes to the model in the most recent reporting season (2017–18).

Probably the strongest 'new' knowledge to arise from the Goulburn LTIM Project in 2017–18 was data linking environmental flow actions much more strongly with ecosystem metabolism outcomes and with flow-on effect on macroinvertebrate biomass in the lower Goulburn River. The consideration of the stream metabolism data in terms of the amount of carbon produced as a usable food resource for river animals, rather than in terms of the rates of oxygen production and consumption, was a major advance. This demonstrated that the wetting of significant proportions of the river channel with major environmental flow actions leads to large increases in the amount of organic carbon available to underpin the river food web. While biomass responses are variable among individual macroinvertebrate species, large-bodied species like shrimp are showing positive responses to flow and are likely to form a significant portion of the food resource for native fish species in the lower Goulburn River.

Movement and spawning responses of golden perch continued much as previously in 2017–18. There is now a very strong understanding of the conditions required to induce spawning in this species, and a belief that spawning can be managed for this species with very high precision and efficient use of environmental water.

The largest knowledge gap within the conceptual model (Figure 3) remains the linkages from the other monitoring matters through to adult fish populations in the Goulburn River. Although large numbers of eggs and larvae of species like golden and silver perch are recorded, the juvenile 'young of year' fish that should appear during the electrofishing surveys approximately six months later are rarely caught. Moreover, although there are strong links between flows, metabolism, carbon and large-bodied macroinvertebrates (i.e. fish food), the current approach to monitoring adult fish cannot detect any direct responses in terms of changes in the numbers and species of fish being caught. Similarly, a link between improved near-bank habitat that results from improved bankside vegetation and fish populations (composition and abundance) also cannot be demonstrated because the adult fish sampling does not target habitats specifically. Some of these knowledge gaps will be further examined in the MER Program through a collaborative research project to address key knowledge gaps in our conceptual model (See Section 6).

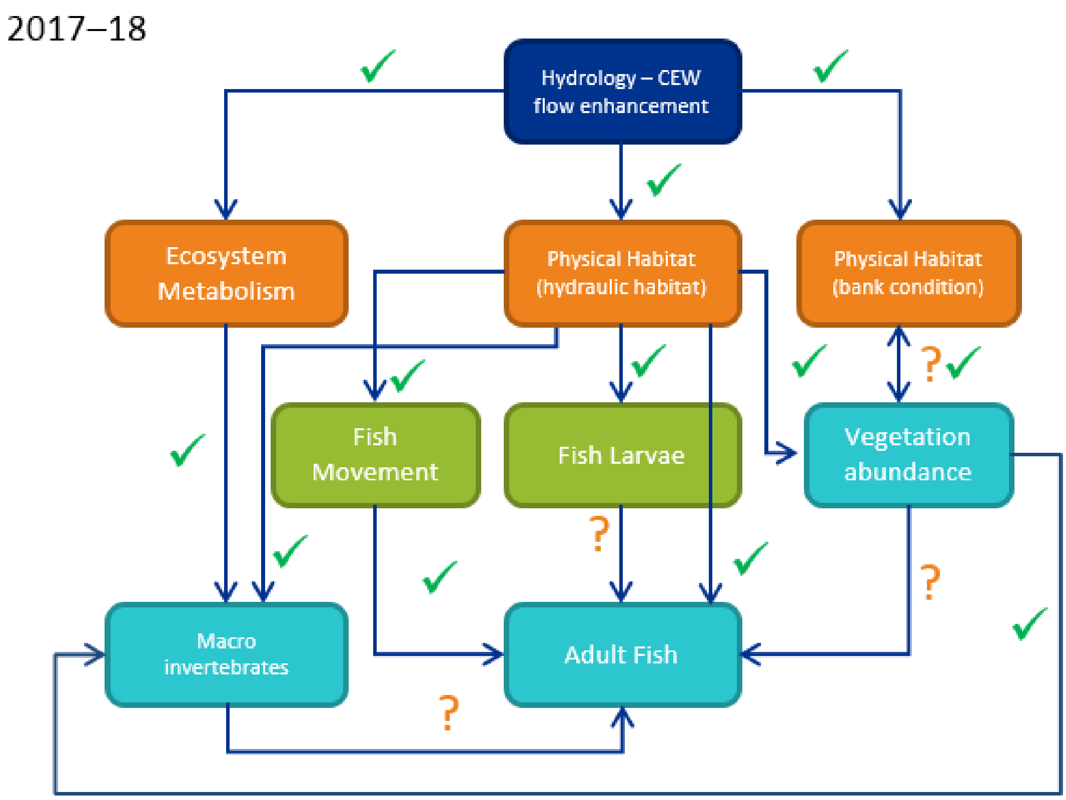

Figure 3 Updated conceptual model of the linkages among the different monitoring matters in the lower Goulburn River Long-Term Intervention Monitoring Project (modified from Webb et al. 2018). The blue 'hydrology' box is the ultimate cause – flow enhancement with Commonwealth environmental water; orange boxes are physical effects of this, with flow on effects to intermediate (green) and ultimate (aqua) environmental variables. Arrows are hypothesized causal linkages posed at the start of the LTIM Project, with several added over the five years of that project. Ticks are linkages that we believe have been demonstrated by the monitoring data, or at least strongly suggested. Question marks are linkages that are yet to be demonstrated. The linkage between bank condition and vegetation diversity, with both symbols, is strongly suggested. No linkages were disproved throughout the LTIM Project.

Links between environmental flow actions and improved fish communities will always be difficult to demonstrate primarily because of issues of scale. Fish respond to multiple drivers over lifetimes that can be literally decades long, and so detecting changes in populations driven by subtle changes in flow regimes will always be difficult. Changes in populations are only immediately evident when catastrophic events occur, such as the January 2016 fish deaths in the Goulburn River associated with the blackwater event. These temporal scales make it impossible to make the kinds of linkages to individual flow actions that are described in Table 2.

Also, many fish species live their lives over spatial scales much larger than the lower Goulburn River. While the monitoring has failed to detect 'young of year' fish for golden perch, older adults continue to be observed in the river. Current integrated monitoring and research across the lower Murray-Darling Basin is pointing to the strong probability that species like golden perch might recruit from different locations in different years, and that autumn flow conditions are important for the survival of sub-adult fish in local populations (Tonkin et al. 2017). For questions of adult fish population response to Commonwealth environmental water, the Basin-scale analyses will have a much greater chance of drawing solid conclusions than any of the current Area-scale programs.

4. Monitoring and Research Priorities

The Goulburn River MER Program team met on March 12 and again on April 30/May 1, 2019 to discuss our reflections on the LTIM Project, strengths and weaknesses of the current monitoring program and proposed changes to methods for the upcoming MER Program. We also identified a range of research opportunities / questions that would help answer gaps in knowledge and improve our ability to interpret results of the routine monitoring activities. The April 30/May 1 meeting also included representatives from the CEWO and Victorian Environmental water Holder (VEWH).

This section provides a summary of the monitoring priorities for the CORE MER Program and research priorities (for funding through the contingency monitoring and research budget) that have been discussed and agreed amongst the project consortium. More specific details are provided in Sections 5 and 6.

4.1. Monitoring priorities for the core MER Program

At the planning workshops, each discipline lead (fish, vegetation, metabolism, macroinvertebrates, physical habitat) provided a summary of the monitoring activities undertaken during the 5 years of the Goulburn LTIM Project. It was generally considered that the current monitoring priorities continue to match those established for the original LTIM Project (see Table 3 and Webb et al. 2018) and should continue as the core MER program. There are, however, several notable changes from LTIM as outlined below:

- Fish - no changes
- Vegetation
  - Removal of the monitoring and reporting of understory plants (>1 m to <5 m high). This vegetation strata is not present in the system and is always scored 0.
  - Removal of the monitoring of overstory canopy condition. With no managed floodplain inundation events in the Goulburn River, this metric does not respond to environmental water deliveries.
  - Inclusion of an autumn monitoring event to establish baseline condition following the conclusion of IVT flows and prior to winter/spring flows.
- Metabolism
  - The inclusion of monitoring of the underwater light attenuation to more accurately calculate whole stream metabolism based on light penetration.
  - Extending the deployment of all oxygen loggers to the full 12 months of the year.
- Macroinvertebrates
  - A shift in the focus of macroinvertebrate monitoring from measures of diversity to measures of biomass, particularly crustacean biomass.
  - Ceasing use of Artificial Substrates Samplers and Replicated Edge samples and replacement with the Rapid Bioassessment Method. This provides similar outcomes in terms of composition and abundance but in a more cost-effective way.
  - Stratification of sampling to highlight the macroinvertebrate response in different habitat types.
- Physical habitat
  - Change in method from manual measurements of erosion and accretion rates using erosion pins to the use of an Unmanned Aerial Vehicle (drone) to achieve greater resolution coverage of a larger range of bank types.

These monitoring priorities also match the needs identified by the Goulburn Broken CMA, other water holders (e.g. the VEWH) and river operators (i.e. Goulburn Murray Water, MDBA River Murray Operator) to be able to:

- Promote benefits of environmental water, how it is being assessed and how the CMA adaptively manages environmental water to meet beneficial outcomes
- Demonstrate the effective use of water, especially during dry times
- Demonstrate that environmental water has benefits for the Goulburn River even if it is part of releases to downstream reaches (i.e. demonstrating co-benefits)
- Help inform discussions around impacts of climate change
- Inform decisions around and optimisation of water delivery arrangement and river operations.

Table 3 Summary of priority monitoring activities in the lower Goulburn River. Activities are concentrated in Zone 2 to address the highest priority evaluation questions for the lower Goulburn River, but some activities extend into Zone 1 (adapted from Webb et al. 2018)

Monitoring activity	Category	Zones	No. sites per zone	Rationale for inclusion
Hydrology	I	1&2	2 + 2 + 1	Accurate flow data is critical for all aspects of the MER Program. Flow data are also required for the lower Broken River to inform the Macroinvertebrate analysis
Fish (River)	I	2	10	Although it would be good to do in both zones, it is not feasible given the costs associated with implementing the prescribed Standard Methods. Zone 2 was chosen because it has the greatest abundance of golden perch and populations in this zone are likely to have greater connection and exchange with populations in the Murray River and other nearby systems.
Fish (Larvae)	II	1&2	1 + 3	A high priority focus for the Goulburn River. Monitoring will target both zones because nursery habitats are likely to vary between each zone. However, given the considerable expense of larval sample sorting, there will only be a single monitoring site in Zone 1.
Vegetation diversity	II	2	2	This monitoring will quantify short term and long term changes in vegetation communities on the river bank. This will be a continuation of the program from LTIM, which focused on 2 sites in zone 2.
Macroinvertebrates	III	2 + Broken	7	Macroinvertebrate monitoring will be conducted at 7 sites in Zone 2 and a site in the Broken River to control for potential confounding effects between flow, season and water temperature
Stream Metabolism	I	1&2	2	Stream metabolism measurements will quantify the energy flow in each system and will inform interpretation of all biological monitoring results. It is therefore being conducted in each Zone where biological monitoring is proposed.
Physical habitat (Bank Condition)	III	1&2	3 + 1	There is concern that environmental flows are contributing to bank erosion in the lower Goulburn River. Moreover, the rate of bank erosion at a particular site is likely to influence riparian vegetation responses to environmental flows. Bank condition monitoring will be conducted at the same sites as Vegetation Diversity monitoring, plus two other sites previously used in the LTIM Project.

4.2. Research priorities for the contingency MER Program

Research questions were identified at the March 12, 2019 workshop. The following principles, which align with CEWO research funding principles[1], were identified for the types of research projects to consider:

- Build on what we've learnt and improve understanding of the processes that drive ecological response to flow
- Address knowledge gaps in our understanding of flow responses, including identification of factors other than flow that may limit responses
- Improve ability to respond to emerging issues / trends / threats / adaptively manage flows for the best outcomes
- Contribute to integration across the basin.

Research ideas for potential funding under the research and monitoring contingency budgets were further considered at the April 30/May 1 2019 workshop and prioritised according to the criteria and scoring in Table 4. Each research idea was discussed and ranked by the MER Program team and then the prioritised list was further discussed and agreed to amongst the team (Table 5). Costs were not considered in the initial ranking because it was felt that the prioritisation should be based on the research need and potential outcomes rather than be driven by cost. Costs will be considered when it comes

[1] Provided in the CEWO Monitoring, evaluation and research program new requirements – selected area providers document

time to allocating budget to actual projects. Opportunities for co-funding were also considered in the prioritisation process but not the scoring. If a high priority idea was suited to co-funding or was considered a monitoring contingency, then it was not considered a priority for direct funding from the MER research budget, although it was kept in the ranked list of project ideas. Further details on specific research projects to be taken forward are provided in the discipline specific sections on research and Section 6. Contingency monitoring are activities that might support improved flow delivery or in response to certain events (e.g. blackwater). Contingency monitoring is different to contingency research in that research is aimed at answering specific questions or hypothesis related to increasing our understanding of the ecological response to environmental water.

Table 4 Criteria for prioritising research and contingency monitoring projects

Criteria	Score for ranking		
	1	2	3
Can it fill critical knowledge gaps in our conceptual model?	May fill a gap, but low confidence of outcome	Could fill a gap	Highly likely to fill a gap with high confidence
Is the research cross disciplinary?	No, only relates to one discipline area	Partly, relates to two or 3 areas	Yes, involves all disciplines
Difficulty in achieving outcome	Standard methods are not available, risks that outcomes will not be achieved	Some methods are available, but may require some innovation and risk	Standard methods are available, high confidence in outcome
Scale	Applicable to watering outcomes at a small (e.g. site) scale		Applicable to watering outcomes at a large (i.e. whole river) scale

Table 5 Prioritised research ideas. Green shaded ideas are priority for contingency research funding, orange shaded ideas are more suited to contingency monitoring funding, yellow shaded cells are important but more suited to co-funding if available or contingency monitoring funding if funds are available after other priorities have been addressed.

Project name	Short summary	cross discipline	critical knowledge gap	difficulty in getting outcomes	scale of benefit	score	Priority for contingency research or contingency monitoring funding
Identification of hydrological and hydraulic metric for ecological response	Aims to identify any hydrological or hydraulic conditions / metrics that will enhance ecological response and then complete a hydraulic risk assessment on flow regimes to identify flow conditions that represent benefits or risks to ecological outcomes. Initially complete as a workshop and using existing information to inform activities associated with the Goulburn MER collaborative research project (see below).	3	3	3	3	**12**	Research funding - to be incorporated into Goulburn MER collaborative research project to inform scope development, although could be funded as a stand-alone item
Goulburn MER collaborative research project: Understanding relationships between in-channel flow, hydraulic habitat conditions and ecological response.	Targeted surveys to identify whether there are in-channel habitats (slackwater, snags, etc) in the Goulburn River that are particularly critical to the river’s ecological function (fish, macroinvertebrates, vegetation and metabolism/om processing), and whether these habitats can be optimised through flow manipulation.	3	3	2	3	**11**	Research funding, plus elements could be co-funded to extend outcomes
Optimal flows for vegetation outcomes	Aims to analyse existing data to better understand the response of vegetation to both duration, timing and depth of inundation to identify optimal flow regime for vegetation response and to understand risks associated with some types of flow delivery (e.g. IVT)	2	3	2	3	**10**	Research funding, predominantly a data mining exercise (relatively inexpensive)
Impacts of flow regimes on physical habitat, bank condition and vegetation in the Goulburn	Further investigation of critical drivers of bank erosion and interactions between vegetation, position on bank and erosion potential using re-deployed erosion pins.	2	3	2	2	**10**	Contingency monitoring but probably can only be part funded, may require additional co-funding or refined scope

Sediment deposition dynamics and vegetation emergence potential	Investigates (using turf mats) sedimentation rates under different bank and vegetation characteristics and also between managed (clear water) and natural (turbid water) flows. Could also include vegetation emergence investigations using turf mats and mesocosms.	1	2	3	2	**9**	Contingency monitoring but probably can only be part funded, may require additional co-funding or refined scope
Fish response to blackwater	Assess fish movements in response to blackwater events. Requires funding for fish tagging.	1	2	3	2	**9**	Contingency monitoring to help improve understanding of and mitigation measures for blackwater events. Also suited to co-funding
Silver perch spawning	Sampling has indicated presence of drifting Silver Perch eggs in early summer sampling (December). Provision for additional sampling at the end of the core monitoring to detect Silver perch (informed by flows at the time)	1	2	3	2	**8**	Contingency monitoring, but could be achieved with a slight variation to timing of current larval surveys.
Expanded metabolism assessments to tributary streams	Uses existing DO monitoring networks to expand spatial scale of metabolism measurements.	1	1	3	3	**8**	Yes, relatively cheap but not urgent. Could be co-funded.
Biofilm dynamics	This project would investigate the role of environmental water in structuring biofilm composition, its potential value as a food resource for macroinvertebrates and the impacts of summer variable baseflows (e.g. IVT) on biofilm structure.	2	2	2	2	**8**	Research but unlikely to be sufficient funds. May be able to be funded via contingency monitoring or co-funding.
Relative sources of GPP	Better understanding of the relative contributions of different habitats (e.g. water column, benthic, epiphytic) to metabolism	2	2	1	3	**8**	Research, but unlikely to be sufficient funds. Could get funded at Basin scale or co-funded as part of the collaboration project

Benefits of flood runner engagement to stream metabolism	Investigate importance of flood runners and anabranch inundation for metabolism - benefits of engagement with floodrunners at flows <bankfull	2	3	1	2	**8**	Research but unlikely to be sufficient funds. Could be funded via contingency monitoring or co-funding
Juvenile fish habitat use and dispersal	Aims to understand habit preferences and dispersal patterns of juvenile Murray cod and trout cod through tagging and radio tracking. Outcomes will help identify flows that provide optimal habitat characteristics (sub set of collaborative project).	2	1	2	3	**8**	Research but unlikely to be sufficient funds. Could be incorporated into collaborative projective with co-funding
Drift contents	Review preserved larval drift samples for other drift items (seeds, zooplankton etc).	1	1	1	2	**6**	Suitable for co-funded student project
Fish diets	Gut analysis of fish that are sacrificed for other needs	1	2	1	2	**6**	Suitable for co-funded student project

Details for high priority research and monitoring contingency projects and associated budgets will be submitted to CEWO as Work Orders.

5. Indicators

5.1 Physical Habitat

The bed and banks of the channel translate the discharge provided through the channel into the physical habitat available to fish, macroinvertebrates and plants. For example, the velocity of flow, depth of water and sediments provide the conditions for biota. Bank condition and the influence on vegetation is directly linked to flow delivery. Further quantifying this link reduces the risk of negative influences of river operations and enhances the opportunities for achieving ecological gains. Furthermore, understanding physical form changes improves our ability to interpret ecological response to flow.

Riverbank vegetation richness and diversity are also impacted by flows, including due to flow characteristics such as prolonged inundation, high velocities, and smothering. These vegetation changes can be independent of bank condition, or extricable linked.

We have previously assessed physical form and bank condition using erosion pins. For the MER Program we are proposing to use Unmanned Aerial Vehicles (UAVs), which provide a greater spatial resolution and also enables additional information to be captured on vegetation extent and changes.

5.1.1 Monitoring

Monitoring riverbank vegetation and riverbank erosion using UAVs

Sediment erosion and deposition will be monitored at the area scale.

The use of UAVs to assess bank condition is a new and exciting tool, which provides greater accuracy and more extensive coverage than the erosion pins used in the LTIM Project. This protocol provides quantitative data tracking bank recession (erosion) or accretion (deposition) over the length of this project and will provide critical information regarding the impact of environmental or variable flows (especially unseasonal flows) on bank response and vegetation regrowth. This protocol will also complement the Vegetation Diversity indicator, generating both bank condition and vegetation response data from each site. Co-locating bank condition and vegetation field work will not only save on cost but will enhance our analytic power to understand observed trends and growth in multiple domains. Use of drones meets all relevant legislative requirements with more details on specific protocols provided in the SOP (Appendix 2).

UAV readings are converted to a digital elevation model (DEM) of the river bank. Consecutive DEMs are subtracted from one another to create a *DEM of difference*. Recordings with positive values (relative to starting position) indicate bank retreat (erosion) and negative values indicate bank aggradation (deposition). A range of flow characteristics are assessed (Table 6).

Table 6 Flow metrics to be related to bank characteristic measurements.

Flow metric	Description	Justification
Duration of inundation	How many days a location on the bank is under water between surveys	The time over which a bank is exposed to inundation and/or flowing water influences bank wetting and saturation, and the effect of cumulative shear stress on erosion. Similarly, deposition may be a function of cumulative time over which sediments can move through the water column to deposit on the bank.
Peak flow magnitude	Peak flow of an event that inundated location on the bank between surveys (the maximum if multiple peaks are experienced)	Erosion/deposition may be driven by the maximum shear stress associated with an event, with bank sediments being mobilised, or accumulated (if scoured from elsewhere) during the period around peak flows.
Flow volume	Volume of flow of the event above the level of the location on the bank that inundates an erosion pin	A metric that combines duration and magnitude to assess the 'work' being done on the bank by water.
Maximum dry weather period	Maximum number of days without inundation of the location on the bank prior to inundation	Banks may become more sensitive to erosion when inundated if they are allowed to dry out completely, inducing desiccation and cracking of clay-rich sediment particles.

Maximum dry weather period by season	Maximum number of days without inundation of the location on the bank prior to inundation by ‘hot season’ (Nov-Apr) and ‘cold season’ (May-Oct)	Banks may become more sensitive to erosion when inundated if they are allowed to dry out completely, inducing desiccation and cracking of clay-rich sediment particles. This is hypothesised to be more severe during the hot season when banks can rapidly dry.
Average and maximum rate of drawdown	Day 2 discharge divided by Day 1 discharge for the falling limb of a flow event	The rate at which flow recession from an event occurs can impact on bank erosion through surcharging a bank (saturating) and affecting the support provided by the water while the bank is saturated. If the rate of recession is too great mass failure (slumping) can occur, particularly on steep banks.

Field Monitoring Protocol

a. Sites are identified as suitable by fulfilling the following criteria: a. sites directly influenced by environmental flow deliveries as assessed by a geomorphologist, b. sites are in close proximity of gauging stations, c. sites have appropriate access, but limited public access, and d. sites have limited overhanging vegetation.

b. Sites are visited during periods of low flow. This will be coordinated with the relevant CMA (Goulburn Broken CMA).

c. Ground control points are distributed in the field – bright objects are placed in surveyed locations, to provide ground-truthing for the subsequent drone flight. They are distributed in areas which can be clearly observed and imagery collected by the drone.

d. Drone is flown to collect both nadir and oblique imagery. The nadir flight is an ‘aerial grid flight’ which is flown at an altitude of approximately 60m, and the oblique flight is a ‘freestyle’ flight focusing solely on the banks and captures imagery at an altitude of approx. 5-25 above the water.

e. Return visits are scheduled for subsequent periods of low flow to assess changes in bank condition and vegetation as a result of variable flows

Desktop Processing of Riverbank Vegetation

a. Photogrammetry software is used to generate an orthomosaic (2D map stitched together by correcting camera perspective from nadir imagery to display a map of uniform scale).

b. Orthomosaic is imported into a GIS program (ArcMap or similar) to perform a supervised image classification. The training data is established by manually selecting areas of the orthomosaic which fall under different image classification categories, with these areas used to interpolate the remainder of the site.

Desktop Processing of Riverbank Condition

a. Photogrammetry software is used to generate a densified point cloud from nadir and oblique imagery. A densified point cloud is a series of 3D points which are used to generate a reconstructed model of a scene captured via UAV based on the position and colour information of the captured images.

b. Densified point clouds are edited to remove noise (high vegetation) in the photogrammetry software, before being exported into a GIS program (ArcMap or similar) where the multiple point clouds are converted to raster files based on their minimum elevation, and overlaid using ‘raster math’ to determine the DEM of difference between subsequent site visits. These DEMs of difference illustrate areas of the bank which have undergone erosion or deposition as a result of variable flows.

Relating to Flows

Channel Size/Channel Condition:

The use of drones to map erosion and deposition can be performed on rivers regardless of their channel size. Larger channels will require more ground surveying markers to be deployed. Mapping channels with significantly overhanging vegetation is however difficult, due to the inability of the drone to penetrate through the vegetation to accurately survey the banks beneath. The degree of overhanging vegetation is one consideration during the site selection process and the selection of ‘patches’ for assessment of bank condition changes, i.e. bare banks are best for this purpose. The focus of bank condition mapping for flow operations is the streamflow influenced sections of the bank and the mechanisms of concern, e.g. notching at the surface of the prolonged IVT flow. The comparison of surveys allows identification of bank changes.

5.1.2 Evaluation

Basin-scale evaluation questions

There are no basin-scale evaluation questions.

Area-specific evaluation questions

1. How do CEWH environmental/variable flows contribute to sustaining bank condition?
2. Are CEWH environmental/variable flows adversely impacting the banks of the rivers?
3. How do timing and delivery of CEWH environmental/variable flows affect bank condition of rivers?
4. What timing and delivery of CEWH environmental/variable flows best sustain or improve bank condition for vegetation growth?
5. How do vegetation responses to CEWH environmental/variable flows vary between sites with different channel features and different bank condition?
6. Are bank erosion rates and processes impacting macroinvertebrate communities?

The main outcomes of the riverbank vegetation and riverbank condition protocol using drones is:

1. Determining links between flow operations and bank erosion or deposition
2. Determining links between flow operations and vegetation changes
3. Identifying how bank erosion/deposition and/or vegetation changes might be linked
4. Explaining how bank erosion/deposition and/or vegetation changes might explain other ecological responses (e.g. for fish or macroinvertebrates)
5. Better informing management of the pattern and timing of delivery of environmental flows to reduce bank instability, maintain/improve vegetation, and achieve ecological objectives.

Statistical Analyses

Statistical analyses will build upon those undertaken for the LTIM Project. Specifically, we will use Bayesian analyses to relate changes in the bank surface elevation to the hydrologic and hydraulic environment. Each year's analysis will build upon the data sets collected to date, rather than being conducted as a year-by-year analysis during the MER Program. For a fuller explanation of the Bayesian approach employed in the LTIM Project see Webb et al. (2018).

5.1.3 Research

Knowledge gaps relate to understanding the dynamics of erosion and deposition and the interactions with vegetation and bank angle. Knowledge gaps also relate to the differences in sediment transport and deposition dynamics between managed flows and natural floods (managed flows tend to carry less sediment load than natural flows).

Research projects that could be considered for contingency funding to address this knowledge gap include:

1. **Erosion and sedimentation dynamics**: This research would examine the differences in sediment deposition (or erosion) rates between bare areas and areas that are vegetated using a combination of erosion pins and turf mats.
2. **Managed flows versus natural flows:** This research would use turf mats to examine the differences in characteristics of deposited sediment between managed (clear water) and natural (turbid) flows.

Decisions around specific project funding will depend on overall selected area priorities and funding availability. Research contingency funding will be requested through Works Orders to the CEWH.

5.2 Stream Metabolism

5.2.1 Monitoring

Dissolved oxygen concentrations will be monitored at the area scale, with these data being converted to estimates of daily Gross Primary Production (GPP) and Ecosystem Respiration (ER).

Stream metabolism will be measured at a daily time step at four sites in the main channel of the Goulburn River for 12 months per year. Inverse modelling of the data will yield daily estimates, with uncertainties of both GPP and ER. These estimates will then be assessed with the corresponding daily flow data at each site to address questions at the Selected Area level about the effects of flow including CEW on stream metabolism.

The same data will also be provided to facilitate Basin Level consideration of the same fundamental questions:

- What did Commonwealth environmental water contribute to patterns and rates of decomposition?
- What did Commonwealth environmental contribute to patterns and rates of primary productivity?

The only difference between Basin Level and Selected Area questions is the spatial scale.

5.2.2 Evaluation

Basin-scale evaluation questions

1. What did CEW contribute to patterns and rates of decomposition?
2. What did CEW contribute to patterns and rates of primary productivity?

Area-specific evaluation questions

3. How does the timing and magnitude of CEW delivery affect rates of Gross Primary Productivity and Ecosystem Respiration in the lower Goulburn River?
4. How do stream metabolism responses to CEW in the lower Goulburn River differ from CEW responses in the Edward Wakool system where the likelihood of overbank flows is higher and nutrient concentrations are generally much lower?

The well-established Category 1 stream metabolism protocol and inverse modelling approach used in the preceding LTIM Project will again be applied in the MER Program. This will involve deployment of a dissolved oxygen/water temperature logger at each of the four designated sampling sites: Murchison, Darcy's Track, Loch Garry and McCoys Bridge. For the MER Program, logger maintenance, data downloading and quality assurance checks will be the responsibility of ALS as part of their larger agreement with the Goulburn-Broken Catchment Management Authority. Ambient light (photosynthetically active radiation, PAR) will also be measured concurrently at two locations within the study region.

Dissolved oxygen, water temperature and ambient above stream sunlight will be monitored concurrently at 10-minute intervals. These parameters form the continuous data set required by the BASEv2 Model (used in LTIM) to estimate rates of GPP and ER. The Bayesian BASEv2 model output includes GPP and ER at a daily time step as well as the reaeration coefficient K and measures of goodness of fit and model convergence.

Acceptance criteria for inclusion of daily results from the BASEv2 model are that the fitted model for a day must have an r^2 value of at least 0.90 *and* a coefficient of variation for GPP, ER and K parameters of < 50%. The convergence measure, PPP, must lie between 0.1 and 0.9. Finally, to exclude occasional data days that meet all these requirements but produce unrealistically high (or) low estimates of GPP and ER, the reaeration coefficient, K, is constrained to the range 0.1 < K, 15 /Day. These very infrequent parameter excursions occur due to the high correlation between ER and K. A K value < 0.1 /Day is extremely unlikely as this would be a lower reaeration than from a completely undisturbed still water surface; values > 15 /Day indicate highly turbulent flow (which is common in small streams but very unusual in low gradient larger rivers such as the Goulburn.

In accord with the MER Standard Method, water quality parameters (temperature (°C), electrical conductivity (mS/cm), dissolved oxygen (%), pH, and turbidity (NTU)) will be measured as spot recordings at the four metabolism monitoring sites during deployment and maintenance of the DO loggers.

Water samples will be collected from the same four sites used for the metabolism measurements, to measure:

- Total Organic Carbon (TOC)
- Dissolved Organic Carbon (DOC)
- Nutrients (Ammonia (NH_4^+), filtered reactive phosphorus (FRP), dissolved nitrate + nitrite (NOx), Total Nitrogen (TN) and Total Phosphorus (TP))

Penetration of light (PAR) into the water column will be measured at the same time as water sample collection.

Statistical Analyses

Statistical analyses will build upon those undertaken for the LTIM Project. Specifically, we will use Bayesian analyses to GPP, ER, Net Primary Production, and Carbon fixed to the hydrologic and hydraulic environment. Each year's analysis will build upon the data sets collected to date, rather than being conducted as a year-by-year analysis during the MER Program. For a fuller explanation of the Bayesian approach employed in the LTIM Project see Webb et al. (2018).

5.2.3 Research

Knowledge gaps relate to understanding the contribution that tributary streams and floodrunners inundated at less than bank full flows make to the energetics of the Goulburn River. The relative proportions of metabolism associated with different habitat types (e.g. water column, versus benthic biofilms, versus epiphytic growth etc) make to total ecosystem system is unknown, as is the relative importance of metabolism associated with these different sources (i.e. is primary production by biofilms a more important source of food for consumers compared with water column primary production?).

Research projects that could be considered for contingency funding to address these questions include:

1. **Additional tributary monitoring**: Water quality monitoring stations already exist in tributary streams (i.e. the Broken River and Sevens Creeks). This research project involves accessing that data and analysing it according to MER protocols.
2. **Benefits of floodrunner inundation**: This project would investigate the importance of flood runners and anabranch inundation for metabolism.
3. **Relative sources of GPP**: This project would provide a better understanding of the relative contributions of different habitats (e.g. water column, benthic, epiphytic) to metabolism. This project can be integrated for the Goulburn MER collaborative project (See Section 6).

Decisions around specific project funding will depend on overall selected area priorities and funding availability. Research contingency funding will be requested through Works Orders to the CEWH.

5.3 Macroinvertebrates

5.3.1 Monitoring

Macroinvertebrate biomass and family-level diversity will be monitored at the area scale.

Macroinvertebrates are an essential part of healthy, functioning aquatic ecosystems, providing essential ecosystem services that range from nutrient cycling to provision of food for larger aquatic organisms such as fish. Macroinvertebrates are frequently monitored in aquatic ecosystem assessments to understand the health of those ecosystems. In large lowland rivers, such as the Goulburn River, the macroinvertebrate communities tend to be dominated by species that favour relatively simple habitats and are able to tolerate moderate to poor water quality. Environmental flows delivered to these rivers are more likely to influence macroinvertebrate abundance and biomass than diversity. Previous work from the Goulburn LTIM macroinvertebrate monitoring program has also shown that crustaceans seem to be particularly responsive to flows in the lower Goulburn River.

The macroinvertebrate indicators that will be measured at the area scale include:

- **Macroinvertebrate composition and abundance – Rapid Bioassessment Methodology (RBA)**. The taxonomic groups (family level) presence and abundance will provide information on how these potential key food sources for fish respond to environmental flows. In particular, it will be important to monitor macroinvertebrates such as chironomids and trichopterans that may be an important food source for young Golden Perch or other smaller fish.
- **Large bodied crustacean (shrimp, prawns, yabbies) life history (size, abundance, reproductive capability) and biomass – Bait traps**. It is believed that crustaceans are an important food source for fish, including the Golden Perch (*Macquaria ambigua*), with literature confirming they may eat macroinvertebrates and large bodied crustaceans and or gudgeons (Hebert, 2005). The monitoring specifically targeting large-bodied crustaceans will provide information on how these potential key food sources for fish respond to environmental flows.

These indicators will contribute to a better understanding of how environmental flow delivery in the lower Goulburn River can affect the abundance and composition of macroinvertebrates and the lifecycle (reproduction and recruitment) of large bodied crustaceans. This has important implications for the river in terms of the services and functions provided by macroinvertebrates. The role of bank vegetation, macrophytes and biofilms play an important role in sustaining these populations, while it is likely large-bodied crustaceans are likely to be an important food source for other riverine species, especially Golden Perch. Macroinvertebrate monitoring, particularly biomass assessments, could thus complement fish monitoring and provide a mechanistic explanation for how environmental flows are affecting fish larvae by affecting a critical food resource.

5.3.2 Evaluation

Basin-scale evaluation questions

There are no basin-scale evaluation questions.

Area-specific evaluation questions

1. What did CEW contribute to the composition and abundance of macroinvertebrate groups in the lower Goulburn River? Specifically, what combination of freshes and low flows are required to maximise key macroinvertebrate groups in the river?
2. What does CEW and other natural flow events contribute to crustacean growth, reproduction and biomass in the Goulburn Catchment and exploitation of novel habitats by these large-bodies crustaceans? Specifically, what combination of flows are required to maximise large-bodied crustacean growth, reproduction and biomass in the river?

Methods

A total of eight sites will be used to monitor macroinvertebrates within the Goulburn Catchment. Two methods for monitoring macroinvertebrates will be employed across the catchment – Rapid Bioassessment sampling and bait traps.

Spatial and temporal comparisons of faunal changes (Identification of macroinvertebrate taxonomic groups and abundance) using Rapid Bioassessment (RBA) for edge sampling and large-bodied crustaceans (growth, reproduction and biomass) using bait traps will be done at eight sites five times a year. Sampling will occur once before the spring fresh and then four times after it, approximately monthly.

Hydrological and water quality measurements

Hydrological and water quality measurements will be obtained from existing flow gauge stations and routine water monitoring as needed.

Rapid Bioassessment Sampling (RBA)

Rapid Bioassessment Sampling (RBA) will be taken five times a year at eight sites along the Goulburn Catchment. This method is modified from the EPA Victoria guidelines (2004). Edge samples using sweep samples will be collected at each site. Macroinvertebrates are live picked on site, preserved in ethanol and identified to family level or higher. During the pick macroinvertebrates larger than 5mm will be targeted and as many of each animal will be picked within the allocated time.

Bait traps

Bait traps specifically targeting crustaceans and will be deployed five times a year at eight sites along the Goulburn River. These sites will be selected based on sites that have suitable habitats for crustaceans (bare, snags, vegetated). Five bait traps will be deployed overnight at each site and placed in the dominant types of habitat (bare, coarse organic particulate matter/depositional areas, macrophytes and snags) that are present at the time of deployment. Upon retrieval, all crustaceans will be removed from the bait traps and stored in 100% ethanol with the exception of yabbies (*Cherax* sp.), which are counted, weighed and released back into the river. The preserved crustaceans will be identified to species in the laboratory and their carapace lengths measured (from the tip of the rostrum to the end of the carapace). They are then air dried for 24 hours, dried in the oven at 60°C for a further 24 hours and weighed.

Data analysis

Macroinvertebrate abundance is to be calculated by determining the number of taxa and abundance of family level or higher taxa observed in the RBA sample.

Large-bodied crustacean abundance, weight and biomass are determined by comparing changes in crustacean presence, abundance and dry weights among different habitat types over different flow periods.

Statistical Analyses

Statistical analyses will build upon those undertaken for the LTIM Project. Specifically, we will use Bayesian analyses to relate presence and cover of key macroinvertebrate species to the hydrologic and hydraulic environment. Each year's analysis will build upon the data sets collected to date, rather than being conducted as a year-by-year analysis during the MER Program. For a fuller explanation of the Bayesian approach employed in the LTIM Project see Webb et al. (2018).

5.3.3 Research

Knowledge gaps relate to the preferred habitats for different macroinvertebrates and the linkages between flow, distribution of optimal habitat types and macroinvertebrate biomass. Research projects that could be considered for contingency funding to address these questions include:

1. **Macroinvertebrate habitat preferences**: This research idea has been incorporated into the Goulburn River MER collaborative project (see Section 6). A range of different hydraulic habitats will be identified and intensively sampled to characterise their physical, chemical and biological characteristics. Outcomes of the research will be used to identify preferred habitats for macroinvertebrates (and fish, vegetation etc) and then delivering flows that optimise the availability or distributions of these habitat types.
2. **Biofilm dynamics:** Biofilms provide food resources for a range of secondary producers, including macroinvertebrates and fish. The food quality of biofilms changes over time depending on biofilm structure and composition. This project would investigate the role of environmental water in structuring biofilm composition, it's potential value as a food resource for macroinvertebrates and the impacts of unseasonal flows (e.g. IVT) on biofilm structure.

Decisions around specific project funding will depend on overall selected area priorities and funding availability. Research contingency funding will be requested through Works Orders to the CEWH.

5.4 Vegetation

5.4.1 Monitoring

Vegetation cover and diversity will be monitored at the area scale.

Vegetation indicators to be monitored include species abundance and structure. These are relevant to the evaluation of vegetation objectives for the Goulburn River selected area and are consistent with riparian vegetation indicators monitored by the Edward-Wakool selected area.

***Species abundance**.* Species abundance will be assessed by measuring the cover of all species in the ground layer (<1 m tall). From this data the cover of different plant groups and target taxa will be determined including:

- Cover of all species in the ground layer
- Cover of inundation dependant species
- Cover of grass species
- Cover of target taxa: these include indicator species for Ecological Vegetation Communities or high threat weed
- Cover of terrestrial species

Structure: The cover of the following selected structural components will be assessed:

- Ground layer vegetation (< 1 m tall)
- Litter (bark, leaves and twigs on ground)
- Lichen crusts and mosses
- Bare ground
- Logs

Canopy cover (trees > 5 m tall) will no longer be recorded (as it was in the LTIM Project) as this is not a key objective of flow management for the lower Goulburn River. Moreover, other remotely-based approaches (e.g. drone imagery or Lidar that can survey large areas would be more appropriate. Understory is mostly absent and is therefore not a sensitive indicator of vegetation outcomes.

Vegetation Monitoring Schedule

Sites will be surveyed at three times each year including.

1. **Pre-spring-fresh**: surveys are undertaken as close as possible prior to the delivery of the spring fresh.
2. **Post-spring fresh**: ~ 8-10 weeks following the recession of the spring fresh. This allow time for vegetation to respond to the spring fresh through new growth and vegetative expansion and colonisation from seed.
3. **Autumn:** Vegetation monitoring in autumn, at the end of the growing season, will inform seasonal trajectories of plant cover and support an evaluation of how flows and weather condition over the season influence vegetation.

All surveys require base flows to enable all elevations can be sampled.

Covariates

Hydraulic variables

Hydrological assessments and the one-dimensional hydraulic models that are linked to them are needed to support the evaluation of vegetation outcomes. Hydraulic models are needed to determine what flows have occurred each year and the depth and duration to which surveyed elevations have been inundated.

The specific hydraulic indictors that will contribute to evaluating vegetation outcomes are listed below:

- Days inundated in the year prior to sampling (where possible to determine considering interactions between depth and duration)
- Days inundated in each of the following depth classes in each season in the year prior to sampling
    - Never inundated
    - >0-<10 cm
    - 10 <50 cm
    - >50<100 cm
    - >100 cm

Bank slope

Bank slope at each sampling location will be derived from surveyed elevations along transects obtained in 2016.

5.4.2 Evaluation

Basin-scale evaluation questions

1. What did Commonwealth environmental water contribute to vegetation species diversity?
2. What did Commonwealth environmental water contribute to vegetation community diversity?

Area-specific evaluation questions

The key area-scale evaluation questions and relevant indicators are listed in Table 7 to provide better linkage to the data being collected and the evaluation method.

Table 7 Vegetation key evaluation questions for the Goulburn selected area and associated indicators and evaluation approaches.

Key Evaluation Questions	Indicator	Evaluation Approaches
Does the CEW contribution to spring freshes increase the abundance of riparian vegetation on the bank face?	• Cover of all ground layer vegetation • Cover of water dependant species	• Bayesian models
Do flows shift the distribution of riparian vegetation communities on the bank face	• Cover of all ground layer vegetation • Cover of water dependant species • Cover of grass species • Cover of target taxa	• Examining relationships between vegetation cover and elevation
Do responses of bank vegetation differ among sites?	• Cover of all ground layer vegetation • Cover of water dependant species • Cover of grass species • Cover of target taxa	• Visual comparison of response between sites
What influence do hydraulic variables and bank slope have on the abundance of riparian vegetation communities?	• Cover of all ground layer vegetation • Cover of water dependant species • Cover of grass species • Cover of target taxa	• Bayesian models
Is there a positive trend in the abundance of riparian vegetation communities over the medium-long term?	• Cover of all ground layer vegetation • Cover of water dependant species • Cover of grass species • Cover of target taxa	• Visual examination of changes over time • Potentially statistical trend analyses
How does the annual flow regime (natural, environmental or consumptive) and weather conditions influence the abundance of riparian vegetation communities at the end of the growth season?	• Cover of all ground layer vegetation • Cover of water dependant species • Cover of grass species • Cover of target taxa	• Bayesian models

Data processing

Prior to statistical analyses the data will be processed using on the steps described below:

- Taxonomic nomenclature aligned with agreed basin scale vegetation naming conventions
- Species attributed with relevant plant groups
- Cover calculated for the key indicators detailed in Table 7 for all survey locations and sample events.
- Bank slope calculated and assigned to all sampling locations
- Hydraulic variables populated for all sampling locations by hydrology team
- Graphical representation to support evaluation as indicated in Table 7.

Statistical Analyses

Statistical analyses will build upon those undertaken for the LTIM Project. Specifically, we will use Bayesian analyses to relate presence and cover of key vegetation species to the hydrologic and hydraulic environment. Each year's analysis will build upon the data sets collected to date, rather than being conducted as a year-by-year analysis during the MER Program. For a fuller explanation of the Bayesian approach employed in the LTIM Project see Webb et al. (2018).

5.4.3 Research

Knowledge gaps relate to vegetation response to interactions between depth and duration of inundation, especially for vegetation on the lower banks. The relationship between depth and inundation is cofounded, but it is unclear whether there is an interaction (i.e. deep versus shallow inundation). There are also knowledge gaps in relation to impacts of unseasonal flows on vegetation emergence, establishment and survival, especially with respect higher summer flows drowning vegetation that may have emerged in spring during drawdown.

Research projects that could be considered for contingency funding to address these questions include:

1. **Vegetation responses to interactions between depth and duration of inundation**: Additional analysis of existing vegetation and hydrology/hydraulic data could inform refinement of monitoring in years 2 and 3. Additional analysis could identify any vegetation responses to depth and duration of inundation, seasonality, responses to flows generated by IVT v natural, position with respect to hydraulic habitat or vertical elevations/bands. Outcomes could be used to scale up vegetation response (from site to reach) based on any relationships between vegetation response and hydraulic conditions (using expanded hydraulic habitat models) i.e. develop up a relationship between veg response and hydraulic conditions and then look elsewhere to see if this prediction / response is widespread.
2. **Vegetation emergence and survival**: Range of possible experiments examining vegetation emergence and survival using mesocosm and seedbank experiments with seed collected from different sediment types or positions on the bank and then exposed to a range of different inundation conditions to test emergence and survival characteristics. Relate these characteristics to flow regimes for optimal survival.

Decisions around specific project funding will depend on overall selected area priorities and funding availability. Research contingency funding will be requested through Works Orders to the CEWH.

5.5 Fish

5.5.1 Monitoring

Abundance and diversity, and spring spawning of the fish assemblage, will be monitored at the area scale.

Category 1 Annual Census

This method involves intensively sampling the fish community annually within each selected area, each autumn, after the flow delivery season (Stoffels et al. 2016). Category 1 censuses involve use of boat electrofishing and fine-mesh fyke nets to sample the fish community. The method is designed to yield a powerful time-series at the levels of the population and community. The method was designed to link inter-annual changes in population and community structure with characteristics of river flows that occurred between each annual sample. This method was designed to detect impacts of flows on entire populations over the long-term (5 years plus).

Electrofishing will be conducted at 10 sites in the Goulburn River during April and May. Sampling will be conducted at each site during daylight hours using a Smith–Root model 5 GPP boat–mounted electrofishing unit. At each site the total time during which electrical current was applied to the water will be 2880 seconds. Ten fyke nets will also be set at each site. Nets will be set in late afternoon and retrieved the following morning

Category 2 Larval Sampling

Like the Category 1 annual census, this method also involves developing a time-series, but at a much finer temporal resolution (Stoffels et al. 2016). The method was designed to determine impacts of flows on fish spawning within an individual year, hence targets response of a single population process to specific features of the hydrograph in the short-term (1 year). The method specifically targets flow-cued spawners using fine-mesh drift nets.

Drift nets will be used to collect fish eggs and larvae in the Goulburn River at four sites (Pyke Road, Loch Garry, McCoys Bridge, Yambuna) every week from October to December using 3 nets set at each site. The nets will be set in late afternoon and retrieved the following morning.

5.5.2 Evaluation

Basin-scale evaluation questions

1. What did CEW contribute to native fish populations?
2. What did CEW contribute to fish species diversity?
3. What did CEW contribute to fish community resilience?
4. What did CEW contribute to native fish survival?
5. What did CEW contribute to native fish reproduction?
6. What did CEW contribute to native fish dispersal?

Area-specific evaluation questions

7. What did CEW contribute to the recruitment of golden perch in the adult population in the lower Goulburn River?
8. What did CEW contribute to golden perch spawning and in particular what magnitude, timing and duration of flow is required to trigger spawning?
9. What did CEW contribute to the survival of golden perch larvae in the lower Goulburn River?

Category 1 Annual Census

Category 1 Annual Census data will be collected to feed into the basin-scale assessment to address the key basin-scale evaluation questions for fish (long-term: What did Commonwealth environmental water contribute to sustaining native fish populations?; short-term: What did Commonwealth environmental water contribute to sustaining native fish reproduction?, and What did Commonwealth environmental water contribute to sustaining native fish survival?) (Stoffels et al. 2016).

At the Goulburn River selected area scale, we specifically aim to qualitatively assess temporal trends in diversity, occurrence, abundance and population composition, and qualitatively summarise any fish flow-ecology relationships through review of above data.

Category 2 Larval Sampling

Category 2 Larval Sampling data will be collected to feed into the basin-scale assessment to address the key basin-scale evaluation question of: What did Commonwealth environmental water contribute to sustaining native fish reproduction? (Stoffels et al. 2016).

At the Goulburn River selected area scale, we specifically aim to determine: What is the influence of flow events and flow regimes, on spawning of native flow-cued species (golden perch and silver perch)?

The objective underlying the larval method was to model the relationship between (a) probability of occurrence (at a minimum), or (b) density (ideally) of larvae, and characteristics of the spring-summer hydrograph, within a year (Stoffels et al. 2016). Quantitative modelling approaches such as logistic regression will be used.

Statistical Analyses

Statistical analyses will build upon those undertaken for the LTIM Project. Specifically, we will use Bayesian analyses to relate fish spawning results to the hydrologic and hydraulic environment. Each year's analysis will build upon the data sets collected to date, rather than being conducted as a year-by-year analysis during the MER Program. For a fuller explanation of the Bayesian approach employed in the LTIM Project see Webb et al. (2018).

5.5.3 Research

LTIM Project monitoring has provided us with a good understanding of the flows required to trigger golden perch spawning. However, there is an absence of juvenile golden perch present in the system. The fate of larvae is currently being investigated through the Victorian Environmental Flows Monitoring and Assessment Program and by research led through the South Australian Research and Development Institute.

Despite our good knowledge regarding golden perch spawning response to flows, there still are knowledge gaps around Murray cod, trout cod and silver perch responses to flow, especially juvenile dispersal and habitat use; and about small bodied fish in general. The link between in-stream habitat types (slackwaters, backwaters, pools, etc.) and usage by different species or life stages remains a knowledge gap, especially interactions between flow, habitat availability and food resources.

The outcomes of research in this area would help to further identify critical flow components and optimisation of e-water delivery for maximising ecosystem function and resource (habitat and food) availability for native fish.

Research projects that could be considered for contingency funding to address these questions include:

1. **Murray cod and trout cod juvenile dispersal**. Understanding the influence of river flow on the dispersal of juvenile Murray Cod and Trout Cod could be addressed using the existing acoustic telemetry array. The aim of tagging juvenile stages would be (1) determining whether juvenile Murray Cod and Trout Cod undertake long-distance movements (upstream or downstream) to specific areas, (2) examining the drivers of movement, including river flow, (3) testing whether environmental water can elicit movement, (4) testing whether artificially elevated flow (e.g. due to Inter-Valley Transfers) alters movement, and (5) assessing the importance of environmental flows to actively maintain or improve populations through the process of movement.
2. **Juvenile habitat use.** Tagging of juvenile Murray cod and trout cod could also be used to understand the ecohydraulic characteristics of habitats used by Murray cod and trout cod, which is another knowledge gap that could inform flow delivery. The aims would be along the lines of (1) determining ecohydraulic characteristics (e.g. depth, velocity) of habitats used by early life stages of native fish, (2), relating the availability of suitable habitat to river flows using existing hydraulic habitat models developed for LTIM, and (3) assessing how flow delivery (such as environmental water or IVTs) can be used to optimise or conversely, prove detrimental to critical habitat availability of native fish populations.
3. **Silver perch spawning**. Sampling has indicated the presence of drifting Silver Perch eggs in early summer sampling (December). Other research in the region (Murray R.) has shown the species will spawn during flow events in January and early February. As such, given forecasts of increased IVT flows in Summer, there is potential for spawning benefits to silver perch. This research could be facilitated through additional drift sampling in Jan/Feb for Silver Perch eggs if there are forecasts for high flows (IVTs).

Decisions around specific project funding will depend on overall selected area priorities and funding availability. Research contingency funding will be requested through Works Orders to the CEWH.

6. Integrated Research

Based on the priority research questions identified in Section 4 the Goulburn River MER Program team has scoped a collaborative research project that aims to answer a range of these knowledge gaps and questions – The Goulburn MER collaborative research project: Understanding relationships between in-channel flow, hydraulic habitat conditions and ecological response. The following sections provide a brief overview of the project scope (incorporating a number of the priority research questions identified in Section 4 and also in monitoring matter research areas from Section 5) .

6.1. What are the questions?

1. Are there in-channel habitat types (e.g. slack waters, backwaters, benches, etc.) with different hydraulic characteristics that are particularly important for ecological processes, specific organisms, or life history stages in the Goulburn River?
2. Does the distribution and quality of these habitat types change with different flow rates?
3. Can flow rates be manipulated to optimise the availability of habitat types that are shown to be important, or to minimise impacts on these habitats during river operations (e.g. IVT flows)?

6.2. Why is it important to answer these questions for the Goulburn River?

Evidence in the literature suggests that certain habitat types are important for particular ecological processes, life history stages, etc. (e.g. as areas for organic carbon retention and processing, low-flow refuges for larval and juvenile fish, sites of sediment and seed deposition, etc.). Research conducted under the Environmental Water Knowledge and Research program has recently identified the importance of anabranches and floodplain wetlands as sources of carbon and zooplankton for fish, and that these habitats generate more 'food' than main channel habitats. However, in the Goulburn River there is limited opportunity for inundation of floodplains so in-channel habitats are critical for providing the types of food and habitat niches that might otherwise be provided by floodplain habitats.

In this context, the proposed research program aims to identify whether there are in-channel habitats in the Goulburn River that are particularly critical to the river's ecological function, and whether these habitats can be optimised through flow manipulation.

6.3. How will we answer these questions?

We propose a collaborative project centred on targeted surveys of specific in-channel habitat types present in the Goulburn River, and how these are associated with the presence of fish (larvae, juveniles, adults), macroinvertebrates (particularly crustaceans), microinvertebrates (targeting zooplankton as food for fish), vegetation types, sediment characteristics, organic matter characteristics, metabolism, etc. Other variables could be added according to available budget, in-kind support or co-funding. Elements of the project could also be completed by PhD candidates. Ideally seasonal sampling would be undertaken for two years (sites to be confirmed but would be aligned with existing monitoring locations). Sampling would also target different flow rates.

The project would commence with an expert workshop to elicit the hydraulic conditions that are expected to be important for plants, fish, macroinvertebrates etc. These hydraulic conditions would then be identified in the field and using maps of hydraulic habitats from existing hydraulic models developed for the Goulburn River LTIM Project. Sites would span a range of hydraulic conditions ranging from optimal to sub-optimal for each species to validate relationships. Surveys would then take place in each habitat type

The hydraulic characteristics of each habitat would be characterised on each sampling occasion and hydraulic models (already available for 4 sites on the Goulburn River through the LTIM Project) would be used to model the distribution of different habitat types across the broader reach.

Analyses would be targeted at determining if certain habitats were (ecologically) more important than others, and hydraulic models used to determine the flow rates or bands that would optimise important habitats at each site.

By identifying flow bands that optimise the quantity / distribution of important habitats, flow releases can be managed to maximise ecological outcomes. This could be done either through delivery of target environmental flow releases, or by informing operational releases to avoid flow bands that might represent risks to habitat availability.

The outcomes could also be used to evaluate the potential benefits or impacts of alternative flow regimes on provision of important hydraulic conditions and hence likely ecological responses.

6.4. Delivery mechanism and funding

The project would be a collaborative effort amongst the Goulburn MER partners, although basin-wide partners could also be involved as the project is further developed. Costs and the exact method of project delivery are yet to be determined, but elements of the research can be packaged and scaled according to available contingency budget and additional co-investment opportunities (including PhD projects). The GBCMA, VEWH and CEWO have indicated in-principle support for this project.

7. Summary of monitoring, evaluation and research activities

The lower Goulburn River MER Program will largely continue the successful monitoring and evaluation undertaken through the LTIM Project.

7.1. Monitoring

The following endpoints and specific responses will form the core monitoring program for the lower Goulburn MER Program

- **Physical Habitat (Bank Condition)** monitored through the use of UAVs. This is a complete change of method compared to the LTIM Project
- **Stream Metabolism** monitored using the single station method of oxygen measurement and converted to daily estimates of gross primary production and ecosystem respiration using the BASEv2 Bayesian method
- **Macroinvertebrates** monitored using bait traps to focus on large animal biomass and rapid bioassessment methods to focus on the identification of species-specific responses to flows. Bait traps were used in the latter years of the LTIM Project, while RBA methods are a new approach
- **Vegetation** monitored using transects on the stream bank and point-intercept methods to estimate cover of key species and vegetation groups
- **Fish spawning** monitored using repeated drift net sampling during the breeding season of target species
- **Fish assemblages** monitored using electrofishing and fyke net surveys

Frequency and timing of sampling varies among the monitoring endpoints (Table 8). As with the LTIM project, much of the monitoring is focused around the spring fresh flow event. Finer-scale adjustments to timing are likely for all monitoring matters, dependent on flow conditions in the river.

Table 8 Summary of monitoring activities to be undertaken in the Core MER Program.

Monitoring activity	No of sites per Zone		Scheduling notes	Schedule of planned and actual activities in 2019–22											
	Zone 1	Zone 2		J	A	S	O	N	D	J	F	M	A	M	J
Adult Fish		10	Timing is dependent on river flows. April preferred, but May often used in LTIM												
Fish Larvae	1	3	Weekly visits, with the possibility of some being timed around flow events												
Vegetation Diversity		2	Timing of Sep and Dec visits affected by managed and unmanaged spring flows												
Macroinvertebrates	8 sites total across the two zones; more sites likely in Zone 2		Visits after Nov may be closer together than indicated here												
Stream Metabolism	2	2	Continuous deployment. Data retrieval managed by ALS												
Bank Condition	1	2	Visits are opportunistic around flow events both natural and managed												

7.2. Evaluation

Evaluation of data at the Selected Area scale will follow the model successfully employed during the Goulburn LTIM Project – centralised analysis of data by the University of Melbourne using Bayesian statistical methods. This approach allows us to maintain consistency of analytical methods across the different monitoring disciplines.

Statistical evaluation will be cumulative over time, building on data collected in the LTIM Project for those monitoring endpoints with compatible earlier data sets. The cumulative approach to analysis takes advantage of the data set as it builds and frees us from the need to conduct separate 'multi-year' analyses at the end of the monitoring program.

The main philosophy behind statistical analysis of the data will be to describe continuous relationships between changes in the hydrologic or hydraulic environment and ecological responses. These continuous models will allow us to make predictions of what ecological condition may have looked like under different (or no) environmental flows – the counterfactual scenario. For a more complete explanation of the Bayesian approach to data analysis employed in the LTIM Project, see Webb et al. (2018).

7.3. Research

Research priorities have been identified during the development of the MER Plan, but no specific projects have yet been put forward for approval by the CEWO. Specific research questions have also been developed for each discipline within Section 5. An integrated research project (see Section 6) has been identified that address a number of the research priorities identified in the both Sections 4 and 5. This project is likely to require the bulk of the contingency research funding, however, this project has the advantage that it requires inputs from many (potentially all) of the disciplines in the monitoring program, addresses a number of research priorities and will help to fill in several of the remaining knowledge gaps in the conceptual model presented in Section 3.

8. Engagement and Communications

The following section describes our preliminary plans for engagement and communication. The plan will be further refined in consultation with the Goulburn Broken CMA, CEWO and Basin scale communications team, with further details provided in a Work Order. The Goulburn Broken CMA will be sub-contracted by UoM to undertake this work over the three years.

8.1 Objectives

The objectives of the proposed engagement and communication activities for the Goulburn River selected area are:

- Inform and educate the community about the project.
- Promote how monitoring activities continually inform the planning of water for the environment deliveries in the lower Goulburn River and downstream systems.
- Provide stakeholders (community, investors, partners etc) with timely feedback on the outcomes and environmental, social and economic benefits of water for environment actions in the lower Goulburn River.
- Engage with Traditional Owners to exchange information, share cultural and environmental knowledge and identify and implement opportunities for meaningful engagement and participation (e.g. through active participation in monitoring and research activities).
- Encourage the community to advocate for water for the environment.
- Complement the broader objectives of the Flow-Monitoring Evaluation & Research Program's Stakeholder Engagement and Communications Plan (May 2019).

8.2 Stakeholder identification (including Traditional Owners)

The GB CMA has more than 20 years' experience in engaging and communicating with the community and stakeholders. Stakeholders engaged in this project can be divided into five broad groups:

- Scientists and scientific institutions (e.g. CSIRO).
- E-flow managers (e.g. CMA E-Water Staff/CEWO communication officers/VEWH).
- E-flow partners (e.g. GMW/CMA Environmental Water Advisory Groups/Parks Victoria/CMA Board/CMA River Health staff/MDBA River Operators/MDBA TLM/DELWP/Yorta Yorta).
- River user groups (e.g. fishing clubs, tourism operators, environmental groups, NRM groups, irrigators, river diverters, Traditional Owners, urban water authorities, RiverConnect).
- Community/general public (e.g. industry, education institutions, local government, elected representatives).

Examples of key community engagement forums include (but are not limited to):

- GB CMA’s Environmental Water Advisory Groups.
- GB CMA’s Indigenous Working Group.
- The Tri-State Alliance (Indigenous Program).
- Shepparton Irrigation Region People and Planning Integration Committee.
- GB CMA’s Partnership Meetings.
- Municipal Co-ordinator’s Reference group.

Tools for communicating with these stakeholders are listed in the Commonwealth Long Term Intervention Monitoring Project - Goulburn River - Communications Plan that will be included in the relevant Work Order.

Approaches and messaging will align with the Environmental Water Communications Strategy Framework commissioned by the Murray-Darling Basin Authority, the Commonwealth Environmental Water Office, Victorian Environmental Water Holder, South Australian Department of Environment, Water and Natural Resources, and NSW Office of Environment and Heritage.

8.3 Potential activities, options for investment

The potential communication and engagement activities and options for investment include:

Scientists and scientific institutions

- scientific papers
- progress and final reports
- presentations at scientific forums/conferences
- publications on websites

E-flow managers

- annual results workshop
- progress reports/summaries highlighting results that may influence or inform current or future environmental water management decisions
- teleconferences to inform adaptive management of environmental water delivery decisions
- discussion papers

E-flow partners

- regularly updated fact sheets based on information provided above
- e-newsletters (includes dedicated CEWO newsletter plus inclusions of information in other GB CMA e-newsletters)
- Traditional Owner events - information exchange on river values, management and goals, youth journey
- media releases celebrating milestones
- updated YouTube videos
- progress reports/summaries
- Yorta Yorta Nation Aboriginal Corporation (YYNAC) work crews help with monitoring activities
- Contribute content as per the Flow-Monitoring Evaluation & Research Program’s Stakeholder Engagement and Communications Plan (i.e. website, newsletters, calendar of events, etc)

River user groups

- fact sheets/flyers
- e-newsletters
- media releases celebrating milestones
- YouTube videos
- Field days/site visits (e.g. electrofishing)
- regular GB CMA website updates – including exploring interactive hydrograph and spatial “story books”
- Facebook/twitter/Instagram

- presentations to groups (using channels and platforms as appropriate such as the Channel 31 Fishing Show, regional partnership forums, group AGMs, fishing events etc)
- Citizen science projects

General public

- fact sheets
- e-newsletters
- media releases celebrating milestones
- YouTube videos
- Facebook/twitter/Instagram
- advertising - newspaper columns; explore cinema and billboards; paid social media posts
- regular GB CMA website updates – including development of interactive hydrograph
- explore signage options
- fun, simple, educational animations

8.4 Protocols for working with private landholders

All monitoring sites are on public land. Land managers and project partners are contacted in advance of monitoring (or any other activities). Monitoring sites or activities on land managed by Parks Victoria are also approved through an annual works agreement with the GB CMA. If access to monitoring sites or activities is via private land, approval from the land owner is obtained in advance.

9. Reporting

We will adhere to the schedule of reporting set out by the CEWO in communications prior to the development of the draft plan and also set out in the Project Operations Manual. Each reporting requirements is described in more detail below. These reports will be uploaded to the CEWO webpage as they become available.

9.1 Annual selected area evaluation report

The Annual selected area evaluation report is the major reporting item from the Goulburn River MER Program. At the end of each monitoring season we will provide details on the monitoring conducted, the evaluation of monitoring data to address the key Selected Area evaluation questions, outcomes of research activities and recommendations for adaptive management based on monitoring and research outcomes. This is a major undertaking and we have budgeted for it appropriately. The report will be prepared in accordance with the performance criteria specified in the Long Form Services Agreement between CEWO and Goulburn River Selected Area, and as outlined below:

9.1.1 Evaluation

a) Evaluate the extent to which the expected outcomes identified in the MER Plan, and identified for environmental watering have been achieved.

b) Evaluate the outcomes of environmental water use based on available information using one or more of the following approaches:

i. monitored results

ii. observations

iii. quantitative evaluation

iv. qualitative evaluation

v. research findings/new knowledge

vi. inferred using scientific opinion and the outcomes framework

vii. inferred using expert scientific opinion and other evidence.

c) Clearly identify which of the above approaches was used for the evaluated outcome.

d) For the expected outcomes identified in the MER Plan, provide clear answers to each relevant evaluation question.

e) Quantify to the fullest extent possible the marginal benefit of Commonwealth environmental water and other held environmental water delivered in conjunction with Commonwealth environmental water.

f) The evaluation of expected outcomes must be cumulative, incorporating an evaluation of annual results and building on previous years' results from the CEWO Long Term Intervention Monitoring Project (2014-2019) and (where available) the MER Program (2020-2022).

g) Provide area evaluation of both Basin and Selected Area matters.

h) Include, where possible, preliminary findings in relation to one to five year expected outcomes (if necessary these may be supported by qualitative results in the earlier years leading to quantitative evaluation in the later years).

9.1.2 Research

i) Improve understanding of the processes that drive ecological responses to flow and / or other drivers in the Selected Area.

j) Provide recommendations for how Commonwealth environmental water can best be managed to influence these processes and encourage desired responses in the Selected Area i.e. to directly inform adaptive management.

9.1.3 Adaptive management

k) Use monitoring, research and evaluation outcomes and expert scientific opinion to provide implications for future management of Commonwealth environmental water and how to improve for the future.

9.1.4 Context

l) Provide context of the environmental condition of the Selected Area for watering actions.

m) Provide brief context to the watering actions and links to the expected outcomes from the watering action and previously evaluated outcomes.

9.1.5 Format

n) The draft and final Annual Selected Area Evaluation Reports will meet the following formatting requirements:

- A summary report of no more than 20 pages including photos, written for a public audience and including interesting outcomes relevant to environmental watering.
- Separate technical appendices for any detailed results and methods for a technical or academic audience.

The draft Annual report will be submitted by September 30 each year and the final Annual report will be submitted by December 30 of the same year.

9.2 Quarterly progress report

These are short reports that are designed to alert the CEWO to any issues that have arisen, how such issues can be resolved, and any other requirements of the Monitoring Provider. The reports will follow the template provided by CEWO and be submitted on the last business day of September, December, March and June.

9.3 Quarterly Outcomes Newsletter

We will compile a quarterly outcomes newsletter in a format / template provided by the CEWO. These will be written in plain English for a public audience and:

- Contain opportunistic photos of ecological outcomes from environmental watering and other visual aids relevant to demonstrating outcomes to the public.
- Contain observational or initial findings and outcomes relevant to environmental watering.
- Set out a description of monitoring and research activities undertaken recently.

The quarterly newsletter will be submitted on the last business day of September, December, March and June.

10. Project Management

10.1. Project governance

Our project team is a collaboration between the University of Melbourne, the Arthur Rylah Institute for Environmental Research, Monash University, the Goulburn Broken Catchment Management Authority, Streamology and Jacobs. The University of Melbourne has the contract with the Commonwealth Department of Environment to deliver the MER Program for the lower Goulburn River and will engage project team members from other partner organisations through sub-contract arrangements.

Our project structure is organised around project administration, technical monitoring disciplines, and stakeholder engagement. Project administration and governance are detailed below. More details on other team members is provided in Section 10.3.

A/Prof Angus Webb (University of Melbourne) will be the Program Leader for the lower Goulburn River Selected Area. He has a project administrative role and will also lead the data analysis and evaluation for the Selected Area monitoring objectives. In his administration role Angus will be the primary point of contact between the CEWO and the broader project team and will be responsible for delivering the MER Program as described in this MER Plan. He will represent the project team at forums with Program Leaders from other Selected Areas, report to the Project Working Group at regular intervals and ensure that each of the sub-contracted discipline leads deliver against agreed project milestones and standards. Angus will also be the primary project contact for the Basin Scale team and will include Discipline Leads and other project team members in discussions with the Basin-scale team as needed.

Dr Simon Treadwell (Jacobs) will be the Program Co-ordinator. His main role will be to manage relationships within the consortium, facilitate annual meetings with the Discipline Leads and represent the project team at relevant stakeholder engagement events. He will help develop templates for reports that require standardised contributions from the Discipline Leads. He will also oversee the internal project audits and review technical reports that are produced by the project team prior to submitting them to the CEWO. Simon will deputise for Angus at Program Leader meetings and Working Group meetings as needed.

10.2. Risk Assessment

A requirement of the MER Plan is to prepare a risk assessment that is compliant with AS/NZ 31000:2009 Risk management – principles and guidelines. At a minimum, the risk assessment must cover risks to the success of the project, risks to the environment and risks to individuals. Additional information on the requirements for the risk assessment are provided in the Project Operations Manual.

MER Programs that involve multi-disciplinary teams that are responsible for implementing different field programs and providing data to another individual or organisation have inherent risks. Those risks can be broadly grouped into four categories:

1) Risks to the success of the project (i.e. inability to deliver certain elements of the planned monitoring program, or inability of data to address specific monitoring objectives).
2) Risks to individuals working on the project (i.e. health and safety of people working on the project, especially those individuals undertaking fieldwork).
3) Risks to the environment (i.e. damage to flora, fauna or landforms due to field monitoring activities).
4) Risks to stakeholders (i.e. adverse outcomes for local landowners and damage to professional reputations).

We have followed a four step process to identify and qualitatively evaluate risks in each of these categories as proposed in the *Project Risk Assessment and Mitigation Guidance Document*. Step 1 involves identifying potential risks. Step 2 assesses the likelihood that a particular risk will occur using the criteria presented in Table 9. Step 3 assesses the potential consequence that the risk poses to the project, individual or environment using the criteria presented in Table 10. Step 4 combines the likelihood and consequence categories identified in the previous steps to rate each risk as low, medium, high or severe using the matrix presented in Table 11.

Table 9 Criteria for categorising the likelihood that a particular risk will occur.

Category	Description / criteria
Almost certain	Is expected to occur in most circumstances
Likely	Will probably occur
Possible	Might occur at some time in the future
Unlikely	Not expected to occur
Rare	May occur under exceptional circumstances

Table 10 Criteria for categorising the consequence of a particular risk

Risk	Consequence				
	Negligible	Minor	Moderate	Major	Critical
Undertaking monitoring activities	Monitoring activities undertaken according to M&E Plan, with data from all planned samples available.	Minor disruption to the monitoring program with a small number of planned samples (<10%) not collected or data not available	More than 10% of planned samples not collected / available, however sufficient data available for planned analyses	Data from more than 50% of planned samples not collected / available. Limited monitoring outcomes reported	No useable data collected, analyses not possible, no monitoring outcomes reported
Environment	Negligible environmental damage	Short term, localised, reversible damage to the environment	Short term, widespread damage to the environment reversible to intensive effort	Long-term damage to the environment and/or risk of continuing environmental damage	Long-term, widespread, irreversible damage
Health and safety	Incident requiring first aid treatment	Minor incident requiring treatment by a medical practitioner	Moderate incident requiring short term hospitalisation	Serious incident requiring extensive hospitalisation	A fatality, permanent disability, or multiple people affected by a serious incident
Stakeholders	Short-term, isolated complaints from stakeholders	Sustained but isolated complaints from stakeholders Relationship with stakeholder temporarily affected	Sustained complaints from stakeholders Relationship with stakeholder damaged	Short-term but significant complaints from stakeholders Relationship with stakeholder significantly damaged	Sustained and significant complaints from stakeholder Relationship with critical stakeholder irreversible damaged
Project objectives	Short delay in achievement of project objectives	Delay in achievement of project objectives	Element or project objective not met	Project objectives not met	Project objectives harmed (negative impact)

Table 11 Risk assessment matrix

Likelihood	Consequence				
	Negligible	Minor	Moderate	Major	Critical
Almost certain	Low	Medium	High	Severe	Severe
Likely	Low	Medium	Medium	High	Severe
Possible	Low	Low	Medium	High	Severe
Unlikely	Low	Low	Low	Medium	High
Rare	Low	Low	Low	Medium	High

The known risks to the MER Program, project members and environment in the lower Goulburn River are presented in Table 12. The measures that the project team will implement to mitigate medium, high and severe risks to the project and the expected effectiveness of those measures in reducing the risk are presented in Table 13. Risks to the health and safety of people and the environment will be addressed specifically through Environmental, Health and Safety (EHS) Plans and associated Job Safety Environment Assessments (JSEA-see Appendix 1 of this MER Plan).

The Risk Register (i.e. Table 12) and mitigated risk assessments presented in Table 13 and the JSEA will form the risk assessment document for the project. The risk assessment will be a live document that can be updated at any time throughout the project to include new risks as they are identified, and to modify existing, or introduce new, mitigation measures as needed. We will also formally review the risk assessment at our annual project workshop with all Discipline Leaders to ensure that it is current and relevant.

Table 12 Identified risks to the project, people, environment and stakeholders including an assessment of their likelihood, consequence and overall level of risk.

Description of risk	Likelihood	Consequence	Risk Level
Inability to meet project objectives			
Loss of key project staff (i.e. Discipline Leaders) due to role changes	Possible	Moderate Would need to find a suitable replacement within the discipline lead's organisation.	Medium
Loss of Program Leader due to role changes	Unlikely	Major Because Angus is also leading the specialised evaluation component of the program	Medium
Loss of other project staff due to role changes	Likely Because staff turnover in assistant roles is more common	Negligible Because other staff can be readily trained to replace them	Low
Competing time demands prevent key staff from working on project as planned	Possible	Moderate	Medium
Cost escalations over the course of the monitoring program that reduce the amount of monitoring and evaluation that can be done within the available budget.	Unlikely Because cost escalations have been considered in developing project budgets.	Moderate	Low
Breakdown in relationships and co-operation among consortium partners	Possible	Moderate	Medium
Lost or damaged equipment resulting in incomplete or inaccurate data.	Almost Certain	Moderate	High
Loss of data post collection due to improper storage of data or samples	Possible	Moderate	Medium

Description of risk	Likelihood	Consequence	Risk Level
Inability to deliver and therefore measure responses to environmental water	Unlikely	Major	Medium
Natural events such as floods, drought or fires that alter the condition of the lower Goulburn River	Possible	Moderate	Medium
Toxic pollution event that changes condition of the lower Goulburn River	Rare	Moderate	Low
Planned monitoring activities are inadequate to evaluate effect of environmental flow releases.	Unlikely	Moderate	Low
Risks to health and safety of individual project team members Note – these risks will be described in detail and addressed in the Environment, Health and Safety Plan.			
Accidents associated with working on or in water (i.e. from boats or wading into the river)	Possible	Major	High
Accidents associated with working on the river bank or woodland adjacent to the monitoring sites	Possible	Moderate	Medium
Exposure to adverse weather such as extremely hot or very wet and cold conditions.	Likely	Moderate	Medium
Exposure to bushfire	Rare	Critical	High
Risks associated with fatigue	Possible	Moderate	Medium
Risks associated with manual handling	Possible	Moderate	Medium
Risks associated with bites and stings from wild animals and insects	Possible	Moderate	Medium
Risks associated with working in a remote location	Unlikely	Moderate	Low
Risks associated with driving to and from field sites	Unlikely	Critical	High
Risks to the environment			
Death or distress to animals caught as part of the monitoring program	Likely	Minor	Medium
Damage to native vegetation or bank condition associated with working on site, driving vehicles off road and launching boats	Likely	Negligible (based on current experience and ability to avoid sensitive areas)	Low
Spills of fuel or chemicals used in the monitoring program	Rare	Minor	Low
Risks to stakeholders and professional reputations			
Inconvenience or disturb local landowners during monitoring activities	Unlikely	Minor	Low
Field staff fail to take account of indigenous heritage values at monitoring sites	Rare	Moderate	Medium
Monitoring brings attention to environmental flow releases and provides a trigger for lobbying by environmental flow opponents.	Likely	Minor	Medium

Table 13 Preliminary assessment of medium and high risks to the project outcomes, mitigation measures to address those risks and a residual risk assessment assuming the mitigation is applied. Specific medium and high health and safety risks identified in Table 12 are addressed in detail in the EHS Plan.

Risk description	Likelihood	Consequence	Preliminary Risk Level	Proposed mitigation	Residual Likelihood	Residual Consequence	Residual Risk Level
Loss of key project staff (i.e. Discipline Leaders) due to role changes	Possible	Moderate Would need to find a suitable replacement within the discipline lead's organisation.	Medium	Documented procedures for handover responsibility in the SOPs. Replacement will preferably come from within home organisation of original discipline lead.	Possible	Minor	Low
Loss of Program Leader due to role changes	Unlikely	Major Because Angus is also leading the specialised evaluation component of the program	Medium	Project administration could be transferred to Project Facilitator permanently or until suitable replacement found at the University of Melbourne Would need to recruit new person to undertake specialist Bayesian analysis and oversee evaluation	Unlikely	Moderate	Low
Competing time demands prevent key staff from working on project as planned	Possible	Moderate	Medium	Ensure staff are suitable resourced. Provide clearer instruction around timing of deliverables and consequences of late delivery	Possible	Minor	Low
Breakdown in relationships and co-operation among consortium partners	Possible	Moderate	Medium	Program Coordinator has specific role to manage relationships among consortium members. Some disagreements are likely, but they should not jeopardise the program.	Unlikely	Minor	Low
Lost or damaged equipment resulting in incomplete or inaccurate data.	Almost Certain	Moderate	High	Costs to replace lost or damaged equipment have been included in the program budget. Regular monitoring events are planned to minimise period of lost data.	Almost Certain	Minor	Medium
Loss of data post collection due to improper storage of data or samples	Possible	Moderate	Medium	Detailed procedures for chain of custody, data storage and timely uploading of data to central databases are outlined in the SOPs. These actions will reduce the likelihood of data loss and reduce quantity of data loss.	Unlikely	Minor	Low
Inability to deliver and therefore measure responses to environmental water	Unlikely	Major	Medium	Climatic conditions will primarily determine availability of environmental water. Therefore difficult to mitigate this risk	Unlikely	Major	Medium

Risk description	Likelihood	Consequence	Preliminary Risk Level	Proposed mitigation	Residual Likelihood	Residual Consequence	Residual Risk Level
Natural events such as floods, drought or fires that alter the condition of the lower Goulburn River	Possible	Moderate	Medium	Cannot control natural events, but monitoring program has built in flexibility to measure responses to extreme events so those effects can be separated from environmental flow effects.	Possible	Minor	Low
Monitoring brings attention to environmental flow releases and provides a trigger for lobbying by environmental flow opponents.	Likely	Minor	Medium	The project communications plan will engage with stakeholders to inform them about the monitoring program and that the results will be used to adaptively manage the flows to maximise environmental outcomes and minimise impacts to the environment and public and private assets.	Likely	Negligible	Low

10.3. **Project personnel**

Our project structure is organised around project administration, technical monitoring disciplines, and stakeholder engagement (Figure 4).

We have separate discipline leads for our six technical disciplines (5 endpoint disciplines, plus hydrology):

- Wayne Koster (Arthur Rylah Institute for Environmental Research) is the discipline lead for Fish, which includes the Fish (River) and Fish (Larvae) Indicators.
- Dr Kay Morris (Arthur Rylah Institute for Environmental Research) is the discipline lead for Vegetation, which will focus on Vegetation Diversity on the river banks.
- A/Prof Mike Grace (Monash University) is the discipline lead for Stream Metabolism.
- Dr Vin Pettigrove (RMIT University) is the discipline lead for Macroinvertebrates.
- Dr Geoff Vietz (Streamology) is the discipline lead for Physical Habitat.
- Ben Baker (Jacobs) is the discipline lead for Hydrology.

Each discipline lead has been actively involved in developing the monitoring plan for their particular indicators and will be responsible for managing sub-teams to safely implement the planned monitoring, collate and analyse the results and provide the agreed data to the CEWO for Basin scale analyses and to Angus for specific Selected Area analyses. The sub-teams to support each of the discipline leads will include trained assistants from their home organisation and staff from other partner organisations, especially the Goulburn Broken CMA, where practical.

Simon Casanelia and Daniel Lovell from the Goulburn Broken Catchment Management Authority will lead and implement the communications and engagement plan for the project, with implementation assistance from Fiona Lloyd. They will liaise with the technical discipline leads, Program Leader and the CEWO to determine the main messages to be communicated and the best way to communicate those messages to community groups and other interested stakeholders.

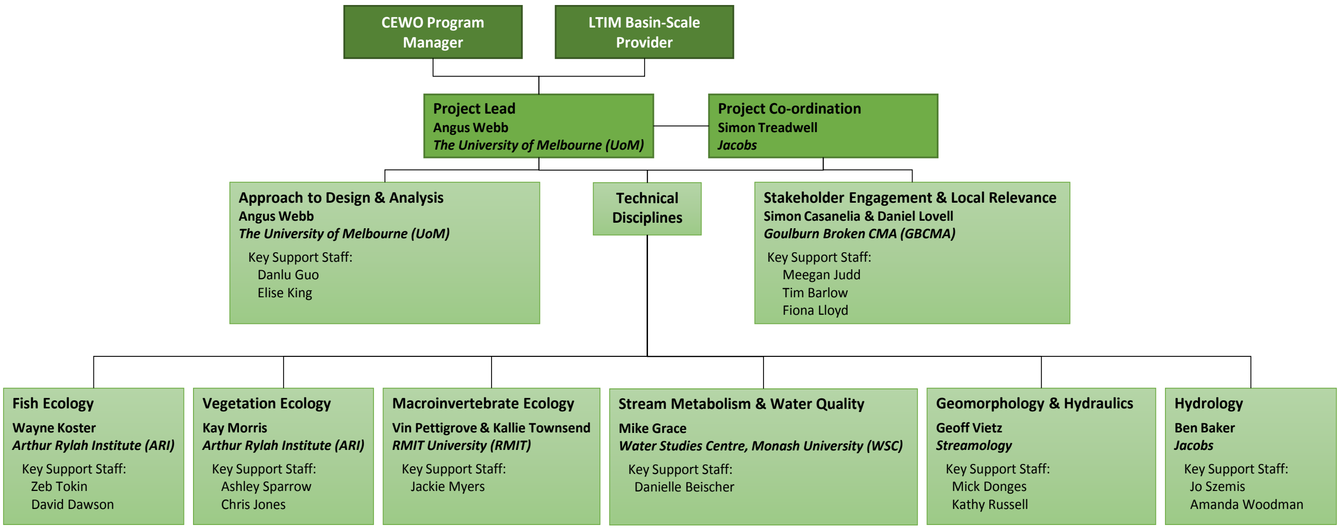

Figure 4 Lower Goulburn Selected Area Project Team structure.

10.4. **Quality assurance**

The following sections (equipment and data/document management) provide more details of the quality assurance process.

10.4.1. Equipment

A list of the relevant field equipment that will be used throughout the MER Program for the lower Goulburn River and details about how that equipment will be calibrated and maintained in provided in Table 14.

Table 14 List of proposed equipment for use in the MER Program including how the equipment will be maintained and where necessary calibrated.

Equipment description			Equipment maintenance				Equipment calibration			
Monitoring discipline	**Equipment description**	**Indicator or method the equipment that will be used for**	**How will equipment be maintained?**	**How frequently will maintenance work be conducted?**	**How will maintenance work be logged or recorded?**	**Who will be responsible for maintenance?**	**How will equipment be maintained?**	**How frequently will maintenance work be conducted?**	**How will maintenance work be logged or recorded?**	**Who will be responsible for maintenance?**
Physical Habitat	Unmanned Aerial Vehicle	Bank Condition	Condition will be checked during inspections, and serviced necessary	Every survey	Field notes will be taken and data filed digitally	Dr Geoff Vietz	N/A	N/A	N/A	N/A
Macroinvertebrates	Field nets, waders, boat	Field work generally	Regular inspection of equipment and cleaning after each field trip to prevent transfer of pests	Each sampling event	On prescribed field sheets	Dr V Pettigrove	Regularly cleaned, maintained and inspected	N/A	N/A	RMIT staff
Stream Metabolism	DO/Temp Loggers	Stream Metabolism	Infield maintenance including battery replacement, cleaning, visual inspection	Every 4-6 weeks by field team	On prescribed field sheets	Maintenance is undertaken by ALS	Infield 100% DO saturation check then recalibration if required	Every 4-6 weeks by field team	NA	ALS
Stream Metabolism	PAR & Barometric Pressure Loggers	Stream Metabolism	Infield maintenance including battery replacement, cleaning, visual inspection	Every 4-6 weeks by field team	On prescribed field sheets	Senior Field Technician reporting to A/Prof Mike Grace	PAR logger calibrated in laboratory against standard light (PAR) fluxes. Barometer checked against Bureau of Meteorology readings.	Prior to first deployment	On initial equipment preparation file	Senior Field Technician reporting to A/Prof Mike Grace
Fish	Boat and motor	Fish - River	Boat serviced annually by Barry Lawrence Marine and whenever issue reported following field trip	Annually and whenever issue reported following field trip	Maintenance records kept at Arthur Rylah Institute	Arthur Rylah Institute (Andrew Pickworth)	N/A	N/A	N/A	N/A
Fish	Electrofishing equipment		Annual service by qualified electricians Berry Rewind Electrical	Annually, plus additional as needed	Maintenance records kept at Arthur Rylah Institute	Arthur Rylah Institute (Andrew Pickworth)				
Fish	Fyke nets	Fish - River	Checked for holes prior to each trip and repaired if needed. Also cleaned and dried between field trips to prevent transfer of pest species	Prior to each trip	Maintenance records kept at Arthur Rylah Institute	Arthur Rylah Institute (John Mahoney)	N/A	N/A	N/A	N/A
Fish	Scales	Fish - River	Checked for function	Prior to each trip	Maintenance records kept at Arthur Rylah Institute	Arthur Rylah Institute (John Mahoney)	Checked for accuracy	Annually	Maintenance records kept at Arthur Rylah Institute	Arthur Rylah Institute
Fish	Larval drift nets	Fish - Larvae	Checked for holes prior to each trip and repaired if needed. Also cleaned and dried between field trips to prevent transfer of pest species	Prior to each trip	Maintenance records kept at Arthur Rylah Institute	Arthur Rylah Institute (David Dawson)	N/A	N/A	N/A	N/A
Fish	Flow meters	Fish - Larvae	Cleaned at end of each trip	Fortnightly during sampling	Maintenance records kept at Arthur Rylah Institute	Arthur Rylah Institute (David Dawson)	Checked for accuracy	Annually	Maintenance records kept at Arthur Rylah Institute	Arthur Rylah Institute (David Dawson)
Fish	Water quality (turbidity) recorder	Fish - Larvae	Cleaned and air dried after each trip, sent to TPS for repair if any problem noted.	After each trip	Maintenance records kept at Arthur Rylah Institute	Arthur Rylah Institute (David Dawson)	Calibrated 6 monthly with a 90 NTU standard and zero calibration.		Maintenance records kept at Arthur Rylah Institute	Arthur Rylah Institute (David Dawson)
Vegetation	No specialist equipment needed									

11. Data Management

All data collected under this Agreement will be quality assured by the technical leads responsible for data collection. Data will be provided to the Basin-scale Data Manager (Angus Webb). The following sections provide more detail on data management.

11.1. Data collection (field and laboratory) – samples and measures

The QA/QC arrangements to ensure the collected data are of high quality are summarised in Table 15.

Table 15 Summary of QA/QC procedures that will apply to each type of data collected during the MER Program for the lower Goulburn River

Monitoring discipline	Data Type	What if any relevant Standard (e.g. ANZECC) will be followed or applied?	What type of field data sheets will be used? Who will develop field sheets, how will information entered to the sheets be checked and how will the field sheets be stored?	What Chain of custody procedures will be used for samples that need to be transported to the laboratory?	Will sample blanks or duplicates be used for QA/QC? If so what and when?	What are the proposed methods for transporting samples from field to laboratory and what are the maximum holding times before laboratory analyses will be undertaken?	What are the Laboratory accreditation requirements (e.g. NATA)?	What quality control methods are in place for laboratory work and how will QA/QC for laboratory work be reported?	Will samples or vouchers need to be kept and if so for how long and how will they be stored or registered?
Physical Habitat	Erosion Pin measurements (quantitative and qualitative)	N/A	Data recording sheets have been developed by Dr. Geoff Vietz. The information will be checked by the second staff on hand and the data will be entered into a spreadsheet upon return from the field. Scanned copies of field sheets to be stored on central LTIM Project server at the University of Melbourne.	N/A	N/A	N/A	N/A	N/A	N/A
Physical Habitat	Bathymetry Survey data	N/A	Results from the survey will be recorded by Dr. Geoff Vietz in the field and then transcribed to a spreadsheet. Scanned copies of field sheets to be stored on central LTIM Project server at the University of Melbourne.	N/A	N/A	N/A	N/A	N/A	N/A
Physical Habitat	Drone data	N/A	The following field sheets and checklists are used when operating the drone in the field and in preparation of flights. These documents are stored in Streamology's file servers and copies are printed prior to use. Copies of the completed field sheets or checklists are stored in the filing system for the project. The documents include; Preflight-Briefing – Developed by Streamology Maintenance Checklist – Developed by Streamology Flight Log – Developed by Streamology	N/A	N/A	N/A	N/A	N/A	N/A
Vegetation diversity	Cover of species, bare ground, ground cover, understorey, overstorey		Data recording sheets have been developed by Dr. Kay Morris for the pin intercept method. All data sheets will be check for errors and completeness after each transects. Field sheets will be copied immediately upon return and stored separately in secure locations. Data will be entered into a spreadsheet upon return from the field and checked for errors. Scanned copies of field sheets to be stored on central LTIM Project server at the University of Melbourne.	Plant material for taxonomic identification will be transported by field staff back to ARI where the discipline lead (Kay Morris) will be responsible for preparing and storing the samples.	N/A	Plant material for taxonomic identification will be labelled and placed in a plant press for transport by field staff to ARI where the discipline lead (kay Morris) will be responsible for preparing and storing the samples. Samples can be held indefinitely once dried.	N/A	N/A	For species that cannot be identified in the field, herbarium samples will be prepared to enable formal identification by experienced taxonomists. Samples will be held for the duration of the project for future reference.
Vegetation diversity	Turf mats	N/A	Field sheets for turf mat deployment and turf mat retrieval have been developed by Streamology. These field sheets record time and date of field visit, field observations and collection details. These field sheets are completed in the field and then stored with the project files both in hard copies and digital scans.	Data from the field sheets are transmitted to the lab data sheets to be used by Streamology. Chain custody forms are not required	N/A	Turf mats are transported from the field suite to the laboratory as soon as practically possible for samples to be dried in drying ovens. If there is any delay to drying samples then the samples will be refrigerated to prevent any seed growth or germination	N/A	N/A	The samples collected are stored to allow retesting at a further date if required. These will be stored at Streamology offices and will be stored for a period of 18 months after collection date.
Macroinvertebrates	Macroinvertebrates	LTIM monitoring data management system	Prepared using suggested format in macroinvertebrate protocol	A field sheet specifying the details of each sample (i.e. time and date of collection, sample type, replicate number, location, and who collected the sample) will be filled out after each sample collection and will be sent with the samples to the laboratory	N/A	Macroinvertebrates are stored in sampling jars in 70 % ethanol for preservation; jars given internal and external labels in waterproof and ethanol proof pen/pencil. Jars are securely transported to laboratory in esky or tub. There are no holding time requirements before samples are analysed.	N/A	N/A	Stored at RMIT for minimum of 5 years
Macroinvertebrates	Macroinvertebrate - species identification	Macroinvertebrate Protocol	Prepared using suggested format in macroinvertebrate protocol	Samples in the laboratory will be given a number from the macroinvertebrate database	N/A	N/A	N/A	10% of samples will be reprocessed by a second person according to EPA Victoria protocols	Stored on RMIT database
Stream metabolism	DO & Temp readings from logger	n/a	field sheet as per LTIM SOP	N/A	N/A	N/A	N/A	N/A	N/A
Stream metabolism	PAR & Pressure readings from logger	n/a	field sheet as per LTIM SOP	N/A	N/A	N/A	N/A	N/A	N/A

Monitoring discipline	Data Type	What if any relevant Standard (e.g. ANZECC) will be followed or applied?	What type of field data sheets will be used? Who will develop field sheets, how will information entered to the sheets be checked and how will the field sheets be stored?	What Chain of custody procedures will be used for samples that need to be transported to the laboratory?	Will sample blanks or duplicates be used for QA/QC? If so what and when?	What are the proposed methods for transporting samples from field to laboratory and what are the maximum holding times before laboratory analyses will be undertaken?	What are the Laboratory accreditation requirements (e.g. NATA)?	What quality control methods are in place for laboratory work and how will QA/QC for laboratory work be reported?	Will samples or vouchers need to be kept and if so for how long and how will they be stored or registered?
Stream metabolism	Total P, Total N, NOx, FRP, NH4+, DOC	NATA-accredited protocol for analysis of these samples by Water Studies Centre (Monash University)	field sheet as per LTIM SOP	field sheet copy to accompany samples in transport to laboratory	as per NATA-accredited protocol for analysis of these samples by Water Studies Centre (Monash University)	Transportation in an esky over dry ice. Max time 24 hours.	NATA for all analyses listed	as per NATA-accredited protocol for analysis of these samples by Water Studies Centre (Monash University). Details of spike recoveries, duplicates, blanks and SRMs to be reported back to project team along with rest of results	As per NATA-accredited lab SOP
Stream metabolism	Chlorophyll-a	NATA-accredited protocol for analysis of these samples by Eastern Melbourne Laboratory (EML)	field sheet as per LTIM SOP	field sheet copy to accompany samples in transport to laboratory	as per NATA-accredited protocol for analysis of these samples by EML	Transportation in an esky over dry ice. Max time 24 hours.	NATA for chlorophyll-a	as per NATA-accredited protocol for analysis of these samples by EML. QC results to be reported back to project team along with rest of results	As per NATA-accredited lab SOP
Stream metabolism	Light Meter	N/A	Field sheets will be updated to incorporate check boxes for light meter readings. Readings will be made at juts below the water surface and at 1 m below the water surface and recorded on the field sheet. Mike Grace will prepare the field sheets. Field sheets will be collated and stored by Mike Grace	Data from the field sheets are transmitted to the lab data sheets to be used by Mike Grace. Chain custody forms are not required	Routine calibration of light meter will be required, Mike Grace will prepare a calibration schedule and instruction sheet	NA	NA	NA	NA
Fish	Electrofishing and fyke net data	N/A	Field data sheets provided in the standard methods will be used. All data sheets will be check for errors and completeness after each survey. Field sheets will be copied immediately upon return and stored at ARI. Scanned copies will be loaded onto the LTIM Project Server hosted by the University of Melbourne. Data will be entered onto spreadsheet upon return from the field and checked for errors. The spreadsheet will follow prescribed template outlined in the standard methods.	N/A	N/A	N/A	N/A	N/A	No
Fish	Larval drift net and light trap data	N/A	Field data sheets provided in the standard methods will be used. All data sheets will be check for errors and completeness after each survey. Field sheets will be copied immediately upon return and stored at ARI. Scanned copies will be loaded onto the LTIM Project Server hosted by the University of Melbourne. Data will be entered onto spreadsheet upon return from the field and checked for errors. The spreadsheet will follow prescribed template outlined in the standard methods.	Label each sample vial in the field (labels inside and outside of vial). Also record on data sheet the vial number(s) that correspond to each net and site. In laboratory cross check vials with data sheets.	N/A	Larval samples collected in field and preserved in 90% ethanol. Transported to laboratory at Arthur Rylah Institute at the end of each sampling trip. Timing is not critical.	N/A	Samples will be sorted and identified by experienced staff. 5% of samples will be checked by another technician to confirm identification accuracy.	Not necessary to keep for QA, but will be stored at ARI.

11.2. Data storage and management

The CEWO will provide a Data Management System for shared data to support evaluation. We are assuming this will continue to be the Monitoring Data Management System (MDMS) employed during the LTIM Project. The Goulburn Selected Area Providers will store and manage access to primary data for the duration of the MER Program. The following sections describe specific data storage and management requirements:

- Describe procedures for management of all primary (raw) data including governance, storage, backup, version control and custodianship.
  - Data will be stored on a secure server at the University of Melbourne in a staff folder controlled by project leader Webb. These servers are backed up regularly, providing security for the data. Discipline leads will transmit data to the University of Melbourne using a cloud service, uploading raw data to the cloud service at the same time as they upload processed data to the MDMS. A University of Melbourne Research Fellow will be responsible for timely transfer of data from the cloud service to the secure server.
  - Each organisation within our project team will also save a duplicate copy of the data that is relevant to their particular monitoring activity on secure servers within their home organisations.
- Identify process for accessing archived primary data (e.g. if required to verify or recalculate derived data at a future date, or to support evaluation).
  - All discipline leads will be able to access primary data stored on the secure server described above by submitting a request to the University of Melbourne Research Assistant. The University of Melbourne Research Fellow will save a copy of the data file/s to the same cloud service that is used to transmit data to the university.
  - External requests for raw data will be handled by the Project Leader. Any request must be made in writing, and include a statement of the proposed use of the data. The contact address on the project website will provide the necessary point of contact for any external party interested in obtaining data. The Project Leader will clear all requests with the CEWO, noting that any use of the data must have an appropriate acknowledgement of the source, before providing data. Data will be provided by upload to a secure file-sharing utility (e.g. hightail). All external requests for data that have not yet been published as part of the annual selected area or basin scale evaluation report will be subjected to a further permissions process as previously specified by the CEWO.
- All derived data submitted for shared evaluation needs must adhere to MER data standards and be traceable to raw data.
  - All processed data will conform to the MER data standards, and indeed will not be able to be uploaded to the MDMS if they do not.
- M&E Providers to submit their data that supports shared evaluation needs within 1 month of collection, and according to the protocols established by CEWO.
  - Discipline leads will be responsible for the timely upload of processed data, in accordance with CEWO requirements.

11.3. Document management

This section outlines document management procedures.

Storage: We will establish a document store on the secure server at the University of Melbourne (mentioned above). This will archive all reports, SOPs, etc. produced throughout the project. A hierarchical directory structure will be used to navigate the store, and a meta-data document will be used to provide details of all documents uploaded to the store.

Version numbers for evolving documents: Standard operating procedure documents (and potentially others) may evolve over the course of the monitoring program. SOPs will be assigned a version number (those attached to this proposal will continue on from version numbers used in the LTIM Project), with new version numbers assigned to reflect minor and major changes to procedures. A change in version number will demonstrate to the user that they should re-read the new document to be aware of changes in procedures. All previous versions will be archived as part of the project document store.

Version control during writing: The majority of reports produced for this project will be quite simple (e.g. quarterly progress reports, outcomes newsletters). These documents will be primarily authored by a single individual, perhaps with minimal input from others. We do not foresee major version control problems for these documents.

The annual selected area evaluation report will be more complex. It will combine inputs from all discipline leads, the project leader, outputs of evaluation, etc. Moreover, it will undergo review and revision before being accepted by the CEWO. The Project Leader will be responsible for maintaining version control of this document. This will primarily be achieved by:

- Discipline leads write individual sections, rather than all working on the same document
- Project lead compiles those sections once they are ready for submission
- Following receipt of review comments from the CEWO and Monitoring Adviser, the Project Leader circulates comments for revision to the relevant discipline lead. The discipline lead works upon the previously written *individual section* rather than the full compiled copy
- Project lead re-compiles the revised individual sections as the final report.

Working documents for the annual report, and for other minor reports will be saved to a 'Dropbox' ™ folder. This cloud storage service automatically archives a copy of every saved version of a file. If files become corrupted during writing, an earlier version of the file can be extracted from Dropbox. Once the report is complete, working documents will be removed from the visible Dropbox directory.

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13. Appendix 1: Workplace Health and Safety

A Health, Safety and Environment Plan (HSEP) will be provided by all field teams prior to undertaking field work. These Plans will be collated to form the MER project HSEP, including procedures and requirements for minimising the risk of injury to persons and harm to the environment. The HSEP will be compliant with the *Work Health and Safety Act 2011*, Work Health and Safety Regulations 2011, Work Health and Safety Codes of Practice 2011 and relevant Victorian legislation.

13.1. Health, Safety and Environment Plan

It is proposed that an overarching Health, Safety and Environment Plan (HSEP) will be developed centrally for the project. The format, structure and requirements of this plan will be a continuation of that developed and approved for the current Goulburn LTIM project. The HSEP will include the following elements:

1. A risk register identifying the potential hazards (such as working in remote locations, working outdoors, working on or near water, travel to remote locations, manual handling)
2. An environmental hazard identification checklist
3. Details of any specific legislation and organisation procedures and work standards that must be followed
4. A description of the relevant training, qualifications and competencies that field staff need to undertake the work
5. A Job Safety and Environment Assessment (JSEA) that describes how medium, high or severe hazards will be mitigated and any residual hazards managed
6. A procedure for responding to emergency situations
7. A procedure for reporting incidents and/or near misses
8. A procedure for checking in with daily contacts during fieldwork.

The overarching HSEP will specify minimum safety requirements such as the need to always have at least two people in the field, to wear an approved Personal Floatation Device (PFD) at all times while working on boats or wading in the river and current first aid qualifications (Level 2 or greater) for all field staff.

Sub-plans will be developed for each of the individual discipline project teams (i.e. fish team, vegetation team, macroinvertebrate team, stream metabolism team, physical habitat team and hydrology team), because each of the discipline leads has the best understanding of the planned field activities and risks associated with them. Moreover, it is critical that those people undertaking the fieldwork have been actively involved in identifying and mitigating risks associated with their work. The sub-plans will be developed in consultation with the relevant EHS managers in each of the partner organisations.

Each partner organisation has its own specific safety plan requirements and formats. We will allow each partner organisation to prepare their safety plans using their own templates. Each of the sub-plans will be submitted to the Project Facilitator (Simon Treadwell) or a nominated specialist in EHS Risk Management for review to ensure that they are compatible with the overarching HSEP. Any items or mitigation measures that are not covered by the home organisation's safety plans will need to be added to ensure the minimum standard is applied across the whole MER Program. Formal endorsement of the respective sub-plans and the HSEP by the project coordinator will take place prior to any fieldwork commencing.

Each discipline lead will be responsible for implementing their respective sub-plan inclusive of the whole of project requirements (the HSEP) and the safety planning requirements of their home organisation.

Safety audits will be conducted at various times during the project by EHS representatives from the relevant discipline home organisation, the Program Co-ordinator or EHS managers from the GBCMA to ensure safety plans are being followed in the field.

13.2. Incident Reporting

The first priority in the event of a health and safety incident and/or near-miss will be to care for those affected and to ensure the safety of others. Once this can be guaranteed a formal process for the reporting of the incident and/or near miss will be implemented.

The reporting of all incidents and/or near misses is a critical first step in identifying causal factors and taking action to prevent recurrence of similar incidents and in identifying trends that may have broader implication. All incidents and/or near misses will be reported so that they can be investigated to the appropriate level.

The discipline lead of the person notifying the incident and/or near miss will be responsible for submitting a formal report to both the relevant EHS managers in each of the partner organisations and the Program Leader (Dr Angus Webb) within 24 hours of occurrence. A project specific incident reporting form will be developed and be used to report the incident. An individual form is to be used for each incident type; for example, if two staff are injured, there is to be a separate incident form submitted for each injured person.

The Program Leader (Dr Angus Webb) will notify Kerry Webber or another designated representative from the CEWO within 48 hours of the incident.

- An investigation into the health and safety incident and/or near-miss will be conducted by the EHS manager in the relevant partner organisations and the Program Leader (Dr Angus Webb) or his delegate. The outcome of the investigation will be communicated to all relevant staff within the partner organisations and the CEWO and will include both lessons learned and any proposed modifications to work practices to further mitigate any residual health and safety risk.

13.3. Auditing

A comprehensive approach to self-auditing of project quality is proposed. Implementation of this plan will ensure that key elements of the quality and safety plans for the project are successfully implemented. The proposed audit method will include verification of filed and analytical data and an annual compliance report.

13.3.1. Verification of Field and Analytical Data

A series of steps are proposed to verify all field and analytical data generated through the project:

1. Visual Checking – A visual check of all data will be undertaken to ensure that there are no obvious errors in data.
2. Regular QA/QC Reports and Audits – regular QA/QC Reports will be prepared by the discipline leads and submitted to the project coordinator to flag whether there are potential errors in data due to deficiencies in instrument calibrations, procedures etc.

13.3.2. Annual Compliance Report

At the completion of each monitoring season, each of the discipline leads will prepare a compliance (acquittal) report and submit to the Program Leader (Dr Angus Webb) or Program Co-ordinator (Dr Simon Treadwell) confirming that they followed the planned methods and schedules exactly and also documenting any deviations from planned approach including justification for such deviations. The compliance report will also include relevant information in relation to the following:

- Details of compliance with maintenance schedule for all nominated equipment
- Details of compliance with calibration schedule for all nominated equipment
- Details confirming adherence to chain of custody requirements for nominated samples
- Details confirming ongoing NATA accreditation for nominated laboratories undertaking sample analysis
- Training records confirming that all staff undertaking field sampling and/or sample identification are appropriately qualified and have undertaken relevant training

The outcomes of the annual spot audit program will be combined with the compliance reports and a summary of this information will be included as a section in the project annual report.

14. Appendix 2: Progress report template

Project Progress Report		
[Name of Project]		
Project Leader:		Phone:
Report period:		

Project Health Summary

Indicator	Traffic light	Comment
Overall Rating		*Traffic light question: Is this Project going to achieve its objective as committed?* *[INSERT TEXT HERE]*
Time (schedule)		*Traffic light question: Is this project (and its elements) forecast date of completion tracking to the baseline schedule?* *[INSERT TEXT HERE]*
Scope (change)		*Traffic light question: Is this Project delivering outcomes directly associated with the agreed project scope?* *[INSERT TEXT HERE]*
Engagement		*Traffic light question: What is the current status of the relationship with project and other stakeholders* *[INSERT TEXT HERE]*
Safety		*Traffic light question: Has there been a safety incident, or have any inadequacies been identified in the safety planning (note, details on any incidents or inadequacies must be communicated to the CEWO as soon as practical)* *[INSERT TEXT HERE]*
Risks		*Traffic light question: Are there any risks that may impact our ability to achieve committed outcomes?* *[INSERT TEXT HERE]*
Issues		*Traffic light question: Are there any issues that may impact our ability to achieve committed outcomes?* *[INSERT TEXT HERE]*

- **Tasks are completed or on track and there are no issues** (green)
- **Tasks are delayed or under pressure, but not influencing the outputs of the project** (orange)
- **Tasks are delayed and are influencing the projects ability to meet its commitments** (red)

Project Progress Summary

Activities completed in the previous period
[INSERT TEXT HERE]
Activities to be undertaken in the upcoming period
[INSERT TEXT HERE]

Summary of Progress towards Milestones

Milestone	Due Date	Complete/ Incomplete	Comment

Critical Risks, Opportunities & Issues

Risk / issue	Action

Outstanding Information

Information required (item)	From Whom	Date required	Urgency (High/Medium/Low)

15. Appendix 3: Standard Operating Procedures

NOTE THAT THE SOPS ARE SUPPLIED AS SEPARATE DOCUMENTS

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