Lake Wellington Land and Water Management Plan

Technical Appendices

Final draft
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Acknowledgement of Country

The West Gippsland Catchment Management Authority would like to acknowledge and pay our respects to the Traditional Land Owners and other indigenous people within the entire West Gippsland catchment area: The Gunaikurnai, the Bunerong and Boon Wurrung, and the Wurundjeri peoples. We also recognise the contribution of Aboriginal and Torres Strait Islander people and organisations in land and natural resource management.

Contents

1 Overview

The *Lake Wellington Land and Water Management Plan* (LWMP) supersedes the 2008 *Macalister LWMP* (WGCMA, 2008) and 2005 West Gippsland Salinity Management Plan (SMP; WGCMA, 2005). Programs delivered under these plans have, with irrigators, contributed to:

- Significant improvements to water quality in waterways within the Macalister Irrigation District (MID);
- Reduced nutrient and sediment inputs into Lake Wellington;
- Water savings and improved agricultural productivity and profitability.

The Lake Wellington LWMP provides a roadmap of priorities and programs for sustainable irrigation in the Lake Wellington catchment. The Plan addresses irrigation land and water management throughout Lake Wellington catchment; this reflects the presence of irrigation outside of the MID and the growing investment in new irrigation developments at various locations in the catchment. The Plan builds on the programs and successes of the Macalister LWMP, capitalises on the advantages provided by the region's rich soils, favourable climate and secure water supplies and contributes to Lake Wellington catchment remaining among Australia's premier irrigation regions.

The Plan supports the *West Gippsland Regional Catchment Strategy* (WGCMA, 2013) and contributes to the objectives and priorities of the *Gippsland Lakes Ramsar Site Management Plan* (EGCMA, 2015). It has four main roles, namely:

- Describing the programs and actions to achieve its vision and targets;
- Providing for agency collaboration and accountability to ensure that public funds align with government and community priorities;
- Guiding investment from the Victorian Government's Sustainable Irrigation Program;
- Establishing adaptive management, monitoring and reporting processes to demonstrate progress and achievements.

This document comprises a series of technical appendices which provide context to the Lake Wellington LWMP and/or additional information or detail which would not be appropriate in a plan developed for general community readership. Much of the information contained in this document is included in summary form in the main LWMP document (WGCMA, 2018).

The technical appendices are presented in three main parts, with sections as follows:

Part A: Context for irrigation land and water management in Lake Wellington catchment

- Chapter 2 *Policy and natural resource planning context:* a discussion of the legislative, policy and strategic planning context for the LWMP.
- Chapter 3 *The Lake Wellington catchment and its community:* a brief description of the Lake Wellington catchment, including its population and community, land uses, economy, environments, Indigenous heritage and environmental challenges.
- Chapter 4 *Nutrient inputs to the Gippsland Lakes: a science review:* a review and synthesis of literature that describes the sources, pathways, impacts and potential management of nutrients and sediments draining into Lake Wellington from its catchment area.
- Chapter 5 *Reducing nutrient loads into Lake Wellington from irrigation areas:* an analysis of the potential effects of irrigation land use change and intensification of dairy and horticultural production systems on nutrient loadings into Lake Wellington.

Part B: Development of the Lake Wellington Land and Water Management Plan

- Chapter 6 *Overview of the Plan development process:* overview of the process by which the Lake Wellington LWMP was developed.
- Chapter 7 *Achievements of the Macalister Land and Water Management Plan:* a summary of the key findings of the independent review of the Macalister LWMP.
- Chapter *8 Future changes, challenges and opportunities:* outputs from research and a stakeholder workshop to explore future influences on irrigation land and water management that are relevant to Lake Wellington catchment.
- Chapter 9 *Irrigation farm planning approach:* a description of the revised irrigation farm planning framework developed for the Lake Wellington LWMP.
- Chapter 10 *Gippsland Irrigation Development Guidelines:* a review of the Gippsland Irrigation Development Guidelines (IDGs).
- Chapter 11 *Stakeholder engagement outcomes and key messages:* a summary of social research and the outcomes of stakeholder consultations undertaken as part of the Plan development process. This chapter includes a list of submissions to the formal stakeholder consultation paper.

Part C: Implementing the vision for irrigation land and water management in Lake Wellington catchment

- Chapter 12 *A vision for irrigation land and water management:* a description of the irrigation land and water management vision, aspirational objectives and long-term outcomes to which the Plan will contribute.
- Chapter 13 *Implementing the Lake Wellington Land and Water Management Plan:* a description of the programs by which the LWMP's objectives and targets are to be achieved. This chapter provides greater detail than the program summaries given in the main LWMP document.
- Chapter 14 *Economic evaluation:* details of the cost benefit analysis undertaken of the LWMP's programs. This chapter provides the economic justification for investment in the Plan.
- Chapter 15 *Monitoring and adaptive management:* the arrangements for adaptive management during implementation of the Plan. The main LWMP document includes a summary of the Monitoring, Evaluation, Reporting and Improvement (MERI) Plan which is documented here. The chapter also includes the final program logic, management action and resource condition targets.

The final chapter (16) is a glossary of the key terms and abbreviations used in this document and the main Plan document.

Part A: Context for irrigation land and water management in Lake Wellington catchment

2 *Policy and natural resource planning context*

2.1 Overview

Irrigation land and water management within Lake Wellington catchment operates within the context provided by legislation, agreements, policies and strategies which have been framed at all scales – from local to international (Figure 2.1). Key policy and strategies which most strongly influence irrigation land and water management within the catchment are described in the following sections.

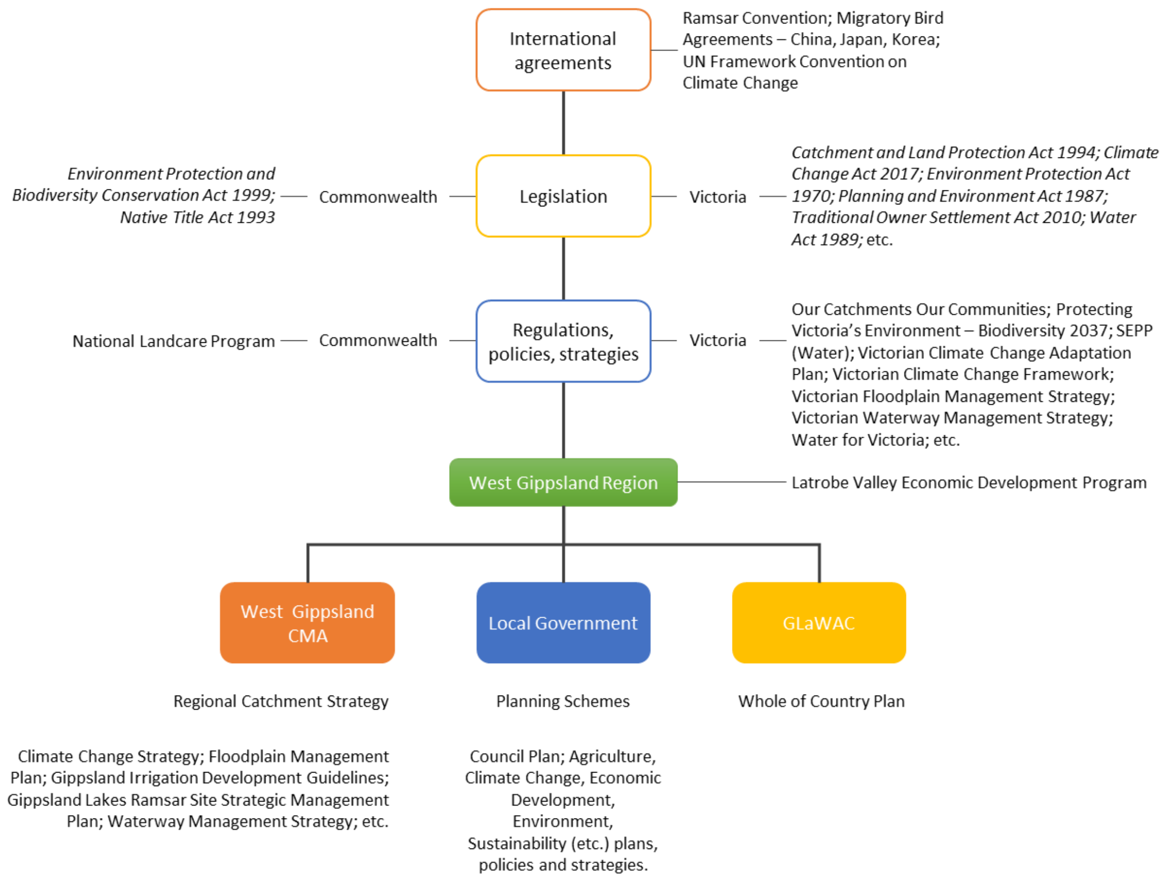


Figure 2.1 Overview of policy and strategy framework for the Lake Wellington Land and Water Management Plan.

2.2 Victorian Government

A range of Victorian legislation governs or influences irrigation land and water management and the operation of the Catchment Management Authorities (CMAs) as regional leads for natural resource and environmental water management (especially the *Catchment and Land Protection Act 1994 and Water Act 1989*; Figure 2.1). Environmental performance requirements are set in various State Environment Protection Policies (SEPPs) under the auspices of the *Environment Protection Act 1970.* Local government planning controls for some irrigation activities (e.g. land-forming) are implemented through their planning schemes, which operate under the *Planning and Environment Act 1987*. The *Climate Change Act 2017* provides the framework for the State to achieve its net zero emissions (NZE) target by 2050 and build climate resilience into major sectors of the Victorian economy and society – including agriculture and water.

State Government legislation underpins key policies, strategies and frameworks which have more direct influence over irrigation land and water management, including in the Lake Wellington catchment, as described below.

2.2.1 Water for Victoria

Water for Victoria: Water Plan (DELWP, 2016a) is the Victorian Government's strategic plan for the management of water resources. It sets out actions to support a healthy environment, a prosperous economy and thriving communities. Water for Victoria commits the State government to significant water-related investments in the Gippsland region, including to: improve the health of the Gippsland Lakes; modernise the MID; promote sustainable irrigation; support irrigation development feasibility assessments and water resource assessments; restore wetlands and waterways; mitigate flooding; and manage salinity.

Historically, the majority of public sector investment in the Macalister LWMP has been sourced through the Department of Environment, Land, Water and Planning's (DELWP's) Sustainable Irrigation Program (SIP), which operates under the auspices of *Water for Victoria*.

Water for Victoria also tailors the Victorian Government's climate change mitigation response for the water sector, including defining how the water sector will lead progress towards the State's 2050 NZE target. It also recognises the potential for adverse impacts associated with reduced water availability and growing populations and seeks to build climate resilience across the water sector.

2.2.2 State Environment Protection Policy (Water)

Targets for water quality (specifically phosphorous) in the Lake Wellington catchment are set by the *SEPP (Waters of Victoria)*. A new *SEPP (Waters)* is currently being finalised by DELWP. It proposes to set a target to reduce phosphorus loading into Lake Wellington from its current 115 t/y (on average) to 100 t/y by 2030. Management of irrigation activities is to contribute half of this reduction, with the proposed SEPP (Waters) requiring this Plan to specify a target to reduce phosphorus loads from Lake Wellington catchment's irrigation areas by 7.5 t/y by 2030.

The targets are being set to reduce the incidence of algal blooms in the Gippsland Lakes and improve the health and amenity of the Gippsland Lakes system. Works to achieve the Plan's target should also help to improve the health of local waterways.

2.2.3 Climate Change Adaptation Plan

Victoria's *Climate Change Adaptation Plan 2017-2020* (DELWP, 2016b), seeks to increase understanding of future climate change threats to assist sectoral, local and regional planning processes under the *Climate Change Act 2017*. It identifies the natural environment, agriculture and water as priority sectors for action to enhance adaptive capacity, strengthen resilience and reduce vulnerability to climate change.

The Plan commits ongoing support to the irrigation sector through upgrades to irrigation infrastructure, improved water efficiency and support to integrate climate change risk management into business strategies.

2.2.4 Our Catchments – Our Communities

Our Catchment-Our Communities (DELWP, 2016c) provides the framework for integrated catchment management in Victoria, based around the themes of land, water and biodiversity management. It coordinates planning, investment and implementation in catchment management at state and regional scales. Environmental and catchment management initiatives funded under *Our Catchment-Our Communities* complement those supported by the SIP in irrigation adjacent floodplain areas.

Integrated catchment management is coordinated locally through the *West Gippsland Regional Catchment Strategy*, which is developed to satisfy requirements of the *Catchment and Land Protection Act 1994*.

2.3 West Gippsland region

2.3.1 West Gippsland Catchment Management Authority

West Gippsland CMA (WGCMA) is the lead agency for natural resource management (NRM) in the West Gippsland region, including the catchment of Lake Wellington. Its *Regional Catchment Strategy* (RCS; WGCMA, 2013) provides the overarching framework for the management of land, water and biodiversity conservation. It is the primary planning document that identifies priorities for natural resource management. It sets the direction for how the region's land, water and biodiversity resources should be managed to maintain or improve their condition over time.

The RCS takes account of relevant international agreements and Commonwealth and State legislation. It provides a framework for the implementation of key government policies on NRM and for engagement with Traditional Owners in the planning and management of land and water resources.

The Lake Wellington LWMP is a sub-regional plan, which operates under the auspices of the RCS. With complementary plans and strategies (Figure 2.1), it seeks to support the achievement of regional NRM objectives and the deliver on the CMA's obligations in relation to irrigation land and water management.

2.3.2 Gunaikurnai Land and Waters Aboriginal Corporation

The Gunaikurnai are the Traditional Owners over much of Gippsland, including the Lake Wellington catchment (see Chapter 3.5). The rights and interests of the Gunaikurnai peoples are represented by the Gunaikurnai Land and Water Aboriginal Corporation (GLaWAC) and legally recognised under the *Traditional Owner Settlement Act 2010* and the *Native Title Act 1993*. These rights and interests are set out in the *Gunaikurnai Whole-of-Country Plan* (GLaWAC, 2015) and include protection of Gunaikurnai land, waters, culture and people.

The *Whole-of-Country Plan* seeks to ensure the Gunaikurnai have a real say in decision making around sustainable and equitable use of resources, which is consistent with the objective of the State Government in Victoria's *Water Plan* (DELWP, 2016). The *Water Plan* commits to recognising Aboriginal values and objectives for water and reflecting these in water planning, as well as supporting Aboriginal access to water for economic. It also supports activities that develop capacity and increase Aboriginal participation in water management. The LWMP, particularly through its innovative irrigation and connected irrigation communities program (Chapter13.8), seeks to give effect to aspects of both the *Water Plan's* and *Whole-of-Country Plan*'s objectives with respect to Indigenous participation in irrigation land and water management.

2.3.3 Local government

The majority Lake Wellington catchment falls within three local government municipalities, those of the Latrobe City Council and Baw Baw and Wellington Shires. The main role of local governments with respect to irrigation land and water management is in the administration of planning schemes. These regulate the uses of land and, in Lake Wellington catchment, help to provide for the protection of higher value agricultural land, particularly irrigated land.

Planning schemes may also regulate some activities associated with irrigation land and water management, including earthworks which change the rate of flow or the discharge point of water across a property boundary and earthworks which increase the discharge of saline groundwater.

3 The Lake Wellington catchment and its community

3.1 Population and community

The Lake Wellington LWMP addresses the management of irrigated land across the entire Lake Wellington catchment. The catchment includes seven local government municipalities (Figure 3.1), with the Baw Baw, Latrobe City and Wellington local government areas accounting for most of the area (96%) and almost all of the population. These three municipalities have a collective population of over 165,000 people, most of whom reside within Lake Wellington catchment (ABS, 2017a).

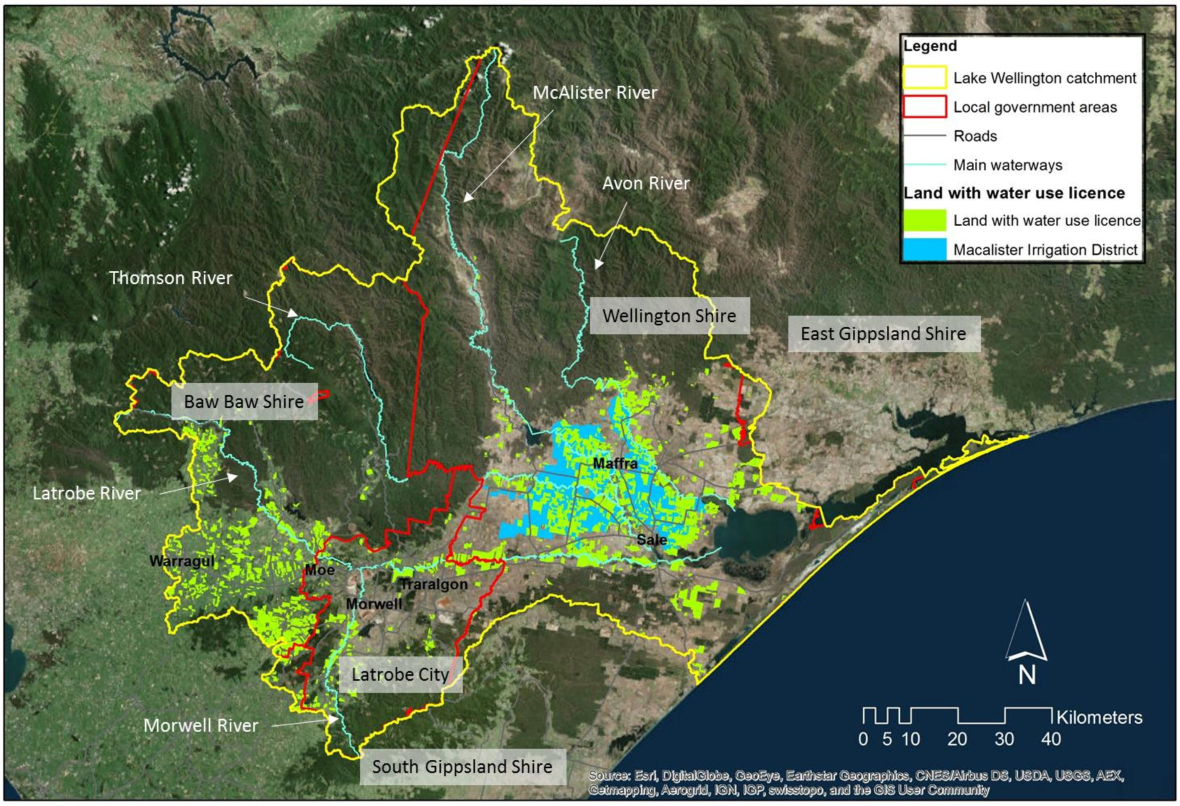


Figure 3.1 Local government areas and main towns in the Lake Wellington catchment

Over half of the catchment community live in the five main population centres of Moe, Morwell, Sale, Traralgon and Warragul. Approximately 20,000 people live in towns, smaller settlements and on farms within or near the Macalister Irrigation District.

The Gunaikurnai are a community of some 3000 people with Indigenous heritage and are traditional custodians over most of Gippsland. The Brayakaulung and Tatungalung family clans of the Gunaikurnai are most closely associated with the Lake Wellington catchment area (GLaWAC, 2015).

3.2 Landscapes

The Lake Wellington catchment (Figure 3.1) comprises some 1.15 million ha and includes the catchments of the Avon, Latrobe, Macalister and Thomson Rivers and their tributaries. The rivers rise in the steep, forested slopes of the Great Dividing Range and the northern slopes of the

Strzelecki Ranges and drain across the river valleys and Gippsland plains before flowing into Lake Wellington.

The Thomson, Latrobe and Macalister rivers are important sources of water for irrigation, domestic and industrial uses and are regulated through major storages and weirs. These include the Thomson Reservoir (the largest storage in Melbourne's water supply system), Cowwarr Weir, Blue Rock Dam, Moondarra Reservoir and Lake Glenmaggie – the region's major irrigation water storage.

The Avon River (with its key tributary, the Perry River), is the only one of the four main river systems that drain to Lake Wellington to remain unregulated. The Avon River provides an important water source for irrigation as well as unregulated flows to Lake Wellington and its fringing wetlands. These river systems are recognized as having both geomorphological and cultural significance, with the Knob Reserve adjacent to the Avon River holding important cultural values for the Gunaikurnai people.

The floodplains of the Thomson and Latrobe Rivers contain a network of paleo-channels and wetlands, which fringe the Gippsland Lakes. Lake Wellington lies within the western section of the Gippsland Lakes, an area recognised for its outstanding environmental value. The Gippsland Lakes form an internationally significant lake and wetland system and is recognised under the Ramsar Convention. Lake Wellington and the other Gippsland Lakes are also valued for recreational pursuits such as boating, fishing, hunting and nature appreciation.

Since 1889, an artificial opening has permanently connected the Gippsland Lakes to Bass Strait, changing them from being naturally fresh-brackish to estuarine. Salinity varies according to proximity to the entrance and sources of freshwater inflow.

About half of Lake Wellington catchment retains native vegetation cover (Figure 3.1, Figure 3.2). About 40% of this area is multiple use State forest and is available for hardwood timber production. Most of the remaining area of native vegetation is reserved as National Park or some other form of conservation reserve.

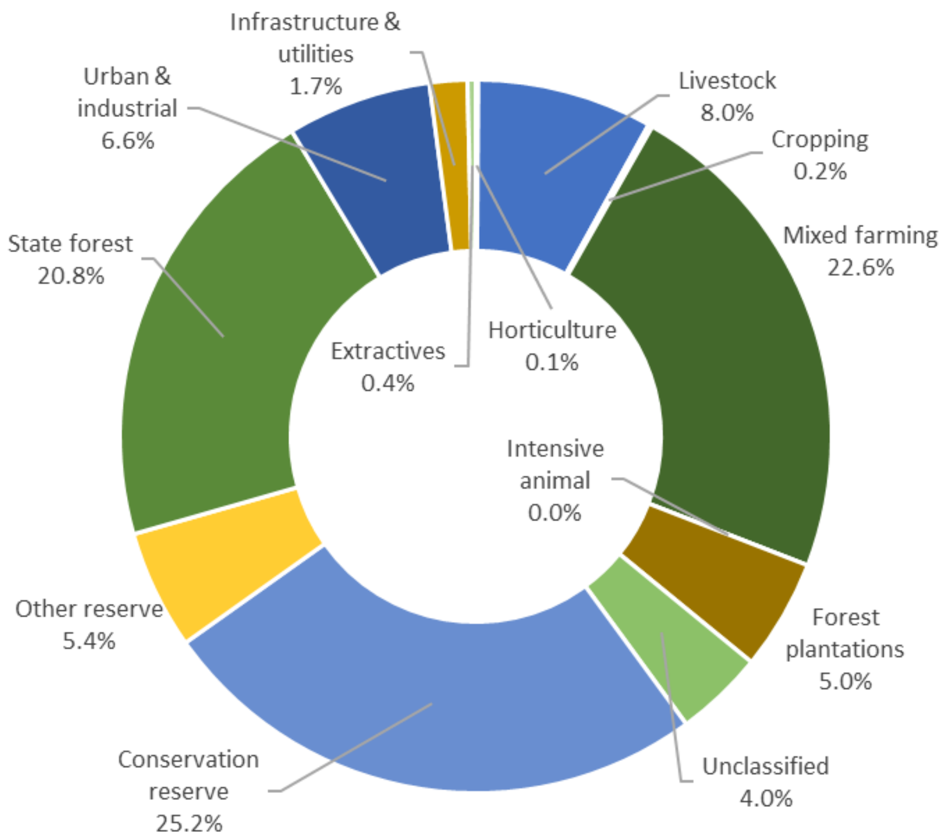
3.3 Land uses

Land uses across Lake Wellington catchment are varied (Figure 3.2), with the three major uses being agriculture (31%), nature conservation (25%) and multiple use native forest management (21%). Urban, commercial and industrial land uses each account for about 7% of the catchment and softwood and hardwood forestry plantations occupy about 5% of the catchment.

While the coal mines of the Latrobe Valley help to underpin economic activity within the catchment, the mines themselves occupy less than 0.5% of its area.

Land use mapping does not consistently classify the various forms of agriculture within the catchment. Much of the area classified as mixed farming (23% of the catchment; Figure 3.2) is likely to primarily be used for dairy farming or other forms of livestock production.

Secure water supplies, supplemented by good rainfall has enabled the development of irrigated agriculture within Lake Wellington catchment. Irrigated land is concentrated in the MID (Figure 3.1), which is the largest irrigation area in southern Victoria and a significant economic driver for the region. Irrigated land is also located around the margins of the MID, along sections of the Latrobe River and across parts of the northern slopes of the Strzelecki Ranges.



Source: Victorian Land Use Information System (Agriculture Victoria, 2016)

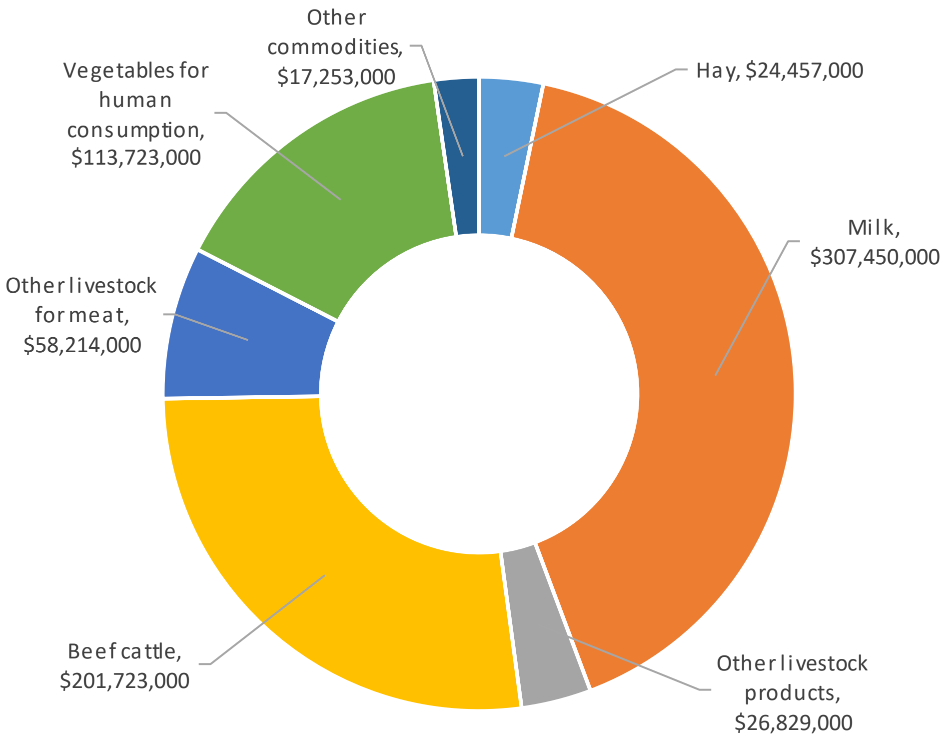
Figure 3.2 Land uses of the Lake Wellington catchment.

Land parcels with a water use licence or take and use licence occupy some 100,000 ha within Lake Wellington catchment. Most of the irrigated area is used for pasture production, mainly to support dairy production. Irrigation also supports smaller areas of vegetable production beef cattle and sheep production.

3.4 Economic profile

The use and management of natural resources help to underpin the economy of the Lake Wellington catchment. About 7% of the population of the three main municipalities is employed in the agriculture, forestry and fisheries sector. The farming sector also supports employment in manufacturing (e.g. dairy processing), transport, retail and professional services.

The total value of agricultural commodities produced within the Lake Wellington catchment was approximately $750 million in 2015-16 (Figure 3.3) or about 6% of the total for Victoria. Milk was the main commodity produced (on rainfed and irrigated pastures) and accounted for over 40% of the value of production in 2015-16 or 12% of the total for Victoria. Beef cattle production (27%) and the production of vegetables for human consumption (15%) are the other main forms of agricultural production.



Note: Estimated values include agricultural production from irrigation and rainfed areas. Derived from Australian Bureau of Statistics agricultural census information (ABS, 2017b).

Figure 3.3 Estimated gross value of agricultural production for Lake Wellington catchment: 2015-16.

3.5 Indigenous heritage

The Gunaikurnai are recognised as Traditional Owners over approximately 1.33 million ha in Gippsland; extending from near Warragul to the Snowy River and from the Great Dividing Range to the coast and sea country. For many thousands of years, Gunaikurnai have lived in the valleys, on the fertile plains and up in the mountains of their traditional country.

The Traditional Owners of the Lake Wellington catchment are the Brayakaulung people, Their Country extended from around the current site of Sale, along the valleys of the Avon and Latrobe Rivers and their tributaries, to as far west and north as Mt Baw Baw and Mt Howitt.

The Gunaikurnai see their land (Wurruk), waters (Yarnda), air (Watpootjan) and every living thing as one. All things come from Wurruk, Yarnda and Watpootjan and they are the spiritual life-giving resources, providing the people with resources and forming the basis of their cultural practices. The Gunaikurnai have a cultural responsibility to ensure that all of it is looked after.

Gunaikurnai culture and identity is embedded in Country. Aboriginal heritage is strong across the Lake Wellington catchment, and cultural sites and artefacts can be found along Gunaikurnai songlines, and trade routes, mountain ridges and waterways. They remind the Gunaikurnai about the ways of their ancestors and show their close and continuing connection to Country. Some of these sites have been recorded, however many have not yet been found and protected. The Gunaikurnai people's spiritual connection is something that cannot be seen, but nevertheless exists strongly in the places they walk and in the paths of their ancestors.

The Gunaikurnai people are actively pursuing their cultural responsibilities to care for country through the management and protection of cultural and natural assets and values within the Lake

Wellington catchment area. They seek to build mutual and respectful relationships with key stakeholder groups, including farming communities, to raise awareness and promote their cultural heritage for its protection and on-going management.

3.6 Environmental risks and challenges

The Lake Wellington LWMP has been developed to address four main environmental threats associated with irrigation land and water management, namely:

- *Off-farm losses of nutrients:* as described in Chapter 4, irrigated agriculture, particularly in the MID, is a key source of the phosphorus (P) and nitrogen (N) which are deposited in Lake Wellington and contribute to periodic algal blooms in that and other Gippsland Lakes. P and N loadings into Lake Wellington are estimated to be 3 and 1.5 times greater, respectively, than prior to European settlement (Chapter 4.2.2). Grazing land uses, including irrigated dairying, are key sources of P and N into Lake Wellington (Table 4.1)[1].
  The main focus of the Lake Wellington LWMP is on reducing nutrient losses from irrigation farms and their impacts on the catchment waterways and the lakes. This is the primary source of public benefit which justifies State Government investment in the LWMP.
- *Irrigation-induced salinity:* the Macalister and Lake Wellington LWMPs incorporate key on-going actions from the West Gippsland Salinity Management Plan. The incidence of elevated water tables, waterlogging and salinity within and adjacent to irrigation areas (the Macalister Salinity Management Zone) ebbs and flows with climate phases. During wetter climate phases, water tables rise and there is a need to operate the regional sub-surface drainage infrastructure (a network of groundwater pumps) to contain the incidence and effects of shallow water tables and salinity.
- *Off-farm losses of sediment:* off-farm movement of sediments from the catchment's lowland irrigation areas (i.e. MID and adjacent areas, Latrobe River floodplain) only occurs episodically, during floods and major overland flow events (see Chapter 4. The sediments and nutrients they carry contribute to poor river health in catchment waterways and algal blooms in the Gippsland Lakes (Chapter 4). Sediment loading into Lake Wellington is estimated to have increased twofold since development of the catchment (Chapter 4.2.2).
  The potential for erosion and sediment movement from upland irrigation areas (e.g. potato cropping areas around Thorpdale) is significant due to the soils and slope of land which is cultivated and irrigated. Soil losses have potential to affect soil health and productivity, as well as the health of downstream waterways.
- *Agricultural flooding:* much of the lowland irrigation area is exposed to river flooding and overland flows during extreme rainfall events. The LWMP's floodplain and off-farm drainage program supports West Gippsland CMA's floodplain management program in managing environmental, financial and social impacts of flooding.

Actions in the Lake Wellington LWMP (e.g. through the farm planning program) complement other West Gippsland CMA programs and activities to address threats associated with biodiversity and river health decline.

Lake Wellington catchment's mild climate and relatively reliable rainfall are considered by some irrigators to confer some measure of resilience to climate change – particularly when compared with irrigation regions in northern Victoria and southern NSW. However, despite this, climate change poses a long-term challenge to irrigation land and water management.

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[1] Forests in the Western Latrobe and Upper Thomson and Macalister catchments are also significant sources of the N reaching Lake Wellington (Chapter 4).

Climate models project that the climate will become warmer and drier and that periodic extreme rainfall events will become more intense (Grose *et al.,* 2015). This has potential (without effective adaptation) to exacerbate the processes contributing to sediment and nutrient movement into Lake Wellington and to increase the incidence of algal blooms. In the longer-term, it may also diminish the availability of water for irrigation and lead to changes in the structure and profitability of irrigation in the catchment. In the shorter-term, more severe impacts of climate change in other regions may increase the (relative) suitability of Lake Wellington catchment for irrigated agriculture.

4 Nutrient inputs to the Gippsland Lakes: a science review

4.1 Preface

This Review was prepared to help inform the development of the Lake Wellington LWMP, which will develop strategies to meet a reduced annual P-load target for the Lake. The Review brought together relevant technical information from various scales and disciplines to form a comprehensive and cohesive body of knowledge.

It is a broad field and the Review was required to set boundaries (e.g. in-stream processes, waterway management, and the feasibility and economics of intervention options have been excluded), and retain focus (e.g. the role of bushfire in the mobilisation of nutrients has not been covered as there are limited management interventions feasible within the likely construct of the Plan).

The Plan will be applicable throughout Lake Wellington catchment's irrigation areas and the major primary industries of dairying, horticulture and beef-sheep grazing. Nutrients (P and N) and sediments are the main focus. This Review has tried to present a similar balance, but within the confines of available literature. In general, there is more information available about the environmental or catchment management aspects of dairy farming than there is for various horticultural crops.

A framework developed by the dairy industry to analyse interactions between land use and catchments - *Understanding Dairy Catchments* – has been used as a guide to the structure of this Review. Although the framework was developed for dairy catchments, it is equally relevant to other forms of primary industry. It provides a structured way to investigate and report on potential links between property management and the environmental condition of receiving waters.

For the sake of efficiency, and to benefit from the analysis of others, much of the literature considered in this Review has been of a 'review' style itself. When possible, reviews of relevant science have been favoured ahead of the larger quantity of original scientific papers – although many have still been sourced for clarification or for additional information. To optimise readability in this report, the authors of reviews are cited, not the authors of papers referenced by those reviews.

This Review should be a 'step-off' point, rather than an 'end-point'. The broad coverage should help readers get to grips with aspects of most interest to them, and to see them in context. From that point further enquiries may be needed for more current and/or local information. Land use, primary industries and production systems are constantly changing. Current local situations may challenge the relevance of literature that is only a decade or so old.

Despite these limitations, it is hoped that this review meets the needs for a comprehensive and coherent stocktake of knowledge, to help inform thinking and planning for programs to enhance the condition of Lake Wellington and its catchments. Copies of most references cited are available via WGCMA.

4.2 Key points

4.2.1 Impacts of nutrient and sediment inputs to the Gippsland Lakes

- Winter and spring floods deliver most of the incoming nutrients and sediments to Lake Wellington, the westernmost of the Gippsland Lakes.
- High N:P ratios following floods suit nitrogen-dependant green algae - algal blooms can occur.
- Sediments carry nutrients and contaminants, increase turbidity, and affect phosphorus cycling. Lake Wellington is a net exporter of phosphorus.

- Water from Lake Wellington carries nutrients and sediments to the deeper, more easterly, Lakes Victoria and King. Lake Wellington is a ‘receiving water’ and a ‘source’.
- In deeper lakes, the decomposition of post-bloom algae releases N as gas and depletes oxygen from lake-bottom waters. P is released from Lake sediments, lowering N:P ratios. Other conditions permitting (e.g. salinity and temperature), nitrogen-fixing blue-green algae can bloom as they then outcompete green algae.
- Nitrogen inputs prime the lakes for blooms of blue-green algae. Phosphorus loads control the extent and duration of any blue-green algal bloom.

4.2.2 Causes

- Annual nutrient and sediment loads are variable, strongly influenced by rainfall.
- Estimated annual loads to Lake Wellington are:
  - Phosphorus: 69 – 140 t P/y (3 times pre-development).
  - Nitrogen: 1,770 – 2,800 t N/y (1.5 times pre-development).
  - Sediments: 110,000 – 190,000 t/y (2 times pre-development).
- Catchment modelling indicates that the main contributing catchments and land uses are as follows (Table 4.1).

Table 4.1 Main sub-catchments and land uses contributing nutrients and sediments to Lake Wellington

	Phosphorus	Nitrogen	Sediments
Catchment areas	Hillslopes, especially in the Upper & Lower Latrobe. MID.	Hillslopes, especially in the Western Latrobe. MID.	Gullies and stream banks, especially in the Latrobe and MID.
Land uses	Grazing (Latrobe) and irrigation (Lower Latrobe and MID).	Forests (Western Latrobe & Upper Thomson-Macalister) – although such N may have limited bio-availability. Grazing (Western Latrobe).	Grazing (Latrobe and MID), and irrigation (MID).

4.2.3 Transport

- Dairy pastures lose phosphorus as dissolved P, in surface run-off. P concentrations in run-off are related to soil P levels (which are often highest in the top 10-15 mms). Dissolved P readily attaches to soil and sediments (e.g. in streams), becoming particulate P.
- Dissolved nitrogen (e.g. dissolved nitrate) can leach through soils as well as being lost in surface flows. Soil macropores and drains (surface and sub-surface) can also transport nutrients.
- Sediments are typically lost from exposed soils in surface run-off. Preferential deposition of larger sediments occurs. Finer sediments, which stay suspended longer, often have higher nutrient concentrations. Particulate P is often lost from annual horticulture in surface run-off.
- The impact of nutrients on a catchment is influenced by the degree of connectivity between the source and the receiving waters in question. Intervening wetlands, dams, lakes or riparian buffers may act as ‘sinks’, and reduce connectivity. Drains may increase connectivity.
- The role of dams, lakes and wetlands, buffers, and possible inputs from groundwater, are not well understood for the Lake Wellington catchment. Nor is there much analysis of any potential net benefits that may come from ‘slowing the flow’ of water from hillsides into waterways.

4.2.4 Sources

- Nutrient losses are a combination of systemic (landscape or production system) and incidental (manageable) factors. Systemic losses can dominate in well-managed operations, but less effective management can result in large incidental losses in storms or following irrigation.
- In studies monitoring run-off from landscapes used for different purposes, nutrient and sediment concentrations are generally higher from horticulture, followed by grazing (including dairy), and then forestry. Such studies reflect systemic and 'typical' incidental losses.
- Nutrient intensive industries create a nutrient rich landscape.
  - Dairy risks include: P-rich soils, stock, urine patches and effluent.
  - Horticulture risks include: bare soils, high fertility, and the erodibility and hydrology of soils.
  - The risk of nutrient loss increases with the solubility of applied fertilisers.
- The management of *critical source areas* (sites with high source and transport risk), and connectivity, has a big influence on nutrient and sediment loss, especially during storms.

4.2.5 Management practices

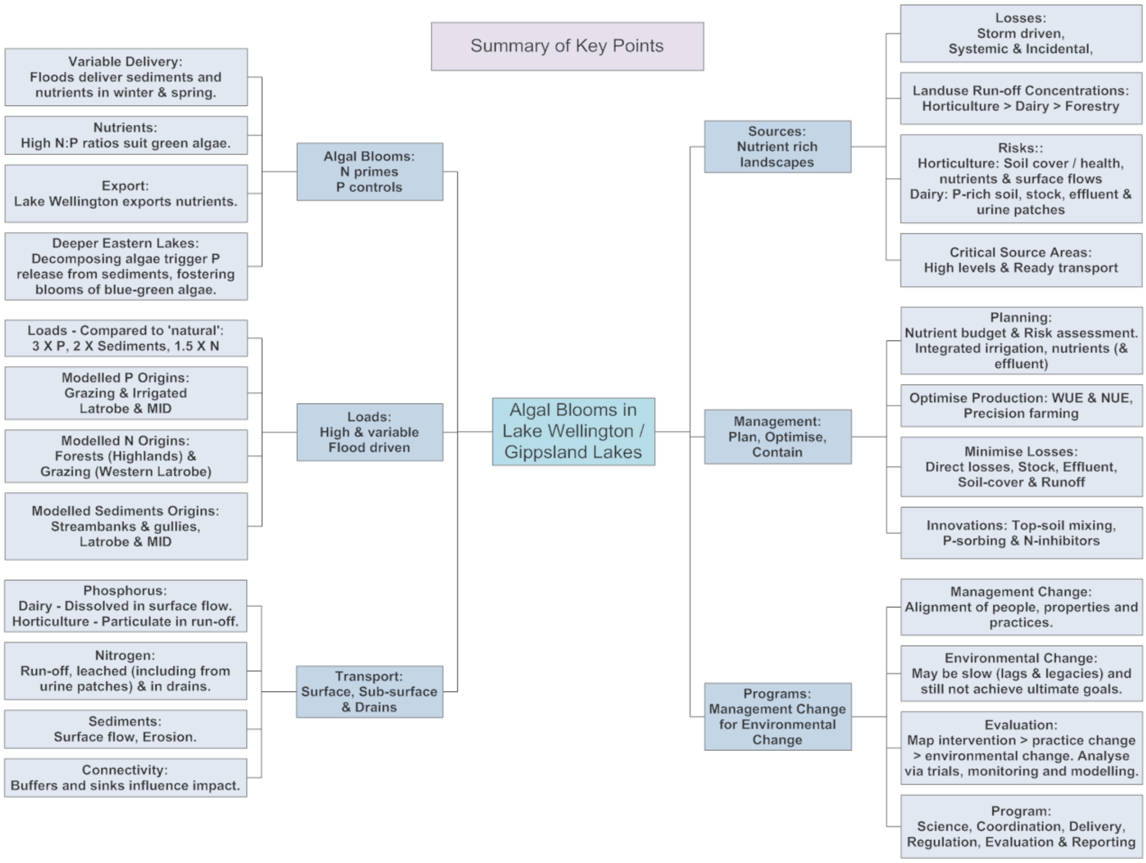
- Minimising the loss of nutrients involves sound planning, optimising production per unit of input (i.e. efficiency), and effort to contain losses.
- Planning begins with 'stock-taking': whole property nutrient budgets, risk assessments and 'best practice' assessment. Planning for integrated irrigation and nutrient management (including effluent) will require: infrastructure design and installation, automation and decision support, plus training (for producers and advisers) and access to advice and information.
- Optimising production per unit of input involves nutrient use efficiency (NUE), water use efficiency (WUE), and sound stock management. Precision farming – the right type or quality, at the right rate, in the right place, at the right time – is applicable for irrigation water and nutrients.
- Minimising nutrient losses involves:
  - Care in the type and amount supplied to meet plant needs and soil constraints.
  - Avoiding direct losses from fertilisers and effluent (e.g. through control of stock access and integrated effluent management).
  - Maintaining vegetative cover, managing run-off to trap sediments and particulate nutrients (e.g. with contour drains, sediment traps and grassed buffers), and minimising the leaching of soluble nutrients (e.g. avoiding over-irrigation to reduce nitrate leaching).
  - Innovative options such as top-soil mixing, P-sorbing coagulants to critical source areas, and the use of N-inhibitors may also be applicable.
- A sub-catchment, or neighbourhood, approach may help identify and manage critical source areas and connectivity issues, to contain nutrient and sediment impacts on catchments.

4.2.6 Management programs

- Change-management programs must align the person, their property, and the promoted practices. Catchment programs often need a multi-faceted approach. It can take decades before environmental changes become apparent and targets may still not be achieved.
- People may be at different stages of understanding and commitment to change for any given practice, so a mix of information, messages and communication channels will be required.
- New practices must be compatible with production systems, property infrastructure and the environment. For high adoption rates, they must offer a relative advantage and be easy to trial. Alignment with industry programs and messages can help.
- Programs seeking environmental gains through changes in resource management need a good science base, strong monitoring and evaluation, and a mix of 'delivery' elements.

- A clear picture of current practice at the commencement of a program provides a firm base for planning (e.g. identifying and quantifying target markets), as well as reporting change and predicting environmental benefits. Modelled results and field data can aid evaluations.

4.2.7 Key points summary



4.3 Impacts of nutrients and sediment

4.3.1 Lake Wellington

Lake Wellington is a shallow, well mixed, turbid ecosystem that is well oxygenated. It was once a freshwater system but is now brackish to saline (especially during drought), with fresher characteristics immediately after major inflows from floods. The Thomson-Macalister and Latrobe Rivers provide most inflow. It is high in nutrients, and generally has the highest phytoplankton biomass of the three main Gippsland Lakes. Lake Wellington is a net exporter of nutrients to Lakes Victoria and King (EPA, undated).

Lake Wellington is generally not vertically stratified (or layered) by salinity or temperature. It is well mixed due to its shallow depth and wind-driven waves, which also contribute to it being very turbid (Karoo, 2014). Wave action can also increase bank erosion.

At a broad scale, the Gippsland Lakes are influenced by sediment and nutrient delivery, such as:

- Seagrasses in the marine influenced Lakes:
  - Sediment smothers seagrass.
  - Increased turbidity inhibits light penetration and hence seagrass growth.

- Nutrient levels in the lakes:
  - Enhanced nutrient levels promote the occurrence of algal blooms.
  - Nutrients also influence other ecosystem processes due to varied responses between species to altered nutrient regimes.
- Fringing wetlands:
  - Sediment smothers vegetation.
  - Increased turbidity influences vegetation and ecosystem processes (Zavadil, 2017).

The Gippsland Lakes have become increasingly saline since the permanent opening was cut to the sea at Lakes Entrance in 1889. Lake Wellington is the least saline of the Lakes, but salinity levels are highly variable; ranging from less than 1 (presumed measured as PSU) after floods, to drought induced levels of over 15 (in 1998) and 20 (in 1982). Brackish water can move into the Lake via the McLennan Strait due to variations in water level in the eastern lakes (Boon *et al*., 2015). Salinity in the Lake has been noted to affect the previously freshwater fringing wetlands, e.g. reed beds (Boon *et al*., 2015).

A mix of salinity, nutrients, resultant algal blooms, and sediments have been linked with changes in aquatic species, fish communities, the nature of fringing wetlands around the Ramsar listed Gippsland Lakes, and the bird life they support – with consequences for the ecology, tourism, recreation and fishing industries (Boon *et al*., 2015).

Harris *et al.* (1998) reported a reduction in rainfall from 55 mm/month to 45 mm/month since the 1950s in the Gippsland region. That, plus the development of dams, the extraction of water, and regulation of rivers led to a reduction in the frequency of floods and the inundation of marshes. Coupled with changes in salinity, the vegetation changed accordingly. The Gippsland Lakes are not in a 'steady state' and are continuing to change in response to changes in the catchments and their connection to the sea.

A marked change in Lake Wellington occurred in 1968, when the salt-intolerant water-plant (or macrophyte) *Vallisneria australis* disappeared during a severe drought. It has since been replaced by phytoplankton as the main form of aquatic 'plant life'. The loss has been linked with increased salinity, higher nutrient loads and reduced water clarity associated with the drought, and subsequent bushfire and flooding (Boon *et al*., 2015).

River inflows are the major source of freshwater into Lake Wellington, although groundwater discharge contributes 24-36% of annual average flow in the Avon River. Quantitative information on groundwater discharges in the Gippsland region is generally lacking, but wetlands on the western side of Lake Wellington are believed to receive increased salt loads from groundwater driven by elevated water-tables, due to irrigation and clearing (Boon *et al*., 2015).

4.3.2 Water quality targets

WGCMA must incorporate an objective into its management actions of reducing total phosphorus (TP) inputs to Lake Wellington by 15 tonnes per year by 2030; by including a 7.5 tonnes per year reduction objective in the Lake Wellington LWMP and a 7.5 tonnes per year reduction objective in the Gippsland Lakes Ramsar Site Strategic Management Plan.

Through measures targeting phosphorus discharges from both irrigation and other diffuse sources in the Lake Wellington Catchment, total phosphorus loads entering Lake Wellington are to be reduced from an average of 115 tonnes to 100 tonnes per year by 2030 (DELWP, 2017).

The earlier *State Environment Protection Policy (Waters of Victoria) 2003*, Schedule F5, included a target to reduce phosphorus loads from the Macalister Irrigation District by 40% by 2005 (from 70 to 42 tonnes per year) (Fitzpatrick *et al*., 2017). The Macalister Irrigation District runs across lower parts of the Thomson, Macalister and Avon Rivers.

It has been suggested that nitrogen load limits may be appropriate for Lakes Victoria and King as nitrogen dependant algal blooms are more common in their higher salinity waters (DELWP, 2017).

Any targets would need to recognise inputs from Lake Wellington and catchments in East Gippsland.

4.3.3 Algal Blooms

The purpose of the load reduction target is to improve water quality in Lake Wellington, and reduce the frequency and severity of algal blooms in the Gippsland Lakes - especially blue-green algae in the deeper lakes. 'Blue-green algae' are photosynthetic cyano-bacteria, many of which are able to fix nitrogen, which enables them to out-compete nitrogen dependant green algae when nitrogen is limiting growth.

Holland *et al*., (2013) report that sediment cores from Lake King indicate there were blue-green algal blooms in the Lake prior to the opening of the artificial entrance at Lakes Entrance in 1889, when there was less flushing of the system. A second phase of blue-green algal blooms commenced in the late 1980's. It followed a steady increase in organic carbon in sediments after the 1940's, which is considered to be from phytoplankton. It is speculated that changing land use and management practices led to the more recent phase, especially high fertiliser use, irrigation and river regulation.

Davis *et al*., (1998) concluded that organic matter associated with phosphate was under-rated as a water quality issue. Dissolved Organic Matter adds nutrients (especially N) and depletes O_2 in water where P-rich materials are deposited. Organic matter inputs could contribute to the release of phosphorus from lake sediments in anoxic conditions.

Although Lake Wellington is relatively shallow and the waters are well-mixed, surface waters warm in summer and, with other measures such as nutrient concentrations and salinity permitting, they become prone to algal blooms (DELWP, 2017). Algal blooms in Lake Wellington are usually green algae, and the lake has the highest phytoplankton biomass of the three main lakes (EPA, 2015).

Ladson (2012) concluded that blooms of *Nodularia* (a blue-green algae) are mostly absent from Lake Wellington due to generally low salinity, continuing nitrogen input in summer, and a low degree of stratification of the water column. Some blue-green algal blooms have been recorded however, including *Nodularia* (July 1965, following bushfires and heavy rains), *Microcystis* (March 1971), and *Nodularia* and diatoms (May 1971; Stephens *et al*., 2004).

Blooms of blue-green algae may be toxic to people, animals and fish, affect dissolved oxygen concentrations, and have detrimental effect on environmental, recreational and production values. Phosphorus and Chlorophyll-a (Chl-a) concentrations are the water quality indicators of most interest for monitoring the risk of blooms of blue-green algae such as *Nodularia* (DELWP, 2017).

Both the total concentration and relative abundance of nutrients (especially carbon, nitrogen and phosphorus) are important to algal growth. Different types of micro-algae flourish in different conditions. As an example, at high N:P ratios green algae may thrive, while blue-green algae prosper in lower N:P conditions, outcompeting through their ability to fix nitrogen (Day *et al*., 2011).

Carbon, nitrogen and phosphorus tend occur in a similar ratio in phytoplankton - C 106, N 16 and P 1 - termed the Redfield Ratio after the discoverer of the relationship. The ratio is regarded as optimal for algal growth, subject to environmental factors (e.g. light, temperature, and salinity), being favourable (Smith et al, 2017).

The majority of nutrient inputs to the lakes are delivered by floods. Particulate nitrogen and phosphorus (60 and 80% of the loads respectively between 2005 and 2011) largely influence the water quality of the lakes (Zhu *et al*., 2017). Dissolved reactive P is mainly in the form of orthophosphate, with some organic phosphate. It is readily taken up by algae and sediment adsorption. Particulate P is adsorbed or contained within soil particles. It takes time for enzymes or physio-chemical processes to release it (McDowell *et al*., 2011).

Lake Wellington is a partial sink. It traps some sediment and nutrients, but others move through the McLennan Straits to Lake Victoria and Lake King. Modelling of the Lakes indicates that up to 70%

of catchment nutrient inputs could be retained in Lake Wellington for a year after a high flow event. The percentage of nutrients retained would be expected to be higher in low-flow years (DELWP, 2017) – though the load may be less.

The shallow, turbulent nature of Lake Wellington results in only about 14% of incoming phosphorus being trapped in sediments, with the rest exported (EPA, 2015). This is typical of shallow lakes where stratification is rare, with any phosphorus released from sediments being likely to be flushed from the system (Sharpley *et al*., 2013). As nutrient rich waters from Lake Wellington enter the more saline Lake Victoria, flocculation occurs, and phosphorus is deposited in the sediments (EPA, 2015).

Dissolved inorganic nitrogen can flow through the Lakes, unless converted to particulate organic nitrogen by photosynthetic plankton (phytoplankton) quickly enough to prevent it being flushed out. Particulate nitrogen can settle to the bottom of the Lakes and have a longer residence time (Zhu *et al*., 2017).

In the long term, all the nitrogen that comes into the Lakes will be removed - by flushing to the ocean, being lost as a gas following denitrification - or buried. The concentration of nitrogen in the water of the Lakes depends on the relative rates of inflow and loss. If there is a large pulse of nitrogen, as occurred in 2007 (following bushfires in the catchment), the nitrogen concentration of lake water will temporarily increase until the processes that remove nitrogen can catch up (Ladson, 2012).

Residence times in the Lakes vary from a few days during floods to 'almost infinity' during droughts (Harris *et al*., 1998). In general, residence times for water are from 85 – 120 days, while it may be many years for nutrients. The Lakes are therefore always still responding to the last big nutrient inflow when the next one arrives.

Some catchments are more sensitive to nutrient pollution than others, and some are more sensitive to phosphorus, while others are affected more by nitrogen (Monaghan *et al*., 2007). Phosphorus levels in the Gippsland lakes are a key cause of blue-green algae blooms, but studies in the more saline Lake King suggest that blooms of cyanobacteria (blue-green algae) are primed by increased nitrogen loads; which drive an increased release of P from anoxic and hypoxic (having low concentrations of dissolved oxygen) bottom water (DELWP, 2017). Both phosphorus and nitrogen can influence the biota of the Gippsland Lakes.

Phosphorus in sediments is generally in equilibrium with the water column above (Day *et al*., 2011). Dissolved phosphorus will be released from sediments if there is marked decrease in dissolved P in the water column – such as may occur from an inflow of low P water (Sharpley *et al*., 2013). Anoxic (depleted oxygen) conditions in sediments are associated with the release of P (Turral *et al*., 2017). The release of P from sediments in anoxic conditions is due to the reductive dissolution of iron oxyhydroxides (Sharpley *et al*., 2013).

It has been suggested that sediments in Lake Wellington have been releasing phosphorus since macrophytes were replaced by phytoplankton in the late 1960s, and that it would take eight years for stores to be depleted if all inputs stopped (EPA, 2015).

A common scenario for algal blooms in the Gippsland lakes is:

- In autumn, concentrations of bio-available nitrogen and phosphorus are relatively low, as are fluxes of nutrients from the sediments. The ratio of bio-available N:P is around or above 16:1, and algal populations are low.
- Floods dramatically increase nitrogen concentrations, lifting N:P ratios above 40:1. Surface waters are fresh and temperatures are low to mild. In these conditions, non-nitrogen-fixing algae (dinoflagellates and diatoms) bloom, using up the available nitrogen before dying out.
- Decaying algae settle on the sediments and are consumed by bacteria, whose respiration uses up the available oxygen, causing the release of phosphorus and nitrogen (significant amounts of which are lost as gas, through denitrification). As phosphorus is released from the sediments

in stratified waters with low oxygen levels, the ratio of bio-available N:P drops to around six in the bottom waters.

- As summer approaches and water temperatures rise, the nutrient scene (low nitrogen levels in surface waters and high phosphorus levels in bottom waters) favours a bloom of nitrogen-fixing blue-green algae, usually *Nodularia spumigena*. Mixing of the water and nutrients by strong winds may trigger a bloom, providing water salinities are suitable (Day *et al*., 2011).

The above is a 'typical' algal bloom scenario in the Gippsland lakes – although other scenarios do occur. Blooms of blue-green algae (cyanobacteria) can occur without a preceding bloom of green algae, and not every green algal bloom is followed by a blue-green bloom.

A 3-D hydrodynamic biological/ecological model has been developed and calibrated to study the dynamics of algal blooms in the Gippsland Lakes. Zhu *et al.* (2017) report the modelling for Lake King indicates the release of phosphorus from sediments was related to the severity and duration of oxygen depletion in bottom waters – which was driven by primary production (algae) in the Lake; which was fuelled by nitrogen inflows in winter and spring. Phosphorus released from sediments was the primary source of phosphorus triggering blooms of blue-green algae. Highlighting the importance of nitrogen to the chain of events, the model showed the release of phosphorus from sediments was more sensitive to total nitrogen loads than to total phosphorus loads, until the P loads were reduced by more than 80%.

More specific findings from the modelling include:

- High carbon delivery to the sediment in winter and spring due to floods and green algae blooms (diatoms and dinoflagellates) can cause depleted bottom-water oxygen in summer, which in turn can lead to large releases of phosphorus from the sediment.
- Large freshwater inflows can supress grazing activities which will also contribute to post-flood diatom /dinoflagellate blooms.
- Temperature and salinity are the primary factors that initialise *Nodularia* blooms in the Gippsland Lakes.
- Phosphorus controls the duration, size and severity of *Nodularia* blooms, if the temperature and salinity are within the suitable ranges.
- The primary source of nutrients that drive algal blooms in the Gippsland Lakes is the catchment. However, a large amount of the phosphorus from the catchment has been stored in the sediment over time and can be released to the water column under certain biogeochemical conditions. Phosphorus released from sediments, rather than catchment load, supplies most of the phosphorus supporting the development of recent *Nodularia* blooms.
- Reducing the external nutrient loading may not result in improvements in water quality in the Gippsland Lakes in the short term, because:
  - The reduced external nitrogen and phosphorus loads may cause nitrogen limitation for non-diazotrophic (i.e. non-nitrogen fixing) phytoplankton, and
  - The high internal phosphorus loading may promote the growth of N-fixing cyanobacteria.
- The focus of *Nodularia* bloom prevention must be on phosphorus reduction, which includes both catchment input and sediment supply. It may take 5 to 10 years' of continuous catchment phosphorus reduction for the effects to become obvious in the Gippsland Lakes as the sediment stores of phosphorus become depleted (DELWP, 2017).

Boon *et al.* (2015) report studies suggesting that recycling of phosphorus in the lakes is fifteen times the loads from catchments. Zhu *et al.* (2017) concluded that the majority of phosphorus fluxes in Lake King were from desorption processes under hypoxic and/or anoxic conditions.

Ladson (2012) concluded that the importance of nitrogen required reassessment, following research showing high nitrogen loads in winter and spring (especially large loads in wet years) may facilitate phosphorus release from sediments - and thus prime the Lakes for a blue-green algal bloom in the following summer. It was also noted that while nitrogen inputs during winter may promote *Nodularia* blooms, inputs in summer tend to suppress them (Ladson, 2012).

In summary, phosphorus controls the duration of blue-green algal blooms, and most of it is from lake sediments – of which there are large stores. However, nitrogen initiates the conditions fostering the release of phosphorus from the sediments. Reducing the nitrogen and phosphorus loads entering Lake Wellington must occur to reduce the further accumulation of phosphorus and the frequency of blue-green algal blooms in the deeper lakes. However, as noted by DELWP (2017) a lag in ecological response is likely.

4.4 Causes

4.4.1 Loads

4.4.1.1 Catchments

Loads of sediment and nutrients to Lake Wellington are highly variable between years, and difficult to measure due to the nature and number of inflowing sources.

Monitoring of TP inputs to Lake Wellington for the years 2012 to 2015 (*Table 4.2*), show total annual loads to be around 100 t P/y; with about 45 t P/y from the Macalister Irrigation District (MID), and 40 t P/y from the Latrobe River. In that period, the MID contributed between 24% to 55% of annual TP inputs, and the Latrobe River from 33% to 53% (DELWP, 2017).

Table 4.2 Sources of TP inputs to Lake Wellington (source: DELWP, 2017)

	Annual TP loads (t) to Lake Wellington (% of total)			
Year	MID	Latrobe	Other	Total
2012	77 (55%)	59 (42%)	4 (3%)	140
2013	46 (43%)	38 (37%)	20 (19%)	104
2014	17 (24%)	37 (53%)	15 (22%)	69
2015	45 (48%)	32 (35%)	15 (16%)	91
2016 (part)	21 (25%)	28 (33%)	34 (41%)	82
Ave (2012 – 15)	46 (46%)	42 (42%)	13 (13%)	101

In the longer period, 2000/01 – 2015/16, P exports from the MID have averaged 50 t/y. There appears to be an influence from rainfall on loads, with exports generally higher in wet years and lower in dry periods (*Figure 4.1*; Fitzpatrick *et al*., 2017). Nutrient loads to a water body are a factor of nutrient concentration and the volume of flow. The variability in annual flows to the Gippsland Lakes, due to variable rainfall, means that loads will also vary.

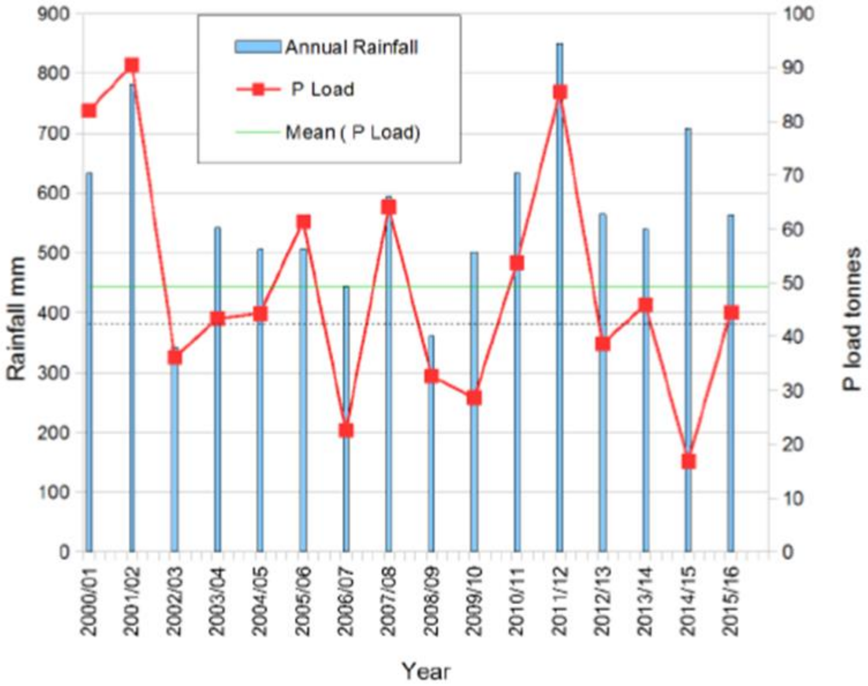


Figure 4.1 Annual rainfall and phosphorus loads from the MID (t/y) (source: Fitzpatrick et al., 2017)

Data from the last few years (*Figure 4.1*) pose the question of whether loads per given amount of rainfall have decreased. Plotting estimated data from that graph shows a trend of reduced P export per mm of annual rainfall (*Figure 4.2*). Analysis of the original data would be needed to confirm the apparent trend. An additional insight may be gained from viewing the annual P load as a factor of both rainfall and applied irrigation water.

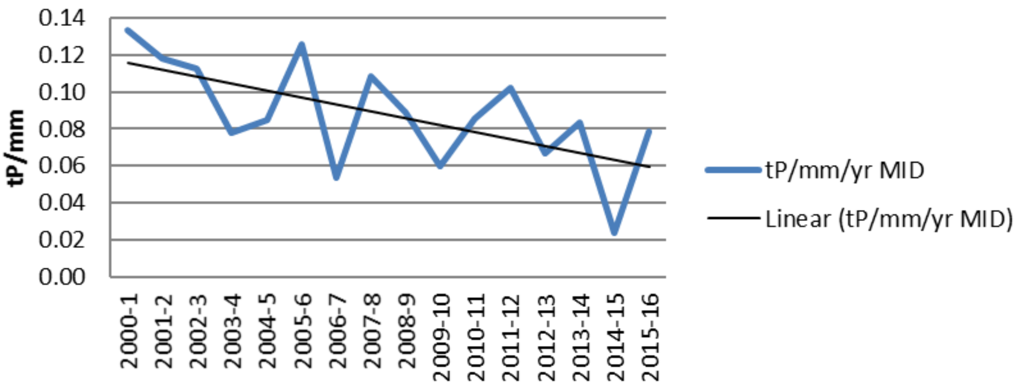


Figure 4.2 Annual P load per unit rainfall for the MID (redrawn from Fitzpatrick et al., 2017)

The P concentration of MID drains is 10 – 100 times greater than that of local rivers (Turral *et al*., 2017).

In other work, it has been deduced that drains from the MID pick up around 86-158 tonnes of P/y (coming from dairy waste discharge – 15-20% - and runoff from irrigation and rainfall). Around 5-35% of that load may be absorbed by sediments in the drains, meaning that from 79 to 97 t of P are exported per year. However, it has been observed that drain sediments now have a low capacity to absorb nutrients, suggesting they are near saturation (WGCMA, 2008). If the drains can no longer take up nutrients then, all other factors remaining static, increased loads of exported P would be expected. There is also the risk that the stored phosphorus could be remobilised during heavy rainfall events, and transported to Lake Wellington.

It was estimated in 2002 that irrigated areas in and around the MID contributed 15% of the total P load to the Gippsland Lakes, although only accounting for 3% of the catchment area (WGCMA, 2008). Modelling of the MID in 2002, down to the local drain scale, estimated annual average loads and flows from the district's drains as a flow of 84,608 ML/y, and exports of 53.7 t P/y and 137.2 t P/y (SKM, 2002).

Other estimates of phosphorus export from the MID have been made by extrapolating drain monitoring data, suggesting annual phosphorus loads of from 21 to 89 tonnes (*Figure 4.3*; WGCMA, 2008).

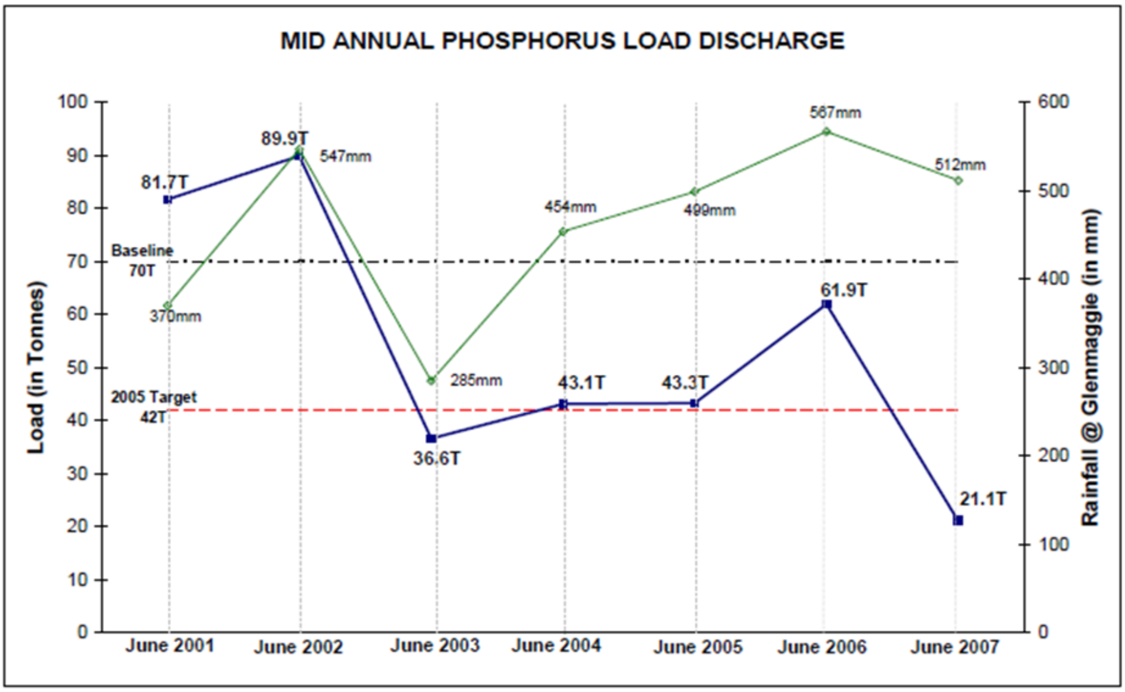


Figure 4.3 Annual rainfall and P loads from the MID, extrapolated from SRW drain monitoring data (Source: WGCMA, 2008).

For 2006-07, EPA has estimated the total load of phosphorus in the Thomson-Macalister and Avon catchments, including Central Gippsland Drain 4 and the Lake Wellington Main Drain, was around 80 tonnes; 39 tonnes from the Thomson-Macalister and 38 from the Avon (EPA, 2009).

Annual nitrogen loads to Lake Wellington are also highly variable, in line with variable inflows, with estimated average annual loads ranging from 1,770 to 2,800 t N/y (Ladson, 2012).

However, following analysis of loads and inflows it was concluded that, once the effect of variable flow was removed, there had been no change in nitrogen loads to the Gippsland Lakes in the period 1978 – 2010; although bio-available forms may be more prevalent, due to changes in land use (Ladson, 2012).

Estimated loads of total suspended solids (TSS) to Lake Wellington are around 165,000 t/y, whereas Lake King and Lake Victoria receive 45,000 and 8,500 t/y, respectively (Zavadil, 2017). These figures compare well with an estimate, based on sediment cores, by Hancock *et al.* (2006) of 170,000 t/y (±22,000) – based on a current accretion rate of 0.23 cm/y, which equates to 1.05 kg/m^2/y. The sediment cores showed more sand in recent times, indicating a change in sediment source or increased stream velocity over the last 50-70 years (Hancock *et al.*, 2006).

Compared to pre-European conditions, current riverine inputs are three times higher for total phosphorus, two times higher for suspended sediments, and 1.5 times higher for total nitrogen (Grayson 2006, cited in EPA, 2015).

The EPA (2015) reported that Grayson *et al*. (2001) estimated the Western Rivers (those flowing into Lake Wellington), to contribute on average about:

- 58 per cent of the total freshwater flow to the Gippsland Lakes system,
- 76 per cent of the suspended solids load,
- 73 per cent of the phosphorus load, and
- 69 per cent of the nitrogen load.

4.4.1.2 Landscapes

Catchment contributions of nutrients and sediments to the Gippsland Lakes have been modelled using SedNet and the ANNEX module, as reported by Grayson (2006) and Hancock *et al.* (2007). Summarised data from Grayson for the catchments entering Lake Wellington is presented in *Table 4.3* and *Figure 4.4*). The Grayson modelling incorporated direct measures of nutrient runoff from the MID (Ladson, 2012).

Table 4.3 Suspended sediment, phosphorus and nutrient inputs by Lake Wellington sub-catchment (Source: Ladson, 2012)

	Area km^2	TSS t/y	TP t/y	TN t/y
Western Latrobe	2,562	41,547	67	406
Lower Latrobe	2,101	59,480	70	267
Upper Thomson / Macalister	2,208	3,752	2	245
Lower Thomson / Macalister	1,311	39,855	45	249
Avon / Perry	2,089	9,871	20	128
TOTAL	**10,271**	**154,505**	**204**	**1,295**

Points of interest from the above include:

- The Lower Latrobe produces the highest total load of sediment and is a close second, behind the Thomson / Macalister, for load per hectare. Much of the sediment is from isolated areas of bank erosion (Ladson, 2012).
- The Western Latrobe catchments contribute a large component of the phosphorus load (largest in terms of actual load, and second in terms of load/ha).
- The Lower Thomson / Macalister, which includes much of the MID, exports the highest loads of N and P per hectare.

Other data from Ladson (2012) indicates:

- Sediments:
  - The bulk of sediments come from gullies and stream banks.
  - Grazed lands in the Latrobe catchment produce the highest loads and rates of loss, although the irrigated areas of the Lower Thomson / Macalister are also significant – with the second highest rate of export.
- Phosphorus:
  - Hillslopes are the major source of phosphorus, especially the Latrobe catchments and, in terms of rates of loss, the irrigated areas of the Lower Thomson / Macalister (i.e. the MID).

  - Grazed lands in the Latrobe catchments and irrigated lands in the Lower Latrobe and Lower Thomson / Macalister are the source of the biggest loads of P and highest rates of loss.
- Nitrogen:
  - Most nitrogen comes from hillslopes, i.e. in dissolved form. The Western Latrobe is the biggest source.
  - Forests in the Western Latrobe and Upper Thomson / Macalister are the major sources of nitrogen, followed by grazing in the Western Latrobe. Ladson (2012) noted that much of the nitrogen to the Gippsland Lakes is from high rainfall forests, and this natural export is likely to be associated with humic material, which has low bio-availability.
  - The rate of nitrogen export from the Lower Thomson / Macalister is close to that from the forests in the Western Latrobe.

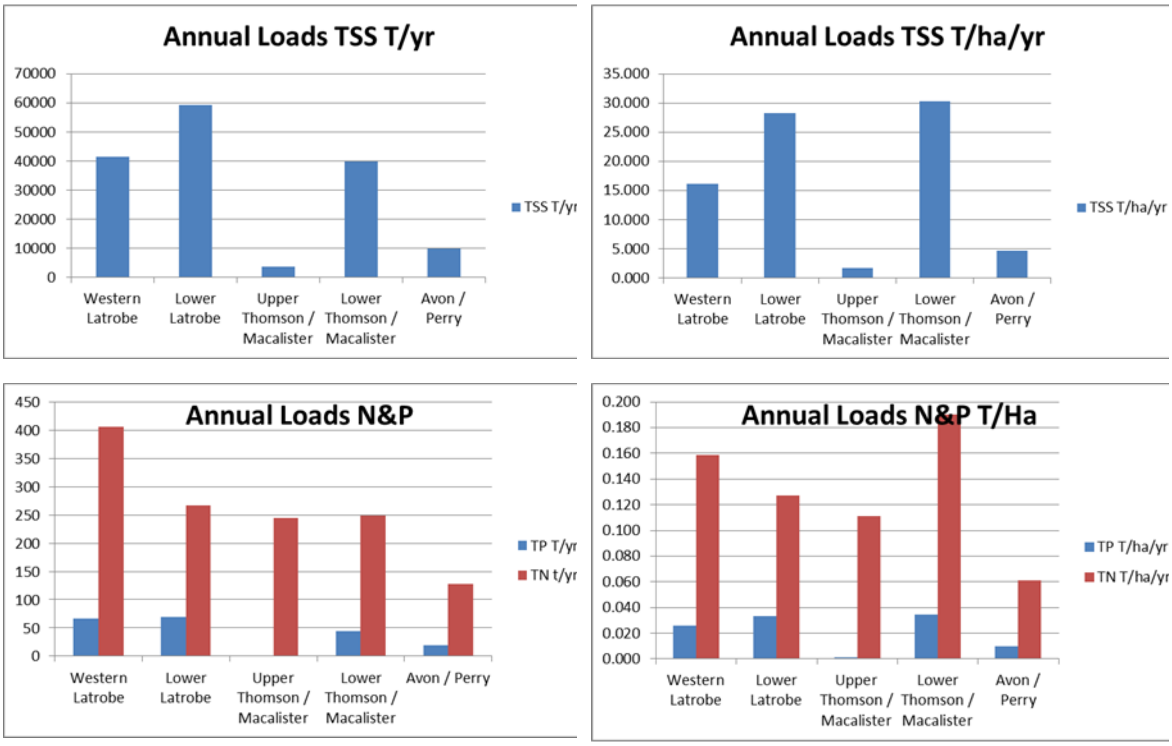


Figure 4.4 Suspended sediment, phosphorus and nutrient inputs by Lake Wellington sub-catchment (Source: Ladson, 2012)

Analysis of model outputs (e.g. rates/ha) reflect the assumptions in the model, but are still insightful as there are usually several variables at work. Another key variable is rainfall run-off. It would be interesting to see some analysis of load/mm rainfall for different catchments and land uses.

As illustrated in *Figure 4.5*, SedNet is a sediment budgeting model consisting of sources and sinks (Wilkinson, 2008). The sources are hillslope erosion (applying the Revised Universal Soil Loss Equation and a hillslope sediment delivery ratio), gully erosion, and riverbank erosion (proportional to stream power, reduced by 90-95% in areas of intact riparian vegetation). Sinks are the deposition of suspended sediment on floodplains and in reservoirs, or the loss of nutrients in reservoirs and in streams. Rivers are assigned a ‘River Delivery Ratio’ reflecting the sinks pertinent to each (Hancock *et al*., 2007).

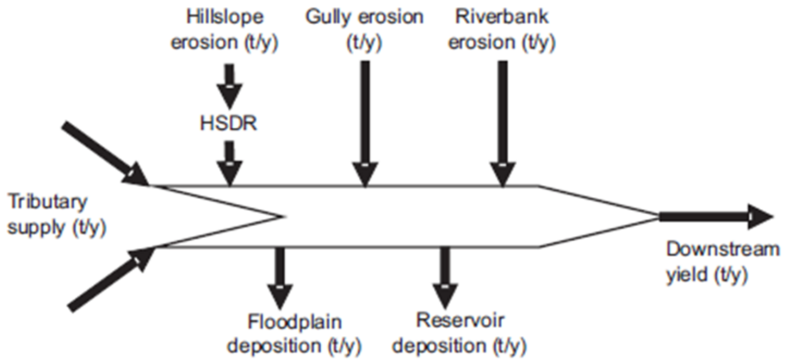


Figure 4.5 Sources and sinks used in SedNet (Source: Wilkinson, 2008).

Hancock et al., (2007) used SedNet and ANNEX, with soil and sediment sampling, and isotopic tracers to model the delivery of sediments and nutrients for river stretches and their sub-catchments (termed 'links'), leading into the Gippsland Lakes. The SedNet modelling assumed 50% of sediments from gully and riverbank erosion to be fine (suspended) sediment, while for hillslope erosion it was assumed to be 100% fine sediment (<63µm) – as only 5-10% of the eroded sediment from hillslopes reaches streams and it will be the fine sediments that do. In their ANNEX modelling, suspended nutrient loads were determined assuming a concentration per sediment load, and additional dissolved loads were determined as a product of a set run-off concentration per land use and mean annual runoff.

As Grayson (2006) notes, in this modelling context, the term 'dissolved' refers to the generation of the nutrient, not its specific form – which may have changed. Dissolved P can rapidly be adsorbed, becoming particulate P, in turbid waters; which may help explain why some paddock and farm scale studies show higher values for soluble nutrients compared to instream monitoring.

Hancock *et al*., (2007) concluded from the modelling that:

- River bank erosion contributes the majority of fine sediment entering the lakes – 84% in the case of the western catchments (those entering Lake Wellington). Hillslope erosion is a distant second in importance, followed by gully and tunnel erosion.
- Eroding channel banks in the Thompson and Macalister Rivers, and the Latrobe River below Lake Yallourn, are the major sources of sediment in the west. The majority of bank erosion comes from active 'non-vegetated' banks. Considering all catchments, 75% of river bank contributions come from just 17% of the area.
- For phosphorus, approximately 34% of catchment-derived phosphorus is delivered in the dissolved form, with the remainder from particulate-bound P sources, including a predicted 44% from river bank sediment, 15% from hillslope soil, and 3% from gully/tunnel erosion.
- For nitrogen, the predicted contributors are dissolved runoff (59%), hillslope erosion (24%), river bank erosion (15%), and gully and tunnel erosion (2%). The same trends were reported by Grayson (2006) with hillslope and dissolved sources providing 80-90% of nitrogen.

Hancock *et al.* (2007) compared the predictions of their model with sediment cores, and model outputs previously presented by Grayson et al (2001) which incorporated water quality data, noting.

- Sediment cores in Lake Wellington indicate sediment loads to the lake of 110-190 kt/y.
- Grayson *et al.* predicted loads of approximately 160 kt/y.
- SedNet predicted sediment loads of 117 kt/y from the western rivers.

It was concluded that SedNet modelling appeared to under-predict bank erosion in the lower Latrobe and Avon catchments. In a further check of model predictions, SedNet was run for an assumed pre-European catchment resulting in a predicted sediment load of 12 kt/y. That result compared favourably with estimates of 15-19kt/y based on sediment core samples.

When comparing their SedNet predictions with those of Grayson *et al*., differences were noted for the Mitchell and Thomson Rivers. The total P yield from the MID has been previously estimated using data from irrigation drains at 55 t P/y. SedNet predicted only 25 t P/y. It was concluded that modelled nutrient fluxes from the MID (especially for phosphorus), were erroneous (Hancock *et al*., 2007).

Maps in the report represent dissolved phosphorus losses in natural runoff, but not runoff from irrigated pastures, as only rainfall is considered. The focus of this work was sediment and attached nutrients. The assessment of dissolved nutrient sources was not intended to be definitive, although contributions of dissolved nutrients from sewage treatment plants were included. Runoff from irrigation drains was not considered separately (Hancock *et al*., 2007).

Modelling by Zhu *et al*., (2017) indicated that 60% of the nitrogen reaching the Gippsland Lakes was particulate.

SedNet predictions of dissolved nutrient losses are a factor of the typical nutrient concentration in runoff per land use, the area of land use, and the mean annual volume of runoff. The runoff concentrations used by Hancock *et al*., (2007) are shown in the following table.

Table 4.4 Concentrations of dissolved nutrients in surface runoff (Source: Hancock et al., 2007 (Table 4))

Land Use	Dissolved N (μg L $^{-1}$)	Dissolved P (μg L $^{-1}$)
National parks, forestry	287	4
Livestock grazing, grasslands	510	8
Mines, quarries	800	8
Cropping	500	22
Irrigated cropping	1350	320
Dryland and improved pastures	700	210
Irrigated improved pastures	1125	500
Urban and industrial areas	3450	605

Vigiak et al, (2016) used a model of the Latrobe catchment, calibrated with data from ten monitoring stations, to compare 'normal seasons' (1990 – 1996) with 'drought' conditions (1997 – 2005). It showed a large reduction in average annual sediment losses during drought and a shift in sediment source from predominantly hillslope in normal seasons to streambanks in drought.

Table 4.5 Modelled sediment yields, Latrobe Catchment; Vigiak et al., 2016

Year	Sediment yield (kt/yr)	Hillslope		Streambank	
		%	Kt/yr	%	Kt/yr
1990-1996	68	60	40.8	40	27.2
1997-2005	13	27	3.5	65	8.5

No references have been reviewed that discuss the consequences of changes in stream velocity to the rates of streambank erosion in Lake Wellington catchments.

4.4.2 Concentrations

4.4.2.1 Data

The surface-water phosphate and Chlorophyll-a (Chl-a) concentrations in the Gippsland Lakes were relatively low between 2000 and 2006, a period of dry years. In Lake Wellington, the median concentrations were 0.00597 mg/L for phosphate and 0.00974 mg/L Chl-a. The Chl-a concentration was very close to the target for an annual median Chl-a concentration of less than 0.008 mg Chl-a/L. Since 2007 the median concentrations for phosphate and Chl-a increased dramatically to 22.96 ml/L of P and 0.02376 mg/L of Chl-a; due mainly to the 2006/2007 bush fires and the increase in river flows associated with the 2007 flood (DELWP, 2017). Climate and episodic events will affect nutrient levels in the Lakes, and lie behind the variability in annual data.

Ladson (2012) has illustrated the variability in concentrations with records showing a peak in nitrogen concentrations associated with floods in 2007 (Figure 4.6).

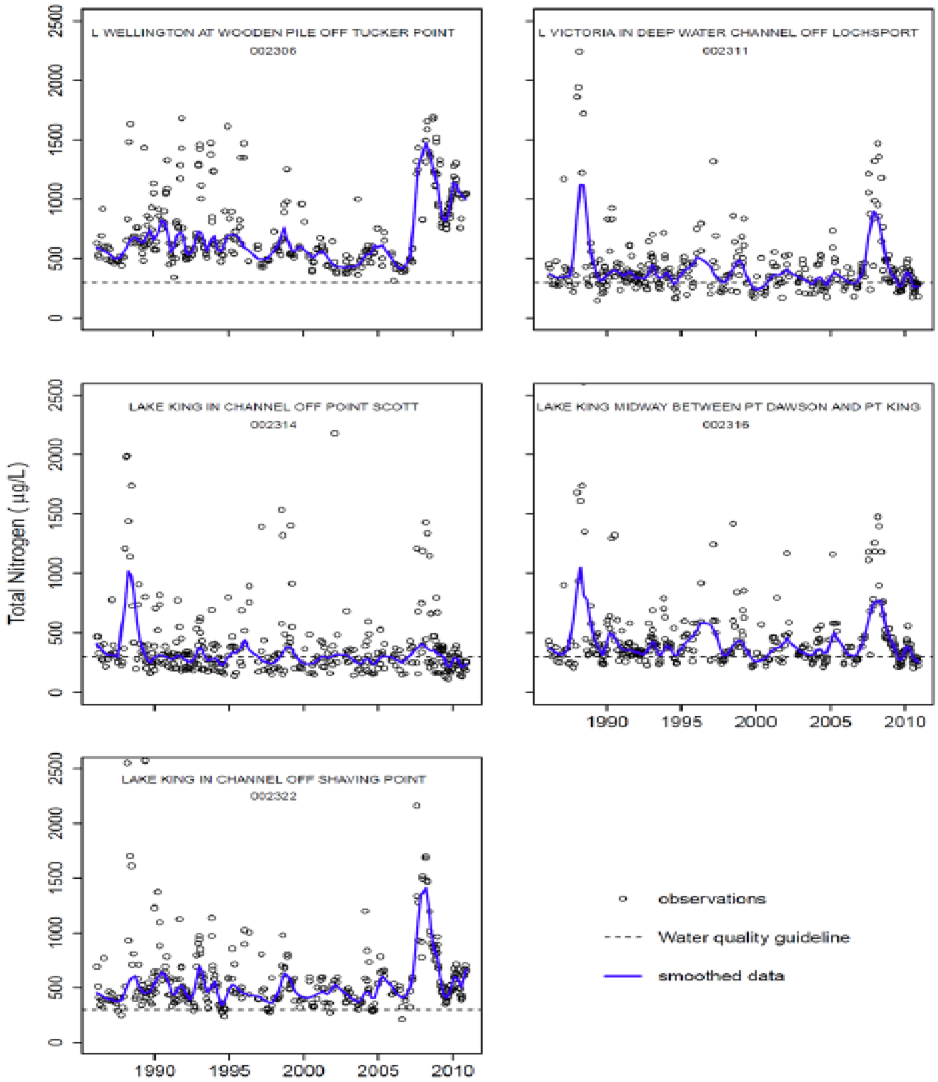


Figure 4.6 Observed total nitrogen concentration at EPA monitoring stations. The ANZECC trigger level of 300 (µg N L-1) is shown (ANZECC, 2000); Ladson, 2012 (Figure 39)

4.4.2.2 Effect of Scale

Catchment and runoff research has been conducted at scales ranging from the laboratory, soil profile, field plot, and paddock or irrigation bay, to watershed. Runoff concentrations observed at one scale may not carry through to a different scale. Any relationship between scale and concentrations will have ramifications for monitoring programs and the analysis of water quality.

At a farm scale, nutrient losses may be less (or more) than expected from loss rates observed at a plot or paddock scale (Rivers and Dougherty, 2009). Reductions can occur on-farm due to nutrient assimilation, capture (e.g. in farm or re-use dams), conversion to less mobile forms, or consumption (e.g. by algae). Increases may occur when multiple sources come into play; such as 'hotspots' like areas of ineffective effluent application, drainage outlets, or erosive gullies.

After reviewing several studies, Rivers and Dougherty (2009) concluded that there is no consistent relationship between the size of runoff generating areas and nutrient concentrations. Examples of the varied relationships discovered follow.

- Barlow *et al.* (2007) measured water and phosphorus loss at paddock, farm-section and whole-farm scales on a research farm in south-eastern Australia and found that the relationship between phosphorus export at these scales and for an irrigated dairy farm was poor (Rivers and Dougherty, 2009).
- A comparison of water quality with stream order for the Oyster Harbour catchment in WA by Weaver *et al*. (2001) found a significant relationship between the two parameters. Phosphorus concentrations decreased with increasing stream order (catchment size; Rivers and Dougherty, 2009).
- Cornish *et al.* (2002) studied runoff water from a dairy in NSW and found no significant difference between water quality measured at the whole farm (120ha) scale and that measured at the 4ha scale. Smaller scale measurements using a hand-held rainfall simulator also gave a similar result (Rivers and Dougherty, 2009).

An early paper by Prairie and Kalff (1986) examined the relationship between catchment size and phosphorus export. They found an assumption that there was a linear relationship between phosphorus export and catchment area was invalid for some cases, but valid in some instances, and in others they were related, but via a more complicated relationship. In general, they found that in agriculturally-dominated catchments, TP export varies as the 0.77 power of basin area. P delivery per unit area decreases with catchment size.

In a recent review of land use runoff data by Bartley et al (2010) it was found there wasn't a statistical difference between the median TSS concentration values at different spatial scales. However, the results differed for the nutrient data which showed that plot scale concentrations were higher than concentrations derived from catchment studies. However, these results were confounded by the proportion of land use represented in each of the size classes; e.g. stream nitrate concentrations have been found to be directly related to the proportion of land use upstream that used fertiliser. The results appeared to be independent of catchment size and suggest that the proportion of land use upstream of the sampling point that uses fertiliser is more important than the size of the contributing area upstream.

The results suggest that unless catchments have 90% or more of a given land use, a monitoring site's water quality signal is potentially contaminated or influenced by other land uses (Bartley et al., 2010).

Water quality data for the Latrobe River shows increased nutrient concentrations along the course of the river (EPA, 2015).

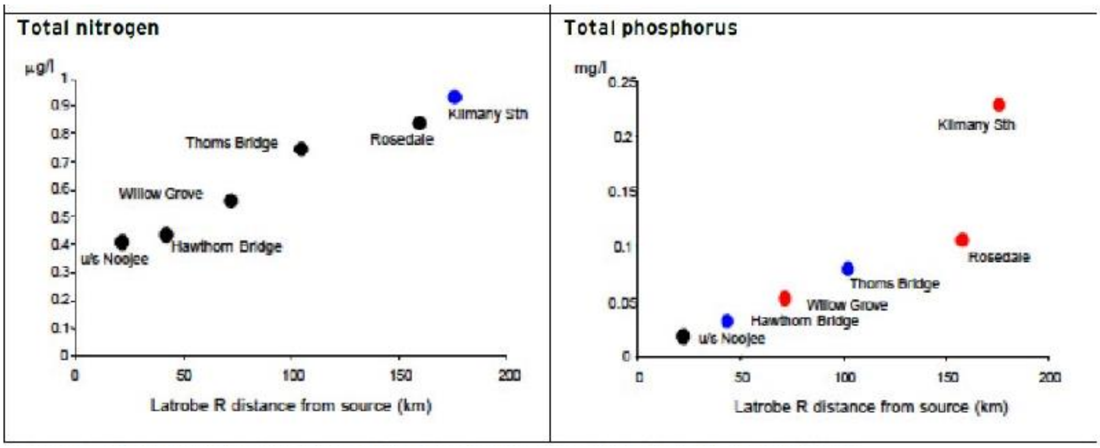


Figure 4.7 Water quality for sites on the Latrobe River in 1998 (EPA Victoria 2002b); EPA, 2015

4.4.3 Implications

4.4.3.1 Impacts

Any increases in catchment nutrient load will further reduce water quality in the Gippsland Lakes, increase the accumulation of phosphorus in sediments, and increase the severity of *Nodularia* blooms in the longer term (DELWP, 2017).

Ladson (2012) reported an annual average load to the Lakes calculated as a load per hectare of lake surface, and compared it with similar data from international studies. Based on load/hectare of lake surface, the Gippsland Lakes were mid-ranked in terms of nitrogen loading; and rated as moderate for risk of estuarine degradation (i.e. within the range of 20-100 kg/ha/yr).

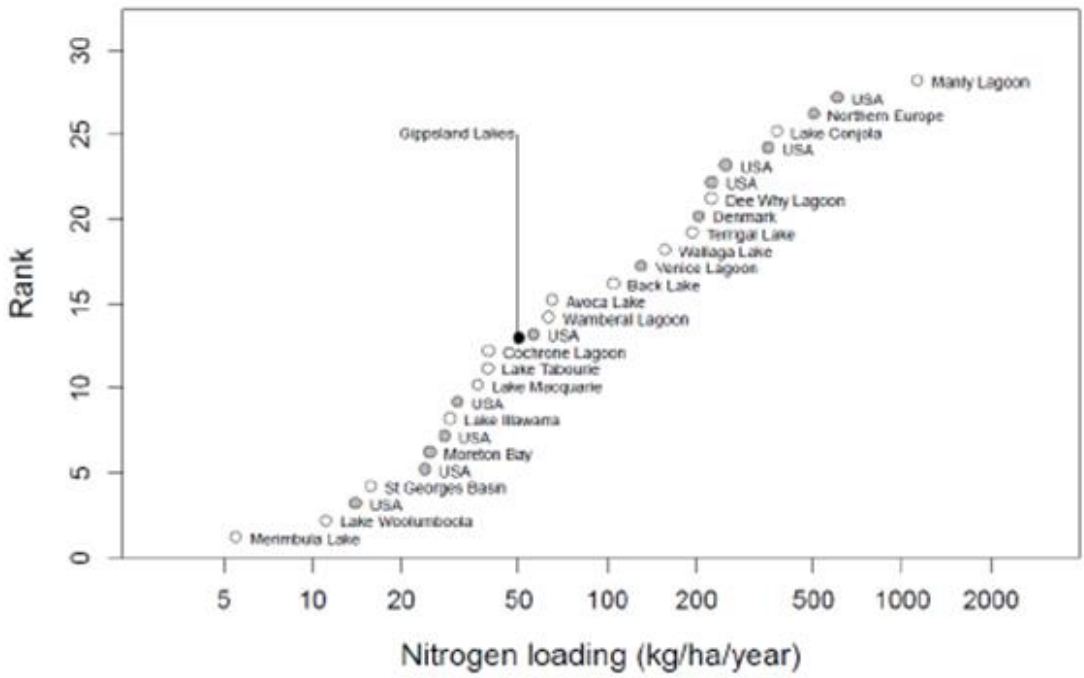


Figure 4.8 Comparison of nitrogen loads to the Gippsland Lakes with values from the literature (Scanes et al., 1998, Bowen et al. 2007); Ladson, 2012 (Figure 4)

The rate of primary production in the Lakes varies proportionally with catchment nutrient loads, both in space and time. A reduction in catchment inorganic nutrient by 30% for the western rivers and 20% for the eastern rivers would be expected to result in a 15% decrease in the total primary production rate. The sediment process rates also vary proportionally to changes in catchment nutrient loads (EPA - WQSCR).

The minimum dissolved oxygen (DO) concentration target (6 mg/L) has been achieved for Lake Wellington, and the 115 t P/yr target has been regularly achieved (EPA - WQSR). However,

EPA's analysis of data since the mid-1990s indicates that the Chl-a objective of 0.008 mg/L for Lake Wellington is not likely to be achieved with Total Phosphorus loads of 115 t/y. Chl-a levels at the upper range 0.012 mg/L were more likely. This is mainly due to sediment stores of P providing large quantities of bioavailable phosphorus to support the growth of phytoplankton (DELWP, 2017).

Modelling results indicate that a further reduction of TP loads from 115 t/yr to 100 tonnes per year to Lake Wellington could achieve a median concentration of Chl-a of around 0.010 mg/L, equal to the mid-point of the range for mesotrophic waterbodies (i.e. having medium levels of nutrients and total productivity) (DELWP, 2017).

According to Cook (2011), an annual total phosphorus loading of 100 t to the Lakes is the practical threshold for *Nodularia* blooms. No blooms have been observed below that level (Day *et al*., 2011).

With continuous nutrient reduction, phosphorus stored in the sediment may precipitate in stable minerals and be buried in the deeper sediment. Decreased sediment phosphorus flux can eventually prevent *Nodularia* blooms in the Gippsland Lakes (DELWP, 2017).

4.4.3.2 Mitigating Losses

When assessing options for the Gippsland Lakes, Ladson (2012) concluded that mitigating nitrogen loads in wet years is likely to be challenging but it is important, especially for loads of bioavailable material. A preliminary assessment based on model outputs suggested it may be feasible to reduce nitrogen loads by 25% as follows.

- Hillslope. A 25% reduction in hillslope sourced nitrogen would reduce loads by 290 t or 11.7%.
- Bank erosion. A 25% reduction in nitrogen derived from bank erosion would decrease total loads to the Lakes by 180 t or 7.4%.
- Gully erosion. A 25% reduction in gully erosion would reduce loads to the Lakes by 26 t or 1%.
- Point sources. A 50% reduction in point sources would reduce loads to the Lakes by 44 t or 1.7%.
- Irrigation related sources. Irrigation provides about 7% of the total nitrogen load to the Lakes. A reduction of nitrogen loads from irrigated areas by 40% would reduce overall loads to the Lakes by about 60 t or 3%.

It was concluded that emphasis should be on reducing erosion sources, because they are likely to be significant contributors in wet years. Velocity is a factor in the erosive power of flowing water. Reducing N loads by 25%, as described above, will not eliminate algal blooms but will likely reduce their frequency (Ladson, 2012).

Irrigated agriculture has a much higher discharge of nutrients per unit area than dryland agriculture so there are greater gains to be made from focusing efforts on reducing nutrients from irrigated agriculture (Fitzpatrick *et al*., 2017).

4.5 Transport

4.5.1 Routes

In agricultural systems contaminants are usually mobilised by detachment or dissolution. Detachment is the separation of fine particles and associated pollutants from soil by physical processes (such as flowing water or cultivation), or physio-chemical processes (such as slaking and dispersion). Dissolution (conversion into a solute) results in small particles in solution – with 'dissolved' generally defined as able to pass through a 0.45um filter. Dissolution is affected by the solubility of the pollutant, its sorption characteristics, and the prevalence of any substances able to block sorption sites (Nash *et al*, 2002).

The main transport routes for mobilised nutrients entering waterways from agricultural landscapes are via surface run-off or through the soil as relatively shallow, sub-surface flow or deep drainage (Melland et al., 2007). Sub-surface flows can be further categorised as interflow (water moving just below the soil surface), matrix flow (water moving slowly through the soil), and macro-pore or by-pass flow (water moving quickly through holes, cracks or tunnels - sometimes termed preferential flow) (Nash, 2013).

The routes taken by nutrients vary with the nutrient, the form it is in, and characteristics of the soil and local hydrology. However, in general terms, whenever water moves over or through soils, so too will nutrients.

Sharpley *et al*, (2013) stress the importance of time when considering transport, especially for phosphorus as it can accumulate in the landscape and be recycled in the environment. The journey from paddock to lake may take years and be associated with many transformations along the way. The term 'legacy P' is used to describe sequential accumulation and later remobilisation or recycling along the journey.

4.5.2 Forms

In Australian dairy landscapes phosphorus (P) is lost mainly in surface water, although leaching to local or regional groundwater occurs in sandy soils (Rivers & Dougherty, 2009). It is usually in dissolved form (McDowell & Nash, 2011).

Phosphorus occurs in either of two forms: as dissolved (soluble) or particulate (attached to matter) phosphorus. Both forms of P may convert to the other, and be present in organic or inorganic states; though organic P is not well understood.

- Dissolved P is usually present as ions of orthophosphate (PO_4---), which are readily taken up by plants or algae and incorporated into organic compounds within cells. It is often referred to as Dissolved Reactive Phosphorus or DRP. Phosphate ions may bond with iron or aluminium in acidic environments or with calcium or magnesium in alkaline situations, becoming particulate phosphorus.
- Particulate phosphorus (PP) may be present in organic or inorganic forms. The microbial decomposition of organic compounds can convert organic particulate P to dissolved P, while chemical reactions can convert P in soil particles to dissolved P. Orthophosphates can attach to the outer layer of soil particles (termed adsorption or sorption), or subsequently become incorporated within the particle (termed absorption or fixation) (Nash, 2012). Fixed orthophosphates are not available to plants, but they can be released over time.

The understanding of organic phosphorus sources is limited, although it is known that the relative contribution of inorganic and organic phosphorus varies. As an example, from field trials at a variety of scales in the UK, Stutter *et al.* (2008) showed that organic phosphorus was the dominant form of P lost in surface waters in their study (Rivers and Dougherty, 2009).

The ability of a soil to sorb or 'fix' P is referred to as its buffering capacity – the more P a soil 'locks up' the higher is its buffering capacity. Olsen P tests record the amount of P in a soil and estimate the amount of phosphorus available to plants in a growing season. If Olsen P levels are very high (above 35 mg/kg) then additional P fertiliser is unlikely to be needed for pasture growth (Nash, 2012).

Nitrogen (N) also occurs in several forms. In regard to water-borne movement the main forms are:

- Nitrate (NO_3-),
- Nitrite (NO_2-)
- Ammonia (NH_3),
- Ammonium (NH_4), and
- Urea ($(NH_2)_2$ CO).

Ammonium or soluble nitrates may be taken up by plants or algae and incorporated into organic compounds. Urea is applied as a fertiliser because it breaks down to ammonia, which converts to ammonium in reaction with water. Through processes known as mineralisation and nitrification, organic forms of nitrogen may be broken down by fungi and microbes to produce ammonium, then nitrites and nitrates. Dissolved nitrates are readily lost in water (e.g. leaching through the soil profile), and ammonium may be lost in erosion (absorbed to soil particles).

Nitrogen may also be lost from systems via conversion to gaseous forms. Denitrification is the conversion of nitrates to oxidised forms, such as nitrous oxide (N_2O), often from saturated, anaerobic soils (Rivers & Dougherty, 2009), or in water bodies and their sediments (Greene, 2005). Volatilisation refers to the conversion of ammonium to ammonia gas (NH_3), often in high pH soils. Nitrogen is not strongly buffered by soils (Gourley et al., 2012).

4.5.3 Mobilisation

Many factors influence P loss and concentration, including management and catchment factors – e.g. travel time instream, rainfall history and intensity. A list of factors influencing P loss is provided by Davis *et al.* (1998). Factors increasing the risk of P loss include:

- Years of fertiliser application,
- Fertiliser rate,
- Soil fertility,
- Grazing pressure (stocking rate),
- Stream flow rate,
- Surface run-off vs sub-surface flow,
- Surface drainage,
- Season (wet seasons),
- Rainfall intensity, and
- Intense land use.

Factors reducing the risk of P loss include:

- Time since fertiliser application,
- In-stream travel time,
- Stream-bank stability and vegetation cover,
- Soil P retention capacity, and
- Land management – soil conservation.

Many of these factors are discussed in more detail in the following sections.

4.5.3.1 Source Influences

Nutrients may be directly available for transport or mobilised by desorption, (the release of adsorbed (onto) or absorbed (into) compounds), dissolution (dissolving), or detachment (erosion). The amount of nutrient transported by water (the load) is a function of concentration and the volume of flow.

For phosphorus, the concentration of leachate or surface water is proportional to P levels in the soil, often measured as Olsen P.

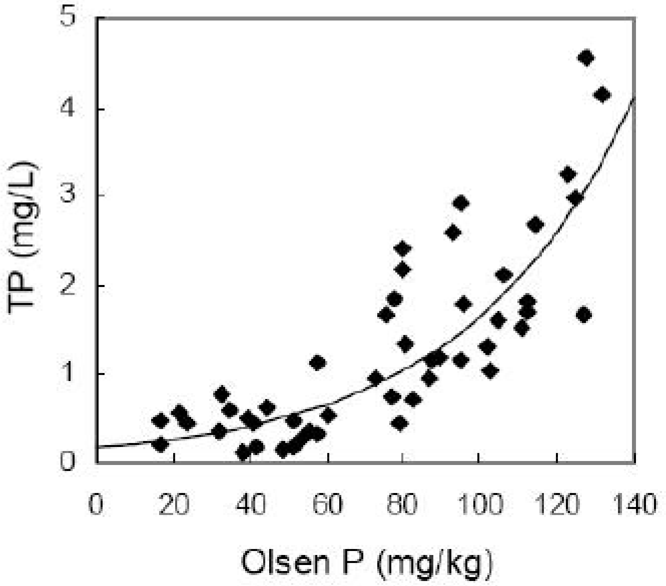


Figure 4.9. The relationship between soil Olsen P and Total P in runoff; Dougherty, 2006

Rivers and Dougherty (2009) concluded that in Australian dairy landscapes, phosphorus is predominantly lost as dissolved and colloidal forms in surface runoff, and phosphorus levels in runoff water are primarily related to increasing soil phosphorus test levels, and the proximity of fertilising events to subsequent rainfall or irrigation.

P mobilisation rates from fresh cow dung are higher than from dried dung (McDowell *et al*., 2009).

Nutrients such as nitrogen can move deep within a soil, but phosphorus is less mobile and is more likely to be concentrated in the top 10-15 mms – a feature termed soil nutrient stratification. Dairy farm pastures have been reported to have P levels in the top 10 mm five times greater than at 50-100 mm depth (Dougherty *et al*., 2006). Water in contact with top-soil can pick up more P than is likely at depth, while water moving through the soil profile loses P as it becomes attached to soil particles.

4.5.3.2 Pathways

Natural macro-pores or sub-surface drains can move water through soil quickly and reduce contact with soil particles, resulting in higher concentrations of leachate than would otherwise be the case. As a consequence, at the catchment scale, the highest P concentrations occur in overland flow, followed by macro-pores, followed by matrix flow. It is difficult to measure the volume of sub-surface water flows, hence the calculation of nutrient loads in sub-surface flows is problematic (Nash, 2013).

Thayalakumaran *et al.* (2016) used combined models (DairyMOD and HowLeaky) to explore nitrogen fluxes under different dairy farming systems, (referred to as Intensive, Moderately

Intensive, Moderately Extensive and Extensive – as described in *Table 4.6*), and across several different soil types.

Table 4.6 Attributes of four dryland dairy management systems of increasing management intensity in Moe River catchment; Thayalakumaran et al., 2016

Attributes of four dryland dairy management systems of increasing management intensity in Moe River catchment. Not that the characteristics are defined for the milking area.					
System	N fertilisation	Supplement feed	Stocking rate	Milk production	
	Kg ha^{-1} yr^{-1}	T DM cow^{-1} yr^{-1}	cows ha^{-1}	L cow^{-1} yr^{-1}	L ha^{-1} yr^{-1}
Intensive (Sys1)	300[a]	2.2	3.0	6300	18,900
Moderately intensive (Sys2)	200[b]	1.9	2.5	6000	15,200
Moderately extensive (Sys3)	100[c]	1.6	2.2	5200	11,500
Extensive (Sys4)	50[d]	1.5	1.9	4200	7,900
A – April, May, June, July, Aug, Sept, Oct, Nov; b – April, May, August, Sept, Oct, Nov; c – May, Sept, Oct; D – May, Sept					

Losses of particulate N in surface runoff were low in all situations, except for moderately draining soils that produced up to 4.2 and 15.1 kgN/ha/yr, due to large amounts of erosion. Mean annual leached N ranged from 0 to 312 kgN/ha, with a wide year-to-year variation. N leaching increased with farm management intensification. A report on the work noted that intensification with increased fertiliser, and to a lesser extent supplementary feed, led to an increase in stocking rates, which led to the increase in N leaching (Stott *et al*, 2012).

The proportion of nitrogen lost via alternative pathways was different under the various farming systems.

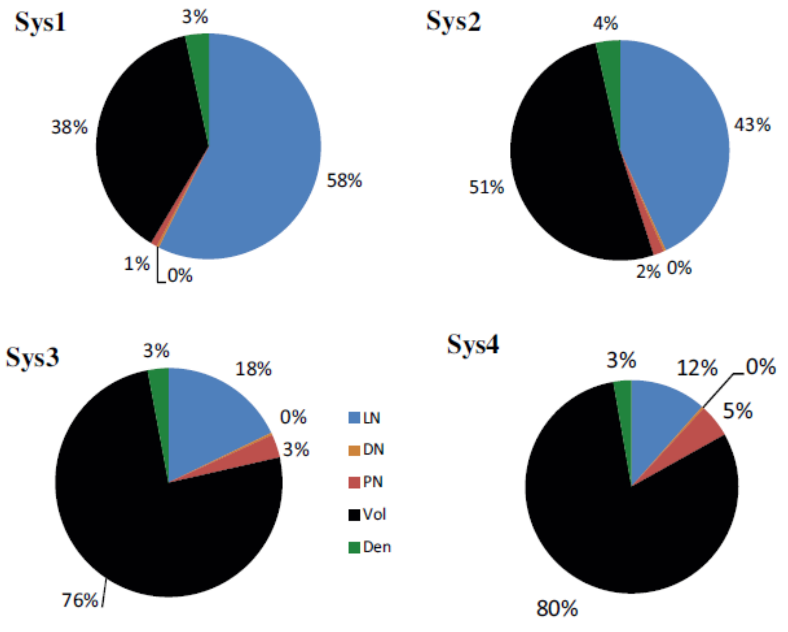


Figure 4.10 Average annual N loads portioned into leaching (LN), dissolved N in runoff (DN), particulate N in runoff (PN), volatilisation (Vol) and denitrification (Den) from Sys1, Sys2, Sys3 and Sys4; Stott et al., 2012

Similar modelling reported by Vigiak *et al.* (2013) considered five farming systems:

- S-I / Dairy Intensive (DI) – 200 kgN/ha/yr fertiliser and 1.7 tDM/cow as supplementary feed.

- S-IV / Dairy Extensive (DE) – 35 kgN/ha/yr fertiliser and 1.0 tDM/cow feed.
- S-A / Advanced Intensive Dairy (DA) – intensification was achieved by substituting applied fertiliser with recycled effluent and with supplementary feeding.
- Current dairying (C) - between intensive dairy (DI) and extensive dairy (DE).
- Beef (B) – no fertiliser applications and minimal supplementary feed.

The study concluded that advanced intensive dairying (DA) had lower total N losses per year than intensive dairy (DI), but they were still 40% higher than current dairying (C; Figure 4.11).

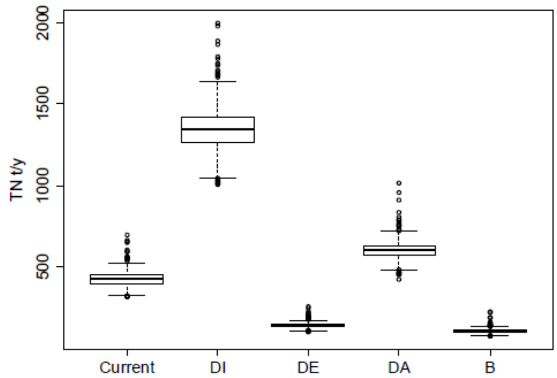


Figure 4.11 TN load (t/yr) estimated for different scenarios with uncertainty: Current = current conditions; DI = intensive dairy system; DE = extensive dairy system; DA = advanced intensive dairy system; B = beef system. Boxplot indicates median output of 500 MCS (thick line), the interquartile range (limits of box). 1.5 the interquartile range (whiskers) and simulation outside these limits (circles); Vigiak et al., 2013 (Figure 3)

It was noted that:

- Runoff was negatively correlated to deep drainage.
- N leaching was positively correlated to drainage volumes.
- N leaching was negatively correlated to N loss in runoff (Vigiak *et al*., 2013).

Phosphorus moves in dissolved, colloidal and particulate form along surface and sub-surface pathways (Sharpley *et al.*, 2013). It can cascade between areas of accumulation and tends to accumulate rapidly and flow on slowly – referred to as 'fast in – slow out'. It can also spiral between forms through biogeochemical cycling, such as mineral precipitation and dissolution, sorption and desorption, organic P mineralisation, cycling through primary producers and micro-organisms, and molecular diffusion. Once mobilised, sorption and desorption are the dominant processes.

Machar (2009) reported on several papers showing that 90% of the phosphorus exported from vegetable properties in the Hawkesbury-Nepean catchment in NSW was in particulate form – attached to soil particles lost via erosion. Twenty-four per cent of nitrogen was lost in the same manner but, depending on soil type, very high levels of nitrogen were also lost via leaching to groundwater (up to 500 kg/ha/yr of nitrogen on well-drained soils). Equivalent data has not been found for the Gippsland region.

4.5.3.3 Incidental and Landscape Risks

Large flows of water, such as from heavy rainfall events in storms, generate high levels of nutrient loss. At those times nutrient concentrations in run-off are often high, volumes of water are high, and there is often a high degree of connectivity between paddocks and waterways (Adams et al., 2014).

Different loss pathways and different ratios of dissolved and particulate nutrients may come into effect during such high flows (Adams et al., 2014). The size (intensity and duration) and frequency of rainfall events will also influence nutrient losses (McDowell et al., 2009). The concentration and form of nutrients in run-off may vary during an event (Rivers & Dougherty, 2009).

As an example, a northwest Tasmanian study showed rapid increases in total P concentrations in paddock run-off as flow rates increased after rain, peaking before flow rates did. Base-flows had the lowest P concentrations recorded (Holz, 2007). The same study showed that after grazing events, NH_4-N makes up the larger proportion of total N in run-off, but the NH_4 concentrations drop quickly and organic then N predominates. The concentration of nitrates decreased as flow increased, with the highest concentrations recorded in base-flows.

Monitoring on a West Gippsland dairy farm showed that not only did phosphorus loss peak with storm activity (total storm flow), but concentrations in surface runoff were also related to days since grazing, and days since fertilising (Nash, 2013). Storms resulted in 70% of the annual P loss, but just over half the runoff. In this study, there was little dilution effect on concentrations due to increased water flow, indicating that P sources were not run-down in the events.

Several 'functional stages of nutrient export' were identified in a Tasmanian catchment with differences in nutrient responses caused by hydrologic events: (i) a build-up of nutrients during periods with low hydrologic activity, (ii) flushing of readily available nutrient sources at the onset of the high flow period, followed by (iii) a switch from transport to supply limitation, (iv) the accessibility of new nutrient sources with increasing catchment wetness and hydrologic connectivity, and (v) high nutrient spikes occurring when new sources become available that are easily mobilised with quickly re-established hydrologic connectivity (Bende-Michl *et al*., 2013).

Studies such as these indicate the role of management in nutrient losses. Some factors are 'systemic' – a consequence of the farming landscape (the production system, topography, soils, rainfall etc.) – while others are driven by management decisions – such as the timing of fertiliser applications - resulting in 'incidental' losses. In well managed, intensive dairy farming landscapes, systemic losses are often greater than incidental losses, although incidental losses can account for 20-40% of annual nutrient loss (Rivers and Dougherty, 2009).

Broad *et al.* (2010) produced the following simple model (*Figure 4.12*) to show how management practices may influence nutrient loads derived from different land uses.

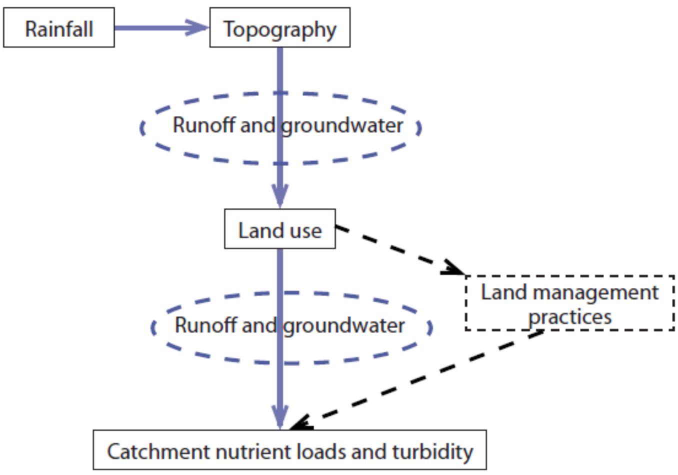


Figure 35. Simple conceptual model of the major drivers of river nutrient loads.

Figure 4.12 Simple conceptual model of the major drivers of river nutrient loads; Broad et al., 2010

The Farm Nutrient Loss Index (FNLI) considers both landscape and management features to assess the risk of nutrient loss from grazing properties in Australia (Melland *et al*., 2003).

A national assessment using the FNLI framework and geographic data on physical attributes and management practices concluded that Gippsland rates:

- High in risk for N loss in deep drainage (due to surplus water, well-drained soils, and shallow rooting pastures), and
- High in risk for P loss in run-off (due to surplus water, high effluent application rates, and soil test P results).

The N risk is due to landscape pressures; the P risk to landscape and management pressures (Melland *et al*., 2017). As management improves, systematic or landscape losses become more important than incidental losses.

4.5.3.4 Erosion

Preferential deposition occurs following erosion; the largest particles drop first. The result is that not all eroded sediment reaches a waterway, but that which does is smaller and suspended – and usually highest in phosphorus concentration (Davis *et al*., 1998).

The West Gippsland region overall is rated moderate in terms of the likelihood of gully or tunnel erosion. At a farm or sub-catchment level, the potential for erosion must be considered when assessing nutrient loss. As noted in the Macalister LWMP, a conflict can occur between reducing water flow, erosion, and nutrient losses, and maintaining natural (environmental) flow regimes (WGCMA, 2008).

4.5.4 Connectivity

In general, the greater the hydrological connectivity between a source and a receiving environment, the greater is the transport of nutrients and other water-borne pollutants.

At the farm scale, connectivity can be increased by features which speed-up the movement of water from paddocks and provide more direct access to waterways; such as sub-surface and surface drains. Features which decrease connectivity are those which slow water movement, increase infiltration in heavy soils, or interrupt flows (such as re-use dams, farm dams or, in some instances, riparian buffers).

In addition, features which slow the flow of water promote sedimentation and the accumulation of phosphorus (Sharpley *et al.*, 2013). They may be landscape features which slow the flow, or instream features where longer retention times result in increased deposition.

A number of these measures are not as straight forward as they may first appear. A feature which acts as a sink in one situation can become a source in another. A sink which is yet to fill reduces connectivity and losses of nutrients, pathogens or sediments. However, once a sink is full it no longer plays that role and may become a source of pollution.

The Latrobe River has been shortened over time by the removal of meanders, resulting in a deeper, wider river, with higher stream power (Dickson 2017, pers. comm.). In a study of the Avon and Mitchell Rivers, Hofman (2011) noted a high degree of interconnectivity between surface and groundwaters, and that the rivers have ‘gaining’ and ‘losing’ sections – which may invert depending on flow conditions.

4.5.4.1 Dams, Lakes and Wetlands

Dams, streams, lakes and wetlands can store sediments and phosphorus. P can accumulate as particulate P in sediments, through the sorption of dissolved P onto sediments, or by the incorporation of water-column P into plant or microbial biomass (Sharpley *et al.*, 2013). When viewed over time (decades or more) the storage is temporary, but can account for 10 – 80% of annual P fluxes.

Dams for P-settling and re-use on irrigated farms have been reported to save from 48% to 98% of losses. Sediment traps can also be effective, if cleaned regularly, with a 10% reduction in Total P recorded. Farm dams are less reliable in rain-fed operations, and may require trade-offs with environmental flows (McDowell *et al*., 2011). Other studies have indicated that dams and associated in-farm drainage systems may reduce phosphorus and nitrogen levels by 76% and 38% respectively (Rivers and Dougherty, 2009).

However, dams, lakes or wetlands which are full of water or are saturated with nutrients provide examples of features commonly being a sink, becoming a source. They reduce down-catchment loads while filling, but once full they no longer store additional loads. That can result in a sudden downstream increase in loads, even though nothing else has changed within the catchment. If scoured out by a breach or a flood, their stores are released into the water system.

Grayson (2006) cited work by Boon *et al*., which concluded natural freshwater and brackish wetlands in Gippsland catchments offered little potential for nutrient interception, but created and constructed wetlands held significant potential. Modelling for created wetlands on a 'typical' Gippsland farm showed potential reductions of concentrations of more than 23% for nitrogen, from 37 – 70% for phosphorus and 49 – 87% for suspended solids. Constructed on-farm wetlands were more successful in moderate rainfall zones, compared to higher and lower rainfall.

The Sale Common, Dowd Morass and Heart Morass lie near the entrance of the Latrobe River to Lake Wellington. This review has not cited any specific reference to the roles they, or major storages in the catchments, may play regarding nutrient transport to the Lake - apart from their consideration in assigning River Delivery Ratios in SedNet modelling.

4.5.4.2 Drains

Drains normally pose a risk of increased nutrient loss, but not always. Farm drains are not inert channels through which water passes; they can be sites of transformation. Dissolved P can bond with soil particles in drains, or sediments may drop out in slow flowing sections, resulting in drains reducing losses rather than enhancing them (Nash, 2013). Rivers and Dougherty (2009) reported that nutrient levels dropped along farm drains in the Peel-Harvey area of WA, possibly due to dilution, assimilation by sediment, and consumption by algae.

It is also possible that drains, especially in warmer weather, can be sites for the growth (or prolonged life) of faecal coliform bacteria (Holz, 2007). In a Tasmanian study, it was found that bacterial concentrations in surface drains increased as flow rates increased (i.e. as run-off from paddocks increased), and following grazing, with base-flow loads possibly influenced by direct deposition of dung by stock. Concentrations were also higher in warmer months when conditions better suited microbial activity.

4.5.4.3 Riparian Buffers

Grassed buffers can reduce sediment and particulate phosphorus loss in run-off by filtration, deposition and improved infiltration. Problems which can occur include; becoming clogged with sediment, saturation or over-flow, and being bypassed by non-sheet flow. They work best with dense swards, e.g. tillers – but that implies the need for grazing, which may introduce nutrients adjacent, or directly, to waterways (McDowell *et al*., 2011). Well managed pastures are comparable to some aspects of grassed buffers.

Sharpley *et al.* (2013) concluded that buffers and wetlands can effectively retain and store phosphorus, smoothing out the peaks of downstream delivery. However, in the longer term those sites can become sources of legacy P with elevated soil P levels, and exporting more nutrient annually than entered them.

Vegetated buffers have been considered as cheap and effective measures to reduce particulate nutrient loads to waterways, but their performance can be compromised at the catchment scale, and their removal efficiency reduced to less than 20%, by subsurface hydrological pathways, breakthrough surface runoff, or by pass flows (Zhu *et al.*, 2017).

Monaghan *et al*., (2007) noted that by-pass flows can be more than first impressions suggest, as micro-topography channels water from paddocks to lower points of entry to waterways (convergence) – increasing velocity and further reducing the prospect of buffering. Riparian buffers are not designed to entrap dissolved nutrients, and most phosphorus leaves dairy paddocks in dissolved form.

Zhang *et al.* (2010) modelled buffer efficiency using data from published field trials. They noted that vegetated buffers are designed to work through filtration, deposition, adsorption and infiltration, and concluded that buffer width explained 37, 60, 44 and 35% of the variance in removal efficiency for sediment, pesticides, nitrogen and phosphorus respectively. Slope and buffer composition were also important.

Model results indicated that for sediments, buffers of 20 m (up to a 10% slope), composed of trees or grasses, could remove almost all sediment from runoff. A 20 m buffer could remove 91-100% of nitrogen and 97-100% of phosphorus, with trees removing more N, presumably because of their roots extracting N from sub-surface flows. Soil type was generally not significant in their findings, apart from for phosphorus. Compaction by animals decreased buffer efficiency and sandy soils had higher retention efficiencies than silty clay (Zhang *et al.*, 2010).

Buffer characteristics (width, slope, composition and soil type), the pollutant in question, and the placement of the buffer can all affect efficiency. A shallow, uniform flow is essential to maintain high pollutant removal efficiency, but convergence is often a problem in the field – with as little as 6% of a buffer being effectively encountered by overland flow. As convergence increases, sediment trapping efficacy is reduced (Zhang *et al.*, 2010).

Studies of grassed buffers immediately downstream of a tilled potato paddock in the Tarago catchment (Hairsine, 1997) showed their sediment trapping ability to be controlled by flow velocities in the buffer, and the cumulative mass of sediment deposited compared to the remaining capacity to store more. Coarse sediment was trapped in the first few metres of the buffer as flow rates decreased. It would only exit the buffer if the ‘fan’ of sedimentation extended across the buffer. Other factors affecting buffer performance were the rate of upslope erosion, the fineness of the sediment, and the structure and density of vegetation in the strip.

A comparison of a grassed filter strip with a near-natural riparian zone indicated similar performance in trapping sediment and attached pollutants. The natural buffer was less effective at higher rates of overland flow, due to higher and less uniform flow velocities within it (Hairsine, 1997).

The Tarago buffers were ‘highly effective’ in trapping phosphorus, but grassed filter strips are less effective in this regard in weakly aggregated soils (Hairsine, 1997).

Broad *et al.* (2010) noted the major driver of sediment and nutrient delivery to surface waters at the catchment scale in Tasmania is intensive land use, in particular the most intensive land uses of cropping and dairy production. They concluded that management interventions should focus on reducing nutrient sources and transport at the landscape scale rather than solely relying on abatement in riparian zones to impact on nutrients and sediment in surface waters. Riparian rehabilitation does play a role, but its effects are not always immediate. They also concluded that greater intensification of land use is likely to result in greater surface water nutrient and sediment loads.

After reviewing Tasmanian catchment monitoring studies Broad *et al.* (2010) concluded that available data showed little detectable change in water quality (in terms of nutrient loads and turbidity) following investment in rehabilitation of the riparian zone.

However, riparian zones do provide landscape connections and cover for terrestrial wildlife and aquatic species, livestock and crop shelter, forage sources, and a source of wood. Investing in riparian zone management to minimise direct stock access to streams, and control channelized flow or runoff from roads and tracks, is critical to minimizing nutrients and sediment in streams (Broad *et al*., 2010). Buffers can also aid steam-bank stability.

Some trial work has added soil ameliorants such as alum and polyacrylamide to grassed buffers to enhance their effectiveness, and ancillary sediment traps in ephemeral flowlines (and in-field) have generated additional (5-20%) savings (McDowell *et al*., 2011).

4.5.5 Instream

In-stream processes are not in the scope of this review, but it is pertinent to note a few key points.

The same factors affecting transport within and from a farm can also be at work within streams, downstream from a contributing property. At the farm scale, contributions of nutrients to the environment may differ from the sum of contributions from components of it. Similarly, downstream contributions from a farm may differ to those exported from the property.

Nutrient cycling, deposition or sedimentation (e.g. in lakes or dams, or on floodplains), adsorption, dispersion and consumption (e.g. by bacteria or algae) may all occur. As an example of adsorption, dissolved phosphorus may attach to sediments assuming a particulate form, which is not readily available to aquatic algae (Nash, 2013). Changes in form can produce changes in environmental impact.

Contaminants may be caught in lakes, dams or wetlands (Rivers and Dougherty, 2009) – and additional sediments may be introduced by stream-bank erosion. If farms are managed to reduce the time that water stays in paddocks, via drains or waterway modification, the water they export may be of greater velocity, with larger volumes leaving in a short time-frame – which may enhance the downstream erosion of streambanks.

Faster flows also translate into reduced 'residence times' for nutrients in any waterbody, and less time for consumption (e.g. algal growth) to occur. It has been estimated that in preferred conditions, phytoplankton populations may assimilate roughly fifteen times their initial phosphorus and nitrogen content, within five days (Wilkinson *et al*., 2008). The fate of the algae will influence the ultimate fate of the consumed nutrients.

In many streams and rivers, sediment from the erosion of past decades is stored in stream channels. This sediment becomes mobilized during high flow events, and may be a source of turbidity for decades (Trimble 1999). Agricultural practices that reduce peak runoff rates may also reduce the problems related to the remobilization of sediments stored instream (Czapar *et al*., 2006).

Additionally, it should be recognized that reducing sediment concentrations in streams may allow for greater light penetration into the water column, which may allow for more algae growth where nutrient concentrations are sufficiently high. This possibility should not discourage conservation efforts, but should inform expectations and strategies of conservation programs (Czapar *et al*., 2006).

4.6 Sources

Water-borne contaminants from farms (nutrients, sediments and pathogens), can be described as coming from paddocks, applied fertilisers or recycled nutrients, 'hot spots' (such as tracks or creek crossings), waterways or drainage lines and, on livestock properties, brought in feed. All of those areas are potential sources of nutrients. Sediment risks are mainly from paddocks, hot spots and drainage lines. Pathogens may come from paddocks, recycled nutrients (effluent), and hot spots (such as effluent ponds).

Sharpley *et al.* (2013) point to the 'decoupling' of nutrient cycles through the mass import of nutrients via fertilisers. The imports overpower the ability of biological systems to mediate nutrient cycles resulting in nutrient surpluses, increased dominance of inorganic forms of nutrient, and shifts in the ratios of N, P and C delivered to waterways. As an example of a consequence, increased export of labile carbon to waterway sediments (e.g. from plant residue, effluent or septic tanks), results in increased microbial respiration, which increase oxygen depletion, resulting in the dissolution of iron oxides which release sorbed P.

4.6.1 Production Systems

Different production systems, or land uses, tend to have different nutrient, sediment and pathogen loss rates. Whole-of-farm nutrient budgets provide an early indication of the potential for loss from a property. This is not to suggest that all of a nutrient surplus will be lost to the environment – actual losses are likely to be less, e.g. as soil stores are built up - but it indicates the scope for loss to occur. See the Management Practices, Nutrient Status section of this report for more detail.

Studies of nutrient and sediments in runoff from different types of land use provide a guide to their systematic and 'average' management losses. In a review of Australian land use run-off studies Bartley *et al.* (2010) concluded that, after considering all the studies:

- The land uses with the highest median TSS concentrations were mining (~50,000 mg/l), horticulture (~3000 mg/l), cotton (~600 mg/l), grazing on native pastures (~300 mg/l), and bananas (~200 mg/l).
- The highest median TN concentrations are from horticulture (~32,000 ug/l), cotton (~6,500 ug/l), bananas (~2,700 ug/l), grazing on modified pastures, including dairy (~2,200 ug/l) and sugar (~1,700 ug/l).
- For TP it is forestry (~5,800 ug/l), horticulture (~1,500 ug/l), bananas (~1,400 ug/l), grazing on modified pastures (~400 ug/l) and grazing on native pastures (~300 ug/l).

Data relevant to this review is presented below (*Table 4.7* - *Table 4.11*) from all studies and from those where the land uses monitored had headwaters where at least 90% of the land use was uniform. It should be noted that the data comes from different commodities across Australia, and changing technologies within industries may mean some older data is now less relevant. The differences in some mean and median rates highlight the variability of results.

Table 4.7 Concentrations from all studies examined; Bartley et al, 2010

Land use		TSS (mg/L)		TN (ug/L)		TP (ug/L)	
		EMC	DWC	EMC	DWC	EMC	DWC
Forests	Median	26	9	436	362	70	30
	Mean	77	9	782	492	222	44
Grazing Modified	Median	188		2,235		355	
	Mean	256		6,763		563	
Horticulture	Median	3,104		32,181		1,451	
	Mean	5,945		31,539		3,233	

Table 4.8 Concentrations from studies with > 90% catchment uniformity; Bartley et al, 2010

Land use	EMC only	TSS (mg/L)	TN (ug/L)	TP (ug/L)
Forests	Median	10	227	19
	Mean	27	385	103
Grazing Modified	Median	315	2,417	429
	Mean	322	3,044	726
Horticulture	Median	3,774	41,497	2,294
	Mean	7,750	40,652	4,195

Table 4.9 Summary of TSS, TN & TP data for major land uses; Bartley et al., 2010 (Table 5)

		TSS (mg/l)				TN (ug/l)				TP (ug/l)			
Commodity	Statistic	No.	Event (EMC)	No.	Baseflow (DWC)	No.	Event (EMC)	No.	Baseflow (DWC)	No.	Event (EMC)	No.	Baseflov (DWC)
Forest	10th Percentile	59	5	54	5	53	179	21	1	68	16	40	10
	Median		26		9		436		362		70		30
	Mean		77		9		782		492		222		44
	90th Percentile		228		13		1533		950		585		112
Forestry	10th Percentile	11	5	0		n<3		15	203	6	76	15	6
	Median		33						445		5800		14
	Mean		50						699		6175		35
	90th Percentile		56						1162		12650		100
Grazing modified pasture (Includes Dairy)	10th Percentile	14	23	n<3		54	1400	n<3		48	100	n<3	
	Median		188				2235				355		
	Mean		256				6763				563		
	90th Percentile		650				18880				1295		
Horticulture	10th Percentile	17	8	0		17	585	0		17	23	0	
	Median		3104				32181				1451		
	Mean		5945				31539				3233		
	90th Percentile		11719				61414				8315		
Number (No.) represents a data point from a single geographic site. In some cases this represents individual event data, in other cases it represents annual or multi event averages. Data are only presented when n>or=3													

Table 4.10 Summary of data for DIN, DON, DIP and DOP for major land uses, for event (EMC) conditions only; Bartley et al., 2010 (Table 6)

Commodity	Statistic	No	DIN	No	DON	No	DIP	No	DOP
Forest	10th Percentile	49	27	35	69	42	3	35	4
	Median		96		119		7		9
	Mean		210		131		13		12
	90th Percentile		531		222		29		17
Forestry	10th Percentile	0		0		0		0	
	Median								
	Mean								
	90th Percentile								
Grazing modified pasture (Includes Dairy)	10th Percentile	14	73	8	85	12	3	6	14
	Median		188		118		13		17
	Mean		2209		299		15		16
	90th Percentile		6530		624		228		18
Horticulture	10th Percentile	7	112	7	185	0		3	1
	Median		369		212				2
	Mean		780		986				3

	90th Percentile		1880		2372				4
Number (No.) represents a data point from a single geographic site. In some cases this represents individual event data, in other cases it represents annual or multi event averages. Data are only presented when No>or=3.									

Table 4.11 Summary of TSS, TN & TP data for major land uses, where land use upstream is >90% single land use; Bartley et al., 2010 (Table 7)

Commodity	Statistic	No	TSS (mg/l)	No	TN (ug/l)	No	TP (ug/l)
Forest	10th Percentile	17	3	15	85	16	8
	Median		10		227		19
	Mean		27		385		103
	90th Percentile		83		527		379
Forestry	10th Percentile	4	2	0		0	
	Median		9				
	Mean		67				
	90th Percentile		177				
Grazing modified pasture (Includes Dairy)	10th Percentile	9	11	9	1652	17	174
	Median		689		2417		429
	Mean		1571		3044		726
	90th Percentile		4825		4920		2174
Horticulture	10th Percentile	13	495	13	20272	13	643
	Median		3774		41497		2294
	Mean		7750		40652		4195
	90th Percentile		12440		65345		8605
Number (No.) represents a data point from a single geographic site. In some cases this represents individual event data, in other cases it represents annual or multi event averages. Data are only presented when n>or=3							

The data, and that from other sources (*Table 4.12* - *Table 4.14*), show the general relativity of nutrient loss from different production systems, and the high variability within each.

Table 4.12 Event mean concentrations (EMC) and dry weather conditions (DWC) for the Duck Catchment and regionally specific changes for the mid and lower regions (mg/L); Broad et al., 2010 (Table 11)

	Upper		Mid		Lower	
	DWC	EMC	DWC	EMC	DWC	EMC
Grazing modified pastures	0.012	0.12	0.05	0.9	0.06	0.09
Grazing natural vegetation	0.007	0.015				
Irrigated cropping	0.6	3.00				
Dairy pastures	0.02	0.18	0.08	1.5	0.08	5.00
Mining	0.11	0.28				
Nature conservation	0.005	0.01				
Plantation forestry	0.008	0.06				
Production forestry	0.008	0.05				
Residential	0.07	0.28				
Roads and powerlines	0.007	0.015				

Table 4.13 Elicited prior nutrient generation rates used in the Bayesian model. Shown are limits used in the uniform priors for TP1 M1 ~Unif(M1,Mμ) and TN. L1 ~Unif (L1,Lμ); Broad et al., 2010 (Table 2)

	TP (kg/ha/yr)		TN (kg/ha/yr)	
Land use	M_L	M_U	L_L	L_U
Cropping	0.2	18.6	4	34.5
Dairy pastures	0.2	11.9	3	30
Forest	0.001	0.8	0.9	13
Grazing modified pastures	0.2	9	0.6	25
Marsh wetland	0.001	0.2	0.5	6
Minimal use	0.001	0.2	0.2	6
Native grassland	0.002	0.4	0.6	5.6
Plantations	0.001	0,8	0.9	13
Production forestry	0.001	0.8	0.5	13
Urban and industrial	0.1	6.2	1	38.5
Waterways	0.001	0.2	0	3

Table 4.14 Non dairy sector annual P loss rates; Rivers et al., 2012 (Table 4)

Model land use	P output kg ha^{-1}
Native vegetation	0.04
Dairy	Model Driven
Grazing	7.84
Cropping	0.3
Horticulture	11.13
Urban	41.88

A report on trial work in a mixed land use catchment in the Mount Lofty Ranges to generate data for a catchment model (Source Catchments - WaterCAST) reported current and proposed figures for Event Mean Concentrations (EMC - storm flows) and Dry Weather Concentrations (DWC - base-flows), as illustrated below (*Table 4.15*; Fleming and Cox, 2013).

Table 4.15 Current and proposed EMC values of total N, total P and Total Suspended Solids for Source Catchment Modelling in the Mount Lofty Ranges; Fleming and Cox, 2013 (Table 2)

Land use	**TN**		**TP**		**TSS**	
	EMC	DWC	EMC	DWC	EMC	**DWC**
	mg/L					
Conservation area	1.8	0.6	0.18	0.05	43	**10**
Managed forest	2.1	1.0	0.16	0.11	66	**23**
Plantations	2.1	1.0	0.16	0.11	66	**23**
Grazing	2.1	0.8	0.24	0.23	184	**12**
Intensive grazing (existing)	2.8	2.2	0.60	0.50	300	**10**

Intensive grazing (new)	2.3	1.8	0.30	0.25	150	**10**
Broadscale agriculture	1.6	0.7	0.13	0.04	131	**10**
Broadscale annual horticulture	5.3	3.4	0.93	0.34	308	**21**
Broadscale perennial horticulture	1.6	1.1	0.13	0.10	146	**12**
Rural Residential	1.6	0.7	0.13	0.04	131	**10**
Dense Urban	1.8	1.5	0.10	0.08	61	**14**
Suburban	1.3	0.8	0.08	0.09	27	**23**
Utilities	1.3	1.3	0.12	0.07	40	**12**
Water Bodies	0	0	0	0	0	**0**
Wetlands	**0**	**0**	**0**	**0**	**0**	**0**

Nash (2013) reported that dairy soil water can be more than 1.0mgP/L, with 0.05 mgP/L considered poor water.

Table 4.16 Nutrient export rates from Currency Creek; Davis et al. (1998)

Land use	N (kg/ha)	P (kg/ha)
Market garden*	200	15.3
Dairy (intensive)*	5.8	6.4
Dairy (extensive)	4.1	1.9-2.5**
Semi-improved pasture / hobby	7.0	0.8
Unimproved	2.4***	0.3****
*Tributary, Currency Ck		
**Camden data, few runoff events (range depended on farm area sampled)		
***Derived from Camden data		
****Published data for the Nepean-Hawkesbury (Cullenn 1991)		

As demonstrated in the tables above, annual horticultural production can have very high nutrient export rates. Most of the P loss from annual horticulture is in particulate form, unless there is a history of high fertiliser application (*Table 4.16*; Davis *et al*., 1998).

In a review of Tasmanian data, Broad *et al*., (2010) noted that data from predominately cropping catchments was a gap in available information, despite a significant vegetable cropping industry and soil erosion rating as a major management issue. From monitoring data and modelling they concluded that the more intense the land use in terms of nutrient inputs, the greater the nutrient enrichment in waterways – implying that greater intensification of land use is likely to result in greater surface water nutrient loads (Broad *et al*., 2010).

P loss rates reported for horticulture range from 2.7 to 20 kg P/ha/yr and 11 to 200 kg N/ha/yr (Roberts, 2017). Lam *et al.* (2016) noted that, of all Australian agricultural systems, horticultural crops pose one of the highest risks in terms of N fertiliser losses as N_2O emissions and via other pathways.

4.6.2 Paddocks

Intensive plant production requires nitrogen and phosphorus, and the fertility of soils is a factor in nutrient losses. Soils, especially the top 10 mm, can become saturated with P (Nash, 2013), and P losses are related to soil P levels. Above optimum levels of soil P are an unnecessary source of P loss and a waste of money (Monaghan, 2007). Loss rates are influenced by the nature of rainfall or irrigation (e.g. the amount and duration of application), soil infiltration characteristics and drainage capacity, and run-off or drainage aspects (McDowell, 2009).

The nature, and varied influences, of factors like those listed above are demonstrated in the following examples.

Soils with high P levels (well above that required for healthy pastures), will release P over time, even without additional fertiliser applications. In addition, Nash (2013) notes that in the absence of fertiliser, P would still be added to the soil surface layer from sources such as live and decaying vegetation, and dung; meaning it may take many years before concentrations in overland flow decline measurably.

Soil carbon can influence nutrient losses, but the processes are not always clear. Organic matter in the soil can interfere with the processes that fix phosphorus to soil particles (Nash, 2013), meaning that the buffering capacity of a soil can be restricted and that soluble P remains available for plant uptake, or export. However, soil organic matter in conjunction with iron and aluminium can increase phosphorus fixation, through what is termed 'metal bridging'. Organic carbon can also influence a range of other factors, from soil structure and pH to microbial activity, which can in turn affect the availability of phosphorus (Nash, 2012). Denitrification occurs in soils with high levels of dissolved organic carbon, and low redox potential. (Latzke, 1998).

Sandy soils used for horticulture in WA show high concentrations of P (38 mg P/L) in shallow groundwater - except where high P-fixing soils or low fertiliser rates exist. There are low concentrations in deep ground-waters due to P fixing by the soil. Very high concentrations of NO_3-N (nitrate nitrogen – the amount of nitrogen in the nitrate ion) were found in shallow groundwater (>10mg N/L), but concentrations dropped rapidly due to dilution (Latzke, 1998).

The variability in paddock sources, and the importance of environmental factors like soil type, is highlighted by two horticultural studies from NSW. In one study, an annual horticultural property generated annual losses in surface runoff of 19 tonne/ha suspended sediments, 11 kg P/ha and 127 kg N/ha. Losses were equivalent to 1.25 mm of soil per year. Over 90% of the phosphorus was transported in particulate form, as a result of surface erosion (Hollger *et al*., 1998). Lettuce was the main crop, along with spinach, capsicum, cabbage and cucumber. The poorly drained soils were formed into semi-permanent raised beds, with furrows averaging a gradient of 3%. A low-gradient drain acted as a sediment trap and was periodically excavated, with the soil returned to paddocks. A similar NSW study recorded N losses of only 16 kgN/ha/yr (compared with the 127 kg reported above), but noted that extremely high levels of nitrate leaching occurred which would have reduced the losses in surface runoff (Machar, 2009).

On livestock properties, especially intensively grazed paddocks on dairy farms, stock also influence paddock losses. High stocking rates affect the amount and distribution of dung and urine, treading and defoliation of pastures (which releases nutrients) (McDowell *et al.*, 2009), and the pugging or compaction of wet soils (McDowell *et al*., 2011). The spatial and temporal spread of cows affects nutrient accumulation and losses (Aarons, 2012). Controlling stock movements and stocking rates is one way to control the volume and location of dung, nutrient and pathogen deposits, and losses from treading, defoliation and pugging.

In dairy paddocks, most N leaching in winter is from urine patches; and the farm scale loss is greater if the losses are generated near drainage lines. N leaching from beef cattle is twice that from sheep due to urine being excreted in fewer patches at higher concentrations, affecting plant recovery and promoting leaching (Monaghan *et al*., 2007).

Erosion and the loss of sediments and particulate nutrients is rarely a problem on well grassed dairy pastures, but it is a risk on horticultural properties during times when soils are bare; e.g. during bed preparation, planting and early growth, and immediately after harvest (Vegetables WA, 2014). Factors such as slope, rainfall and soil type, will affect the degree of risk, along with management practices. Raised beds used in annual horticulture can transmit phosphorus through the surface soil into furrows, and thence into drains (Davis *et al.*, 1998).

A review of nitrate leaching in temperate agroecosystems (Di *et al.*, 2002) concluded that the potential for nitrate leaching typically ranged from forestry (least), through grazed pastures, to highest in market gardens (annual horticulture). Matching nitrogen supplies to plant needs was one of the management responses proposed to reduce risks of nitrate leaching.

A recent review of horticulture best management practice literature relevant to the Gippsland region concluded that horticulture appeared to have significant potential for P loss. Runoff losses are likely in response to the winter rainfall excess, and from large easterly weather events (Roberts, 2017).

4.6.3 Applied Nutrients

Fertilisers are the most common form of applied nutrients, but nutrient rich effluent may also be spread on dairy farms. Whenever fertiliser or effluent is applied to soils that are wet at the surface, diffuse nutrient-rich run-off or leaching can occur. Mobilisation and transport readily occurs in soils with low buffering capacity and those with high leaching rates (Davis *et al*., 1998).

However, with good management, direct leaching of N from fertiliser is generally low; except in late autumn/winter, when losses may be higher. P losses from fertilisers are usually less than 10% of the total P lost from dairy pastures under best management practice, but can account for the majority of P losses from a farm under poor management. As examples from studies, up to 6% of P applied as superphosphate in winter was lost in surface flow or drainage (equating to 66% of plot loss), and in another case soluble P fertiliser applied a few days prior to flood irrigation accounted for a large proportion of the P lost (Monaghan *et al*., 2007).

Monaghan *et al*., (2007) reported that superphosphate is more soluble than serpentine super, which is more soluble than reactive phosphate rock. In general terms, the more soluble a fertiliser, the greater is the risk of nutrient loss – but soil type, moisture levels and hydrology can influence that and the pathways taken. Nash *et al*., (2004) reported studies in the MID that showed higher concentrations of total dissolved P in run-off following rainfall when diammonium phosphate (DAP) had been applied, compared to single superphosphate (SSP). Laboratory experiments had previously shown P to be more quickly mobilised from DAP than SSP. Yet, following irrigation, SSP produced higher concentrations in surface run-off than did DAP – a result thought to arise due to increased infiltration of P from DAP in the rapidly infiltrating water at the wetting front of irrigation-induced overland flow.

Table 4.17 Fertilised Solubility Table; GrowCom Water for Profit (Table 2)

Product	Solubility	Product	Solubility
	Kg/100 L @ 20°C		Kg/100 L @ 20°C
Ammonium nitrate	192	Calcium nitrate	60
Ammonium sulphate	75	Magnesium sulphate	71
Mono-ammonium phosphate MAP	37	Soluble boron	9.5
Mono-potassium phosphate MKP	12	Zinc sulphate	44
Potassium chloride	34	Liquifert N (Urea)	25
Potassium nitrate	8	Liquifert P (Tech MAP)	20
Potassium sulphate	10	Liquifert K KCL)	20
Urea		45 (water temperature 5°C)	

Note: the solubility of fertiliser is dependent on the temperature of the water in the fertigation tank. Fertiliser is less soluble at lower water temperatures and more soluble at higher water temperatures.

Applied effluent, which would also contain pathogens, is often in liquid form via an irrigator; so extra care is needed to minimise risks of run-off or leaching. Some horticultural production uses fertigation techniques – the combined irrigation of water and soluble fertilisers.

Table 4.18 Nitrogenous fertiliser use in East and West Gippsland NRM regions; Ladson, 2012 ABS data (Table 5)

		2007-2008			2009-10		
Fertiliser	%N	Area (ha)	Fertiliser (tonnes)	Nitrogen (tonnes)	Area (ha)	Fertiliser (tonnes)	Nitrogen (tonnes)
Urea	45	122,600	25,700	11,565	125,621	30,454	13,704
Ammonium sulphate	21	1,100	200	42	109	62	13
Urea ammonium nitrate	33	5,600	600	198	2,033	130	43
Potassium nitrate	13	9,700	1,600	208	2,674	158	21
Ammonium phosphate	10	24,100	4,900	490	25,072	4,398	440
All other manufactured fertiliser	10	107,200	40,100	4,010	104,283	31,109	3,111
Animal manure	1	14,800	41,100	411	9,720	31,234	312
Total		285,100	114,200	16,924	269,511	97,545	17,644

Ladson (2012; *Table 4.18*) calculated that around 17,000 tonnes of nitrogen was applied annually as fertiliser in the East and West Gippsland regions - 8.5 times the annual load to the lakes. Urea was the most common form, with 3-9% lost in runoff and drainage. It was noted that it is not necessarily the fertiliser that is being lost directly; rather the application of fertiliser allows more grass growth, increased stocking rates, increased production of dung and urine and increased organic matter in the soil.

A 3% loss equates to 540 tN/yr; 25% of the annual load to the lakes. Other investigations concluded that irrigation as a whole contributes 7% of the total N load. A survey in 2002 revealed an average annual application of 47-56 kgN/ha/yr in irrigated dairy in the Macalister Irrigation District (Ladson, 2012).

A review across twelve farms from a Fert$mart program in Corner Inlet concluded that better matching fertiliser applications to need could save an average 40% of fertiliser costs, reduce P applications by 50% and increase N applications by 12% (Turral *et al*., 2017).

4.6.4 Hot Spots

Sites with very high nutrient levels, high run-off, and/or high erosivity can readily generate high nutrient losses. They include things like tracks and creek crossings, hay or silage stores, fertiliser bins, feedpads, and dairy sheds and effluent ponds, or any relatively small areas onto which effluent is regularly disposed, regardless of soil conditions (McDowell et al., 2009 and Nash, 2013). High concentrations of stock are a common source of high nutrient levels; e.g. dairy sheds, stock yards, holding yards, waters, feedpads or stand-off areas (Aarons, 2012). In most cases the likelihood of loss can be contained by sound management.

A package of good infrastructure and management is needed for optimal dairy effluent management, including capture (e.g. from sheds, yards and feedpads), treatment/storage, and disposal/recycling. Advanced pond systems can reduce the concentration of faecal bacteria in effluent ponds, but not their nitrogen or phosphorus levels (Monaghan *et al*., 2007). Irrigating treated effluent requires attention to the nutrient status of soils and their capacity to take additional water. As with any irrigation the timing, amount and rate of application – i.e. ‘when, how much, and how long?’ - should match soil characteristics and not exceed infiltration rates or soil holding capacity.

Dairy cows excrete large numbers of pathogens, pathogens from dairy sources are found in surface waters, and pathogens of the general type found in dairy excretions do impact upon public health. Bacteria like *Campylobacter* and parasitic protozoa such as *Giardia and Cryptosporidium*, are examples. As a generalisation, if water moves off a dairy farm, then pathogens are likely to as well. (Day, 2010).

However, those same pathogens may easily come from numerous other sources (including septic tanks), and via pathways other than via water. The uncertainty that exists makes it difficult to ever prove, or disprove, any claimed links between dairy farms and individual health issues. A 'multi-barrier' risk management approach is advocated for public health security, with measures adopted in various situations and at various scales, e.g. minimising losses on-farm, with-holding periods following effluent irrigation, and treatment prior to water use off-farm (Day, 2010).

4.6.5 Drainage

Natural and constructed drainage is a source and conduit of contaminants from farms. Erosion of paddocks (e.g. annual horticulture), of tracks, and of surface drains or natural drainage lines, all contribute sediments and particulate nutrients to waterways. As noted by Nash (2013) 'sediments detached (eroded) from gullies and channels clearly contribute to phosphorus exports from many catchments'. Gullies and stream banks can be major sources of sediments, and saturated soils (especially in low-lying areas near streams), are potential sources of nutrient rich run-off (Davis *et al*., 1998). The control of erosion and management of riparian areas can be important in reducing whole-of-property sediment and nutrient losses.

Dissolved nutrients are also affected and channelled by natural and constructed drainage, as discussed in this paper; Transport, Connectivity - Drains.

A review of the Macalister LWMP reported that outfalls from drains had reduced, and salinity increased, due to improved irrigation efficiency and more tailwater reuse. That decrease, and the associated increase in the use of centre-pivot irrigation, was considered to have reduced exports of nutrients from the District (Turral *et al*., 2017)

4.6.6 Feed

Feed is a substantial import of nutrients on many dairy farms, with supplementary feeding being a driver of increased milk production. In a study of 41 farms across Australia, imported feed, as grain by-products, hay and silage, contributed 40% of total N imports - but there was wide variability ranging from 4 to 79%. The largest source of P was generally imported feed, with a median contribution of 47% (range 4–98%) (Gourley *et al*., 2012).

Although imported feeds can be a big contributor of nutrients to a farm, they are not generally associated with being a direct source of nutrient loss – rather it is the efficiency of conversion to produce by stock and the management of effluent that matter. The exceptions are on-farm stores of feed, especially silage, which could become sources of direct loss if poorly located or managed.

4.6.7 Critical Source Areas

The combination of two factors can govern how much nutrient or sediment loss occurs from a farm. They are the presence of a large source and its degree of connectivity to a waterway. A large source of nutrients that lacks connection to water will pose little immediate threat to waterway pollution. Areas which have high source and high transport potential are termed Critical Source Areas (McDowell *et al*., 2009; *Figure 4.13*). They may only occupy a minor area of a farm, but be responsible for a major proportion of losses (McDowell, 2011).

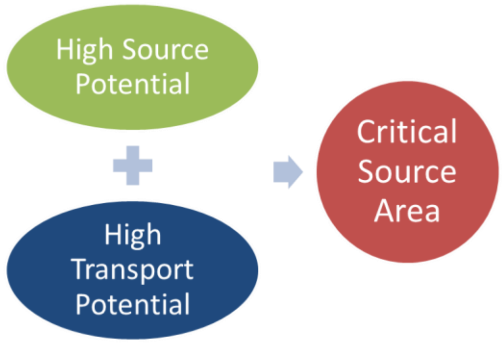


Figure 4.13 Critical source areas

The concept of Critical Source Areas applies at all scales but from a management perspective it can be very important at a farm, or within that at a 'management unit', scale. It prompts consideration of how water flows across and through a property or management unit (land with similar management requirements) to a watercourse, in conjunction with the identification of probable high source areas. As water moves across farm boundaries it might be necessary for property managers to work together in identifying Critical Source Areas and finding management solutions to contain the risk of nutrient loss. The Farm Nutrient Loss Index (FNLI), and even the Revised Universal Soil Loss Equation, can help property managers in this regard.

Eroding gullies or streambanks and saturated soils in low areas with good connectivity to a river are examples of potential Critical Source Areas.

Phosphorus can accumulate at various points along a transport route, such as in soil, in downslope areas, in waterway sediments, and in biomass – and 'cascade' between them. Remobilisation or recycling of phosphorus from such areas results in the accumulation points becoming sources of nutrient; as sorbed P is released to solution from saturated soils. This 'legacy P' can obscure or over-ride reductions in P generation through changes in land management. Phosphorus may also 'spiral' between water, sediment and biota (Sharpley *et al.*, 2013).

4.7 Management Practices

4.7.1 Introduction

The dairy and horticulture industries have both been active, singularly or with partners, in developing tools, guides and frameworks to help producers understand and adopt sustainable management practices. They, and the cotton and sugar industries, are currently collaborating in a More Profit from Nitrogen program. Other examples include:

- 'Best practices'
  - DairySAT
  - Guidelines for Environmental Assurance in Australian Horticulture
- Soil and nutrient management
  - Dairy Soils & Fertiliser Manual
  - Effluent & Manure Management Database for the Australian Dairy Industry
  - Farm Nutrient Loss Index
  - Healthy Soils for Sustainable Vegetable Farms – Ute Guide
  - Soil Wealth
  - EnviroVeg Manual – updated version due in early 2018
  - Irrigation Essentials

Producers in those industries are important resource managers in the Lake Wellington catchments. The industry-wide relevance of the guidelines and the frameworks they present makes them useful to programs aiming to work with producers. The structure of this section borrows from that of the Dairy Soils and Fertiliser Manual. It, and others of those from the dairy industry, can be accessed at the Dairying for Tomorrow website: www.dairyingfortomorrow.com.au – while the Horticulture for Tomorrow website offers similar materials for that industry: http://horticulturefortomorrow.com.au/

Management practices are reviewed below under groupings of:

- Plan – understand risks and opportunities, and plan integrated (whole-of-system) solutions,
- Optimise production – convert as many inputs as possible into produce, and
- Minimise losses – contain risks from excess inputs as economically as possible.

Roberts *et al.* (2012) used expert opinion to build on previous assessments of the likely practices, adoption levels, benefits and costs involved in reducing phosphorus loads to the Gippsland Lakes. Management practices considered included tailwater re-use systems, irrigation pressurisation and automation, effluent management, irrigation farm plans and riparian management. They concluded that achieving a 40% reduction in loads would not be cost-effective, but a 20% reduction could be cost effective, requiring only modest levels of change in agriculture.

A review of actions from the Macalister LWMP that improve irrigation efficiency, increase the re-use of irrigation drainage water, and reduce runoff from irrigated land concluded these practices would also decrease phosphorous loads to waterways and ultimately to Lake Wellington. However, the Review found that it was not possible to quantify the reduction in TP loads achieved by the Plan or to attribute reductions to particular actions at particular locations. Problems encountered were the climate driven variability of flows and loads to Lake Wellington, and the impracticability of establishing a monitoring network to measure the effects of individual works and measures (DELWP, 2017).

The Macalister LWMP (DELWP, 2017) review proposed that the types of actions that should be considered include:

- Increasing the reuse of irrigation runoff on farm.
- Continuing to promote on-farm irrigation modernisation on farms serviced by delivery systems that are being modernised.
- Promoting improved dairy shed effluent management.
- Promoting improved fertiliser management.

Experience over the last two decades suggests the approaches which are most effective are:

- Reducing runoff from irrigated land.
- Diverting runoff from irrigation land.
- Improving dairy shed effluent management.
- Improving fertiliser management, particularly in high rainfall areas.
- Reducing erosion of the bed and banks of waterways.
- Excluding stock from waterways (DELWP, 2017).

4.7.2 Plan

4.7.2.1 Nutrient Status

Understanding the nutrient budget of an enterprise, and the nutrient requirements of soils and crops or pastures, provides solid information on which to begin planning for sustainable nutrient management.

Whole property nutrient budgets indicate whether a nutrient imbalance (and the potential for nutrient losses to the environment) exists or not. Nutrient budgets can also provide some guidance on where the major imbalances occur and, with reference to industry norms, the best opportunities for improved efficiency in the conversion of nutrients to produce. The ability of nutrient budgets to provide information on the efficiency of nutrient use and examine potential environmental impacts makes them a valuable tool (Monaghan *et al*., 2007). In some countries, a nutrient budget is a mandatory requirement in order to apply fertilisers.

Neville *et al.* developed nutrient budgets for properties across a range of commodities in south west WA, as shown below. Their observations included:

- Input:Output ratios vary significantly within land uses, possibly due to management practices and environmental differences.
- The P Input:Output ratio provides some indication of production P loss, but estimated levels of P loss to the environment are also strongly correlated with farm P inputs.
- The selection and prioritisation of management practices needs to consider how each management action addresses the issue of 'nutrient balance' (Neville *et al*.).

Table 4.19 P Input:output ratios and production P losses. (Within columns, values with different letters are significantly different and increase alphabetically, P < 0.005); Neville et al.

		IO Ratio			Production P loss (kg ha^{-1})		
Land use	Count	Median	Range	Group	Median	Range	Group
Annual horticulture	2	15.0	10.5	e	26.5	34.2	ab
Beef feedlot	3	2.3	1.0	abc	300.2	1167.2	c
Cattle for beef	31	6.0	75.0	d	9.5	32.8	a
Cattle for diary	18	3.8	11.2	cd	17.8	88.6	a
Horses	7	7.4	36.0	e	12.9	392.2	ab
Mixed grazing	16	4.7	12.6	cd	6.3	19.4	a
Perennial horticulture	7	n/a	11.1	e	0.3	165.9	a
Piggery	5	3.2	11.5	bcd	73.8	726.8	b
Poultry eggs	2	3.3	4.8	ab	34.3	74.4	ab
Poultry meat	9	0.9	0.2	a	-35.5	464.9	a
Sheep feedlot	2	1.0	0.03	a	34.1	8.4	ab
Viticulture	6	17.4	90.5	e	25.5	47.1	ab

Nash (2013) reported data showing dairy farms with an annual P surplus of 34 kg/ha/yr; compared to sheep ranging from 3 to 20 kg P/ha/yr, and beef 13 kg P/ha/yr. A New Zealand study reported dairy farm deficits of 1-10 kg P/ha/yr, and 0.1-2.2 kg P/ha/yr for sheep/beef (McDowell *et al*., 2011).

In a nation-wide survey of 84 Australian dairy farms, Gourley *et al.* (2012) reported a median P surplus of 26 kg P/ha/yr, and a median N surplus of 193 kg/ha/yr. Annual horticulture can also exhibit an imbalance in nutrient applications, with surpluses reported for brassicas (67 kg P/ha/yr and 33 kg N/ha/yr) and leafy vegetables (19 kg P/ha/yr and 15 kg N/ha/yr) (Roberts, 2017).

In the Gourley *et al.* (2012) study of whole-farm nutrient balances, Inputs included feed, fertiliser and nitrogen fixation, while Outputs included milk, animals and crops. There was considerable variation between enterprises, but indicative overall values are:

- For N, imports were fertiliser 43%, feeds 40%, and legumes 16%. Milk was 82% of exports.
- For P, imports were feed 47% and inorganic fertiliser 46%. Milk was 74% of exports.
- Median N surplus was 193 kgN/ha, with median efficiency of 25%.
- Median P surplus was 26 kgP/ha, with median efficiency of 32%.
- Soil P levels were often above agronomic levels – i.e. the level required for productive pastures.
- Total N import correlated with milk production/ha, and the N surplus was correlated with stocking rate and milk production (MP).

- There was a wide range of P surplus and deficits, which were poorly related to milk production/ha.

Section 15.11 of the Dairy Soils & Fertiliser Manual provides a worksheet for the development of a nutrient budget for dairy farms.

The Gourley *et al.* (2012) study provided an estimated national milk production N surplus of 12.1 g N/Litre of milk produced, an equivalent figure to those reported in overseas studies. Further intensification of milk production per hectare is therefore likely to result in increased nutrient surpluses and increased risk of adverse environmental impacts. A modelling study in the Moe catchment by Stott *et al.* (2012) reached the same conclusion, noting that increased use of fertiliser and supplementary feeds increased stocking rates and nitrate leaching – the more intensive dairy operation was more profitable but at the cost of increased N loss.

In horticultural and cropping industries, producers are encouraged to develop a nutrient budget to ensure nutrients lost via crop removal are replaced through well timed fertiliser applications. Nutrients should be applied as frequently as needed but in amounts matched to the crop growth curve, i.e. rapid growth means higher demand (RMCG). Dairy farmers are encouraged to target optimal soil P levels and to develop a corresponding P budget (McDowell *et al*., 2011).

Kelly (2014) describes a nutrient budget as being like an accounting system for nutrients. For horticulture, it involves:

- Estimating the amount of nutrients available from the soil (soil test results),
- Obtaining uptake and removal figures for the target crop and the previous crop (to account for nutrients in crop residues, e.g. from legumes),
- Determining the target yield to calculate actual uptake and removal figures,
- Calculating the amount of nutrients, especially nitrogen, that will be applied with irrigation water (50 ppm nitrate in irrigation water will add about 1 kg N/ha with every 10 mm of irrigation water applied),
- Calculating the amount of nutrients already applied to a paddock,
- Estimating the amount of nutrients that will be removed through harvested product,
- Determining possible nutrient losses through leaching, volatilisation or soil erosion, and
- Replacing nutrients lost to the system through appropriate fertiliser applications.

Lam *et al.* (2016) reported that management strategies aiming to better match N supply to crop demand can help reduce N_2O emissions and N fertiliser losses through other pathways, such as leaching. Irrigated vegetable crops rarely take up more than half of N fertiliser applications and N uptake can be as low as 20%, highlighting the potential to improve Nutrient Use Efficiency (NUE) in the sector. The horticulture industry accounts for about 10% of nitrogenous fertiliser use in Australia, an amount comparable to that used on pastures.

Blaesing (2010) describes an experimental learning project (including trials, surveys and training as requested by growers in the Victorian tomato industry) to improve soluble solids (brix) levels in tomatoes and reduce nitrate leaching. It emphasised the importance of nutrient budgeting and monitoring throughout the growing season, and resulted in growers shifting from reliance upon urea (which is suited to flood irrigation) to using calcium nitrate and liquid UAN for fertigation. It showed that nitrogen uptake was influenced by factors other than fertiliser rates, such as soil constraints to root growth or the lack of root mycorrhiza. It was concluded that a purely technical focus and traditional research and extension approach may be insufficient to support new decision-making processes by growers.

Soil testing and mapping nutrient status provide useful, objective information on which to base nutrient management plans. Regular review (re-sampling) provides insights into any trends occurring, such as a build-up of phosphorus levels. For horticultural crops, plant tissue testing, sap testing and visual inspection are all encouraged to monitor post-planting nutrient availability and guide fertiliser programs (Kelly, 2014).

In the Gippsland dairy industry, 95% of producers use soil tests, 52% have a fertiliser plan and 14% use tissue testing (Watson *et al*., 2015). In Victoria, around 25% of horticulture producers soil test (Barson *et al*., 2012; *Figure 4.14*).

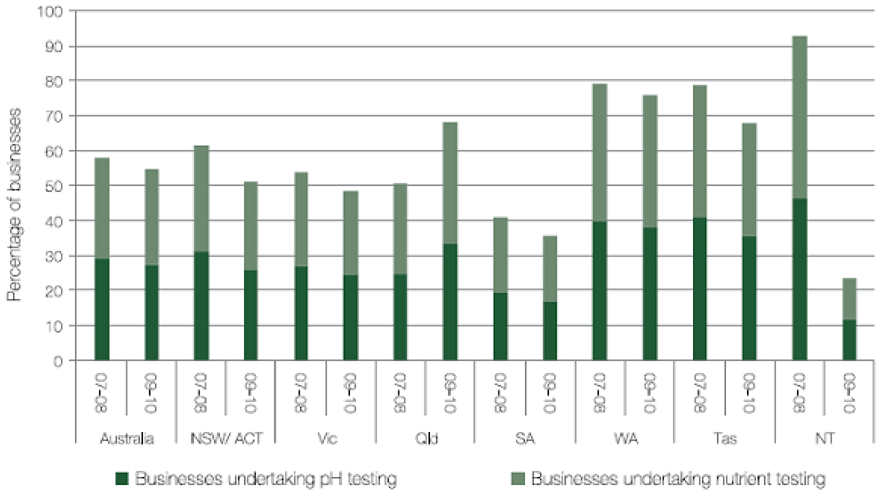


Figure 4.14 The percentage of horticultural businesses (farmers) undertaking pH and nutrient soil testing in 2007-08 and 2009-10; Barson et al., 2012

4.7.2.2 Risk Assessment

The identification of high risk activities and critical source areas (sites with high nutrient levels and high connectivity to waterways) helps target situations in which nutrient loss mitigation practices should be employed. Management practices may be reviewed with the assistance of tools such as DairySAT and the Guidelines for Environmental Assurance in Australian Horticulture.

The Farm Nutrient Loss Index (Melland *et al*., 2007), was developed for all forms of grazing enterprise. It addresses risks arising from the physical landscape and from relevant management practices, down to the scale of a farm management unit. A Nutrient Management Risk Matrix is also available as part of Cracking the Nutrient Management Code – a set of guidelines developed for industries by the Fertiliser Industry Federation of Australia (2001).

The Revised Universal Soil Loss Equation can be employed to help assess the risk of erosion. Soil loss is a factor of rainfall erosivity, soil erodibility, slope (length and gradient), ground cover and management, and erosion control practices.

4.7.3 Optimise Production

4.7.3.1 Nutrient Use Efficiency

Optimising production from areas that are more resilient and a lower-risk in terms of nutrient or sediment loss is one way to profitably manage risk at a farm scale. Striving for peak production in resilient areas and reducing the pressure on critical source areas, should be one outcome from any property management plan.

Understanding and managing any limitations to plant growth (e.g. soil constraints) and the nutrient requirements of plants in order to meet production goals, enables more precision in the application of fertilisers, and optimal production from the inputs applied.

Recycling nutrients also helps to reduce surpluses in farm nutrient budgets, and drive increased production from the nutrients available on-farm. Examples include recycling irrigation run-off or drainage (which is likely to contain nutrients) and recycling effluent.

Dung beetles have been promoted as a means to, amongst other things, enhance nutrient cycling. Several species have been introduced to Australia and can break down cow pads, which are buried as balls (containing their eggs and larvae) in tunnels they dig into the root zone. It can take from hours to up to three days for a cow pad to be buried (Griffiths, 2015). Larval beetles consume the dung balls and excrete a black humic substance that lines the tunnels. Trials in temperate Australia showed increased earthworm populations, soil permeability, phosphate, carbon and organic matter, in plots to which the dung beetle *Bubas bison* were added. Nitrate and ammonia levels were elevated in the vicinity of the tunnels. It was concluded that reduced water pollution would follow (Doube, 2008).

Some of the major inefficiencies in cycling nitrogen in dairy farming systems are the high protein content of pastures compared with needs, and the high nitrogen concentration of urine patches. Nitrogen from fertilisers increases pasture growth, enabling an increase in stocking rates, resulting in more urine being excreted (Monaghan *et al*., 2007). Using more low protein feed, like maize, improves nitrogen use efficiency.

Gourley *et al.* (2012) noted that nutrient use efficiency (i.e. farm nutrient balances) could be improved by;

- Reduced, or more strategic, use of inorganic fertilisers.
- Optimising home-produced manure.
- Reduced pasture grazing time.
- Lowered nutrient concentrations in rations.

On-farm practices for horticulture that aim to maximise Nutrient Use Efficiency and minimise N_2O emissions include:

- Soil and tissue testing to predict crop fertiliser requirements,
- Assessment of soil constraints, such as waterlogging,
- Nutrient budgeting,
- Better timing and placement of fertiliser to deliver N when and where it is needed by the crop, and
- Use of enhanced efficiency fertilisers, such as nitrification inhibitors and controlled-release fertilisers (Lam *et al*., 2016).

An overview of a new EnviroVeg program presents key messages of:

- Nitrogen (N) is dynamic and needs to be managed accordingly (remember the 4 Rs - right product, right time, right rate, right place).
- Standard N rates (or recipes) are not useful for effective N use, but may be used as a rough guide.
- Soil reserves and plant uptake of N should be monitored to make good decisions.
- Check the success of N application by calculating the nitrogen use efficiency (NUE%).

Gourley *et al.* (2012) advise on the importance of avoiding 'pollution swapping' – closing off one nutrient loss pathway (e.g. surface flow), only to divert nutrients to another (e.g. gaseous loss or sub-surface flows). Variations between the leaching of nitrate, emission of nitrous oxide, and the volatilisation of ammonia are an example. An emphasis on nutrient use efficiency lowers the risk of 'pollution swapping'.

Yiasoumi *et al.* (2016) noted the loss of nutrients, particularly nitrates, from inaccurately scheduled fertigation of shallow rooted crops was a looming issue for the vegetable industry. Tools such as solute samplers and FullStops have been largely dis-adopted due to issues with installation and maintenance. They concluded that the combination of over-irrigating and high nitrogen inputs, inevitably results in off-farm impacts which contribute to diffuse pollution.

Stirzaker *et al.* (2017) recently reported on an experiential learning trial in Africa to help improve irrigation and nitrate management – as the two are inextricably linked and 'unless farmers can reduce over-irrigation they will continue to leach nitrate from their soils'. In that work, the Chamelion soil moisture sensor and the FullStop wetting front detector and solution sampler, were used in conjunction with a mobile phone App to monitor soil tension and nitrate levels respectively, and resulted in changes in practice and, in one district, increased yields.

N-Check is another approach offering timely data to monitor plant available nitrogen in the root zone.

4.7.3.2 Water Use Efficiency

Optimising the efficiency at which water is converted to produce (yield/ML) can enhance profit and reduce the risk of nutrient or sediment movement, as excess water inevitably results in the movement of nutrients (and in some situations, sediments). An Irrigation and Drainage Management Plan is a good foundation for management, along with monitoring and decision support tools to guide the scheduling of irrigation – determining the 'when, how much and how fast' of each irrigation.

Findings from the multi-commodity National Program for Sustainable Irrigation (NPSI) were presented in a framework titled 'Irrigation Essentials'. The 'essentials' apply to all commodities, and to any form of irrigation - be it for extracted water or recycled effluent. The 'Updated' version (Day *et al*., 2012) sets out the framework as follows. It highlights the importance of aligning infrastructure with irrigation management and crop / soil management:

- Business Planning
  - External influences
  - Business fundamentals
- Irrigation Planning
  - Site suitability
  - Production systems and crop selection
  - Irrigation and drainage systems
- Irrigation Management
  - Water budget
  - Irrigation scheduling
  - Irrigation strategies
- Crop and Soil Management
  - Plant performance
  - Soil condition
- Monitoring
  - Monitoring and evaluation
  - Continuous improvement.

Laser grading heavier flood-irrigated soils, and using sprinklers rather than flood irrigation on lighter soils, can help improve water use efficiency, and reduce nutrient loss. Laser grading and no significant additional fertiliser has resulted in a 40% reduction in P loss (Nash, 2013). Laser-levelling and widening irrigation bays, reuse dams, higher stock entry points, and scheduling irrigation with consideration of infiltration rates and to avoid rain are practices recommended by McDowell *et al.,* (2011). Sound irrigation management could help avoid losses of from 3-5, to up to 20 kgP/ha/yr, on flood irrigated pastures. Ensuring no outwash occurred and that there was no irrigation earlier than 7 days after a fertiliser application were recommended by Monaghan *et al.* (2009).

Recycling treated effluent onto paddocks can relocate nutrients, as well as recycle them. Risks occur when effluent is applied to saturated soils resulting in nutrient-rich run-off, and when the same area continuously receives effluent resulting in high soil nutrient levels. An application of 100mm of effluent can equate to 34 kg of phosphorus and 210 kg of nitrogen (Rivers e*t al*., 2009).

Recommendations and options for irrigating dairy effluent (Monaghan *et al*., 2007) include:

- Farm dairy effluent irrigation should not exceed soil infiltration or water holding capacity. It should ideally be stored for deferred application if necessary, to limit the application depth to the soil water deficit in the effective pasture root zone.
- Distribute effluent via more frequent small irrigations – which may necessitate increased pond storage or larger application areas, along with effluent block nutrient budgets and soil water balance monitoring.
- Aerate soil to increase the soil/effluent contact area.
- Adding P-sorbing compounds to effluent ponds.

Monaghan *et al.,* (2007) also described a future role for integrated, or precision-based, effluent application scheduling incorporating weather data, along with simulation models or sensors to track pond volumes and soil moisture deficits. Their use would be on the premise that effluent irrigation areas were well-sited in the landscape. Further investment in infrastructure for the collection, storage and distribution of effluent are also likely to be required for improved distribution of manure (Gourley *et al*., 2012).

The Australian effluent planning and decision support tool, MEDLI (Model for Effluent Disposal Using Land Irrigation), is along the lines of an integrated effluent scheduling tool, and is available for use to help design and manage sustainable effluent disposal systems (DSITI, Qld).

A recent national project interviewing vegetable growers, consultants, processors and researchers found that the overwhelming majority opinion was that vegetable growers were generally low adopters of irrigation technology (Yiasoumi *et al*., 2016). The report authors cite ABS 2014 data indicating that irrigation scheduling has declined to 14% of irrigators across agriculture. Scheduling technology has often been 'dis-adopted' and needs to be simple to install, adopt and interpret, or made simple through ongoing support. Smartphone Apps are often integral to user friendly options. G-Dot soil moisture sensors are used by vegetable growers due to their user friendly interface, and Chameleon is considered to have similar potential.

4.7.3.3 Stock Management

Nutrients may be redistributed on-farm by stock in urine and dung, by recycling treated effluent, and through harvesting and feeding out home-grown feeds such as silage or hay. Changing where stock spend their time can change where they redistribute nutrients, although cows tend to excrete more in response to certain stimuli, such as entering yards or crossing a creek (Davies-Colley *et al*., 2004).

Stock management options include; on:off grazing, spelling paddocks prior to wet-soil pugging, and seasonally managing or excluding stock from riparian and other critical source areas. Monaghan *et al*., (2007) suggested restricting grazing of crop-lands in winter. Relocating cows to a feedpad from autumn until calving (four months) could reduce N leaching by 60%. It was also suggested that effluent from feedpads should be stored and applied to pastures in spring or summer.

4.7.3.4 Soil Health

Maintaining soil health, particularly soil structure, can be an issue within horticulture. Soil compaction is noted as a risk, requiring increased tillage effort for remediation (McPhee *et al*., 2015). It impairs root growth and the movement of water from the soil surface to the roots. Sandy and sandy loam soil types are highly susceptible to compaction, even when porous and free draining (Anderson *et al*., 2007).

Organic matter can enhance soil structure and, as it is porous, infiltration. Ground cover buffers the soil from the impact of raindrops, acts as a short term reservoir for water and slows the velocity (and erosive power) of surface water. Cover crops aid infiltration as water moves down plant stems and into the soil along plant roots.

The carbon to nitrogen ratio of a cover crop influences how quickly it decomposes through microbial activity – a high C:N ratio is slower. A Fact Sheet 'Managing cover crop residues in vegetable production' provides more information. It and other Fact Sheets on topics such as reduced till and carbon storage can be found at the Soil Wealth / Integrated Crop Protection website www.soilwealth.com.au

Anderson *et al*., (2007) provide a comprehensive guide to healthy soils for vegetable farms, while Cockcroft (2012) advances ideas for the improvement of soil structure for horticulture through the use of cover crops with fibrous roots and healthy mycorrhizae. Practices that reduce water erosion can reduce the loss of sediment-bound nutrients.

The Revised Universal Soil Loss Equation highlights the factors most important to reducing soil erosion:

Erosion = Rainfall factor × Soil erodibility factor × Length of slope factor × Slope factor × Cropping system / ground cover factor × Management practices factor.

There is limited Australian data on the environmental aspects of annual horticultural production, but the Conservation Effects Assessment Project (CEAP) in the Lower Mississippi River Basin shows the importance of detailed analysis. The project used surveys, sampling and modelling to assess the effects of conservation practices on croplands, used mainly for soybeans, cotton and rice production, in the period 2003 – 06. It is an example of the type of information needed to keep track of issues as production systems change and, as Jarvie *et al*., (2013) note, the type of inputs needed to supplement long term catchment monitoring programs.

The project found a reduction in runoff due to conservation tillage may increase leaching of nitrates into shallow water tables. About 51% of the area studied had an increase in total nitrogen loss due to conservation practice use, although most of the increases were small. The result occurs primarily on soils with relatively high soil nitrogen content, and generally low slopes where the surface water runoff is re-directed to subsurface flow by soil erosion control practices. The higher volume of water moving through the soil profile extracts more nitrogen from the soil than under conditions without conservation practices, offsetting the reductions in N loss in surface run-off (CEAP, 2013). No-till cereal cropping has also been found to build up phosphorus at the soil surface, which then became a source of dissolved P in runoff (Sharpley *et al*., 2013).

On average, the CEA Project found conservation practices had reduced phosphorus loss with waterborne sediment by 31% and soluble phosphorus loss to surface water by 47%. However, for about 17% of the area, conservation practices resulted in increased phosphorus loss to surface water; although the increases were relatively small. In some cases, the increases in phosphorus loss were due to small increases in surface water runoff. In other cases increases in phosphorus loss were due to a combination of practices and landscape conditions that cause phosphorus levels to concentrate near or on the soil surface, where it is more vulnerable to surface runoff. On these types of landscapes, improved phosphorus management, along with light incorporation and maintenance of crop residue on the soil surface, may be necessary to reduce soluble phosphorus loss (CEAP, 2013).

4.7.4 Minimise Loss

4.7.4.1 Precision Farming

The '4 R Nutrient Stewardship' framework involves the:

- **Right source of fertiliser** – matching fertiliser type to crop needs, at the
- **Right rate** – right amount to meet crop or pasture needs, at the
- **Right time** – making nutrients available when crops or pastures need them, and

- **Right place** – keeping nutrients where crops or pastures can use them.

All four can reduce the risk of nutrient losses to the environment. Examples of recommended practice to minimise nutrient loss from fertilisers include:

- Avoid applications to waterways.
- Apply 2 weeks or more before run-off or irrigation occurs.
- Use less soluble forms of P (e.g. reactive phosphate rock).
- Don't exceed soil/crop needs - stop applications above required levels (McDowell *et al*., 2009).

Nash (2013) noted that 'days since fertiliser' has a big effect on P concentrations in run-off, but losses are now rare as summer/early autumn applications (avoiding high run-off) have become the norm. The ever evolving nature of primary production systems means that data on nutrient losses from agricultural practices can become dated relatively quickly and less relevant to current situations.

McDowell *et al.,* (2009; 2011) report that, given good management practices as a starting point, there is limited scope for reductions in nutrient losses from dairy pastures – likely to not exceed a 10% improvement. With good management, systemic losses are more challenging than incidental losses. Holz (2007) concluded that dairy farmers in a 'hump and hollow' farming system could reduce annual phosphate losses by 12% by excluding fertiliser losses.

Melland *et al*., (2017), Machar (2009), and Eckard collectively recommend the following to minimise nutrient losses from grazed pastures:

Rate and timing:

- Match the rate and timing of fertiliser applications to meet pasture needs - Only apply N when pasture is actively growing and can utilise the N.
- Do not apply above 50 kg N/ha in any single application and do not apply N closer than 21 (30 kg N/ha in spring) to 28 (50 kg N/ha) days apart, as this will increase N losses exponentially.
- Manage the risk of nitrogen loss by maximising pasture uptake of soil-water and nitrogen (especially in wetter periods).
- Delay irrigation after fertiliser application to ensure that any excess water does not transport fertiliser off-farm.
- While soils are near field capacity (mid-July to September), or on free draining soils (sands or kraznozems), avoid applying N fertiliser before heavy rainfall and for at least 2 to 5 days after heavy rains, depending on how readily the soils drain. If N must be applied, then apply lighter rates of N and use urea rather than a N fertiliser containing nitrate.
- Avoid heavy stocking intensity (i.e. sacrifice blocks) on a single paddock during high rainfall periods, as this will result in significant urinary deposition in a small area, with pugged soils resulting in either increased denitrification or surface run-off loss of N.
- The risk of phosphorus loss can be managed by minimising fertiliser and effluent applications.

Placement:

- Minimise the development of nutrient hotspots in naturally or artificially well-drained soil, and avoid applications when there are high water-tables or saturated soils.
- Minimise grazing in high risk paddocks (e.g. waterlogged and connected to, or near, waterways) or time on un-bunded hard surfaces at high risk times (e.g. storms or prolonged wet periods).
- Avoiding high rates of P fertiliser to seasonally waterlogged parts of the landscape, and consider retiring them from production to maintain year-round ground cover (Melland, 2003).

Effluent:

- Ensure that laneways drain back to paddocks and not to drainage lines and waterways.
- Effluent dams can be enlarged to allow increased storage capacity in times of rain when pastures are already saturated.
- Irrigation systems can be upgraded to better distribute effluent across a property to avoid saturation (both nutrient and hydrological) in any one paddock.
- An effluent irrigation buffer zone can be left adjacent to watercourses to filter runoff.

Pastures can be managed to reduce the risk of N leaching by; promoting high root density, increasing root depth, and aiming for active growth in winter (the highest risk time). Having a high sugar content, low N concentration and tannins also assists (Monaghan *et al*., 2007).

Managing livestock as nutrient spreaders and adopting a 4R framework can also be done. McDowell *et al*., (2011) recommended fencing stock from streams, and providing waters and shade elsewhere (to avoid attracting them to riparian vegetation) – keeping them in a 'right place'.

Monaghan *et al*., (2007) reported on measures to target reductions in nitrogen losses associated with urine, including:

- Feeding stock N inhibitors, which are excreted in urine to inhibit nitrification on soil deposition.
- Giving cows diuretic salt supplements to increase their water intake, causing them to urinate more frequently, with lower N concentrations in their urine.
- Applying a soil N process inhibitor (e.g. the nitrification inhibitor, dicyandiamide - DCD), to target urine N leaching in critical the autumn/winter period, when a 68-76% decrease in NO_3 leaching is possible. Urease inhibitors target ammonia volatilisation.

For horticulture, applying the most suitable types of fertilisers and soil conditioners (e.g. manures) at the right rate and frequency or time is important to minimise nutrient losses. Application equipment must be set up and operated correctly as well. Some general rules recommended for horticulture include:

- Avoid applying fertiliser to saturated soil or when heavy rain is forecast.
- Avoid applying fertiliser during extended drought.
- Use contour drains to minimise run-off on slopes.
- Monitor soil moisture to avoid irrigation water running past the root zone; carrying nutrients with it.
- Maintain a vegetation cover through typically rainy periods to take up nitrogen that may otherwise be leached.
- Use stubble retention to avoid soil and nutrient loss during windy and dry periods.
- Nitrogen should not be applied upfront in large amounts, if volatilisation or leaching may occur.
- Select the most suitable fertiliser type, depending on the speed of availability of nutrients in relation to crop demand, acidity, alkalinity or salinity (salt index) of fertiliser.
- Foliar application is a useful method for applying targeted amounts of micronutrients as a supplement to correct imbalances, or if root-zone or weather conditions affect root uptake.
- Be careful not to apply fertiliser to non-crop areas or adjacent to waterways. Take steps to prevent contamination of water sources from pump backflow during fertigation (RMCG).

4.7.4.2 Run-off Management

Grassed buffers reduce P loss in run-off by filtration, deposition and improved infiltration. However, they can become clogged with sediment, and saturated. They can also be bypassed by non-sheet flow, and operate best when grasses have produced many tillers (as they do upon being grazed – which may negate a goal of keeping stock out of waterways) (McDowell *et al.*, 2011). Grassed buffers can help reduce erosion along in-field flow lines. This review has not focused on streambank erosion, hence the role of riparian buffers in streambank stabilisation has not been covered.

Broad *et al*., (2010) noted that catchment nutrient loads are driven largely by rainfall and topography, which results in flow to rivers via various land uses. Nutrient delivery to waterways is modified by land management practices as outlined above. Strategies for improving water quality should focus on the paddock and landscape scale, as well as the riparian zone.

Czapar *et al*., (2006) grouped practices to avoid soil erosion into:

- Conservation tillage, reducing in-field sheet and rill erosion.
- Run-off management, reducing slope length e.g. through contouring, contour strip cropping or terracing.
- Velocity and erosive power control, reducing channel and gully erosion e.g. through grassed waterways, grade-control structures, and sediment control basins.

They also noted that most of the soil and nutrients losses in surface runoff tend to occur in a few events that involve large quantities of runoff. However, most conservation measures are more effective at reducing runoff and erosion from smaller and more frequent events, and are less effective as the amount of precipitation and runoff increases (Czapar *et al*., 2006).

Reviews of nutrient management options for dairy pastures show the importance of well-designed and managed nutrient loss mitigation structures:

- Monaghan *et al*. (2007) reported that micro-topography (uneven ground) often causes flow to converge and increase flow rates, rather than favouring sheet-flow of surface water. As a consequence, rivulets by-pass riparian strips.
- Sediment traps can retain coarse sediment if cleaned regularly, and can produce a 10% decrease in TP concentration. Dams constructed for P-settling and drainage reuse can save 48-98% of loss from irrigated paddocks, but are less effective in rain-fed landscapes, where they also present issues with any policies to maintain environmental flows (McDowell *et al*., 2011). Ponds can, however, increase particulate P, due to algae growing in them – which also reduce dissolved oxygen levels (McDowell *et al*., 2011)
- Open drains can be both a sink and source, as can wetlands. Furthermore, particulate P can become dissolved P in them (and vice versa). Better options could include using constructed wetlands with P-sorptive materials, or floating (harvested) wetlands or crops, if economic (McDowell et al., 2011)

Many dairy pasture soils have high concentrations of phosphorus in their top soil, and the concentration of P in surface run-off is tied to those levels. Topsoil mixing is a suggestion to reduce P in run-off by burying or cultivating and redistributing the topsoil (McDowell *et al*., 2011; Monaghan, 2007). This could be investigated as an option at the time of pasture renovation, or in and adjacent identified critical source areas. Holz (2007) noted that soil mixing had potential in sites with nutrient stratification and stable surfaces (i.e. little soil mixing by stock, as may occur in wet soils grazed during winter).

Sharpley (2003) concluded that ploughing P-stratified soils can reduce P loss in surface flow, as long as ploughing-induced erosion is minimised. In trials in the US, P-stratified soils were chisel-ploughed to 25 cm and sown with orchard-grass (*Dactylis glomerata*). Once the grass was established total P concentrations in surface flow reduced to 1.79 mg/L compared to 3.4 mg/L prior to treatment. Dissolved P reduced to 0.3 mg/L from 2.9 mg/L.

Soil nutrient stratification is an issue in the grains industry associated with minimum or zero-till and has been researched by the Grains Research & Development Corporation.

'Hot spots' such as milking sheds and yards, effluent treatment ponds, and feedpads are potential sources of nutrients. To best manage risks from such areas, McDowell *et al.*, (2011) recommend systems including; effluent capture, storage, deferred irrigation, low rate application, no drainage, and application to summer-growing crops. Farm planning and infrastructure development are prerequisites.

4.7.4.3 Soil Amendments and Inhibitors

Chen *et al.* (2008) concluded that management practices alone would not prevent all nitrogen losses from applied fertilisers, and that enhanced efficiency fertilisers were needed – such as controlled release products, and urease and nitrification inhibitors. Yield increases or reduced losses of nitrogen in irrigated crops have been recorded when nitrification inhibitors have been used, but there is little Australian information available on their value in containing environmental losses of nitrogen.

Nitrogen measurements indicate that up to 60% of the applied N may be lost to the atmosphere or leached in high N use vegetable systems in Victoria (Porter and Riches, 2016). Victorian trials reported by them, showed great potential to reduce N inputs and to mitigate N_2O losses by using nitrification inhibitors on manures and fertilizers, compared to the standard grower practice, without reducing yield. DMPP, and to a lesser extent 3MP/TZ, reduced N_2O emissions by up to 64% over three crops.

Nitrification inhibitors, chemicals such as Dicyanimide (DCD) applied to paddocks to retard the nitrification process in soil, are a mitigation practice that reduces pollutant loads. They can potentially increase farm profit through promoting pasture production – and subsequent higher stocking rates. However, a New Zealand dairy study showed there is little overall impact on profit. Doole *et al.* (2011) concluded that inhibitors can result in large reductions in nitrate leaching and could become a critical mitigation practice for farmers if they had to reduce nitrate leaching.

A range of P-sorbing soil amendments have been trialled to 'lock-up' phosphate within soils. McDowell *et al.* (2011) noted that sorbents can work around points like lanes, creek crossings, gates and troughs. They recorded the following:

- Mole or tile drains (especially if fed by macropores) can be filled or backfilled with P-sorptive materials, resulting in gains in nutrient retention of up to 45%.
- Alum (aluminium sulfate) is a P-sorbing agent which, if not washed off, decreases P loss by 30-50%.
- Red mud (Alkaloam) increases soil pH and decreases P loss (while increasing production) on acidic, sandy soils.
- Alum and polyacrylamide, have been trialled via spreading and in sediment traps. Savings of 5 – 20% were achieved when used in ephemeral drainage lines and in-field.

Fly ash, Fe gels, struvite and fluidised gas desulfurization gypsum have also been used. P-sequestering materials can also be applied to lakes to manage P stores in sediments (Sharpley *et al*., 2013). Steel melter slag and aluminium chlorohydrate have also been used as P-sorbing soil amendments (McDowell *et al*., 2009).

PolyDADMAC is used as a coagulant in effluent treatment and in water purification, often as an alternative to metal-based coagulants such as alum. It has been shown to remove orthophosphate from solution, as a possible aid to combat the environmental risks posed by run-off following rainfall or irrigation (Goebel *et al*., 2016). An Australian trial raised the prospect of using PolyDADMAC in buffer zones, but the results were inconclusive (Churchman *et al*., 2007).

Weng *et al*. (2012) reported that soil pH, calcium concentration, and the presence of natural organic matter affected the adsorption of phosphate to iron oxides, explaining some of the variability in results of using ameliorants to lock-up P. An increase in dissolved organic carbon can more than halve the amount of P adsorbed.

Vegetables WA reported that polyacrylamides (flocculants which bind soil particles, increase infiltration, and reduce run-off) can reduce the leaching of nutrients from annual horticulture and assist plant growth.

Sojka *et al*. (2000) reported that polyacrylamide (PAM) had resulted in decreased losses of sediment, nutrients and pesticides in Australian tests, although the results were not as consistent as in the United States. PAM is attracted to soil particles, stabilising soil structure which reduces erosion (and nutrient loss) and increases infiltration. Reducing sediment in run-off is thought to also reduce the risk of spreading soil-borne diseases like fusarium. PAM is able to reduce losses of coliform bacteria in surface run-off, and can accelerate the settling of solids, and partially sequester micro-organisms and nutrients, in animal waste lagoons. In Australian conditions PAM may be less effective in irrigation waters with a high sodium adsorption ratio (SAR), and it could have less persistence due to high UV levels.

Steel melter slag 'P-socks' placed in streams were effective at low flows. Steel slag backfill in tile drains decreased dissolved P loss by 90%, while Fe, Al, and Ca enriched coal fly ash decreased P concentrations in overland flow (Monaghan *et al*., 2007). Egemose *et al*., (2012) reported laboratory trials showing that crushed concrete could be an effective filter material to remove dissolved and particulate P from urban or agricultural drainage water. P retention rates were highest at high pH levels.

Salinity is often managed at a district or regional scale, especially in irrigation areas. Examples include sub-surface drainage in the MID, salt interception schemes along the River Murray, and irrigation drainage schemes with disposal to sealed evaporation basins. Each is a part of a multi-scaled approach to tackling a district wide issue. There may be scope for district wide approaches to the management of nutrients in drainage water from the MID. Using P-sorbent materials to line drains could be one example, although no literature on the feasibility of such measures has been cited in this review.

Alternatively, Cribb (2006) speculated on a future when nutrients may be harvested, e.g. from drainage waters, and used to feed the growth of algae being farmed for oil production. Similarly, algae could be grown for stock feed or heated in the absence of oxygen (pyrolysis) to release oils and produce biochar. Reports such as those by Laurens (2017) and Lawrence *et al*., (2010) provide an overview of the status and prospects of algal bio-fuels.

4.8 Management Programs

4.8.1 Management Change

Programs to encourage changes in farm management practice often recognise three elements, described in the Social Cognitive Theory Model as personal, environmental and behavioural factors (ComGAP). For practical purposes they can be considered as:

- Person (personal factors) – e.g. objectives, motivations, capacity, and sense of place.
- Property (environmental factors) – e.g. physical attributes, management system, infrastructure, and equipment.
- Practice (behavioural factors) – e.g. trialability and relative advantage.

This theory suggests people may need support or resources to gain confidence before making a change, that incentives may assist, and that it might be necessary to change the external environment to encourage practice change.

As Monaghan *et al*. (2017) observed, programs promoting changed management to reduce nutrient losses often face barriers of cost, compatibility with production systems, and uncertainty of actual environmental benefits. These challenges stress the importance of having well designed change management programs.

The role of regulations, as part of the external environment, should also be considered when designing programs to promote changes in resource management. Producers can find it difficult to adopt measures they see as being more sustainable (e.g. with water resource management) when confronted by regulations to achieve different objectives (e.g. environmental flows). Regulations can also dictate behaviours. As an example, tradeable permit schemes have been used overseas, including in New Zealand to control nitrogen loads to Lake Taupo (DELWP, 2017).

A stocktake of industry, agency and regional NRM programs operating in the study area has not been undertaken as part of this review. Nor has there been any effort to report on the current levels of adoption of various management practices, using industry or government survey data.

4.8.1.1 Person

Seeing a problem or accepting a need for change, and believing a change will be effective and provide net benefits, can be pre-cursors to change. The Theory of Planned Behaviour emphasises the importance of intention for a person to change. In application, the theory highlights the value of promoting positive attitudes toward a changed behaviour and of giving people confidence they have the skills and resources needed to make a change (CommGAP).

The Transtheoretical (Stages of Change) Model proposes that people move through stages, from pre-contemplation, to contemplation, to preparation, to action and then maintenance or termination. It can be summarised as in *Figure 4.15*. The model emphasises the importance of a program having materials and messages to reach people in each of the stages, and the occasional need for an ‘intervention’ to shunt people to another stage – e.g. a personal evaluation or an assessment, or an awareness raising event (CommGAP).

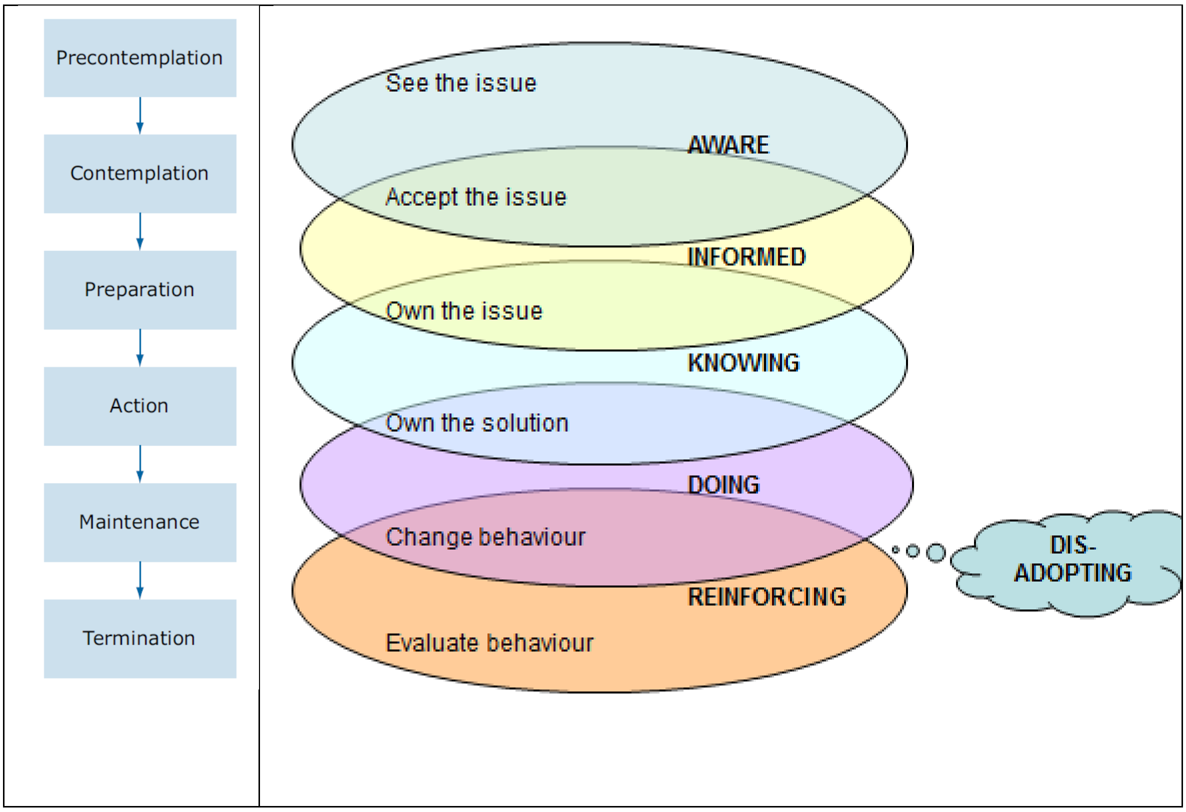


Figure 4.15 Stages of Change Model; CommGAP

Coutts *et al*. (2005) provide a useful categorisation of program delivery options (*Figure 4.16*), to match the materials, practices and people involved:

- Group Facilitation / Empowerment – helping groups to define their needs and to realise them.
- Programmed Learning – providing targeted training programs and/or workshops.
- Technology Development – the co-development of management solutions through trials, demonstrations, field days and site visits.
- Information Access – making information available to meet user needs in terms of content and delivery, e.g. libraries, websites, and information centres.
- Consultant / Mentor – one on one support ranging from one-off on-farm technical advice to ongoing mentoring.

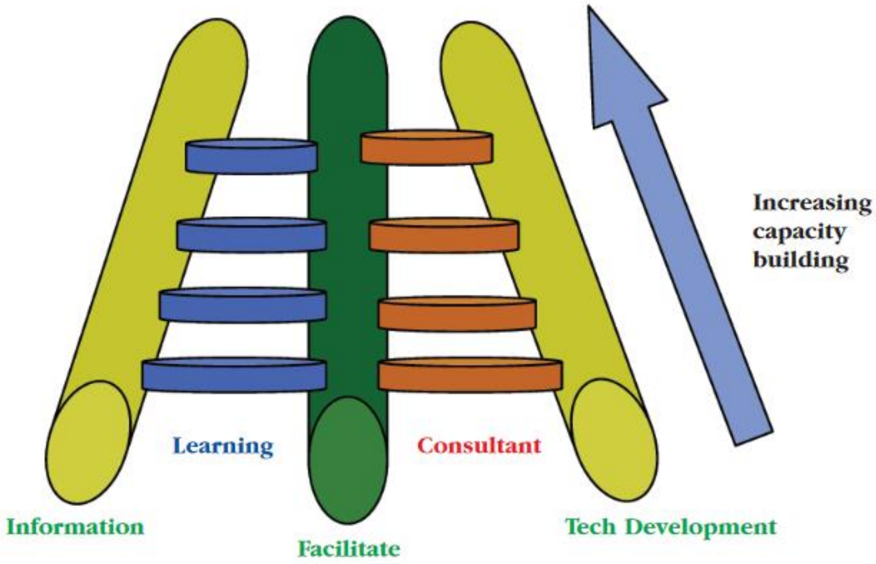


Figure 4.16 Program delivery options; Coutts et al., 2005

4.8.1.2 Property

For a change in agricultural management to occur the new practice must fit with the production system – either currently being used or about to be adopted – and the environment of the property.

In the Lake Wellington catchments there are changes occurring in land uses and production systems. A shift from family run dairy businesses to corporate dairy and to vegetable production is underway (Dickson, 2017). It will influence the nature of practices advocated and the delivery or extension methods selected.

The local dairy industry typically has high stocking rates (around 2.13 cows/ha), and uses a mix of irrigation practices – 64% use flood, 58% sprinklers and 20% centre pivots. Some producers experience problems with water-tables reflected in salinity or wet-soils. Nutrient planning and integrated effluent and water recycling systems are of interest, highlighting a need for new or improved infrastructure (e.g. larger dams, extended pipes, and irrigation scheduling technologies like timed pumps; Dickson, 2017). Soil health and increasing water-holding capacity are also issues for producers.

Although new producers may be entering the industry, inter-producer competition is considered to retard the sharing of information within horticulture (Dickson *et al*., 2017). The understanding of technology and data can be challenges for producers, who must also be confident in their ability to apply it before changing management practices.

Integrated systems (e.g. fertiliser and irrigation management) and precision farming can require new machinery or infrastructure, high levels of automation, and sophisticated decision-making. The training of producers and advisors, and on-going access to skilled advisors, or the development of an easy-to-use App, may be needed for adoption to be widespread.

4.8.1.3 Practices

Pannell *et al*. (2006) highlight the importance of the trialability and relative advantage of a practice to its adoption. Kuehne *et al*. (2017) describe how factors such as those can be used to predict the likely level of adoption of specified practices amongst specified target audiences. ADOPT, the Adoption and Diffusion Outcome Prediction Tool, is a freely available software package which models and applies Kuehne *et al.*'s understanding of practice change. Through a series of questions about the practice and target community it generates an adoption curve, predicting adoption levels and rates (*Figure 4.17*).

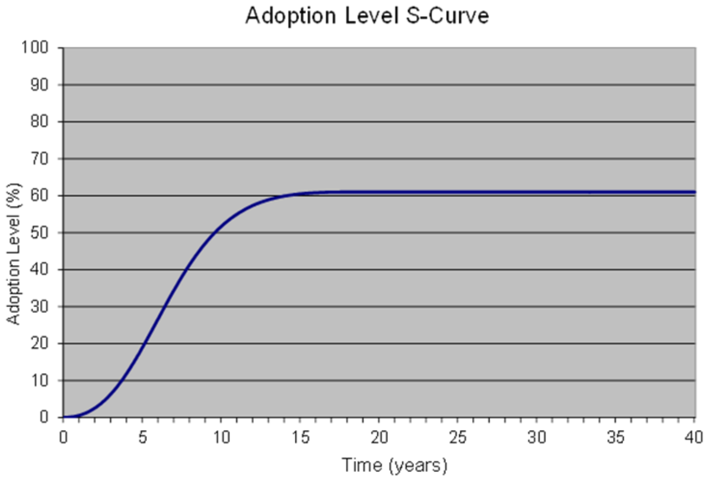


Figure 4.17 An Adoption Curve generated by ADOPT

The increasing technical complexity of irrigation systems is a challenge for dairy producers and extension programs in Lake Wellington catchment. System layout and the design of channels, drains and reuse dams, laser grading, sprinkler irrigation and automation were all of interest to farmers in a consultation process, as was soil moisture monitoring and scheduling the timing, rate and duration of irrigation. Under current systems, 69% of dairy irrigators rely on experience for scheduling (Dickson, 2017).

Targeted 'whole system' extension using 1:1, discussion groups, and on-farm demonstration may all be needed, along with ways to celebrate farmers improving the Lakes (Dickson, 2017).

Water use efficiency is thought to be better in horticulture than in dairy, marked by little surface run-off occurring. There is some use of tape and drip irrigation systems – when compatible with harvest methods. Fertiliser planning, e.g. plant tissue testing to determine needs, is of interest to producers, as is soil health and soil carbon (Dickson et al., 2017). Producers have also raised the possible issue of contamination of produce from using irrigation water containing pathogens.

Face-to-face (1:1) and discussion groups are favoured extension vehicles, along with single page notes via email or the Infoveg newsletter, local bus tours or the annual horticulture conference (Dickson *et al*., 2017).

The Stirzaker *et al*. (2017) and Blaesing (2010) both stressed the importance of a holistic approach to the adoption of new technologies and practices, and the importance of experimentation as part of the process. Australian industry bodies, such as the Research and Development Corporations, can assist in such approaches. They can be a ‘trusted source’ for producers. In any event, it is best to ensure that mixed messages are not being directed to producers from different programs. Industry can sometimes provide data on adoption levels for management practices as well.

4.8.2 Catchment Management

4.8.2.1 Environmental Change

Following a review of measures used to quantify water quality changes due to programs promoting changed management in agricultural catchments, Melland *et al*., (2013) reported that nutrient loss mitigation measures had no measurable effect on water quality for 3 to 20 years after changes in management – and that measured, beneficial effects usually came from a combination of measures that address source, nutrient pathways, delivery and impact. These system-related aspects of nutrient reduction need to be factored into programs seeking to advance changes in resource management, and reinforce the value of a multi-layered approach to nutrient reduction targets.

Jarvie *et al*., (2013) concluded that phosphorus reduction programs in Europe and North America had largely been unsuccessful in reducing the eutrophication of waterways and achieving targets such as reductions in nuisance blooms of algae. This is in spite of programs having been successful in reducing P concentrations and loads in run-off at a farm scale, and some even producing improvements in river ecology. The reasons are more than difficulty in seeing trends through the variability and complexity of catchments. They include:

- Legacy P – response lags as landscapes continue to release P from accumulated stores.
- Nutrient reductions failing to reach limitation thresholds for algal growth.
- The decoupling of algal responses to P loading due to stressors, including physical-chemical and biological factors – such as the release of legacy P from sediments.
- Environmental recovery trajectories that may be non-linear, with 'state-and-transition' type thresholds, and alternative stable states. They may differ from degradation trajectories.

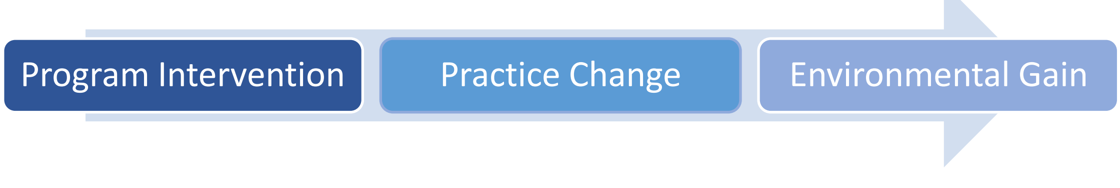
The lack of clear environmental responses to nutrient mitigation programs is seen as a potential challenge to retaining farmer goodwill, especially if management requirements put them at a competitive disadvantage with producers outside the influence of such programs (Jarvie *et al*., 2013). The authors suggest a more holistic approach is required, with a broader scope to pollution control and the inclusion of river restoration (including functional food-webs) to promote resilient water quality and ecosystem functioning.

A review of the Macalister LWMP concluded that actions that improve irrigation efficiency, increase the re-use of irrigation drainage water and reduce runoff from irrigated land must decrease phosphorous loads to waterways and ultimately to Lake Wellington. However, given current knowledge and natural variability, it was not possible to quantify the reduction in phosphorous loads achieved by plan implementation, or attribute any reduction to particular actions. Nevertheless, the review concluded the Plan had been successful in reducing phosphorus loads to Lake Wellington and made an important contribution towards achievement of the SEPP (WoV) Schedule F5 phosphorus export target (Fitzpatrick *et al*., 2017).

4.8.2.2 Evaluation

Turral *et al*. (2017) noted that simple relationships between changes in management and nutrient exports cannot easily be observed over the short term, due to the complexity of pathways, and masking by variability in climate and economic factors governing fertiliser use. Improving the tracking and reporting of practice change, and the benefits of extension activities, has been recommended in regard to Lake Wellington catchments. It would help respond to those conclusions, along with an evaluation of the farm incentives program (DELWP, 2017).

For evaluation, and to guide future efforts, it is essential to explain the link between a program, changes in management, and environmental benefits.



The complexity of systems, high degrees of variability, and potential lags between each of those steps makes it difficult to provide hard evidence. Clear logic and projections are essential to support information from program monitoring. The use of ratios, or models if available, can help sort through variability. A clear picture of current practice at the commencement of a program provides a firm base for planning (e.g. identifying and quantifying target markets), as well as reporting change.

Considering the Gippsland Lakes, Harris *et al.* (1998) recommended the use of an integrated catchment model to predict the impacts of management changes on the Lakes as a basis for measuring improvements. It was proposed that it consider things like flow control, catchment and farm management, and urban issues of stormwater and sewage treatment.

Carroll *et al*., (2012) provide an overview of the 'Paddock to Reef Program' – an integrated, multi-scaled mixture of trials, monitoring, and modelling - used to quantify the impact of changed land management on water quality and the health of the Great Barrier Reef. The adaptive process uses 'five lines of evidence' to deal with issues such as the variability of the natural system and the time lags involved in generating environmental improvement. The five lines are:

- Effectiveness of management practices to improve water quality (including farm trials and catchment monitoring);
- Prevalence of, and changes in, specified management practices;
- Long-term catchment water quality monitoring;
- Linked paddock modelling (APSIM, GRASP and HowLeaky) and catchment modelling (Source Catchments); and
- Marine monitoring.

The modelling permits data to be normalised for seasonal climatic variability, and enables assessments of progress against management action and water quality targets.

Examples like the Paddock to Reef Program (Australia) and the Conservation Effects Assessment Project (USA - Mississippi), and the experiential learning through farm trials mentioned by Blaesing (2010) and Stirzaker *et al*. (2017), show the type of long term, multi-faceted approach needed for the implementation and evaluation of catchment programs. Funds may not be readily available for such large programs in all regions, but elements of the approach may be feasible with collaboration and planning between different organisations – and if it builds on infrastructure, programs and models already available.

4.8.2.3 Program Components

The observations above highlight how important it is for programs aiming to improve catchment health, by changes in resource management, to be based on strong science and have a good understanding of the drivers of management change. They may need a long term, multi-tiered approach to collectively address sources, nutrient pathways, delivery and impact.

Successful programs include elements of the following (also *Figure 4.18*), often provided by collaborating partners:

- A foundation of environmental monitoring and research at various scales, including producer involvement in experiential learning;
- Strategic planning and coordination;
- A mix of change-management components; communication, extension and incentives – often in collaboration with industry bodies and their programs;
- An understanding of the influence of any regulations;
- Long-term, multi-tiered monitoring, based on clear logic (and modelled predictions if available), to support analysis, evaluation and reporting.

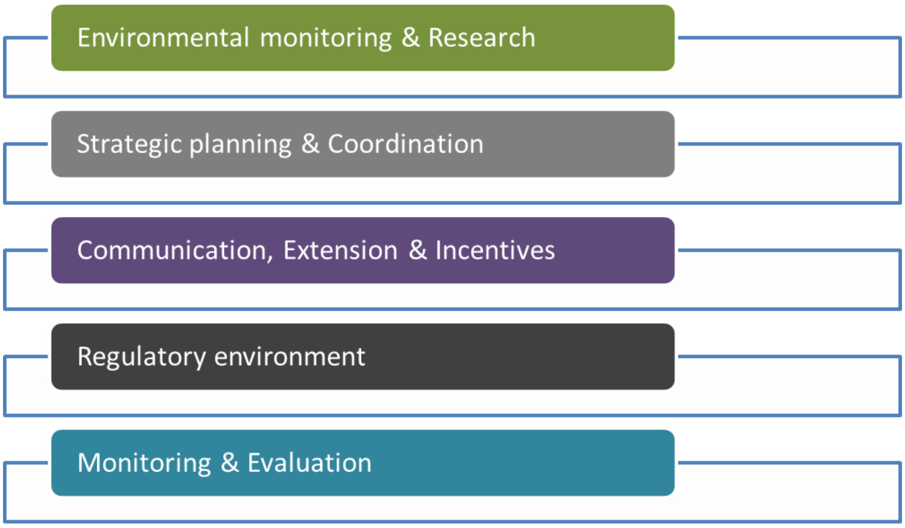
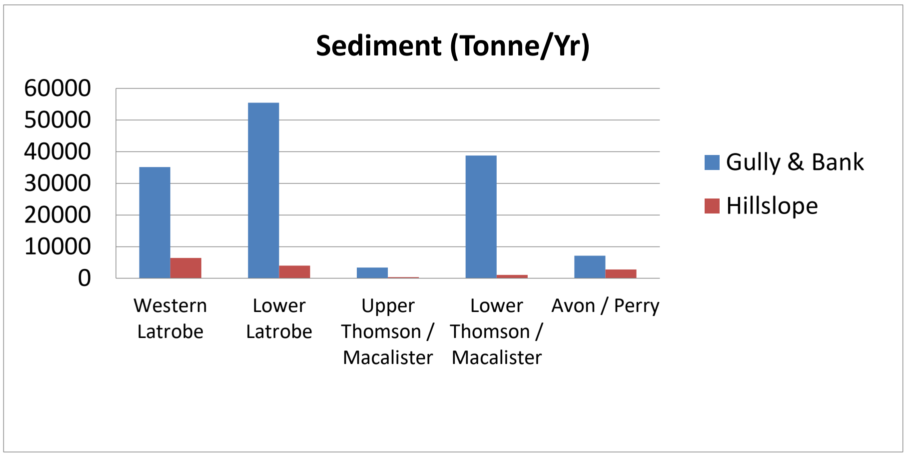
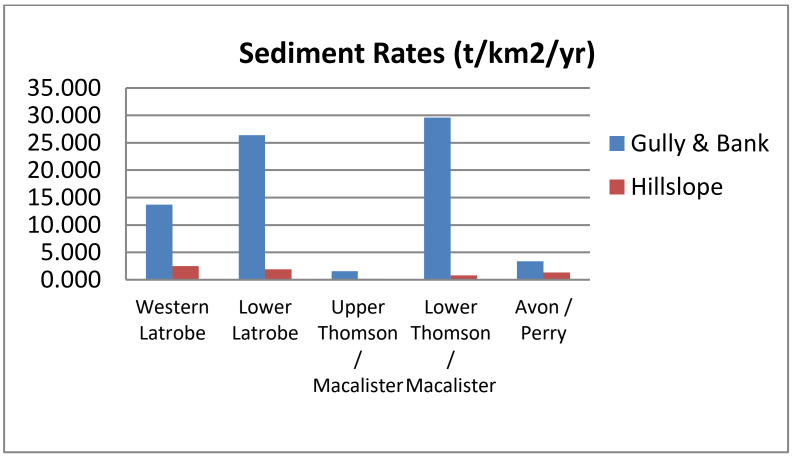
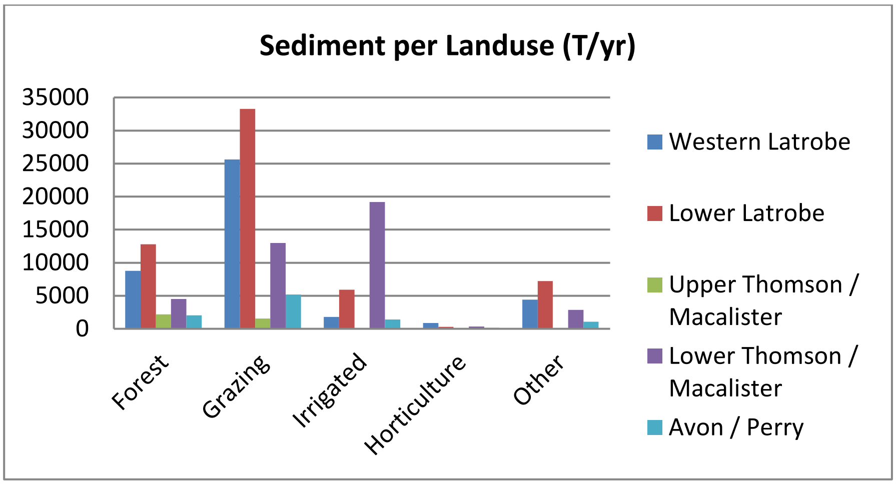


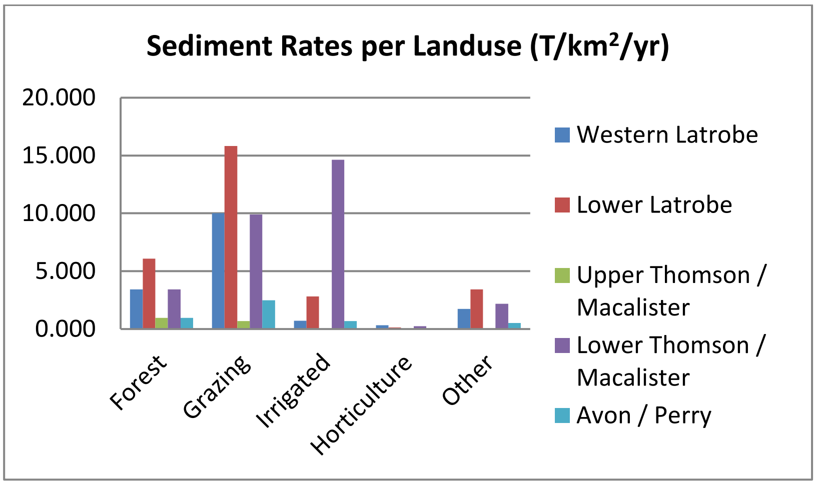
Figure 4.18 Components of a successful program

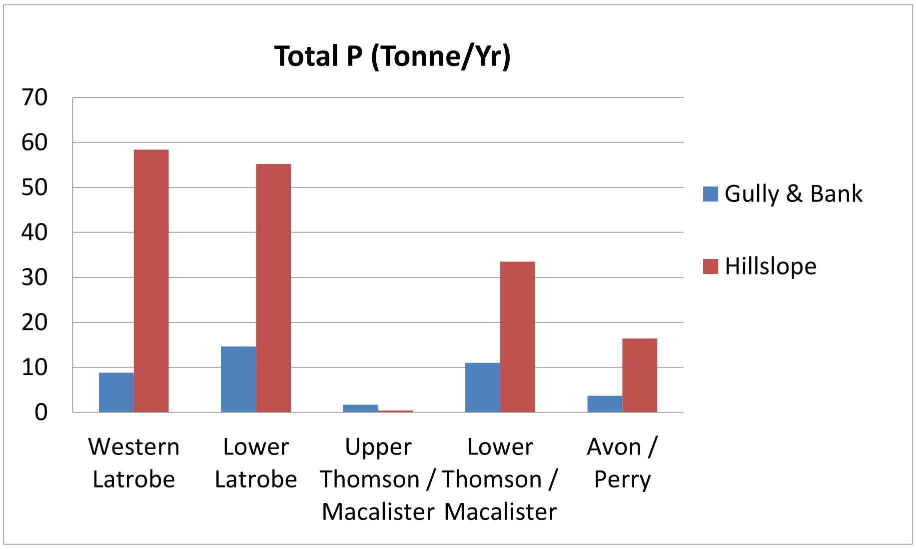
4.9 Appendix: Modelled Catchment Contributions (Grayson, 2006)

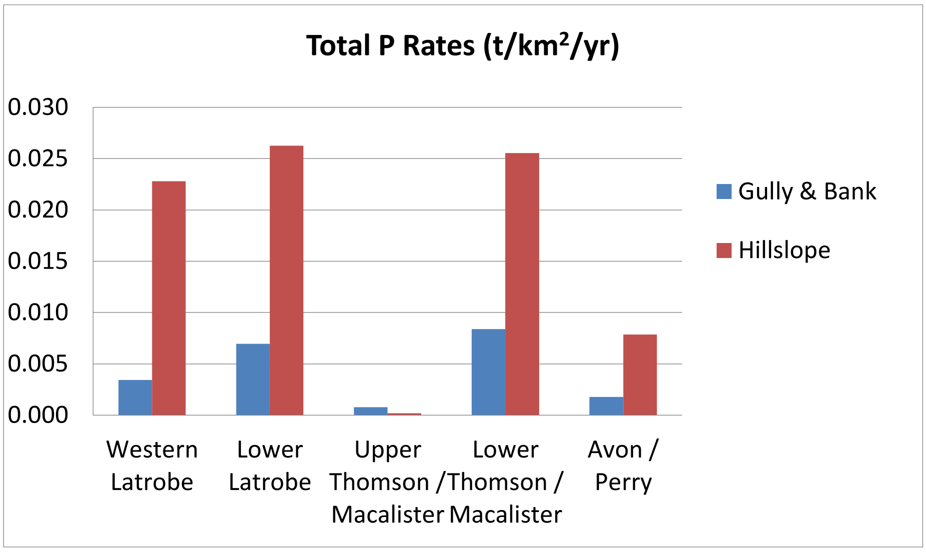


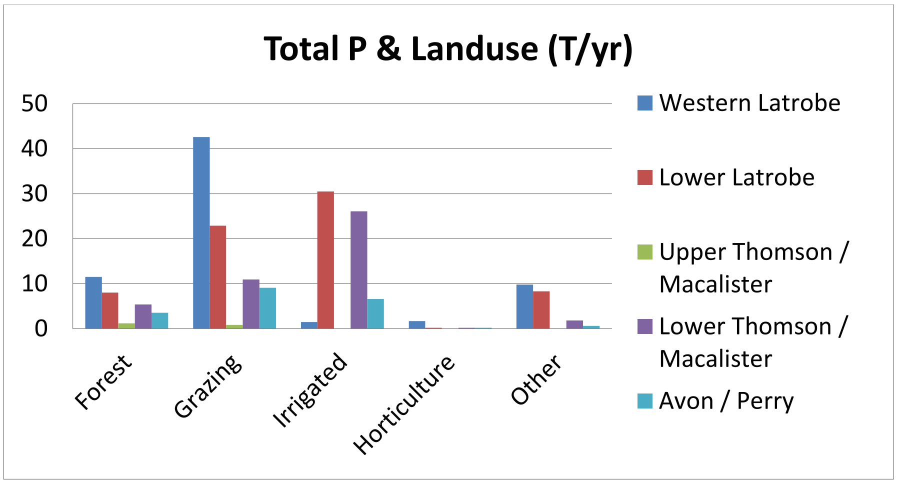


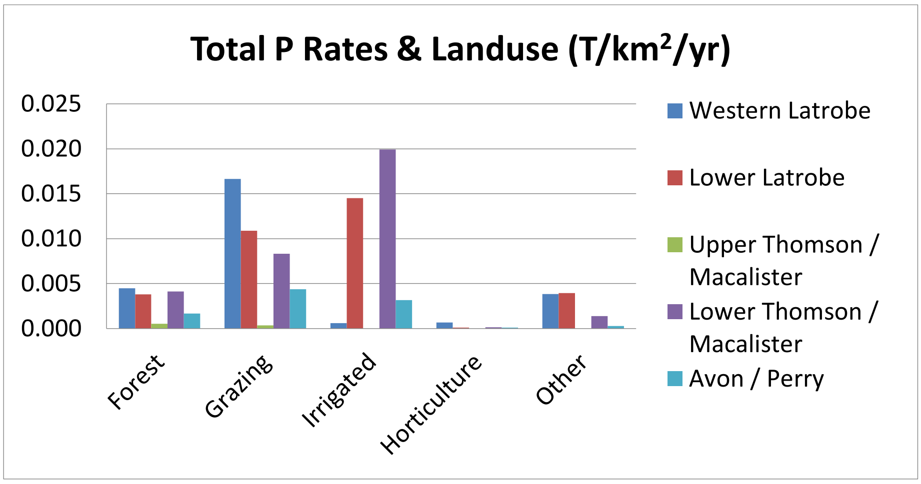

Sediment per Landuse (T/yr)
35000
30000
25000
20000
15000
10000
5000
0
Forest
Grazing
Irrigated
Horticulture
Other
Western Latrobe
Lower Latrobe
Upper Thomson / Macalister
Lower Thomson / Macalister
Avon / Perry

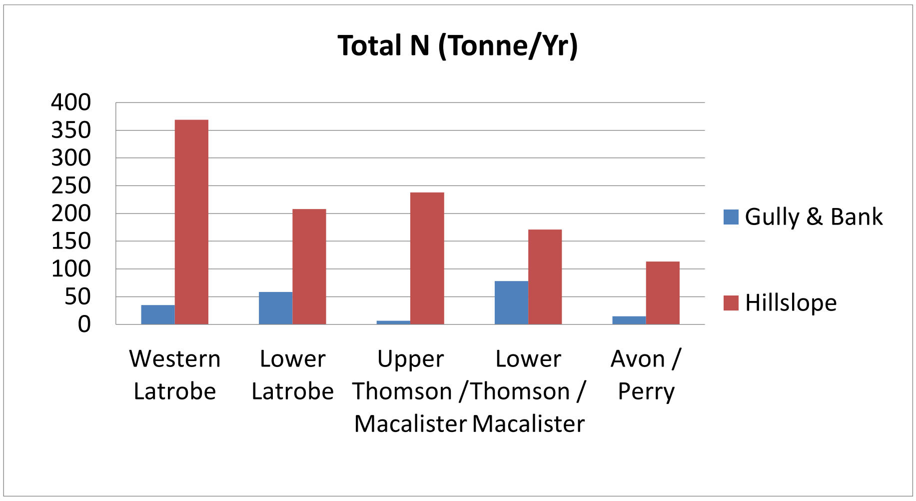

Sediment Rates per Landuse (T/km2/yr)
20.000
15.000
10.000
5.000
0.000
Forest
Grazing
Irrigated
Horticulture
Other
Western Latrobe
Lower Latrobe
Upper Thomson / Macalister
Lower Thomson / Macalister
Avon / Perry

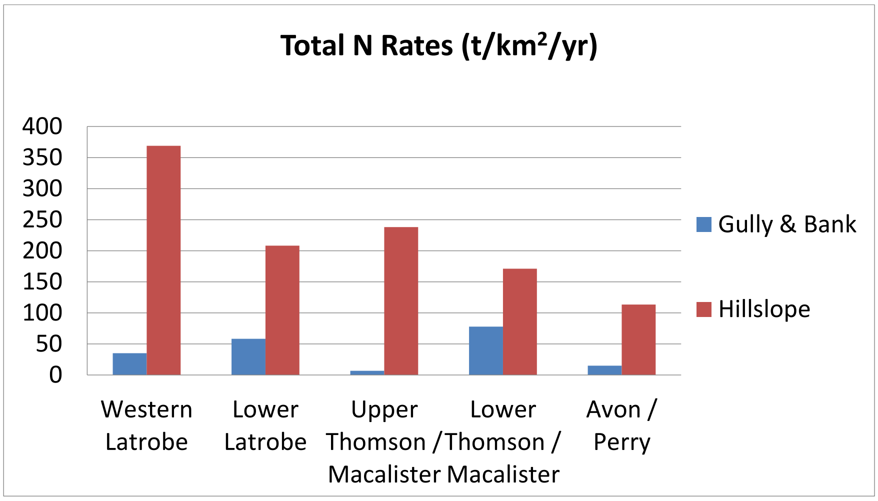

Total P (Tonne/Yr)
70
60
50
40
30
20
10
0
Western Latrobe
Lower Latrobe
Upper Thomson / Macalister
Lower Thomson / Macalister
Avon / Perry
Gully & Bank
Hillslope

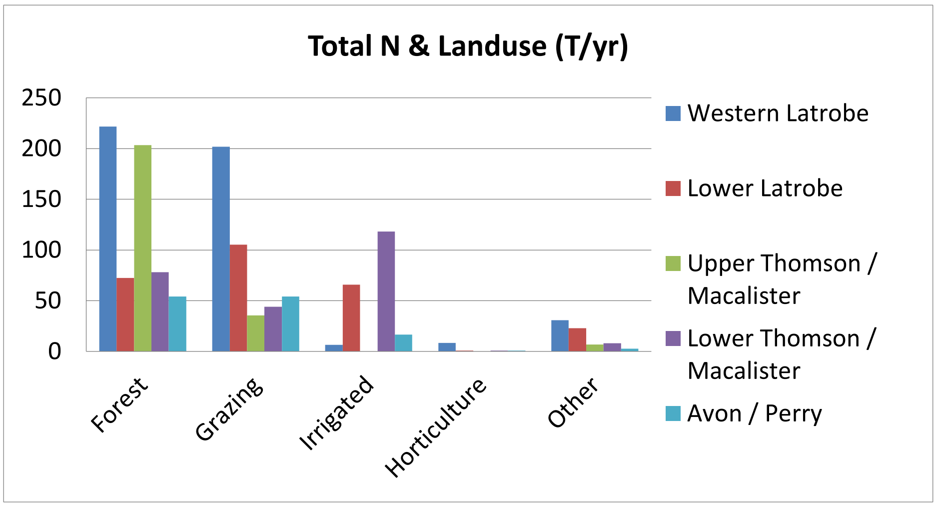

Total P Rates (t/km²/yr)
0.030
0.025
0.020
0.015
0.010
0.005
0.000
Western Latrobe
Lower Latrobe
Upper Thomson / Macalister
Lower Thomson / Macalister
Avon / Perry
Gully & Bank
Hillslope

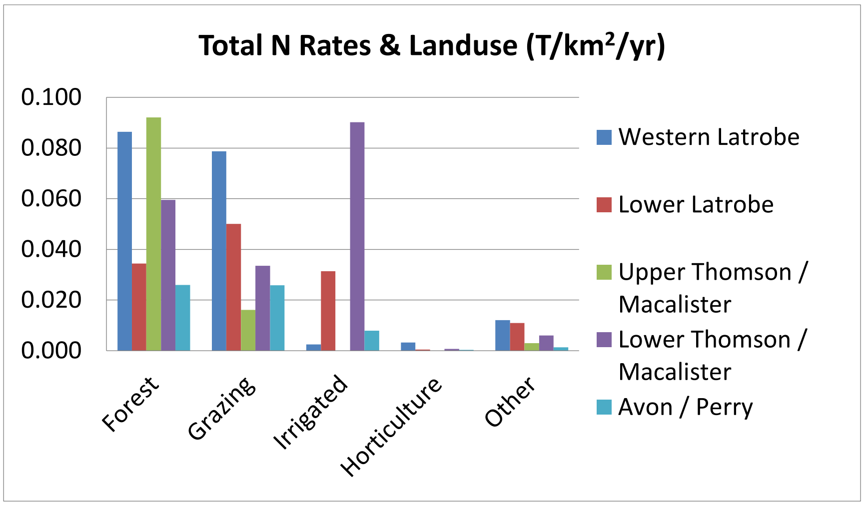

Total P & Landuse (T/yr)
50
40
30
20
10
0
Forest
Grazing
Irrigated
Horticulture
Other
Western Latrobe
Lower Latrobe
Upper Thomson / Macalister
Lower Thomson / Macalister
Avon / Perry


Total P Rates & Landuse (T/km²/yr)
0.025
0.020
0.015
0.010
0.005
0.000
Forest
Grazing
Irrigated
Horticulture
Other
Western Latrobe
Lower Latrobe
Upper Thomson / Macalister
Lower Thomson / Macalister
Avon / Perry


Total N (Tonne/Yr)
400
350
300
250
200
150
100
50
0
Western Latrobe
Lower Latrobe
Upper Thomson / Macalister
Lower Thomson / Macalister
Avon / Perry
Gully & Bank
Hillslope


Total N Rates (t/km²/yr)
400
350
300
250
200
150
100
50
0
Western Latrobe
Lower Latrobe
Upper Thomson / Macalister
Lower Thomson / Macalister
Avon / Perry
Gully & Bank
Hillslope


Total N & Landuse (T/yr)
250
200
150
100
50
0
Forest
Grazing
Irrigated
Horticulture
Other
Western Latrobe
Lower Latrobe
Upper Thomson / Macalister
Lower Thomson / Macalister
Avon / Perry


Total N Rates & Landuse (T/km²/yr)
0.100
0.080
0.060
0.040
0.020
0.000
Forest
Grazing
Irrigated
Horticulture
Other
Western Latrobe
Lower Latrobe
Upper Thomson / Macalister
Lower Thomson / Macalister
Avon / Perry

5 Reducing nutrient loads into Lake Wellington from irrigation areas

5.1 Introduction

This chapter describes an analysis of the challenges in meeting the proposed SEPP (Waters) phosphorus load reduction target for Lake Wellington catchment resulting from likely pressures due to agricultural land use change and intensification. The analysis applies a simple nutrient load calculator, which had previously been developed for the Gippsland Lakes (Pannel and Roberts, 2010). It is based on information referenced in the science review (Chapter 4) and a series of assumptions about the catchment and links between management practices and catchment nutrient loads (documented below). The limited information base on land uses within Lake Wellington catchment and their contribution to nutrient loading into catchment waterways means that estimates of the effect of management practices and land use change on nutrient exports into the Lakes are uncertain.

5.2 Nutrient load calculator overview

The nutrient load calculator is based on the following information sources and assumptions:

- Average P loads to Lake Wellington under current land use is approximately 115 t P/year and needs to be reduced by 7.5 t P/year by this Plan (as per the proposed SEPP (Waters)).
- Relative P loads from major sub-catchments in the Lake Wellington catchment are based on estimates from catchment modelling work of Grayson (2006).
- Current and future land uses have been estimated (by WGCMA) using a mix of spatial mapping and local knowledge. Land use mapping using the Victorian Land Use Information System (VLUIS) has been used, but has limitations due to it not reliably representing irrigation land uses or discriminating between various forms of livestock grazing and vegetable production in the Lake Wellington catchment.
- Assumptions about relative contributions from different land uses were made based on the previously developed Gippsland Lakes P tool (Pannell and Roberts, 2010) and inferred from information contained in a science review undertaken as part of preparations for the LWMP (Chapter 4).
- Assumptions about the overall effectiveness of management practices to reduce P and/or N loads were made from several sources including the Gippsland Lakes P tool (Pannell and Roberts, 2010), previous Victorian Government research (Stott and Roberts, 2013) and a review of horticulture information conducted as part of this project (Roberts, 2017). Note that the tool assumes a single effectiveness figure for management practice change. This means it is assumed that all best management practices are adopted to the extent they can be.

Further detail on the assumptions made for P and N are outlined below.

5.3 Assumptions about phosphorus sources and exports

The key assumptions about phosphorus sources and exports are as follows:

- Average load into Lake Wellington is 115 t P/y. Under the proposed SEPP (Waters), this is to be reduced by 7.5 t P/y as a result of activities supported through the Lake Wellington LWMP.
- Relative P loads from major sub-catchments in the Lake Wellington catchment are based on P loading estimates from catchment modelling work of Grayson (2006).

- Relative contributions of P from different land uses are:
  - P loads from forests are 33% of dryland beef/sheep grazing (P tool suggests a 2.75 multiplier from forest to grazing);
  - Rainfed dairy has four times the P loss of rainfed beef/sheep (P tool suggests 4.9 multiplier)
  - Irrigated dairy in the lower catchment has 2.5 times P loss of rainfed dairy or 10 times that of beef/sheep (P tool says 12.9 times beef/sheep or 2.6 times that of rainfed dairy). Note that irrigated and rainfed dairy would not be expected to differ this much. The reason the load from irrigated dairy is assumed to be so much higher is due to the proximity of the MID to the Lakes relative to rainfed dairy in the Moe catchment. The proximity of irrigated dairying in the MID to Lake Wellington, means that there are fewer opportunities for P to be intercepted prior to deposition in the lake than for P generated in rainfed dairy areas in the Moe catchment.
  - Irrigated dairy in upper catchment areas is assumed to have the same losses as rainfed dairy, reflecting the much longer delivery pathway for P from upper catchment areas.
  - P loads from all horticulture are assumed to be the same. There is very limited information on horticultural P loads. Potatoes are grown on sloping land in the Thorpdale area: other factors being equal, they would be expected to have higher P losses than horticulture on flat land. However, while irrigated vegetable production occurs on flat land, it is much closer to Lake Wellington and therefore is expected to have a higher nutrient delivery ratio to the Lake.
  - P loads from horticulture are assumed to be double those of irrigated dairy. The science review (Chapter 4) outlines relativities from different sources.
  - P loads from residential and other sources are assumed to be same as for irrigated dairy.
- Estimated P effectiveness of best management practices (BMPs) for dairy and horticulture are given in Table 5.1 and Table 5.2, respectively. The assumed overall BMP effectiveness for P reduction for dairy is 20% and for horticulture is 15%.

Table 5.1 Estimates of effectiveness of P export reductions with recommended management practices for irrigated dairy (based on Gippsland Lakes P tool).

Best management practice (BMP)	Area on which BMP can be applied	Effectiveness of BMP in reducing P export if adopted	Overall effectiveness
On-farm re-use systems for tailwater: heavy soils, flat	40%	80%	32%
Conversion to pressurised irrigation – light soils	50%	60%	30%
Irrigation automation	50%	15%	7.5%
Effluent management (enforcement of compliance)	100%	10%	10%
Irrigation farm plans	100%	5%	5%
Drainage line/riparian buffering	100%	25%	25%
Mean			**18%**

Table 5.2 Estimates of effectiveness of P export reductions with recommended management practices for horticulture

Management practices, including current agricultural practice (CAP)[1] and best management practice (BMP)	Effect on reducing P exports[2]
Groundcover management: • Current agricultural practice (CAP): Unclear. • Best management practice (BMP): All growers use cover crops over winter. Blocks are planted resulting in a mosaic of groundcover.	15%
Nutrient balance - need to understand amount and timing of P application and when it exceeds plant demands: • CAP: Unclear. • BMP: Nutrients are applied in response to soil testing (Colwell P and PBI) and tissue testing).	5%
Sediment and nutrient treatment systems (includes sediment traps, swale drains, wetlands, re-use dams or treatment trains which are a combination of the above): • CAP: Not used; • BMP: Not used;	20% (not included)
Management of drainage lines (fencing, revegetation and appropriate crossings): • CAP: Not discussed in workshop, assumed not used. • BMP: Not used.	10% (not included)
Riparian area management (fencing, revegetation or replanting, min acceptable buffer width): • CAP: Unclear. • BMP: At least 10 m of functioning riparian corridor.	25%
Erosion stabilisation and protection (e.g. minor works to stabilise gullies and streambanks): • CAP: Not generally relevant in lowland irrigation areas. • BMP: Not included.	5% (not included)
Headland management (appropriate design and utilisation to minimise sed. and nutrient loss): • CAP: Unclear. • BMP: Not included.	5% (not included)
Larger scale wetlands and retention basis: • CAP: Not used. • BMP: Not used.	50% (not included)
Community drains: • CAP: Soils generally well drained, not raised by irrigators and not used. • BMP: Not included.	Negative? (not included)
Irrigation practices: • CAP: Water applied in different ways in different enterprises and scale of operations. • BMP: Water applied in response to crop water requirement using soil moisture probes.	Effect incorporated in other effectiveness estimates. Assume effectiveness estimates are under current industry average irrigation.

Note:

1. CAP was determined through a workshop with MID and region horticultural irrigators. If practices were not used or not considered in discussions, BMP was not considered to be applicable.

2. Practices that irrigators did not report using were not included in estimates of the overall effectiveness in reducing P exports.

5.4 Assumptions about nitrogen sources and exports

The key assumptions about nitrogen sources and exports are as follows:

- No load reduction target has been set for N under the proposed SEPP (Waters). However, as discussed in the science review (Chapter 4), N may have an important influence on the incidence of algal blooms in the Gippsland Lakes and needs to be addressed by the Lake Wellington LWMP.
- N loads to Lake Wellington range from 1,030-1,625 t N/year. Average N load is assumed to be 1,341 t N/year (based on Grayson catchments, including 70% of the area proximal to the Lake's catchment).
- There is limited information on the effectiveness of management practices to reduce N losses. The most locally relevant information is from an Accountable Dairying Project (Stott and Roberts, 2013) where BMP effectiveness was estimated using expert knowledge (Table 5.3). This suggests that effectiveness of N practices is similar to or lower than for P; as would be expected given the very high mobility of N. Overall, the N effectiveness of BMPs is assumed to be around 10% for dairy systems.

Table 5.3 Technical effectiveness estimates for a typical dairy farm in south Gippsland (Accountable Dairying work and estimated using expert opinion; Stott and Roberts, 2013)

	% effectiveness in reducing nutrient and sediment exports		
Management practice	**Sediment**	**Phosphorus**	**Nitrogen**
Nutrient application: • CAP: Nutrient application rates determined by a trained advisor or retailer and informed by economic or seasonal conditions. • BMP: Nutrient application rates also informed by a nutrient management plan/budget and application is targeted to different areas of the farm to avoid nutrient build up.	0	2	5
Effluent application: • CAP: Effluent is collected from hard surface, heavy-use areas (i.e. dairy, feedpads) and stored for treatment or safe discharge to paddocks. • BMP: Upgrade to pond system with capacity to store all effluent from June to mid-Sept.	0	10	10
Effluent management/application: • CAP: The effluent system is in place. Farmers are actively managing according to the herd size and within constraints of current infrastructure. Effluent is recycled (making use of its nutrient and water content). • BMP: Deferred effluent application to 50% of the milking area, to maximise re-use and prevent loss of nutrients to waterways, drains and off-farm.	0	10	10
Tracks and waterway crossings: • CAP: Run-off from tracks and laneways are sometimes diverted into paddocks. • BMP: Tracks are well-shaped and graded, and runoff is well filtered and dispersed away from waterways and sensitive areas. Creek crossings are designed and maintained to ensure runoff does not enter waterways.	5	5	5

Management practice	% effectiveness in reducing nutrient and sediment exports		
	Sediment	Phosphorus	Nitrogen
Wet areas • CAP: High risk areas are grazed at low intensity where possible and traffic is minimised when wet; e.g. on-off grazing, spreading grazing over a larger area and feeding out in sacrifice paddocks. • BMP: Stock are excluded from problem areas during wet seasons. Alternative feeding options are in place, e.g. feedpads, higher ground/better drained areas. Run-off is minimised.	10	10	10
Gully erosion control • CAP: Most actively eroding gullies are fenced to exclude stock and some are revegetated. • BMP: All gullies are being managed to control minimise erosion, i.e. fenced to exclude stock and vegetation to stabilise the gully.	20	5	5
Permanent waterways: • CAP: Some riparian management –some farms have excluded stock from permanent waterways and established native vegetation. • BMP: Wetlands and waterways are permanently fenced to control stock access. Riparian areas are managed to control weeds, well vegetated. Fences are at least 10 metres on average either side of the waterway. Plantings stabilise stream banks. Alternative watering points are established away from waterways.	40	20	15
Natural ephemeral streams: • CAP: Some riparian management – some farms have excluded stock from ephemeral streams (assume 50%). • BMP: Stock have no access to waterways. Streams are well fenced from stock – at least 3 m in width either side. Native grass, shrubs and/or trees are established to stabilise the banks	25	13	10
Constructed drainage lines: • CAP: Drainage lines are fenced and stock are excluded, many are not vegetated. • BMP: Drainage lines are fenced and stock are excluded. Drainage lines are broad shallow, are well grassed and maintained.	5	2	2
Nutrient application: • CAP: Nutrient application rates determined by a trained advisor or retailer and informed by economic or seasonal conditions. • BMP: Nutrient application rates also informed by a nutrient management plan/budget and application is targeted to different areas of the farm to avoid nutrient build up.	0	2	5

- Dairy systems have much higher N application rates than beef systems, with N rarely applied to beef pastures. It is assumed that extensive dairy systems have double the N leaching losses of beef/sheep systems.
- Dairy intensification suggest N loads could increase a further 3-fold (Thayalakumaran *et al*., 2016) for the Moe River catchment, compared with more extensive dairy systems. While this estimate is for rainfed farming systems, intensification pressures would be similar to those in irrigated dairy: N application rates are assumed to be 300 kg N/ha/year for intensive systems

and 100-200 kg N/ha/year for current systems. This could triple N loads (up to 1350 t N/year). Extensification (little or no use of N fertilizer) could reduce N loads to about 30% (i.e. 110-140 t N/year) of current levels.

- Management of intensive systems through adoption of appropriate BMPs (nutrient budgeting, making full use of recycled nutrient opportunities, use of feedpads and appropriate effluent management) can reduce nutrient losses from intensive systems by approximately 30%, but this does not fully offset the N losses from intensification. The costs of BMP implementation are substantial, which is likely to reduce their attractiveness to irrigators. It is therefore concluded that management can only partially offset the impacts from dairy intensification from an N perspective. With this in mind, it is assumed that N intensification has three times the N loss of current more extensive dairy systems and the effectiveness of improved practice adoption is 30% (Thayalakumaran *et al*., 2016).
- For horticulture:
    - There is scant information on N application rates in horticulture and the effectiveness of BMPs. Table 5.4 (as reproduced from Roberts, 2017) suggests not markedly different figures for the effectiveness of BMPs in reducing N and P exports. Calculations for N application are based on a discussion with Pat Feeney, who suggested N application rates of 132 kg N/ha. Noel Jansz suggested 60-120 kg N/ha. These rates are at the lower end of dairy farm N application rates.
    - The science review (Chapter 4) cited the work of Bartley *et al*. (2010), who reported highest median TN concentrations from horticulture (~32,000 µg/l), cotton (~6,500 µg/l), bananas (~2,700 ug/l), grazing on modified pastures, including dairy (~2,200 µg/l) and sugar (~1,700 µg/l). Work by Davis *et al*. (1998) suggested that annual horticultural production can have very high nutrient export rates, higher than dairy (e.g. 200 vs 5.8 kg N/ha and 15.3 vs 6.4 kg P/ha).
- There is limited information on the relative N losses of dryland beef/sheep grazing, irrigated dairying, horticulture and forestry. We have used the above information as well as data from Fleming and Cox (2013) and have assumed that forest, grazing and urban/point have the same losses, whilst dairy and horticulture have three times the N losses of beef/sheep. Grayson (2006) shows irrigated land use has much higher N losses than forest or grazing. Based on the land use descriptions of Stott and Roberts (2013), we have assumed the relativities for N losses are:
    - Forest, rainfed grazing and other (rural residential, mining etc.) have similar N losses;
    - Rainfed dairy systems and less intensive dairy systems have double the N loss of rainfed grazing;
    - Less intensive irrigated dairy systems have the same N losses as rainfed dairy systems;
    - Current more intensive irrigated dairy systems have 1.5 times the N losses of rainfed dairy or less intensive irrigated dairies (3 times loss of rainfed grazing);
    - Future intensive dairy systems have 1.5 times the losses of current more intensive dairy systems (6 times loss of rainfed grazing);
    - Horticulture N losses are the same as current intensive dairies (3 times dryland grazing);
- Use 10 % effectiveness figures to estimate potential for N load reduction assuming current land use.
- Use 10% effectiveness figures to estimate potential for P load reduction assuming changed land use and current systems, with the exception of intensified dairy, as outlined previously (based on Thayalakumaran *et al*., 2016).

Table 5.4 Suggested effectiveness of best management practices in reducing nutrient and sediment exports (from Roberts, 2017).

	% effectiveness in reducing nutrient and sediment exports		
Management practice	**Total N**	**Total P**	**Sediment**
Conservation tillage (2013)	8	22	30
Conservation tillage (2009)	3	5	8
Cover crops – coastal plain	11-45	0-15	0-20
Grass buffer (2009) – inner coastal plain	46	42	56
Grass buffer (2009) – outer coastal plain well drained	31	45	60
Grass buffer (2009) – outer coastal plain poorly drained	56	39	52
Forest buffer (2009) - inner coastal plain	65	42	46
Forest buffer (2009) - outer coastal plain well drained	31	45	60
Forest buffer (2009) - outer coastal plain poorly drained	56	39	62
Off-stream watering with fencing	25	30	40
Off-stream watering without fencing	15	22	30
Wetland creation and restoration (2009) – coastal plain	25	50	15
Urban wetlands and wet ponds (2009)	20	45	60
Dry extended detention basins (2009)	20	20	60
Dry detention ponds/basins and hydrodynamic structures	5	10	20

5.5 Future land use patterns

WGCMA estimated current land use for relevant catchments, based on VLUIS land use mapping and local knowledge of current land uses. This information provided a basis for projecting changes in land use during the life of the Plan (Table 5.5).

The main projected changes are the shift from rainfed dairy to beef or sheep production, the expansion of irrigated vegetable production in the lowlands of the Lake Wellington catchment and the associated reduction in irrigated dairying in these areas.

5.6 Future changes in nutrient loads in to the Gippsland Lakes

Despite irrigators' uptake of BMPs for nutrient management, average P loads into Lake Wellington from its catchment under current land use is assumed to be 115 t P/y, as defined in the proposed SEPP (Waters). The target for P load reduction proposed SEPP (Waters) is 15 t P/y for the Lake Wellington catchment, half of which is to be achieved through this Plan.

Over the life of the Plan, it is projected that irrigated agricultural and horticultural production will expand in the catchment and that irrigated vegetable production will increasingly occupy land that is currently used for irrigated dairying (Table 5.5). This and further intensification of agricultural production are projected to l increase the baseline P load into Lake Wellington from about 115 t P/y to almost 117 t/ha.

Assuming full adoption of the management practices supported through this Plan's programs (at recommended locations and/or on suitable soil types), it should be possible to reduce P loading into

Lake Wellington to about 108 t P/y (Table 5.6), which is consistent with the proposed SEPP (Waters) target.

Projected land use changes are likely to lead to reduced nitrogen loadings in the catchment, despite the likely intensification of N use in dairying and some other land uses (Table 5.7). With full adoption of the practices supported by this Plan, N export to Lake Wellington is projected to decline by a further 20 t N/y. While this change is greater than the projected change in P loadings into the Lakes, it is much smaller in percentage terms (1.5% for N, compared with 7.7% for P).

Table 5.5 Current and projected future land use patterns in the Lake Wellington catchment

Sub-catchment land use areas (ha)	**Western Latrobe**		**Lower Latrobe**		**Upper Thomson-Macalister**		**Lower Thomson-Macalister**		**Avon/Perry**		**Longford-Loch Sport**		
Land uses	Current	Projected	Current	Projected	Current	Projected	Current	Projected	Current	Projected	Current	Projected	**Change**
Forest	109,940	109,940	68,716	68,716	172,082	172,082	68,429	68,429	104,313	104,313	30,909	30,909	0
Rainfed dairy	7,226		6,489		2,521		2,080		5291		4,173	4,173	-23,607
Dryland beef/sheep	113,204	120,075	101,665	108,154	39,491	42,012	32,585	34,665	82,886	88,177	66,692	66,692	23,252
Irrigated potatoes	3,550	3,905											355
Other irrigated horticulture - orchards, onions, vineyards	1,475	1,623											148
Other irrigated horticulture – other vegetables	-		817	1,634	-		523	5,000	1,575	5,000	450	900	9,169
Irrigated dairy (current intense)	3,285	3,285	12,124	11,716	67	67	22,820	20,582	12,583	10,871	1,289	1,289	-4,358
Irrigated dairy (current less intense)	-		-	-	-	-	-	-	-	-	-	-	-
Other (residential, mining, etc.)	17,536	17,388	20,196	19,787	6,638	6,638	4,628	2,389	2,219	506	18,072	17,622	-4,959
Total	**256,216**	**256,216**	**210,007**	**210,007**	**220,799**	**220,799**	**131,065**	**131,065**	**208,867**	**208,867**	**121,585**	**121,585**	0

Table 5.6 Estimates of change in phosphorus exports and loads with land use change and intensification of farming systems

Land uses	Current area (ha)	% total land use	P load assumption	% contribution to P load	Current P load	P load reduction	Projected change in land use (ha)	Future P load	P load with Plan & BMPs (t/y)	Change in P load (t/y) with Plan
Forest	554,389	48.3%	0.33	0.4	10.0	10.0	0	10.0	10.0	0.0
Rainfed dairy	27,780	2.4%	4	4.5	6.0	6.0	-23,607	0.9	0.9	0.0
Dryland beef/sheep	436,523	38.0%	1	1.1	23.76	23.8	23,252	25.0	25.0	0.0
Irrigated potatoes	3,550	0.31%	20	22.4	3.9	3.3	355	4.3	3.6	-0.6
Other irrigated horticulture - orchards, onions, vineyards	1,475	0.13%	20	22.4	1.6	1.4	148	1.8	1.5	-0.3
Other irrigated horticulture – other vegetables	3,365	0.3%	20	22.4	3.7	3.1	9,169	13.6	11.6	-2.0
Irrigated dairy (current intense)	52,168	4.5%	10	11.2	28.4	22.7	-4,358	26.0	20.8	-5.2
Irrigated dairy (current less intense)	-	0.0%	4	4.5	0.0	0.0	0	0.0	0.0	0.0
Other (residential, mining, etc.)	69,289	6.0%	10	11.2	37.7	37.7	-4,959	35.0	35.0	0.0
Total	**1,148,539**	**100%**	**89.33**	**100.0**	**115.0**	**108.0**	**0**	**116.6**	**108.4**	**-8.2**

Table 5.7 Estimates of change in nitrogen exports and loads with land use change and intensification of farming systems

Land uses	Current area (ha)	% total land use	N load assumption	% contribution to P load	Current N load	N load reduction	Projected change in land use (ha)	Future N load	N load with Plan & BMPs (t/y)	Change in N load (t/y) with Plan
Forest	554,389	48.3%	1	5.9	573	573	0	573	573	0.0
Rainfed dairy	27,780	2.4%	2	11.8	57	57	-23,607	9	9	0.0
Dryland beef/sheep	436,523	38.0%	1	5.9	451	451	23,252	475	475	0.0
Irrigated potatoes	3,550	0.31%	3	17.6	11	10	355	12	11	-1.2
Other irrigated horticulture - orchards, onions, vineyards	1,475	0.13%	3	17.6	5	4	148	5	5	-0.5
Other irrigated horticulture – other vegetables	3,365	0.3%	3	17.6	10	9	9,169	39	35	-3.9
Irrigated dairy (current intense)	52,168	4.5%	3	17.6	162	146	-4,358	148	133	-14.8
Irrigated dairy (current less intense)	-	0.0%	1	5.9	72	72	0	66	66	0.0
Other (residential, mining, etc.)	69,289	6.0%	1	5.9	573	573	-4,959	573	573	0.0
Total	**1,148,539**	**100%**	**17**	**100.0**	**1341**	**1322**	**0**	**1328**	**1307**	**-20.4**

Part B: Development of the Lake Wellington Land and Water Management Plan

6 Overview of the Plan development process

The Lake Wellington LWMP was developed in three main stages (Figure 6.1):

- *Stage 1 Review of the Macalister LWMP:* this stage extended between December 2016 and March 2017. A thorough review of the Macalister LWMP was undertaken (Turrall *et al.*, 2017) and achievements and key learnings identified (see Chapter 7). A discussion paper was prepared to offer initial thoughts on directions and priorities for the Lake Wellington LWMP.

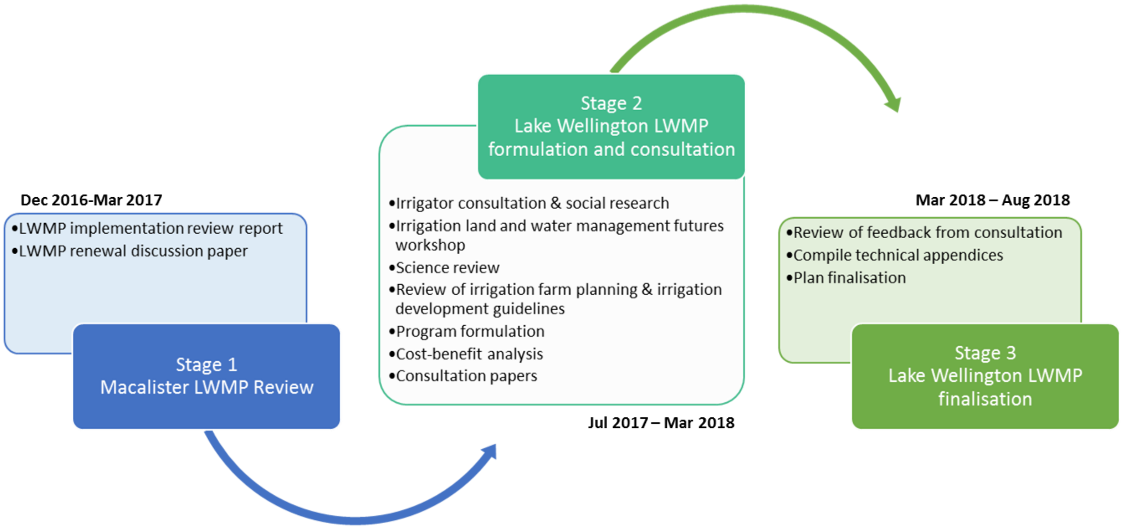


Figure 6.1 Overview of the process to develop the Lake Wellington Land and Water Management Plan

- *Stage 2 Lake Wellington LWMP formulation and consultation*. the second stage ran between June 2017 and March 2018. It built on lessons from the review of the Macalister LWMP and formulated content for the new Plan. It included:
  - Initial consultation - with irrigators and stakeholders from industry, local government and key State Government agencies (see Chapter 11) to understand their perspectives on current and future issues in irrigation land and water management and programs and priorities for the new Plan;
  - Futures thinking – a workshop with industry and public sector stakeholders to consider the risks and opportunities which the future may pose to irrigation land and water management and how these should be addressed by the Plan (see Chapter 8);
  - Science review – a review of the best available science regarding the sources, transport and impacts of nutrients and sediment reaching Lake Wellington and their management (see Chapter 4). This work was supplemented by analyses to assess the implications of projected changes in irrigated land and nutrient use on capacity to reduce phosphorus and nitrogen loadings into the Gippsland Lakes (Chapter 5);
  - Plan formulation – a series of workshops with a Technical Working Group (TWG) and a Stakeholder Advisory Group (SAG) formed to review the Macalister LWMP and guide the development of the Lake Wellington LWMP. The workshops developed the vision and objectives of the new Plan and guided the development and prioritisation of programs and actions and reviewed key contents of the Plan.
  - Consultation papers - two versions of a consultation paper on the Plan were produced. One version provided an overview of the Plan development process and details on the Plan's

vision, objectives, programs and adaptive management arrangements. This version was written for technical stakeholders and formed the basis for the community version of the Lake Wellington LWMP. The second version of the consultation paper was a four-page non-technical summary of the main consultation document.
Both versions of the consultation paper included questions to guide and encourage community and stakeholder feedback on the plan.
  - Exhibition and consultation – the consultation papers were widely circulated among irrigators and stakeholder groups and comment invited. Engagement activities were run to elicit feedback on the proposed Plan and its programs (see Chapter 11).
- *Stage 3 Lake Wellington LWMP finalisation:* the final stage involved the development of the two main Plan documents – a community summary, based on the main consultation paper, and this set of technical appendices. It built on the stage 2 work, stakeholder feedback on the consultation papers and guidance from the TWG and SAG.

7 Achievements of the Macalister Land and Water Management Plan

Stage 1 of the process to develop the Lake Wellington LWMP comprised a comprehensive review of implementation of its predecessor, the 2008 Macalister LWMP. The review considered the inputs to and achievements of the Macalister LWMP. A summary of the review's findings is given in the following sections.

7.1 Overall findings

The review of the Macalister LWMP found that total government funding for the Plan was about $8.7 million over its life. Total government investment was lower than hoped for, reflecting the generally withdrawal of Commonwealth funding for irrigation land and water management and decreased State investment between 2008-09 and 2014-15.

Commodity price cycles and seasonal conditions affected private investment in support of improved irrigation land and water management, particularly by dairy producers.

Despite the contraction in government funding, the review found that management action targets (MATs) for the Plan's key programs were largely achieved. This enabled the Plan to make a substantial contribution towards improving the sustainability of irrigation in the MID and reducing phosphorus exports to Lake Wellington, as required by the SEPP (Waters of Victoria). Phosphorus loads into Lake Wellington were below or near the SEPP target in 10 of 16 years from 2001.

The review found that there was a strong case – based on the appropriateness, effectiveness and likely legacy of the programs - for renewing the Macalister LWMP (as a Lake Wellington LWMP).

7.2 Farm planning program

The Macalister LWMP's farm planning program was responsible for delivering high priority farm planning MATs – particularly irrigation farm plans (IFPs; see Chapter 9). IFPs were prepared for approximately 14,500 ha of irrigated land during the life of the Plan, bringing the area with farm plans to over 36,000 ha (since 2001). Farm planning activities were considered to be instrumental in improving knowledge and adoption of efficient irrigation practices and taking advantages of opportunities afforded by connecting to SRW's upgraded water delivery infrastructure (under its MID2030 program).

The review found that collaboration among SRW, Agriculture Victoria and WGCMA was enhanced through participation in farm planning programs. Farm planning also helped to create a strong ethic of collaboration among irrigators and a commitment to minimise any environmental impacts from irrigation water use.

7.3 On-farm irrigation and drainage program

This program provided financial incentives for the uptake of more efficient irrigation systems and management practices, including flood to spray conversion, construction of re-use systems and implementation of high flow flood irrigation. About 70% of the overall implementation target for this program was achieved between 2008 and 2016. Re-use systems servicing 6,637 ha were constructed on 234 properties and flood to spray conversion took place on over 1,970 ha of land on 129 properties. Conversion to best practice surface irrigation (high flow flood irrigation with automation) was implemented on almost 700 ha of land across 27 properties.

Works supported by this program were estimated to deliver over 34,000 ML/y of water savings and retain an additional 132 tonnes of phosphorus on-farm each year[2].

The on-farm irrigation and drainage program is also responsible for the implementation of Regional Irrigation Development Guidelines (IDGs). These were found to play an important role in providing a clear pathway for new irrigation developments and minimising the off-site effects of these new developments (see Chapter 10). The approvals process for new developments is intended to provide a cost-effective mechanism to minimise future increases in the off-site effects of irrigation. IDG referrals were reported to have increased from two in 2013-14 to 12 in 2015-16.

Although funding for extension services declined towards the end of the Plan's implementation period, extension staff continued to deliver irrigation design and management advice across the MID.

The review found that there was good cooperation between SRW, Agriculture Victoria and Environment Protection Authority (EPA) around identification of issues with dairy effluent systems.

7.4 Floodplain and off-farm drainage program

Surface drainage is an important part of the overall strategy to reduce nutrients and salt flowing from the MID into Lake Wellington. Saline effluent from groundwater pumping is generally discharged into surface drains, which can restrict the re-use of drainage flows and can augment saline flows to the lake system, although this is not currently considered to be a serious problem.

The management of the constructed drainage system is primarily the responsibility of SRW. The main actions in this program were the maintenance of the constructed drainage network (which is funded by irrigators) and the transfer of drain-heads to irrigators to enable construction of reuse systems.

Some irrigators have licences to divert water from the surface drainage system for irrigation. However improved irrigation efficiencies and the development of reuse systems has meant that drainage flows have been reduced and about 25% of drainage diversion licences have been relinquished.

Drainage outside the MID and waterway restoration activities that were included in the Macalister LWMP are now managed under other WGCMA programs.

7.5 Groundwater program

The groundwater program primarily concerns management of the network of public groundwater pumps that provide sub-surface drainage for the MID and its environs. The sub-surface drainage (SSD) system is designed to protect land and infrastructure from the effects of irrigation-induced salinity and so improve economic and social prosperity.

The SSD system was initially established in the 1960s, with variations in the intervening years. Since 2006, the pumps have operated at 26% of full time capacity extracting an average of 2,400 ML of water and 9 tonnes of salt per year at a current annual operating cost of around $90,00. The pump network has not been operated at the intended intensity, in part due to the effects of the Millennium drought on water tables and private groundwater use.

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[2] Note that estimates of phosphorus retention on farm do not directly translate to reductions in phosphorus exports to Lake Wellington. These are also affected by rainfall run-off and the store of phosphorus within the drain network itself. The estimates are based on assumptions about the effectiveness of various practices. These may or may not be fully reliable for the MID.

7.6 Addressing nutrient discharges to the Gippsland Lakes program

This program provides for the monitoring of nutrient discharges to Lake Wellington from the MID. The review found that a new river-based monitoring network had been developed and used effectively to gather information on phosphorus loads entering and leaving the MID.

7.7 Resource condition targets

The Macalister LWMP set seven targets for change in resource condition. The review found that only one of these was directly addressed by programs funded under the Plan[3], namely:

- *RCT1:* By 2015, the maximum phosphorus load discharge from the drained area of the Macalister Irrigation Area is to be no greater than 25 tonnes per year;

RCT1 was significantly more ambitious than the corresponding SEPP (Waters of Victoria) target to reduce MID phosphorus discharges from 70 to 42 t/y. The review found that average phosphorus discharges from the MID (2000-01 to 2015-16) were 50 t/y and that the phosphorus load discharge target was met for 10 years of this 15-year period. Phosphorus exports varied significantly between years and increased with annual rainfall.

An aspirational target of the West Gippsland Salinity Management Plan (superseded by the Macalister LWMP) was to reduce land salinity by 50% from 2003 levels in areas of irrigation induced salinity. The review concluded that it was not possible to determine if this target had been achieved, but that the management programs as a whole, and the public groundwater pumping program in particular, continue to adequately manage water table levels, waterlogging and land salinity across the MID.

[3] The remaining targets were considered to be better aligned with other programs delivered under the West Gippsland Regional Catchment Strategy.

8 Future changes, challenges and opportunities

8.1 Overview

The Lake Wellington LWMP must both address current concerns for irrigation land and water management and anticipate and address risks and opportunities which may emerge during and beyond its life. As part of the Plan development process, a scenario analysis workshop was held with technical and industry stakeholders to consider the key factors which influence irrigation land and water management in the Lake Wellington catchment, how these may play out during and beyond the life of the new Plan and what this may mean for the Plan itself. Three scenarios were developed, based on workshop discussions. These characterise some plausible alternative futures for Lake Wellington catchment.

Scenario analysis discussions were used in formulating the program logic for the LWMP, as well as its aspirational objectives and long term outcomes (Chapter 15). The program logic (Figure 15.2) helps to provide "line of sight" between what the Plan and its programs do and produce and the outcomes they are intended to accomplish. It also helps in the articulation of assumptions which underpin programs. The program logic provided the foundation for the development of the programs and activities which, after further stakeholder consultation, has been documented in the new Plan.

8.2 Scenario analysis workshop

On Tuesday August 15th, 2017, a scenario analysis workshop was held with 16 stakeholders to consider influences on future irrigation land and water management in the Lake Wellington catchment and how the new LWMP might respond effectively to foreseeable and unforeseen changes.

Workshop discussions considered what might happen over the life of the new LWMP and in subsequent decades, focusing on issues of critical influence and uncertainty. Discussions centred on:

- Trends and drivers that will shape the future;
- Influential and uncertain factors shaping the future;
- Potential shocks to the system associated with irrigation land and water management in the Lake Wellington catchment;
- Potential scenarios born out of the critical change drivers;
- Opportunities, risks and the role of the new Plan.

8.3 Trends and change drivers

Much changed during the almost 10-year life of the Macalister LWMP. Some of the key changes, trends and influences on the catchment and irrigation land and water management that were raised by participants in the irrigation futures workshop are described below and summarised in Figure 8.1.

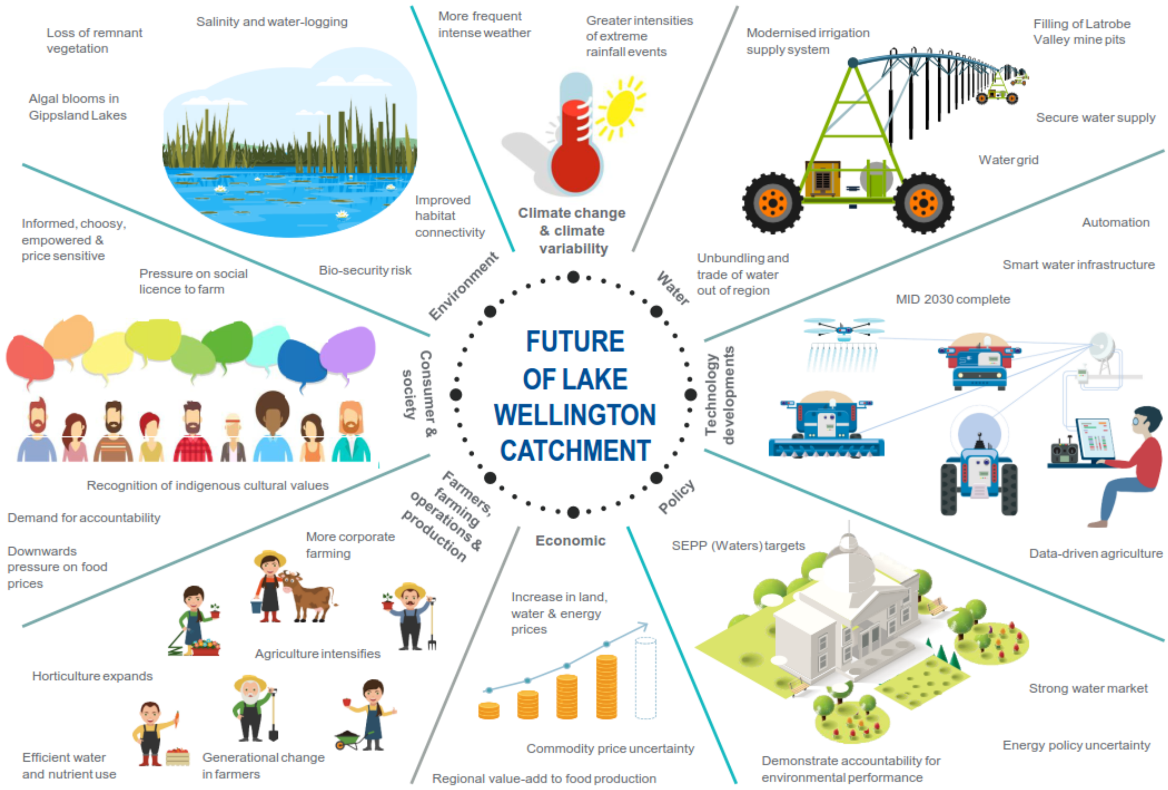

Figure 8.1 Some indicative trends, drivers and some potential futures for the Lake Wellington catchment

8.3.1 Farmers and farming operations

The growing regional presence of corporate and amalgamated farms is symptomatic of changes which are occurring globally. This pattern is expected to continue, which potential impacts including: reductions in the number of farm owners; larger farms; increasing land prices; wealth inequality and associated community tensions.

While the farming population (like the general community) is aging, some workshop participants expected that this trend would reverse as older dairy farmers exit the industry and younger dairy farmers and horticultural producers enter the region. This will mean a loss of “corporate memory” from the catchment, but may provide a more technologically knowledgeable group, with different mindsets and perspectives.

Farmers are also experiencing a frustrating lack of access to technically knowledgeable private and public sector farm production and irrigation land and water management advisers – particularly for the dairy industry.

Workshop participants identified that farmers from outside the catchment are looking to ‘future-proof’ their operations by purchasing land within the Lake Wellington catchment (particularly in or near the MID). This is seen by some as ‘squeezing out’ local farmers by raising resources prices. In other cases, it is leading to an expansion in the total irrigated area.

Farm debt has been increasing and is expected to continue to do so.

Reflecting external trends, foreign investment in land has increased. This pattern may continue, with China a potential source of international investment.

8.3.2 Changes in farm production

The global trend of increasing intensity of agricultural land use is evident in the Lake Wellington catchment. This involves greater inputs of chemicals, capital, technology and (in some cases) labour. The influx of horticulture to the catchment is one expression of this trend. Intensification of agricultural land use is expected to continue through the life of the Lake Wellington LWMP.

A combination of low milk prices in recent years and high(er) profitability of vegetable growing has contributed to the observed transition from dairy and beef to vegetable production in places within the catchment. This is expected to continue, with parts of the dairy industry in the region anticipated to relocate. It is also expected that with changes in climate, dryland cropping to provide supplementary fodder for dairying in the region will also increase.

Developments and redevelopments of farms and expansion of irrigated land area are expected to continue, increasing land and water demands. Dairy and drainage effluent continue to be important issues, with potential to affect the health of waterways and the Gippsland Lakes.

The analyses in Chapter 5 suggest that notwithstanding potential changes in land and nutrient use in irrigated agriculture, it should be possible to achieve the proposed SEPP (Waters) phosphorus load reduction target for the Plan and also to reduce nitrogen exports.

8.3.3 Climate variability and climate change

Major drought and flood events have driven changes in agriculture, irrigation practice and water resource regulation the world over. Whilst the Lake Wellington catchment area is exposed to droughts, floods and fires (in the headwaters), the region's climate is (at least) perceived to be less variable and uncertain than in many competitor regions in Australia. Farmers from elsewhere are buying into the region to reduce their exposure to climate risks.

Climate change is projected to result in a drier climate overall, with more intense drought events, more severe flooding and, possibly, more severe bushfire events in the headwater catchments. This has potential to affect infrastructure, water security, agricultural yields and profitability, natural environments and social conditions.

Climate change may also increase exposure to biosecurity risks, both from weeds and diseases. It may also affect old remnant vegetation, waterways and the Gippsland Lakes.

8.3.4 Environmental changes

Water quality and periodic algal blooms are key issues for Lake Wellington catchment and the remainder of the Gippsland Lakes. Poor water quality in rivers and the Gippsland Lakes is influenced by multiple factors, including agricultural run-off and floods (see Chapter 4).

While some revegetation has taken place, patches of remnant vegetation are often declining and the habitat provided by old trees is being lost.

8.3.5 Developments in technology

Technological developments have contributed to the modernisation of farming in the catchment. Implementation of the Macalister LWMP has contributed to the adoption of more sustainable irrigation practices. Irrigation efficiency has increased as a result of the adoption of efficient irrigation systems, improved farm layout and the development of reuse systems. As a result, there are fewer drainage discharges.

MID2030 is expected to continue to complement Plan efforts to improve irrigation water use efficiency and reduce drainage discharges. Irrigation system improvements have potential to support further horticultural development within the region.

A key barrier to the uptake of improved irrigation practice is the high and rising cost of electricity, low quality of supply and lack of three phase power. This may be increasingly compensated for in the uptake of solar power and other local-scale renewable energy opportunities (e.g. dairy waste to energy conversion).

Future developments in technology may present opportunities in reducing input costs, generating renewable energy, managing environmental impacts, improving decision-making, production and profit.

8.3.6 Changes in consumer preferences

Changing consumer preferences may also influence the farming industry's response to environmental challenges. Informed, choosy and empowered consumers are demanding certain ethics, provenance, sustainability and health attributes from agriculture producers (in some sectors). Fortunately, the Gippsland region and Australia as a whole, is renowned for premium products and the proximity to Asia and the trend of an expanding middle class mean more opportunities.

However, the growing awareness of the environmental impact of agriculture – related to land, vegetation, water, greenhouse gases - will likely increase pressure on farmers to improve practices and monitor and report on their impacts. Technology will play an increasing role in data collection and dissemination, as perception and reputation will become increasingly important.

8.3.7 Input and commodity prices

As demand for scarce resources increase, the price of water, land and energy have and most likely will continue to increase. This may affect the financial viability of production and lead to changes in infrastructure and crop selection. The effect of increasing input costs is exacerbated by the currently low return from dairying.

8.3.8 Regulatory change

Changes in water regulation are expected, particularly with the proposed SEPP (Waters). The catchment's water market is emerging and is likely to strengthen over the life of the new Plan. This could lead to the loss of irrigation water from the catchment (via unbundling and the possible development of a State water grid[4]) or (more likely) to the movement of irrigation water within the catchment.

Instability in energy policy in Australia contributes to high and rising prices and lack of investment in new energy generation capacity.

8.3.9 Social licence for agriculture

Growing population, expanding cities and regional centres, reduced water availability and rising resource prices will likely increase competition for land and water in the region, leading to potential further urban encroachment onto agricultural land and possibly less water available for irrigation.

While the social licence of agriculture is currently considered to be strong, urban encroachment, competition for water and any adverse environmental stories relating to agriculture (e.g. a major algal bloom in the Gippsland Lakes – if it was linked to agriculture) could jeopardise this. Accountability for environmental performance will increase, likely driven by regulators and customers.

[44] Note that a State water grid linking to Lake Wellington catchment was suggested as a possibility by some workshop participants. It does not reflect current thinking or planning within the Victorian water sector.

8.4 Potential future shocks

The Plan must consider both the trends which may incrementally drive change over time and potential "one-off" shocks that may also occur (e.g. Table 8.1).

Table 8.1 Potential shocks which may affect irrigation land and water management in the Lake Wellington catchment

	Lake Wellington catchment	*External to Lake Wellington catchment*
During life of Plan	Protracted drought Major flood event Mega-fire in catchment headwaters Earthquakes (impacting Glenmaggie) Dam bursts (flooding damage; water supply interruption) Contamination of groundwater/ surface water (water supply quality) Biosecurity incident – with new pests, weeds or diseases Commodity prices crash Algal blooms in Gippsland Lakes Loss of major dairy producers/processors	War on Korean peninsula New global financial crisis Major biosecurity crises Terrorism Dysfunction of Australian government Disruption to global economic and environmental agreements
Beyond life of Plan	The above and… Regulation of nitrogen	The above and… Geopolitical instability Fracturing of global trade Civil unrest

8.5 Drivers of future change

After much discussion, workshop participants agreed that the following (Table 8.2) summarised the most influential and uncertain factors driving change into and through the life of the new Plan. These were key to framing the potential future scenarios in the workshop and must be addressed by the new Plan.

Table 8.2 Most influential and uncertain drivers of future change

Most influential	*Most uncertain*
1. Commodity prices	1. Climate
2. Water availability, quality and quantity	2. Water availability, quality and quantity
3. Consumer preferences	3. Global market conditions
4. Governance	4. Technology change
5. Regulation	5. Political stability
6. Biosecurity	
7. Social licence for farming	
8. Urbanisation / migration	

8.6 Potential future scenarios

Building on the trends and change drivers, the scenario analysis workshop explored what the future might look like. Three scenarios were developed: a business as usual (BAU) scenario (reflecting a continuation of more likely changes), and two scenarios indicating much better and much worse conditions for irrigation. These scenarios were over the life of the new Plan and beyond it and are summarised in Table 8.3.

The scenarios represent workshop participants' ideas about what the future may look like. The Plan accounts for some of the changes, but is not necessarily advocating for or looking to drive any of them.

8.7 Risks, opportunities and key actions for the Lake Wellington LWMP Renewal

In light of potential shocks and future scenarios, workshop participants were invited to consider the risks and opportunities of the future. Discussions focused on opportunities to attain the "much better" scenario, and associated risks that could prevent success or lead to the "much worse" scenario. Some events present both risks and opportunities, for example, the risk that energy prices will increase to unaffordable levels increases the costs of irrigation and drives down profits. However, it also incentivises and drives more efficient energy use and uptake of energy saving and renewable energy technologies. Key actions were derived which the renewal of the Lake Wellington LWMP ought to consider (Table 8.4).

Table 8.3 Potential future scenarios for irrigation land and water management in Lake Wellington catchment

		Much worse	Business-as-usual	Much better
Social	During Plan	Pressures cause dairy farmers to lose money or be locked in because of low land prices. Some will exit the industry and tensions will arise between dairy and horticulture farmers. Chemical usage causes tension. Youth are lost from the region to cities and economic stresses cause mental health issues. Biosecurity scares and negative and poorly managed environmental impacts (esp. algal blooms) results in loss of social licence of agriculture.	Increased un- or underemployment in towns, meaning agriculture will have an increasing importance for employment. Towns will continue to support farms but peri-urban development will increase social licence pressure on agriculture. The region will have a more socially and culturally diverse community. Knowledge will be lost as older irrigators retire. More technical specialists will come in. Farms are fewer but larger. Consumers demand clean and green produce.	Younger people are fully engaged/ informed/ willing to get into agriculture, supporting generational change in farming. A more collaborative approach to farming develops with better relationships amongst producers (including dairy-horticulture), between producers and consumers and producers and agencies. Towns are highly supportive of agriculture and agriculture contributes significantly to employment. Family farming remains strong. The region is prosperous and the community is resilient.
	Beyond Plan	Social pressures from earlier have been exacerbated and the area is neither prosperous and/or contains very little agriculture industry. Towns have high unemployment due to poor adaptation of agriculture, lack of resources and economic diversification. Social distress high with low morale.	Fewer people live on farms and more people live in towns – in part due to decentralisation from cities. Industry hubs developing. Growing role for technical specialists and advisers in region. Inequality between employed/business owners and un- or underemployed grows. Growing understanding between consumers and producers.	The region is prosperous. Consumer insights are well-understood and responded to by producers. An ingrained mentality of thinking locally and acting globally.
Technological	During Plan	On-farm investment reduces. Agriculture is accounted in carbon pricing. Changes in weather and technology cause disruption or obsolescence of existing irrigation technologies. New technology is too expensive to adopt, up-take is low and practices fall behind “best practice” and are unsustainable. Agriculture continues to intensity, with poor management of off-site impacts.	Increase in intensity of agriculture (more horticulture, more intense dairying, greater use of supplementary feed, nutrients and pesticides) and concurrent relocation of parts of dairy industry. Dairy farmers will have off-site dry farms for fodder production. Changes in on-farm irrigation practices: modernisation of infrastructure and delivery; reduced losses. Increasing adoption of automation and associated implications on employment. Less investment and reduced R&D. Effluent management and waste-to-energy technologies increase in use and alternative energy supplies will be established. Alternative crops in use. Modernisation of MID finalised, contributing to increased water security.	Information revolution drives improved decision making via real time water data/efficiency, increased use of apps and better weather forecasting accuracy. Technologies also allow better tracking of production and clarity for reporting. Large increases in local and on-farm energy generation.

		Much worse	Business-as-usual	Much better
	Beyond Plan	Connection to a Victorian water grid leads to water used for agriculture being bought or taken up for purposes other than agriculture.	Automation is the norm in irrigation and irrigated production. Reliance on big data to inform management – which is enabled by the NBN. Advances in waste management/minimisation tech / bio-digesters increases renewable energy generation. Reduced gene pool in crops and pastures.	Fewer people on-farms due to technologies. Fully renewable energy sources. Production is streamlined and technology is fully integrated into agricultural practice. Protected cropping and vertical farming supports a growing population.
Environmental	During Plan	Climate variability causes the area to become relatively dry and much less productive. Sediment and nutrient loss during periodic big flood events cause damage to the health of waterways, soil and Gippsland Lakes. Fire-flood combinations cause damage to Lake Glenmaggie and downstream towns and water infrastructure and towns, causing disruptions, social distress and resource pressures. High incidences of algal blooms in the Lakes. Biosecurity hazard events occur, harming environment, people, and agricultural produce	Stable water security but variable availability/supply. This means rising competition for water from other sectors, increase in dryland cropping and more uptake of fodder cropping. Increased incidences of wildfire in catchments from drier weather. Continued salinization of estuaries and Lakes but increases in riparian / wetland fenced/revegetated areas. A greater understanding of contaminant hotspots will develop but still uncertainty around unknown effects of some chemicals in use. Algal blooms to occur periodically in Lakes and on-farm. Biosecurity hazard events possible. More needed to provide fresh water to environment. Water utilised for mine rehabilitation with uncertain effects.	Maturation of revegetation works results in improved riparian/wetland conditions. Environmental water benefits for wetlands. Water and nutrient use efficiency has increased. Landholders are more aware of and engaged in environmental programs (particularly with younger farmers).
	Beyond Plan	Large contamination incident because of poor quality chemicals. The health of waterways and the Gippsland Lakes deteriorates further. Biosecurity hazards lead to loss or significant contraction of horticulture / dairy. Land is bare, over-used and exposed to erosion.	Increasing climate variability. A second opening of the Gippsland Lakes is formed as a result of sea level rise. Reduced water availability, smarter water collection and use of different water sources.	Distributed localised energy production that uses waste and is renewable – closed cycle. Waste recycling / repurposing. Sediment/nutrients are managed sustainably and are not lost off-farm (except in products). Producers understand environmental values and support environmental programs as the norm.

		Much worse	Business-as-usual	Much better
Economic	During Plan	Dairy prices crash again and the industry becomes unviable financially. Many participants exit the industry. Energy prices increase, leading to a return to low energy irrigation. Farm debts increase as profits decline and costs increase. Water is owned by investors and prices increase. Towns are in economic distress. Uncertainty about commodity prices increases.	Horticulture expands around MID, largely at the expense of dairy farming. Horticulture processing and transport hubs established. Increases in water and energy prices consistent with reducing / unstable supply and increasing demand. Changes in infrastructure and crop selection. A strong water market emerges with increased trade but water transfer out of catchment contributes to reduce access to water. Greater uncertainties around commodity prices.	Whole of life cycle costs incorporated in production. Projects (environmental/tech/social) are crowd-funded. Clustering drives sharing of resources (e.g. equipment, materials) or use of contractors. Energy prices stabilise. More Free Trade Agreements (FTAs) enable secure and easy access to global markets, particularly Asia.
	Beyond Plan	Little economic diversification and lack of agriculture industries lead to economic distress.	Decline in dairy and rise in vegetable production. Increased efficiency in irrigation water use (farm and system level). Cost/price squeeze on margins continues. Increased demand for dairy/vegetables driven by domestic and international population growth. Diversification opportunities arise from Latrobe Valley Renewal Plan	Well connected markets. Prosperous industries that are paid well. Markets for payments for ecosystem services (PES) operate. Sustainable increase in agritourism.
Political & Legal	During Plan	Business environment is highly regulated creating barriers. No government support for agriculture R&D and reduced infrastructure/program investment by State and Commonwealth governments. Curtailed access to natural disaster funding and recovery is slow.	'Hopscotch' of conservative / non-conservative politics with implications for environmental policy. More environmental reporting by licence holders and accountability for environmental performance (consumer demands). EPA empowered to act on environmental protection and apply regulatory pressure to farms with poor environmental performance. New SEPP (Waters) to influence irrigation land and water management. Higher stringency of water quality targets.	Bipartisan climate change policy. Clear and well understood / effective regulation. Improved transparency for production. Increased funding for environmental programs
	Beyond Plan		Regulated society: 'regulator knows best' attitude. Electoral reform. Global/Asian impacts on sector. Rights for a healthy environment in place. Policy "revolution" regarding waste, energy and water.	Legal enforcement and serious consequences for polluters. Greater integrity in government leaders with social credentials

Table 8.4 Risks, opportunities and potential actions for the Lake Wellington catchment

Risks		Opportunities	
What?	Why?	What?	Why?
During Plan			
Poor access to internet by choice/infrastructure limits.	Limits exposure to and uptake of technology; assumptions made that messages are communicated however farmers are left out/alienated. May lead to cultural separation.	Big data / real-time information; water management and communication technologies.	Better informed decision making and improved efficiency.
Technology reliance and access to large amounts of information	Lack of useful appropriate data synthesis capabilities can lead to 'analysis paralysis' under excessive information.	Widespread internet access and data capturing/storage technologies.	Better connectivity and technology usage; ability to capture and share knowledge (especially knowledge held by older farmers).
Extended drought periods.	Profitability reduction, capital depletion.	Best practice uptake and communication of farmer achievement enhance brand / trust / local provenance.	Better operations and information transparency improves the sector's reputation.
Reduction in government funding for sustainable agriculture.	Reduced adoption of sustainable practices.	Dry conditions.	Drives practice change towards greater irrigation efficiency.
Increases in energy prices and no three phase power.	Increased costs of irrigation/production (but drives efficient use).	Latrobe Valley attracts government investment.	Source of people / funds / programmes for sustainable agriculture.
Disconnect between urban and farm (changes, roads, urban encroachment) and agencies and farms.	Loss of social licence; increase in regulatory pressure; increase in EPA reporting.	Horticulture industry expands.	Provides local employment but also presents risks.
Dairy industry a price taker.	Dairy industry exits area.	Corporate farms.	This group may have influence and set high standards. It is more exposed to regulation and is sensitive to sustainability when investing. Greater access to technology.
Horticulture industry expands.	Increase in sediment and nutrient losses.	Recognise cultural values of water (Gunaikurnai).	Work with Gunaikurnai to determine culturally appropriate way to incorporate their values and also learn of some sustainable practices (important to be done sincerely). Also a SEPP (Waters of Victoria) beneficial use.
Limited on-farm re-use.	Limits flexibility to manage water variability.	A more open-minded, enthusiastic and socially and environmentally conscious younger generation.	To tap into younger farmers' values/mind set and leverage their motivation
Horticulture a fragment industry.	Lack of collaboration leads to poor adaptation of environmentally sustainable practices and higher biosecurity risks.		
Young/early adopters are relied upon too heavily but are not engaged properly.	Young/adopters do not 'revolutionise industry' as desired		
Some members of older generation unwilling to adapt to modern/sustainable practices.	Continued use of practices which are sub-BMP		

Risks		**Opportunities**	
What?	Why?	What?	Why?
Complacency: at farm-level and also agencies/ shire councils.	Inaction in response to change.		'readiness' to take on new information and adopt sustainable technologies and management practices.
Lack of collaboration between agencies.	Leads to silos and uncoordinated action; slow, expensive and less effective.	Continued environmental improvement.	Better understanding of adverse impacts; improves reputation of sector, environment and allows for tourism.
BMP standards are not available / gap in education/qualifications of administrators/policy-makers.	Leadership is ill-informed or does not have the right connections with those most affected by decisions. Poor decision making that does not align with reality.	Waste-to-energy.	Reduces waste and a source of energy.
		Further on-farm investments and modernised MID.	Complementary works that increase profits and savings.
		Greater understanding of consumer preferences improving predictability of markets and reducing waste.	Less wastage, better decisions about crops.
		Greater clarity around regulatory regulation and consumer standards.	Greater compliance with regulation (better understanding and acceptance) Costs are better incorporated into production.

Beyond the life of the Plan			
Increased scrutiny on farms (on welfare, environment impact, biosecurity risks); regulatory pressure.	Complaints; pressure on water corporations for drinking water; lack of confidence in water quality supplies and loss of agriculture's social licence.	Corporate farms are consistent with family farms	Greater cohesion of sector.
Shocks to system push farmers out of catchment.	Contraction of agriculture industry in catchment.	Greater collaboration and education/ awareness: agencies (incl. Vic Roads and shire councils) have consistent messaging and involve decision-makers	Better decision making and more efficient governance.
Sediment and nutrients from Thorpdale area.	Environmental impacts.	Latrobe Renewal Plan	Investment opportunities in sustainable agriculture and economic and energy security to the region.

Potential actions
Identify implications of energy insecurity and how this will drive change → waste-to-energy opportunities in region; technology adoption and expansion of irrigation impeded by energy insecurity.
Facilitate whole-of-farm changes through financial means other than grants.
Consider strategic nutrient intercept options.
Ensure fact-based decision making and continuous improvement drives management.
Consider variety of approaches, formats and opportunities to interact with farmers of all ages and improve communication between farmer and government agencies / shire councils (test messages with various organisations to ensure consistency and buy-in; continue MIDSIG forum).
Facilitate social connections between farmers and open discussions and sharing of sustainable practices; foster a 'sustainable, cohesive and prosperous' farming community (regular meetings between agencies and farmers).
Facilitate the connection of those on farms with those in towns/cities to ensure social licence of agriculture is sustained.
Engage with younger farmers to see how they want to be supported (e.g. on farm demos; cross-sectoral farmer groups).
Facilitate education of farmers: • Identification and development of young talent; run workshops on using new agri technologies; • Get research results on to farm; provide access to modelling results and case studies; • On regulation and compliance (potential to use Macalister Demonstration Farm); • On consumer trends and demands.
Identify other opportunities to improve land and water conditions such as irrigating east into Avon River catchment.

9 *Irrigation farm planning approach*

9.1 Overview

This paper describes a renewed approach to irrigation whole farm planning which is to be delivered as part of the implementation of the Lake Wellington LWMP. The concepts described draw on reviews of farm planning in the Goulburn Murray Irrigation District (GMID) and MID (Johnson and Wood, 2014; RMCG, 2017, respectively), as well as a workshop with irrigation farm planning providers and advisers working within the MID.

9.2 Whole farm and irrigation farm planning

Whole farm planning is strategic planning tool for farming properties. It is used in a wide variety of settings to help landholders make decisions about the management of their natural resources and environments. As generally applied, whole farm planning is an encompassing process, whose scope extends beyond the property's natural resource base to include tactics and actions that address financial, marketing, environmental and/or personal goals (SKM, 2011).

Whole farm plans (WFPs) typically identify existing property assets, including natural assets (e.g. native vegetation, waterways), cultural values (e.g. Indigenous heritage sites), infrastructure (e.g. tracks, fences, water supplies, irrigation pipes or channels, drainage features, buildings, planted shelterbelts), soil types and land classes. These features and any management constraints (e.g. saline or flood-prone areas, weed infestations) are typically represented via digital or hard copy plans or maps. WFPs may also identify proposed changes on the property, including to environmental management, land use, infrastructure and its layout, farm enterprises and/or management practices. They may be accompanied by risk assessments and planned and budgeted works implementation programs.

In most settings, WFPs are developed as part of a capacity building or training process (SKM, 2011), in which a group of participants are taken through a structured process to equip them with the essential insights, data and tools. Irrigation farm plans are not typically developed in this way. While they may have a similar overall scope to conventional WFPs, they require specialist survey and irrigation engineering inputs. As a result, they are generally developed for the land manager by a specialist farm planning consultant. Capacity building remains a feature of the process, but it has not traditionally been as explicit as it is with conventional whole farm planning.

In Victoria, whole farm and irrigation farm planning activities are typically complemented with access to on-going by agency or CMA advisory or extension services and, in some cases, access to financial incentives or other forms of cost-sharing (SKM, 2011).

9.3 Irrigation farm planning under the Macalister Land and Water Management Plan

The Macalister LWMP recognised the critical first step that farm planning plays in creating potential economic and environmental opportunities from improved farm layout and management. It also raised the prospect of a new farm planning model which was proposed to apply to both irrigation and dryland agricultural areas and encompass all industries.

However, under the Plan's implementation arrangements, incentives for farm planning focused on areas of the MID which had been irrigated in the previous five years. Priority subsequently applied to properties linked to the SRW outlet modernisation program (Johnson and Wood 2014), which formed part of the MID2030 initiative.

9.4 Reviews of irrigation farm planning

Two reviews of irrigation farm planning have been undertaken in recent years: Johnson and Wood (2014) reviewed irrigation farm planning as it applied to both the GMID and MID; and RMCG (2017) undertook a further review of irrigation farm planning for the GMID.

Johnson and Wood (2014) proposed a farm planning program which connected irrigators to modernised advisory services and on-line resources. The WFP framework was to help align practices and farm design with industry and government recommendations and regulatory requirements, as well as complement any applicable regional and market environmental compliance reporting. Farm planning was to be supported by access to targeted financial incentives.

RMCG (2017) subsequently devised a two-step, whole-of-property farm planning approach for the GMID:

- A Property Concept Plan that would cover the essential features of the whole farm plan including a minimum set of natural resource management issues (which are the subject of referrals by local government), such as: excess rainfall run-off, native vegetation protection and protection and management of Aboriginal cultural heritage;
- A traditional irrigation survey and design plan which features any proposed modifications to farm layout, drainage or other infrastructure in the areas to be upgraded.

9.5 Framework for farm planning

The Lake Wellington catchment farm planning framework is based on two principles:

- H*olistic*: farm plans should reflect a long-term planning approach that addresses whole-of-farm and broader catchment objectives. Farm plans should address:
  - Longer-term objectives and/or succession processes for the farm business and operators;
  - Shorter-term operational requirements of the irrigation, drainage and effluent management systems;
  - Any on-farm biodiversity, waterway, shelter or surface water drainage features and/or heritage values;
  - Opportunities to integrate farm infrastructure and the management of environmental and heritage features across property boundaries;
  - Risks and implications of farm layout and management for water quality and flows in local waterways and the Gippsland Lakes.
- *Flexible:* the farm planning framework must be able to complement extension service provision, incentives delivery and on-farm actions (largely) regardless of the investment priorities at any particular time. Changes in government policy and priorities over time may alter the relative emphasis on particular environmental risk factors and hence the advisory and cost share support provided under land and water management programs.

The farm planning framework must be adaptive and allow for shifting emphasis between agricultural system types (e.g. dairy or horticultural land uses) and risk issues (e.g. nutrient exports, erosion and sediment movement, flooding and salinity management, energy costs).

The farm plans generated through this process should be reviewed periodically and their appropriateness and effectiveness tested. They should then be revised accordingly; following a conventional *Plan-Do-Review* planning cycle.

Figure 9.1 conceptualises the proposed farm planning framework, which would be applicable to contiguous (or near-contiguous) areas of any property or farm holdings which have water access or take and use licences.

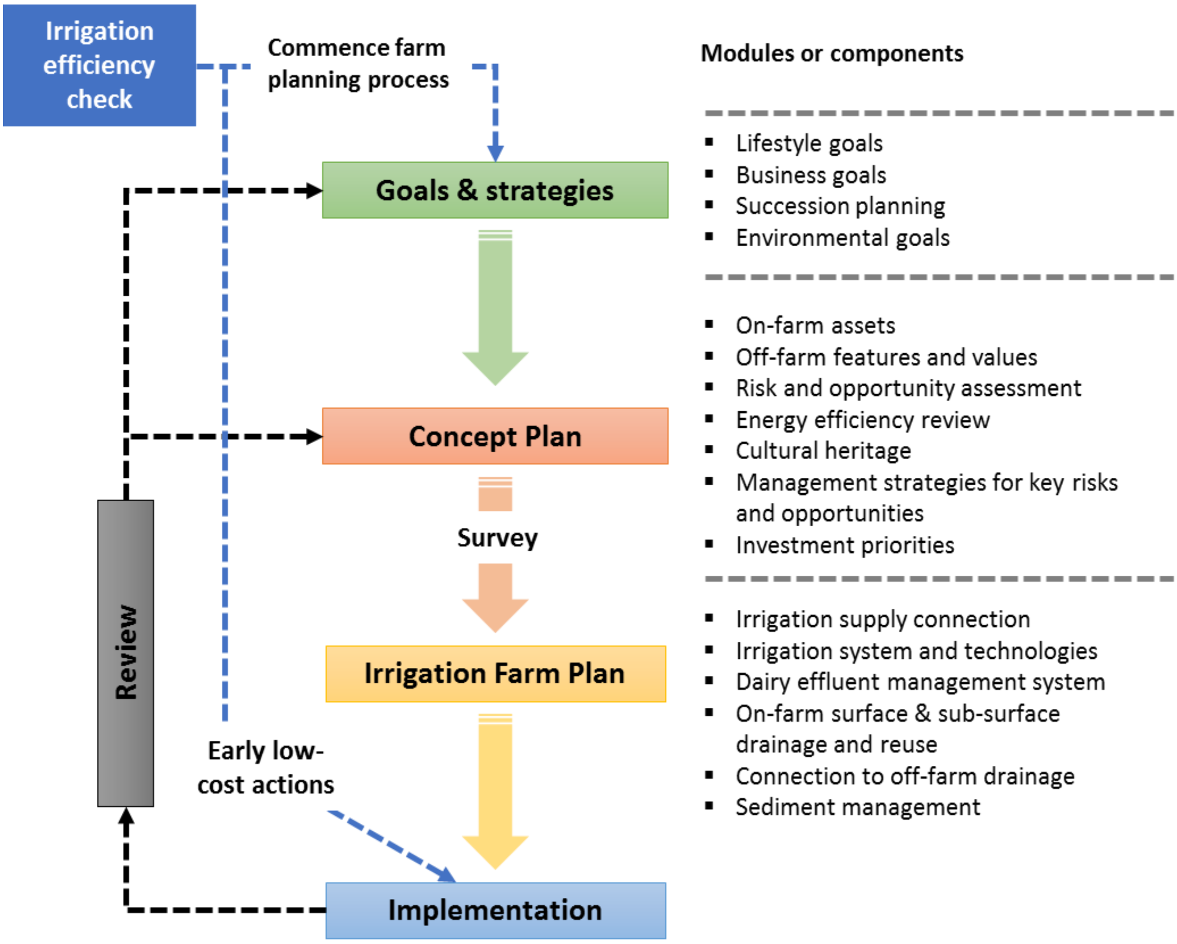

Figure 9.1 Lake Wellington Land and Water Management Plan irrigation farm planning framework

Key elements for the farm planning framework include:

- *Irrigation efficiency check:* an Agriculture Victoria extension office will undertake a check on the efficiency of current irrigation systems and (for dairy operations) the management and operation of dairy effluent management systems. A brief report will advise on low cost, early actions to address key risks and/or opportunities.
- *Goals and strategies:* the farm plan should be driven by a clear sense of the values, aspirations and goals of the farm business operators. These may or may not be documented before the farm planning process commences. If not, the farm planning "journey" should commence with a "process" or discussion to clarify and document these.
  The Plan will fund the development or adaptation of farm business planning tools to assist Agriculture Victoria extension officers in working with irrigators to define and understand goals and objectives to help set directions for the concept plan and irrigation farm plan.
- *Concept Plan:* this has been adapted from the model proposed by RMCG (2017) for the GMID. It incorporates map and/or text-based information on:
  - On-farm assets – these include all key built, natural and cultural assets, such as sheds, fences, laneways, feed pads, effluent ponds, native vegetation, shelterbelts, waterways and wetlands and aboriginal heritage sites etc.
  - Off-farm features – nearby off-farm features which are relevant to environmental or cultural values or farming or irrigation operations would be identified and mapped. These could

  include irrigation water supply infrastructure, surface and/or sub-surface drainage infrastructure, remnant native vegetation to which farm vegetation is or could be linked, as well as waterways and wetlands which may connect to the property or whose condition may be influenced by any off farm movement of water, nutrients or sediment.
  - Risk assessment – which would identify and assess risks to the irrigators' values and goals, as specified for the farm plan, as well as to on and off-farm assets. These might arise from aspects of the farming operations (e.g. irrigation, dairy effluent management, fertiliser use, cultivation, stock access to waterways) or the external environment (e.g. floods, drought, biosecurity risks). Responses to key risks would be reflected in the irrigation design and farm operations. Locations of key risk areas (e.g. critical areas for off-farm nutrient or sediment losses) may be depicted on the map-based farm plan.

  The concept plan will then be used to inform how farm layout and management (etc.) can address key risks to both on and off-farm assets and values. It will incorporate risk mitigation strategies which address, as appropriate: nutrient management, protection of remnant vegetation and any nearby wetlands or waterways, maintenance of cultural heritage values, flooding management, provision of shelter and/or salinity risk mitigation. These strategies may be implemented through engineering works (as per the IFP) and adoption of "best" or recommended management practices.

  For dairy producers, the concept plan could incorporate an *Effluent Use Plan.* These are developed AgVic's dairy team and consider the distribution of effluent and results of soil tests.
- *Irrigation farm plan (IFP):* outputs from a detailed topographic and soils survey, the concept plan and goals discussion will inform the development of a detailed IFP for the property. It will address the management and movement of water around and from the property and all key risks (including nutrient and sediment movement) associated with this. Depending on the individual property, the IFP could include:
  - Irrigation delivery, layout, earthworks, drain and re-use design;
  - Irrigation pump/pipeline/sprinkler design;
  - Dairy effluent management and reuse system design. An *Effluent Management Plan*, that considers pond size, herd size, and effluent distribution and management, could be developed as part of this process;
  - Sediment trap locations and design.
- *Review:* the farm plan should be reviewed periodically (at 1-2 year intervals) to ensure it remains appropriate to the farm operators' goals and strategies and that design and works remain effective. Parts of the farm plan may need to be revised if they are no longer appropriate and/or effective.

Irrigators will be encouraged to develop their concept and/or irrigation farm plans collaboratively with their neighbours to taken advantage of cross-boundary opportunities associated with irrigation infrastructure, drainage, environmental features and/or shelter establishment.

A checklist of the components of the farm planning process, with descriptions of the roles of key stakeholders is given in Table 9.1.

9.6 Extension

The process of developing farm plans is a "*form of strategic extension… bringing a range of government and private industry partners together*…" (Johnson and Wood 2014). Incentives for farm planning and the works which follow this have been a mechanism for "getting a seat at the kitchen table" to encourage irrigators to consider both farm scale and catchment management objectives (Sarah Killury, personal communication).

On-going agency participation in a farm planning program is required to ensure appropriate standards are maintained and that regional objectives for food and fibre production, modernisation of irrigation systems and environmental outcomes (Johnson and Wood 2014) are appropriately incorporated.

Private sector providers also play a significant role in farm planning programs. While private sector farm planners-designers have traditionally been focussed on the IFP component of the farm planning framework, those consulted in developing this framework report that the scope of most engagements also include goals and strategies discussions and aspects of the concept plan. Farm planners-designers bring experience which is based on broad exposure to management challenges and their solutions from across the Lake Wellington catchment and beyond. Like agency extension staff, they play a key role in capacity building, in developing the farm plan and mentoring irrigators through its implementation.

9.7 Horticultural producers

The engagement of dairy producers in irrigation farm planning was one of the strengths of the Macalister LWMP. Implementation of works documented in these plans has resulted in significant improvements in irrigation water use efficiency, water savings to support expansion of irrigation and retention of nutrients on-farm. It is also considered to have helped irrigators unlock key benefits from the modernised irrigation supply system as part of MID2030.

While engagement with dairy producers through the Macalister LWMP has been strong, engagement with horticultural producers in or near the MID has been limited, as has engagement with horticultural and other irrigators in other parts of Lake Wellington catchment. Given the expansion of horticultural production in the MID and the risks posed by sediment and nutrient export from these and other horticultural areas, it is critical that appropriate farm planning processes (and best management practices) are developed and applied to these systems.

The Plan supports the engagement of lowland (i.e. MID area) and upland (i.e. Thorpdale area) horticultural producers-vegetable growers in farm planning processes. The lowland farm planning process is to be adapted for upload irrigation with support from the Plan.

9.8 Applying the farm planning framework

The Lake Wellington LWMP's farm planning program aims to encourage the adoption of technologies, farm layout and management practices that help irrigators achieve their business and management objectives and contribute to improved catchment health outcomes. Whilst ideally the framework (Figure 9.1) should be implemented in its entirety, irrigators will independently evaluate the benefits they expect to receive relative to the costs (financial and time) in participating in the process and implementing their farm plan.

The program is to be applied as follows:

- *New irrigation developments:* new irrigation developments which trigger the Gippsland Irrigation Development Guidelines (IDGs; WGCMA, 2011) are required to develop an irrigation farm plan (called an Irrigation and Drainage Plan; IDP). Once the IDGs are harmonised with this revised farm planning framework (as proposed under the Plan, see Chapter 10.4) the IDP will incorporate the whole process depicted in Figure 9.1.
- *Redevelopment of existing irrigation operations:* as there is no regulatory requirement for farm planning as part of most irrigation re-developments, a process for engaging with farm operators will continue to be required as part of the LWMP's farm planning program. Irrigators will be encouraged to participate in the full process. This encouragement will take the form of communication about the potential value to them, as well as (potentially) through the way in which financial incentives are allocated (for farm planning and subsequent works).

Standard water-use conditions under the *Water Act 1989* and the IDGs specify that IDPs for new developments must also include plans for monitoring nutrient balance and movement, as well as groundwater depth and quality (Chapter 10.2).

Table 9.1 provides guidance on responsibilities pertaining to the various components of the farm planning framework. The expectations of roles generally follow this breakdown:

- Agencies work with irrigation designers and industry as partners to encourage the adoption of BMPs and develop new BMPs to address any gaps.
- Agencies quantify any gaps in understanding of the risks posed by farming operations (such as sediment loss from cultivated soils), develop extension materials and inform irrigators, planners and food processing industries of the risks.
- Designers engage irrigators in discussions about the benefits offered by farm planning and the adoption of applicable BMPs. They mentor irrigators through the implementation of the farm plan.
- Irrigators make use of extension materials and give due consideration to the opportunities provided.
- Agencies and planners work co-operatively in the delivery of the program. This includes each party, with the irrigator, participating in meetings at which the farm plan is presented.
- Advisers participating in the IFP process signpost to other programs and financial support measures available through WGCMA, AgVic or other agencies.

Table 9.1 nominates somewhat different farm planning requirements for dairy and horticultural operations. This reflects differences in the on and off-farm risks associated with each type of farming.

9.9 A role for local government

Local governments play an important role in irrigation farm planning in some other irrigation regions (e.g. GMID), with municipalities[5] requiring planning permits for land-forming works associated with implementation of the farm plans (specifically the IFP component, as per Figure 9.1). Irrigation farm plans are submitted to local government for approval, a process which involves referring the plans to key agencies, such as Goulburn-Murray Water, the respective CMA, DELWP and Agriculture Victoria (AgVic).

This referral process may lead to conditions being placed on the farm plans to address particular risk issues. It is an important additional control in ensuring farm plans address statutory issues, such as biodiversity, cultural heritage, effluent management and surface drainage. It also ensures that farm layout modifications which operate outside of regional land and water management programs are subject to review and are developed to a consistent standard.

There is currently no similar process operating in Lake Wellington catchment. However, schedules to the Farming Zone (35.07) in Wellington and Baw Baw Shires' planning schemes require planning permits for earthworks which *change the rate of flow or the discharge point of water across a property boundary* (confined to the MID in Wellington Shire). This same schedule to Baw Baw Shire's planning scheme also requires a planning permit for *earthworks which increase the discharge of saline groundwater*. These provisions provide scope for reviews of irrigation farm plans and related earthworks. No similar provisions exist in Latrobe City Council's planning scheme.

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[5] Except Gannawarra Shire.

The Lake Wellington LWMP proposes that West Gippsland CMA work with local governments within the catchment to develop and implement a consistent process for review and accreditation of at least the IFP components of farm plans (see Chapter 13.3).

Table 9.1 Proposed components of the Lake Wellington Land and Water Management Plan farm planning program and proposed roles of organisations in program delivery

Farm planning element	Application		Suggested role in delivering the farm planning program				
	Dairy	Horticulture	Irrigators	Agencies (AgVic, EPA, SRW, WGCMA)	Private farm planners, & designers	Industry, agricultural suppliers	Local government
Irrigation efficiency check							
Irrigation efficiency check	✓	✓	Invite AgVic extension officer to visit and inspect property and provide advice on early options for improving irrigation efficiency.	Develop checklist or process for irrigation efficiency check. Inspect property and advise on early and low cost irrigation and dairy effluent efficiency opportunities.	Refer clients to AgVic for service as entry point into farm planning.	Refer clients to AgVic for service as entry point into farm planning.	Refer irrigators to AgVic for service as entry point into farm planning.
Goals and aspirations							
Lifestyle/family aspirations Business aspirations Environmental aspirations	✓ ✓ ✓	✓ ✓ ✓	Family dialogue on: • Future role in farm business and operation • Business and lifestyle goals • Environmental objectives • Property expansion, contraction or consolidation • Connection to upgraded irrigation supply system Engagement with AgVic extension office in goals, aspirations and business planning dialogue	Development or adapt process for farm goals and aspirations discussions. Develop competency of extension officers to facilitate goals, aspirations and business planning discussions.	Encourage clients to participate in goals, aspirations and business planning discussions. Reflect these in planning for and design of irrigation layout.		Refer irrigators to AgVic for service as entry point into farm planning.

Farm planning element	Application		Suggested role in delivering the farm planning program				
	Dairy	Horticulture	Irrigators	Agencies (AgVic, EPA, SRW, WGCMA)	Private farm planners, & designers	Industry, agricultural suppliers	Local government
Concept plan				Adapt farm planning framework & processes to upland irrigation operations.			
On-farm assets	✓	✓	Dialogue with AgVic extension officer to identify and locate all on-farm infrastructure and environmental or heritage assets.	With irrigator, identify and locate all on-farm infrastructure and environmental or heritage assets.	Use information on on-farm assets in irrigation design.		
Catchment (off-farm) features & values	✓	✓	Dialogue with neighbours, WGCMA or others to identify important connections between on and off-farm assets and opportunities for cross-boundary collaboration.	Support individual and groups of irrigators to collaborate during farm planning to identify cross-property boundary risks and opportunities.	Reflect any cross-boundary collaborative opportunities in irrigation design.		
Risks & opportunity assessment	✓	✓	Work with AgVic extension office and irrigation designer on identifying and prioritising risks and opportunities to improve water, nutrient and energy efficiency and to minimise off-farm impacts.	Work with irrigator on identifying and prioritising risks and opportunities.	Work with irrigator on identifying and prioritising risks and opportunities. Reflect these in the irrigation design.		
Energy efficiency review	✓	✓	Understand energy usage and identify opportunities to improve energy efficiency.	Develop energy efficiency and renewable energy module for farm planning.	Reflect energy efficiency opportunities in irrigation design.		

Farm planning element	Application		Suggested role in delivering the farm planning program				
	Dairy	Horticulture	Irrigators	Agencies (AgVic, EPA, SRW, WGCMA)	Private farm planners, & designers	Industry, agricultural suppliers	Local government
				Develop competency of extension officers to deliver energy audits and provide advice to irrigators.			
Cultural heritage	✓	✓	Build understanding of Indigenous cultural values and heritage management. Collaborate with Traditional Owners in management of any heritage features.	Develop cultural awareness in farm planning extension officers. Develop cultural heritage farm planning module and cultural engagement programs with Traditional Owners.	Reflect cultural values in irrigation design.	Develop cultural awareness in field staff.	
Strategies for risks & opportunities, including effluent use plans	✓	✓	Work with extension officer to develop strategies to address key risks and opportunities.	Work with irrigator to develop strategies to address key risks and opportunities.	Reflect strategies in irrigation design		
Investment priorities	✓	✓	Work with financial and farm advisers to prioritise investments to manage risks and opportunities.	Support irrigator in prioritising responses to risks and opportunities.	Work with financial advisers and irrigator to prioritise investments to manage risks and opportunities.		

Farm planning element	Application		Suggested role in delivering the farm planning program				
	Dairy	Horticulture	Irrigators	Agencies (AgVic, EPA, SRW, WGCMA)	Private farm planners, & designers	Industry, agricultural suppliers	Local government
Irrigation farm plan							
Survey	✓	✓			Property-scale survey of soils, topography and key drainage and other features		
Irrigation supply connection	✓	✓		Upgrade irrigation supply infrastructure to provide modern irrigation supply connection.	Design farm layout for most efficient access to irrigation supply connection(s).		
Irrigation system & technologies	✓	✓	Adoption of efficient irrigation system & associated technologies for automation & scheduling.	Develop extension materials and programs to support successful adoption of efficient irrigation systems.	Advise and support irrigator in implementation of efficient irrigation system and technologies.	Advise and support irrigator in implementation of efficient irrigation system and technologies.	Review and referral of planning permit application for earthworks earthworks to support more efficient irrigation.
Dairy effluent management, including effluent management plan	✓		Comply with regulations on reuse and management of dairy effluent.	Develop extension materials and programs to support improved management of dairy effluent.	Integrate dairy effluent management with irrigation layout for dairy farms.	Develop extension materials and programs to support successful adoption of efficient irrigation systems.	
On-farm surface drainage and reuse	✓	✓	Develop tailwater reuse for areas with surface irrigation.	Develop extension materials and programs to support successful adoption of efficient irrigation systems	Design irrigation layout (for surface irrigation) to support reuse.		Review and referral of planning permit application for earthworks earthworks to support more reuse.
Off-farm drainage	?	?	Maintain sections of regional surface drainage system transferred to irrigator from SRW.	Maintain remainder of surface water drainage system.	Design irrigation layout to manage connections to surface drainage network.		

Farm planning element	Application		Suggested role in delivering the farm planning program				
	Dairy	Horticulture	Irrigators	Agencies (AgVic, EPA, SRW, WGCMA)	Private farm planners, & designers	Industry, agricultural suppliers	Local government
Sub-surface drainage	✓	✓	Operate any private groundwater pumps and use water – under appropriate conditions.	Maintain public sub-surface drainage systems.	Incorporate risks and opportunities associated with private groundwater pumping within IFP		
Erosion control – sediment traps	✓	✓	If reuse dams not present, construct sediment traps to reduce off-farm movement of sediment during rainfall events.	Develop extension materials and programs to support successful adoption and management of sediment traps in appropriate settings.	Incorporate sediment traps into irrigation layout - as appropriate.		

9.10 Irrigation Development Guidelines

The Gippsland IDGs (WGCMA, 2011) specify the requirements of Irrigation and drainage plans (IDPs) which are must be produced where a new or varied water use licence is to be granted. While the requirements of these plans are broadly consistent with the revised farm planning framework described here, there are several inconsistencies which should be addressed as part of the Plan's implementation and the proposed updating of the IDGs (see Chapter 10).

10 Gippsland Irrigation Development Guidelines

10.1 Overview

The Gippsland IDGs were developed in 2011 by the WGCMA in conjunction with East Gippsland CMA, SRW and the (then) Department of Sustainability and Environment (now DELWP). The guidelines aimed to provide consistency, accountability and clarity to the process of assessing new irrigation developments and ensure that they only proceed when it can demonstrate that they are sustainable through the implementation of standards reflecting best irrigation practice and minimise off-site impacts or irrigation water use.

The Gippsland IDGs guide government agencies and irrigation developers and in exercising or responding to powers in the *Water Act 1989.* They are intended to be used to help avoid or minimise environmental effects of new irrigation developments. The IDGs outline what will be taken into account in setting conditions for licences issued under Sections 51, 64L (Water-use Licence) and 67 of the *Water Act 1989*. These apply to Take and Use Licences, Water-use Licences and Licences to construct works for irrigation, respectively.

The IDGs aim to ensure that irrigation developments satisfy water use objectives specified in the *Water Act 1989*, specifically:

- *Managing groundwater infiltration:* to avoid or minimise waterlogging, land salinisation, water salinisation and groundwater pollution.
- *Managing disposal of drainage:* to avoid or minimise waterlogging, or the salinization or eutrophication of waterways, wetlands, native vegetation, native animal habitats, groundwater and other persons' property.
- *Minimising salinity:* to ensure water use licence-holders bear the costs of any measures to reduce risks from land or water salinization or offset them.
- *Protecting biodiversity:* from risks associated with irrigation water use;
- *Minimising any adverse cumulative effects of water use:* resulting from a series of individually acceptable expansions in water use within a defined area.

The onus is on the proponent of the irrigation development to demonstrate the impacts of their proposal and the means by which these will be mitigated and the water use objectives satisfied.

The IDGs do not apply in several settings, including:

- Where the land is already being irrigated, provided there is no net increase in the annual use limit, the area allowed to be irrigated or the average irrigation intensity and the drainage classification of the land is unchanged.
- Where irrigation is to be extended to some new land but will be within the annual use limit of the existing licence.
- Where an irrigation development is proposed using reclaimed water (in this case, the development must comply with Environment Protection Authority (EPA) requirements.

The IDGs also define roles and responsibilities in approving irrigation development.

10.2 Irrigation and drainage plans

Consistent with the Standard Water-Use Conditions under the *Water Act 1989*, the IDGs require that irrigation and drainage plans (IDPs) are developed for new irrigation developments or redevelopments that fall under its auspices. The IDP is intended to ensure the way land is irrigated and drainage disposed of is consistent with the characteristics of the land and soil, so that the objective of minimising harmful side-effects is met efficiently.

In regions covered by a LWMP or a Salinity Management Plan approved by the Minister, an appropriate overlay from within a certified whole-farm plan may be accepted as an IDP.

IDPs in southern Victoria are required to include:

- Map of the proposed development;
- Topographic survey with elevation data and contours;
- Soil assessment – supported by a written report describing the assessment;
- Irrigation design and management – with details of crop water requirements, proposed maximum application rates, irrigation system specifications, irrigation delivery supply point and proposed irrigation scheduling arrangements;
- Nutrient balance and movement monitoring plan;
- Groundwater depth and quality monitoring plan;
- Arrangements for drainage disposal;
- Arrangements for the protection of biodiversity from the use of water for irrigation.

While the requirements of IDPs are broadly consistent with the farm planning framework developed for the Lake Wellington LWMP, there are several important inconsistencies, namely:

- *Risk management:* the IDPs have no specific requirement for a site-based risk assessment or management process to identify and address key off-farm risks associated with the new or modified irrigation operation. Risk assessment and management is a useful process in framing the irrigation design in ways that minimise adverse off-farm impacts.
- *Nutrient management:* while the IDGs reference nutrients, the document does not explicitly require consideration of the management of nutrients from any source, including the management of dairy effluent. Given the significant risk posed (to the Gippsland Lakes and LWMP objectives) by off-farm movement of nutrients, a requirement to address nutrient management (as per this farm planning framework) should be incorporated. The IDGs provide for nutrient balance and movement monitoring.
- *Sediment management:* sediments are potentially an important source of nutrients (and other pollutants) from horticultural operations in which cultivated fields remain bare for significant periods. The IDGs include no requirement that this risk is assessed as part of the IDP and that, as appropriate, relevant management responses are included.
- *Indigenous heritage:* while there is a statutory requirement for Indigenous cultural values to be protected, including in irrigation developments and redevelopments, this issue is not specifically considered in the IDPs guidance.

10.3 Application of Irrigation Development Guidelines to new irrigation developments and redevelopments

The review of the Macalister LWMP considered the implementation of the IDGs. It found that they played an important role in providing a clear pathway for new irrigation developments and in minimising the risks these pose to the environment. The IDGs were found to have been implemented effectively and had contributed to new irrigation developments adopting best practice irrigation management. IDG referrals have increased in the Lake Wellington catchment in recent years (two in 2013-14, compared with 12 in 2015-16), reflecting the attractiveness of the catchment for irrigation development.

The Macalister LWMP review also found that many significant irrigation redevelopments – particularly conversions from dairy to horticultural production – are not captured by the IDGs because of the exclusions listed above (Chapter 10.1). Understanding of the scale of these redevelopments and the risks they pose to the environment is poor because they occur outside of the currently regulatory framework.

The Macalister LWMP review supported Action 4.7 of the Victorian *Water Plan*, that government, Water Corporations and CMAs will ensure that regional IDGs are contemporary to emerging knowledge and risks and are applied to both new irrigation developments and significant redevelopments. Until changes to the scope of IDGs are effected at a state level (which the *Water Plan* anticipated to take 4 years) – through amendments to the *Water Act 1989* - the IDG's limited traction with significant irrigation redevelopments will remain.

The only current opportunities for review and referral of such redevelopments are triggered by schedules to the Farming Zone (35.07) in Wellington and Baw Baw Shires' planning schemes. These require planning permits for earthworks which *change the rate of flow or the discharge point of water across a property boundary.*

10.4 Revising the Irrigation Development Guidelines

The Macalister LWMP review found that the IDGs were being effectively implemented and recommended that their implementation should continue to be supported. It also recommended that their application should be extended to the entire Lake Wellington catchment and to significant irrigation redevelopments. It proposed that arrangements with local government were strengthened to ensure that land use approvals apply IDG requirements where appropriate.

The Plan includes specific actions to address these recommendations, as follows:

- *Farm planning program:* Work with local government to ensure that statutory planning processes for irrigation farm planning are consistent across Lake Wellington catchment and ensure high quality new and modified irrigation developments.
- *On-farm irrigation and drainage program*: Revise and update the Gippsland IDGs to set best practice standards for on-farm irrigation systems and practices for new or modified irrigation developments. This action was proposed to be implemented in two stages. The first stage would involve a minor refresh of the IDGs to harmonise the requirements for an IDP with the farm planning framework developed for the Plan. The second stage would involve a more significant review of the IDGs and follow (potential) changes in legislation and policy that would also allow most significant irrigation redevelopments to be regulated through the IDGs to ensure they satisfy the Minister's irrigation water use objectives.

11 Stakeholder engagement outcomes and key messages

As described in Chapter 6, there have been two main phases of stakeholder engagement in developing the Lake Wellington LWMP. These occurred early in stage 2 and following the release of the consultation paper on the draft LWMP. This section provides a summary of the key messages or learnings from both phases of consultation.

11.1 Initial stakeholder consultation

The focus of initial stakeholder consultations was on the engagement of irrigators and their advisers operating in the three main industry sectors, dairy, horticulture and beef production. Consultation took place via semi-structured individual interviews (generally by phone) and small focus group discussions. Consultation was supported and informed by a review of recent social research.

11.1.1 Dairy industry

Social research and engagement activities among dairy industry participants involved:

- Reviewing available recent social research on the adoption of recommended practices for irrigation and nutrient management;
- One focus group workshop discussion with dairy industry representatives;
- Semi-structured phone interviews with irrigators, farm advisers and industry body representatives.

A total of 14 individuals participated in the social research activities, including nine participants in the focus group and five participants in semi-structured phone interviews. The participants included 12 dairy irrigators from the Lake Wellington catchment and two farm advisers.

Social research

Dairy Australia's *Dairy situation and outlook* report identifies trends and drivers for the Australian dairy industry on annual basis. The most recent report (Dairy Australia, 2017) identifies profitability, trust in milk processors and confidence as the most pressing issues across the dairy sector. Other key issues for dairy producers in the Lake Wellington catchment include:

- *Water security and availability:* water security was a major issued for farm businesses, with many survey respondents citing access to water and better irrigation systems as the key for increasing or improving agricultural production. Around 15% cited lack of water as a barrier to realizing opportunities.
- *Increasing proportion of farms irrigating:* while nationally there has been little change in the proportion of dairy farms with irrigation since 2000, there has been a steady growth in Gippsland.
- *Change in land ownership and land use:* an increase in corporate farms and conversion of land from dairy to horticulture were identified as key trends in the MID.

Dairy Australia's NRM Survey provides data on practices being undertaken on dairy farms to minimise impacts on land, soil and water due to farming practices. A summary of relevant findings Gippsland survey responses (in 2015, 41% of which were from irrigation farms) are provided below:

- Flood irrigation is the dominant irrigation system type, with 64% of farms using this. Spray irrigation occurs on 58% of farms and centre pivot irrigators are used on 20% of farms.

- Irrigation systems are being upgraded over time, with investment linked to profitability. The main upgrades among Gippsland dairy producers were: delivery structure upgrade (16%), high flow flood (9%), centre pivots (7%), increased on-farm storage (7%), laser grading (7%) and reuse (4%).
- 49% of farmers have some form of automated irrigation system.
- Key land management issues reported were: wet soils and pugging (47%), weeds (25%) and statutory infrastructure requirements (15%).
- The reported use of soil testing by Gippsland dairy farmers increased from 82% in 2012 to 95% in 2015. Use of a fertilizer management plan also increased over this period (from 35% to 52% of respondents).
- Almost half (47%) of Gippsland dairy farms have renewable energy sources installed on farm and/or make use of energy efficiency technologies (e.g. variable speed pumps).

Land and water management challenges for the Lake Wellington catchment

Discussion group and interview participants were asked to identify the most important land and water management challenges. These were reported to be:

- *Changes in land use and demographics:* participants reported that many areas of dairy and beef irrigation were shifting to vegetable production. Changes in demographics were also reported with a shift to more corporate farmers. Participants raised concerns about the implications of more corporate farms on the competition for land, the social dynamics of the community (reduced population) and potential issues if corporate farms fail financially. Concerns were also raised about the attractiveness of dairy for younger farmers because of perceived profitability challenges.
- *Water availability and security:* participants noted that many producers rely on a combination of high reliability, low reliability and spill to achieve production goals. The annual fill storage of Lake Glenmaggie means that producers have low confidence they will receive sufficient water during dry years. They also do not have access to “carry-over water”, as do irrigators in most other regions.
- *Electricity supply and cost:* unreliability (frequent brown-outs) and lack of three phase power in some areas of the MID were noted as major barriers to the uptake of sustainable irrigation practices (particularly pressurised or spray irrigation) and improved production. Participants are also concerned about potential increases in electricity costs which may result in spray irrigation becoming unprofitable.

Land and water management opportunities for the Lake Wellington catchment

Discussion group and interview participants were also asked to identify the big land and water management opportunities for dairy irrigators in the Lake Wellington catchment. The most commonly reported opportunities were:

- *Improving security of supply:* whilst most participants reported that it ‘would never happen’, many reported that the construction of another major storage in the catchment would be an excellent opportunity for the district.
- *MID2030 efficiencies:* many participants reported optimism associated with the savings made through MID upgrades. Strong support was expressed for water savings coming back to producers under the modernisation program.
- *Responding to consumer demands:* there is a trend from consumers wanting “clean and green produce” and increased pressure via social media. Participants reported a need to respond to an increased demand for organic produce, and better communication about the practices being adopted in conventional dairy production.

On-farm land and water management challenges and opportunities

Discussion group and interview participants were asked to identify the most important on-farm land and water management challenges in the context of their own dairy or the dairy farmers they work with. The most commonly reported challenges were:

- *Enterprise profitability:* this was the most commonly reported challenge. Participants reported challenges in maintaining a flexible and robust business in the face of fluctuating input costs and milk price, as well as variable seasonal conditions.
- *Complexity in managing irrigation systems:* participants reported that irrigation is a complex management challenge. Complexity is driven in part by the uncertainty of supply and cost of irrigation and a lack of continued focus on best practice. In some cases, this complexity results in producers who think they are applying best practice not actually doing so.
- *Regulation and "red tape":* the complexity of regulation and red tape was reported to complicate making improvements to farming operations in some places. This included floodplain planning requirements, vegetation removal regulations and siting and capacity restrictions on re-use dams. Participants expressed a belief that their management of nutrients would ultimately be regulated.
- *Electricity supply and cost:* as discussed previously, lack of three phase power is considered to be a major barrier to on-farm development and efficiency. Frequent 'brown outs' in parts of the MID have driven some producers to switch to fuel-based generators, which are more expensive to operate.
- *Irrigation practices:* participants commented that flood irrigation flow rates are too slow on many (not modernised) systems, with implications for waterlogging, nutrient use and production efficiency. Other issues include not irrigating frequently enough under the belief that it results in a water saving.

Participants were also asked to identify core on-farm land and water management opportunities. The most common responses (apart from improving profitability and margins) were:

- Increased development of re-use dams (more and/or larger reuse dams);
- Spray irrigation and centre pivots;
- Shift from bore water to channel water;
- Installation of solar power to help offset the increased costs of electricity;
- More automation in on-farm irrigation systems;
- Surface water management (drainage) best practice;
- Nutrient planning and better on-farm use of dairy effluent;
- Improved irrigation practices;
- Improving soil health and soil management.

Barriers to adoption of sustainable irrigation

Discussion group and interview participants were asked to identify any barriers that would prevent them from making the changes they had planned. A lack of capital and associated profitability issues was consistently reported by producers as the main barrier. Other factors linked to this included uncertainty about short-term seasonal conditions, water allocations (and price), increasing cost of energy and the complexity of management.

Supporting change in irrigation land and water management

Discussion group and interview participants were asked how the government could best support farmers to make changes to improve land and water management practices. Financial support in the form of incentives, co-investment and low-cost loans to enable infrastructure upgrades was commonly reported as the best way to support producers. Extension and advice was also reported as an important way to support farmers and flexibility was recommended for both the incentives program (eligibility and timing) and extension programs (access to specialists, coaching as well as traditional programs).

- *Incentives low-interest loans and co-investment for infrastructure upgrades:* continued support for irrigation upgrades was reported by all participants as the most important way government could support irrigators to be more efficient and productive. Co-investment by producers was reported by almost all producers and advisers as being an important aspect of the incentives program, as producers have a stake in the success of the measures being undertaken. Many respondents remarked that it wasn't appropriate for government to pay the full amount of infrastructure upgrades.
- *Provide greater flexibility with incentives:* participants made a range of suggestions around the theme of more flexibility with incentive programs including: extending the timeframe for submitting applications, broadening the scope of eligible activities (i.e. to include pipe and pump solutions for river irrigators, more flexibility with siting of re-use dams and funding for sensors/remote sensing technology) and enabling irrigators to participate regardless of the status of their outlet.
- *Holistic extension and education programs drawing on recent research:* these were considered to have an important role in improving nutrient, irrigation, pasture and drainage management. The continued need for irrigation extension programs was consistently raised by participants. An emphasis on new research innovations that have been 'tried and tested' was identified as an area for improvement for extension programs. Several participants reported that often extension programs only looked at one aspect of an irrigation system without a view to the whole system and or the business case for particular practices. One participant noted that it is important to keep running programs on a cycle so that farm turnover is accounted for (estimate 25% turnover in a 10-year period).
- *Assistance with specialist expert advice for system design and operation:* participants identified a desire for access to specialist advisers for system design (irrigation and drainage and automation specialists) in addition to the traditional farm planning services. The need for tailored systems that align to the individual dairy system and business plan was highlighted as was the challenges in accessing the appropriate expertise, with the best advisers often based interstate or in other regions.
- *Low cost courses and workshops:* participation fees were identified as barrier for some producers to attend workshops and courses. Linking financial incentives to courses was reported as having been a successful way of encouraging participation in the past.
- *Coaching or mentoring support:* producers recognise they do not always have the knowledge and focus on achieving best practice even after irrigation upgrades have been made. Whilst some producers use an independent farm adviser or consultant, many rely on supply companies for advice. Provision of monitoring/coaching support through an adviser would assist producers to maintain focus on implementing best practices.

Communicating with irrigators

Participants provided the following feedback in response to questions regarding the preferred communication media.

- Link with existing communications processes such as; 'How Now Gippy Cow', GippsDairy Focus Farm discussion groups, ABC Gippsland rural report, processor newsletters.
- Discussion groups and face to face communications are best.
- Surveys are not viewed favourably by producers

- Make appointments and planning events to be held a time convenient to farmers is important, some participants preferred morning or lunch time, whilst others preferred events not to be held between 9 am and 4 pm.
- Plan communication events with consideration of the annual production cycle.

SRW, AgVic and GippsDairy were identified as trusted messengers and participants suggested the WGCMA consider communicating with farmers under the auspice of these agencies and/or linking with their events.

Messaging around communications was noted as being important – preferred messages included:

- 'Let's work together to be more productive'
- 'How you can retain your nutrients and make better use of it'

11.1.2 Horticulture industry

The horticulture industry was engaged through a discussion group involving nine irrigators and several other agency and industry representatives. The discussions covered a similar set of issues to those explored with dairy irrigators.

Land and water management challenges for the Lake Wellington catchment

The key land and water management challenges identified by horticultural irrigators included:

- *Risks from dairy farms:* participants reported that dairy farms are a large risk to the catchment as they are sources of nutrients, sediments and pathogens. Unfenced open channels create food safety risks for leafy vegetable production.
- *Water availability and security*: participants reported that they felt the MID irrigation systems are geared towards dairy farmers. There are no opportunities for irrigation during winter, which horticulture operations may need. For irrigators in unregulated catchments, concerns were raised about the restrictions on irrigating over summer. This has a major impact on production levels and profitability.
- *Regulation (red tape and complexity):* is a major issue for horticulture producers. It takes a long time to get permission to do things in flood overlay zones. There are unused easements that hold back some works. Drains are old and poorly maintained and the irrigation infrastructure is considered to be poor. Complexity in dealing with council, WGCMA and SRW is reported to be problematic.
- *Aging infrastructure:* MID irrigation infrastructure was considered to be "third world" by some irrigators. Open channels are very inefficient and do not directly support pressurised irrigation systems. Piped water would also reduce public health risks associated with dairy cows having access to irrigation channels. This would also be better for organic production systems.
- *Potential impact from proposed sand mine*: the proposed quarries at Glenaladale and Stockdale are of concern to irrigators because of the potential impact on groundwater resources, surface water and water quality.

Land and water management opportunities for the Lake Wellington catchment

The main opportunities identified for horticulture in the Lake Wellington catchment are:

- *Continued growth of horticulture*: participants indicated that they believed more horticultural producers will enter the region and there will be more area under horticultural production. It was reported that land prices are increasing, but are still cheaper than many other areas. The region has good soils, good water, is close to markets and there are good opportunities to expand.

- *Potential for co-operative arrangements*: some participants reported that there could be opportunities for some type of co-operative arrangement, particularly around selective window crops. However, the highly competitive nature of horticulture means that would be difficult to implement.
- *Potential for increase in organic production*: the premium paid for organic produce could contribute to an increase in organic production if suitable sites can be found.
- *Potential for more protected (covered) cropping*: some participants reported that there is likely to be growth in covered cropping systems in the area, however others considered that covered cropping / soil-less production only makes sense close to cities.
- *Potential to use big data to drive production efficiency*: it was noted that there is increasing appetite among growers to adopt technological solutions that help them to better understand their production system. The challenge is making meaning of the data and having the expertise to adjust management accordingly.
- *Competitive advantage in the future:* it was noted that in the future the climate of the Maffra area will remain reliable and whilst the frost will limit some crops, there is a huge opportunity in comparison with other areas.

On-farm practices to improve irrigation and nutrient management

Opportunities to improve irrigation and nutrient management include:

- *Irrigation system:* some participants reported that there is an increase in the use of drip and tape systems for some crops. However, fixed sprinklers are probably the most efficient for many crops because it is difficult and costly to use tape when harvesting by machine (i.e. baby leaf). In general participants reported that irrigation practices in horticulture were much more efficient than dairy.
- *Soil and tissue testing:* increasing use of these techniques was reported by participants as a way of informing fertiliser application.
- *Soil health improvement:* improvement in soil health and carbon stocks was noted as being of interest to some producers, including through the use of minimum till practices. This was anticipated to help with water retention.
- *Use of farm advisers:* the reported use of on-farm advisers was variable. It was noted that unlike other industries, there are few independent farm advisers in horticulture. Larger growers tend to have in-house agronomists and advisers and other growers obtain advice from their re-seller. It was also noted that organic growers tend to have a network that they draw on to build their knowledge base.
- *Drainage and cultivation:* it was reported that drainage and cultivation practices are aimed at opening the soils up to ensure that crops can be grown based on optimum moisture levels and therefore irrigation run-off is not an issue.
- *Rainfall run*-off - most participants reported there were no run-off issues even as a result of high rainfall events. One participant noted that East Coast Low rainfall events can result in run-off. One option some growers reported using was modifying their irrigation to dry soils prior to a forecast major rainfall event to enable them to take in more water.
- *Groundwater use:* some participants reported that they tend not to use groundwater as a source of irrigation water because of iron and pathogen issues. Other participants (mostly those located in the unregulated areas) reported using a combination of groundwater and surface water. This helped to improve security of supply in summer months when rostering and bans were in place.

Riparian areas and managing biodiversity

Some participants reported that there was no need to fence out riparian areas on horticultural properties and that revegetation causes maintenance problems. Others reported they had fenced off waterways or billabongs either to reduce health and safety risks to workers or if grazing areas as part of a rotation. Participants had mostly negative views about the programs implemented by WGCMA along waterways. They expressed concerns that rivers were becoming clogged up with vegetation and weeds were not being maintained.

Wind was identified as an issue of concern for some participant either causing erosion of light soils or affecting irrigation efficiency. Some participants reported that they had planted narrow windbreaks to provide some protection.

Supporting change in irrigation land and water management

Several participants reported that small grants of $5-$10,000 (as were available from WGCMA) were of no value and the administration process took up too much time and effort. They also indicated that if they wanted to make a change on-farm to improve production or efficiency then they would make the change themselves.

Other participants reported that they would like to be offered rebates for making changes on-farm for more efficient irrigation practices or improving soil health.

The other main opportunity to support growers would be to improve the security and reliability of the water supply system, for example through:

- Support for construction of on-farm storages;
- Improving the ability of growers to capture winter flow (particularly on unregulated systems);
- Upgrades of supply systems, including channels;
- Provision of a piped water supply.

Participants raised concerns about the short-term nature of support programs for growers.

An increased emphasis on research and development programs, such as investigating the water requirements of new and emerging crops/varieties and new irrigation technology were supported by participants.

Influence of consumer preferences on the horticulture industry

Participants noted that the big supermarkets are the major forces in the horticulture industry. Their standards and pricing can make or break individual producers. Consumer preferences in regards to traceability, local provenance and increased demand for organics were reported as some of the factors that influencing the industry. “Clean and green” and “sustainability” were buzz words reported by participants that need some substance behind them.

Marketing based on convenience, freshness and health properties were opportunities for producers. Some participants also noted the massive impact health outbreaks (i.e. *E.coli* in pre-packaged salad) have on the demand for their products. This reinforces the importance of high irrigation water quality.

Perceptions of environmental regulation

Participants reported that current environmental regulations were restrictive especially by comparison with other states (particularly Queensland). Examples included regulations regarding the construction of crossings, native vegetation removal and water harvesting restrictions.

It was noted that in addition to environmental regulations, horticulture is already tightly regulated in terms of quality and food safety and there are a range of standards imposed by the different supermarkets.

Participants were asked if they were concerned about the potential for additional regulation in the future, particularly relating to nutrient management. Some participants reported that they were not concerned and understood that regulations were in place in other locations (i.e. New Zealand, Queensland). It was noted that some producers may decide to opt out if the risk to their operation from increased regulation outweighed the reward. Other participants indicated that additional regulation is a concern and that more red tape has the potential to impact on profitability in already tight market conditions.

Communication with horticultural producers

Participants provided the following feedback in response to preferred communication streams.

- Discussion groups and face to face communications are best;
- One page of information via email;
- Article in the Infoveg newsletter;
- Events such as bus tour / speaker;
- Ensure that events are specific to horticulture;
- Attend / participate in industry-led events and conferences i.e. annual horticulture conference;
- Afternoons were identified as the best time of day to hold events.

A number of participants indicated that they felt the Plan would have little impact on the way growers would do things and therefore many were unlikely to be interested in receiving communication or attending an event. Other participants were more positive and the inclusion of horticultural stakeholders in the planning processes and indicated they would be interested in attending industry specific events related to the Lake Wellington LWMP.

11.1.3 Beef industry

A single beef producer was engaged to provide a perspective on irrigation land and water management issues for that industry. The semi-structured interview followed a similar format to those conducted with dairy producers.

Land and water management challenges

Two key challenges were identified, as follows:

- Seasonal variability in rainfall and supply of irrigation water: seasonal variability affects capacity to grow grass year round.
- Uncertainty about allocations: spill entitlements are a bonus, but tend to bank on it happening nine in ten years.

Adoption of improved land and water management practices

Recommended practices that have been adopted include:

- Soil testing (twice in 10 years);
- Agronomist advice on fertiliser rates and timing;
- New farm plan for one block and updated farm plan for another block;
- Laser grading to improve flood irrigation bays;
- Upgraded outlet;
- Timers are used to control irrigation applications;

Barriers to adoption of improved land and water management

Key barriers to making improvements to irrigation land and water management are:

- Having land out of production whilst upgrades are completed;
- Access to experienced contractors and technical advisers with good practical experience;

The participant did not consider that cost was a barrier. The investment was worth it because of the improvements in productivity. They could not understand why more farmers do not access the support that is available.

Communication preferences

These include phone, email or via other farmers and contractors. The participant does not currently participate in any formal beef producer discussion groups.

11.2 Land and Water Management Plan consultation paper

The LWMP consultation paper was written, in part, to seek feedback on the proposed programs by which the Plan would be implemented. It posed a series of questions that were designed to help frame written responses and discussions with stakeholders. While the questions were specifically targeted towards the Plan's programs, stakeholders were encouraged to provide feedback on other aspects of the consultation paper or on broader issues of irrigation land and water management in the Lake Wellington catchment.

This section provides a summary of key messages from feedback on the consultation paper. Many of these points have been addressed in the finalisation of the Plan and its programs.

11.2.1 Farm planning

- Farm planning has been a great success of the Macalister LWMP.
- The farm planning framework should encourage irrigators to look across boundary fences engage with their neighbours to (e.g.):
  - Share infrastructure, such as new delivery pipelines;
  - Share earth works costs, materials used on laneway from adjoining farms from reuse dams;
  - Collaborate on revegetation along boundaries and to form wildlife corridors (etc.);
  - Share renewable energy generation facilities.
- New plans should consider climate change outcomes and aim to build on-farm climate resilience.
- Farm planning should encourage irrigators to become "carbon neutral".
- Farmers may not always get good value for money under the standard farm plan incentive rates. These may be too low for the service required, at least in some instances.
- There is a need for quality control and the development of standards for farm planning and farm planning providers. Extension staff delivering the irrigation efficiency checks and concept plans will require appropriate training, experience and support.
- Development of a best practice farm planning guide is supported.
- Farm planning should also consider tree lanes and shelter belts.
- The farm planning process should reference other WGCMA (and industry) functions and programs so that irrigators are exposed to the full range of issues and opportunities while planning for their property's future.

11.2.2 On-farm irrigation and drainage

- Support for farmers should go beyond "extension" to mentoring or coaching. This level of engagement allows focus on the issues and gets people interacting and figuring out how the farming system should work. A longer term relationship is needed so that advisers check in on how projects are going.

- Extension and programs by AgVic and GippsDairy should be delivered as package that addresses grazing, nutrient and irrigation.
- Many farms could improve their on-farm drainage to get water off more quickly. A simple measure would be increased shallow spoon drains to help get water off the farm.
- There is often a gap between what a farmer thinks they are doing (with "best practice") and the what they are actually doing. Unfortunately, the combination of infrastructure and knowledge of practices doesn't necessarily translate to best practice is being implemented on farm. This may reflect:
  - Lack of or waning confidence that "best practice" is actually more profitable;
  - Loss of management focus to ensure the best practice keeps getting implemented;
  - Belief that production outcomes are a result of 'chance' rather than good management.
- Rather than setting up farm-scale demonstrations, a demonstration sub-catchment should be set up where the farm planning, on-farm irrigation and drainage and on-farm nutrient management resources are primarily focussed. This would enable the impact of recommended practices to be demonstrated at an appropriate scale.
- It was suggested that irrigators at the head of drainage lines should be permitted to have a larger storage capacity than the 1 ML/ha permitted under the *Water Act*. This would help irrigators to capture floodwater run-off (and associated nutrients).
- Systems to encourage the use of drainage water (by drainage diverters) and shallow groundwater should be considered.
- Outlet rationalization is an important issue, but is not currently supported by SRW. This means that opportunities to improve irrigation efficiency are being lost.
- The level of public benefit and availability of incentives for some irrigation efficiency measures (reuse, best practice surface irrigation) was questioned.
- Cash flow issues make it had to participate in incentive programs.

11.2.3 On-farm nutrient management

- Some nitrogen from fertiliser is released to the atmosphere as a greenhouse gas. Is WGCMA concerned with this?
- The "Action on nutrients for Sustainable Ag program was successful in changing on-farm behaviours without offering direct subsidies to farmers. Key learnings from that program included:
  - Nutrient exports are not one of the key issues farmers are asked to address;
  - Innovative extension activities and strong, good market research dramatically improve the effectiveness of conventional extension activities; and
  - Upskilling farmer champions and farm advisors can very quickly increase the reach of extension programs and thereby their effectiveness.
- There needs to be focus on upskilling commercial and government advisers and key farmers on the processes responsible for nutrient exports.
- Waterwatch should be reinvigorated in a structured way to support a sub-catchment demonstration of the effects of nutrient management programs.
- Tailwater reuse is one of the most effective mechanisms for lessening phosphorus exports from farms in the MID. However, the price of energy affects the economics of water reuse. The effect of energy pricing on the economics of water reuse should be assessed. Subsidising the variable costs associated with water re-use may be far more effective in increasing water use efficiency

and lessening P exports from the MID than many of the activities currently suggested in the Plan.
- While CORE 4 provides a good model for works to improve on-farm nutrient management, the scale of capital investment is often far higher than the incentive cap, which may reduce uptake. Alternative measures, including low or no interest loans should be considered.
- Increased flexibility in timeframes for the provision of incentives and delivery of works is required. The short timeframe discourages reflection and may lead to inferior outcomes being achieved.
- Accreditation or some other form of quality assurance for advisors/agronomists would help to ensure that high and consistent quality advice is provided.
- Phosphorus is not the whole story of nutrient issues in local waterways and Lake Wellington. Nitrogen and other contaminants may be important issues as well.

11.2.4 Groundwater and salinity

- Maintenance of the regional salinity infrastructure including the surface and sub-surface drainage systems is important and should be supported. Salinity impacts are long-term and preventative management (through the drainage system) is an essential investment.
- The salinity program needs to acknowledge that there are areas within the MID that have a salinity problem.

11.2.5 Floodplain and off-farm drainage

- The farm planning program should map high value floodplain environmental assets and support the management of their values.
- The program should consider previous investigations on the feasibility of landscape-scale capture of nutrients using wetlands.
- The Plan should investigate links with the Draft State Rural Drainage Strategy.
- The Plan should encourage natural hydrology and not use wetlands as reuse dams. If they are kept dry they will have capacity to capture nutrients and storm runoff.

11.2.6 Innovation and connected irrigation communities

- More education on the right to farm is required to manage risks to agriculture from lifestyle and other residents moving into the MID.
- There may be a need for regional plan to achieve carbon neutral outcomes.
- The Plan needs stronger wording and actions to drive towards carbon neutral outcomes.
- Social and cultural understanding and studies are important to the region. It is important that clear and achievable objectives are set for the cultural engagement and awareness activities.

11.2.7 Engagement and extension

- Successful extension may depend on one-on-one work to build rapport and respect, particularly where businesses are competing against each other.
- The Plan needs to get upland irrigators onside and excited about doing something. They currently have limited awareness of offsite impacts of their irrigation land and water management and need to be engaged to be “part of the solution”. This will take time, resources and possibly monitoring, trials and demonstrations about sustainable irrigation land and water management.
- Horticultural irrigators should be engaged via industry and seek to find points of common interest (e.g. food safety, irrigation supply).

- There is a need to improve environmental awareness and for people to take pride in their farms. Farmers' understanding of connections to the Lakes needs to be improved. New Zealand provides a good model of the standard.
- Additional government investment should be directed towards extension services supporting irrigation land and water management.

11.2.8 Research, development and demonstration

- The Plan should support a demonstration of the latest Biodigester technology to convert dairy effluent to energy (heat and electrical energy). This technology may be viable for adjoining dairy farms. It could support diversification opportunities, with heat used in greenhouses (e.g.) and the "waste" used for fertiliser.
- Best practice for dairy effluent management – integrated with best practice nutrient management - needs to be demonstrated within the region to lift environmental performance and avoid the "dirty dairy" tag used in New Zealand.
- Demonstrations and trials are needed for vegetable producers.
- Energy efficiency opportunities for water transfer, pumping and pipeline operations should be explored. This may extend improving control of low energy flood irrigation systems.
- Greater promotional effort is required to review or test "Apps" to assist irrigators.

11.2.9 General comments

- *Governance:* WGCMA should consider having irrigator representation on the proposed Lake Wellington Sustainable Irrigation Group (LWSIG).
- *Change drivers:* changing consumer needs and climate change resilience requirements must be addressed in the Plan.
- *Water security:* security of water will be fundamental for the development of agribusiness in the region.
- *Nutrient pathways:* the consultation paper does not adequately and explicitly detail the influence of large storm events (especially under climate change scenarios) on nutrient run-off.
- *Energy security:* the Plan should lobby for better power supply to the district (including 3 phase power).
- *Water quality target:* the (SEPP) target of 7.5 t/y reduction in phosphorus exports does not seem sufficiently ambitious.
- *Future land use:* the scenario of expansion in irrigation should be challenged, particularly given the threat to water supplies provided by climate change.
- *Regulation:* over-regulation and "red tape" are big issues. Government is perceived as hindering development, particularly compared with Queensland.

Part C: Implementing the vision for irrigation land and water management in Lake Wellington catchment

12 A vision for irrigation land and water management

12.1 Vision for irrigation land and water management

A draft vision for the Plan was developed as during the Stage 1 review of the Macalister LWMP. That vision was modified during Stage 2 to incorporate a reference to cultural as well as environmental assets. The Plan's vision for irrigation in Lake Wellington catchment is for…

a highly productive and sustainable irrigation community that values and protects its natural and cultural assets.

The vision recognises the vital role that irrigated agriculture has in the region's economy. It describes a promising future where agriculture is profitable and resilient and community aspirations for waterway health, social and cultural connections are achieved. The vision is consistent with the aspirations of the State's water plan, *Water for Victoria* (DELWP, 2016a).

The vision reflects Lake Wellington catchment's current status as an attractive and highly productive irrigation region and the aspiration of irrigators and the broader community for irrigated agriculture to be profitable, environmentally sustainable and resilient in the face of the changes and challenges it will experience. The Plan aims to achieve this by supporting irrigation farming operations in being future-focussed, productive, efficient and connected with each other. The vision also highlights the value placed on the social and cultural connections which exist to land and Country among irrigators, Traditional Owners and the catchment community.

12.2 Objectives and long-term outcomes

The review of the Macalister LWMP proposed that the scope of the Lake Wellington LWMP be narrowed to consider two main objectives: reducing nutrient exports to the Gippsland Lakes and containing salinity and high water tables. However, early consultation through Stage 2, including the "futures" workshop (Chapter 8), suggested that such a narrow focus was inconsistent with the concept of a *sustainable irrigation community*, which had been envisioned. As a result, the scope of the plan was expanded to consider four aspirational objectives and five key, long-term outcomes (Table 12.1).

Table 12.1 Aspirational objectives and long-term outcomes of the Lake Wellington Land and Water Management Plan

Aspirational objectives	*Long-term outcomes*
• Healthy, resilient lakes, wetlands and waterways • Profitable and sustainable irrigated agriculture sector • Collaborative and innovative farming culture • Cultural and social values are maintained and respected	• Reduction in nutrients and other pollutants in the Gippsland Lakes • Contain impacts of salinity and high water tables • Sustainable regional economic growth • Increased economic value from agricultural emissions • Improved understanding and management of social and cultural values

The Plan has the strong focus on reducing nutrient exports from Lake Wellington catchment's irrigation areas and containing salinity and shallow water tables, which was recommended by the Macalister LWMP review. These remain fundamental priorities of the Plan.

However, the Plan also accommodates several additional *Water for Victoria* priorities, including climate resilience, Indigenous engagement and greenhouse gas emissions reduction.

Climate resilience is implicit in the first two aspirational objectives. Healthy and resilient lakes, wetlands and waterways will depend, in part, on the management of environmental pressures associated with the use of water and nutrients in irrigation. Irrigation can only remain profitable and sustainable, if it is resilient to pressures resulting from projected climate change.

The Plan aspires to have social and cultural values associated with Lake Wellington catchment's irrigation areas maintained and respected. This includes both Indigenous and non-Indigenous values.

Strong support for reducing emissions from irrigation was received in responses to the consultation paper (see Chapter 11.2). This support is consistent with *Water for Victoria's* requirement for the water sector to provide leadership in making progress towards the State's 2050 net zero emissions target. The Plan recognises that net zero emissions is not an appropriate ambition for an irrigation region that is dominated by dairy production. However, the Plan advocates for other actions to improve energy efficiency, generate renewable energy and reduce agricultural emissions associated with effluent management and nitrogenous fertiliser use. Adoption of these measures should enable significant improvements in the economic value generated by greenhouse gas emissions resulting from irrigation land and water use.

13 Implementing the Lake Wellington Land and Water Management Plan

13.1 Overview

This section describes the programs and actions that will guide implementation of the Lake Wellington LWMP. The programs include support for on-ground works, as well as enabling interventions, such as planning, extension service provision, research and monitoring.

Actions to implement the Plan have been grouped into six program themes, as depicted in Figure 13.1. Two programs – farm planning and innovative and connected irrigation communities – are primarily enabling activities, which support the four main implementation programs. While the latter include a mix of works and enabling activities, they are primarily responsible for delivering the actions by which the Plan's objectives (Chapter 12) will be achieved.

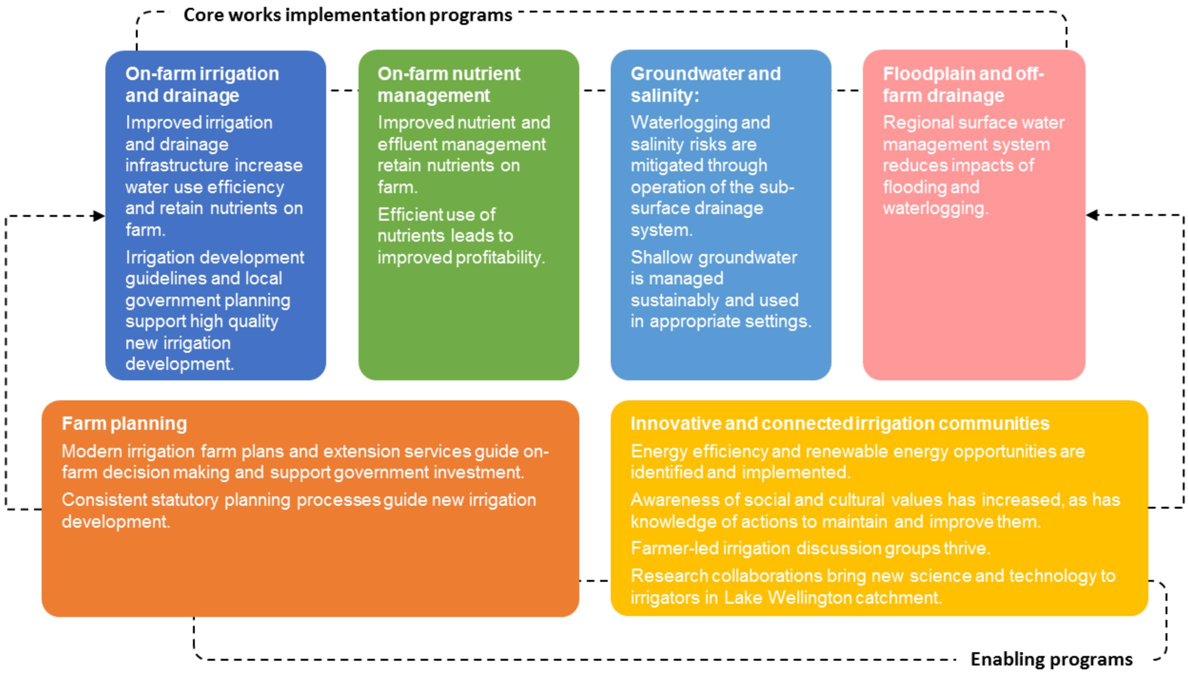

Figure 13.1 Lake Wellington Land and Water Management Plan programs and program goals

The programs are described below (Chapters 13.3-13.8). These descriptions reiterate the program goal, provide the rationale and context for the program and highlight the activities which the Plan proposes to support. Each of the program descriptions includes a graphic which summarises the benefits of enabling and on-ground works actions for the Plan's aspirational objectives and outcomes.

Assumptions underpinning the programs and activities are noted in Chapter 15.8.

The Lake Wellington LWMP will initially continue the Macalister LWMP's focus on irrigated dairying in MID and adjoining areas. As the Plan is implemented, opportunities to involve vegetable growers and other irrigators from across Lake Wellington catchment will be explored and developed. The activities described in the following sections may be adapted and new activities introduced through the Plan's adaptive management processes (Chapter 15.6) following engagement with other industries and irrigators from across the catchment.

13.2 Prioritising actions

Government funding for natural resource management is relatively scarce and strongly contested. In choosing where to allocate resources, decision-makers need to consider community interests, environmental and cultural values and risks to the environment. Recommended actions for each program (see Chapters 13.3-13.8) have been assessed and prioritised based on:

- How well they help to meet the Plan's objectives;
- Their relative costs and benefits;
- The balance between provision of public and private benefit;
- Their overall cost in relation to reasonable estimates of overall public investment;
- Their likely adoption by irrigators.

The Plan's work program was developed in conjunction with a TWG comprising representatives of key State Government agencies, regional authorities, local government and irrigation industry organisations. Key steps are depicted in Figure 13.2.

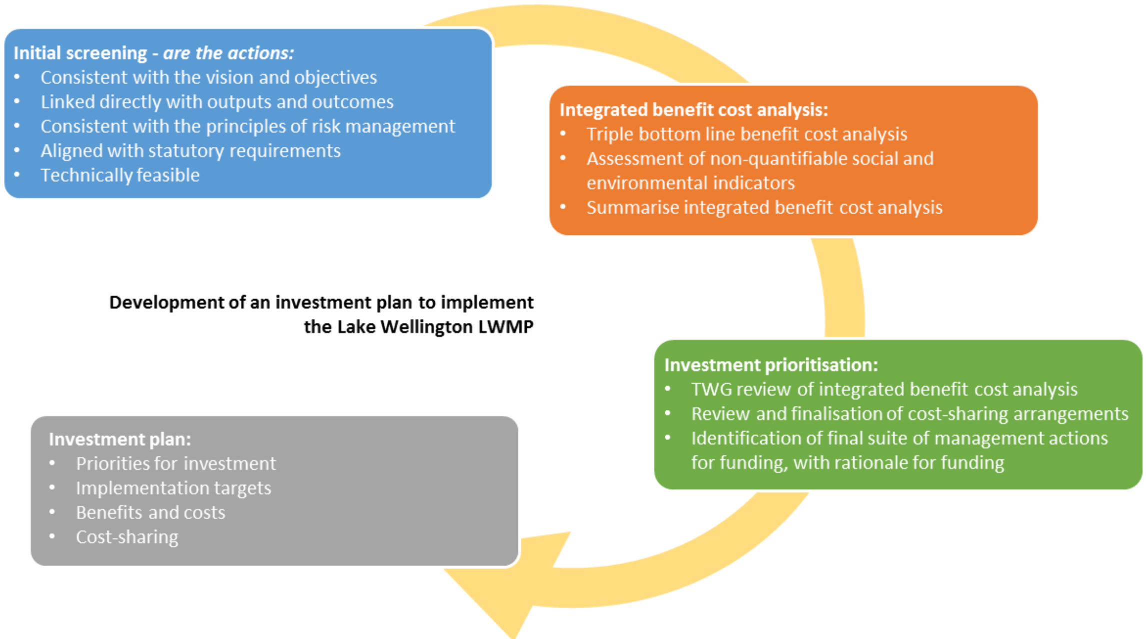

Figure 13.2 Steps in formulating the work program and investment plan for Lake Wellington Land and Water Management Plan

Details of the financial analysis of the Plan's programs are provided in Chapter 14, as are the proposed cost-sharing arrangements and the rationale for these.

13.3 Farm planning program

13.3.1 Intended program outcomes

Irrigation and drainage infrastructure improve water use efficiency and retain nutrients on farm. Irrigation development guidelines and local government planning support high quality new irrigation development.

13.3.2 Rationale

Farm planning is a tool to help irrigators consider their long-term objectives and drive infrastructure investments and the farm management activities that will help to achieve them. Farm plans help irrigators take full advantage of opportunities associated with the land and water available to them and the irrigation supply and drainage systems to which they may connect – including supply systems upgraded under MID2030. They lead to on-ground action which can improve productivity, deliver water and labour savings and enable more efficient use of fertilisers.

Farm planning is a critical enabling action, which is essential in setting a framework for practices and on-ground works that contribute directly to the Plan's aspirational objectives and outcomes.

13.3.3 Overview and key actions

The irrigation farm planning framework that was being implemented in the MID was renewed as part of the process of developing the Lake Wellington LWMP. The renewed farm planning framework (Chapter 9) recognises the critical role farm planning can play in realising the economic and environmental opportunities which result from improved farm layout, irrigation supply system modernisation and upgraded irrigation systems and methods.

Key features of the renewed approach are depicted in Figure 9.1. Its four main components are:

- *Irrigation efficiency check:* AgVic extension officers will undertake a check on the efficiency of current irrigation systems and (for dairy operations) the management and operation of effluent systems. A brief report will advise on low cost early actions to address key risks and/or opportunities.
- *Goals and strategies:* AgVic extension officers will work with the irrigator to define or understand goals and objectives to help set directions for the concept plan and irrigation farm plan. This process will be supported by a new decision support tool, which will be adapted (with support from the Plan) for Lake Wellington irrigators from existing business planning and goal-setting tools[6].
- *Concept plan:* maps and text which describe on-farm assets (of all kinds, including environmental features, farm infrastructure, soils etc.) and the landscape setting for the farm. The concept plan will reflect risks and opportunities associated (e.g.) with existing or new native vegetation (or provision of shelter), flooding (and other reflections of climate variability and climate change), high water tables, waterways and irrigation and drainage systems. It will inform how farm layout and management can mitigate key risks and enable opportunities to be taken up.
  Where neighbours are willing, concept plans will provide a mechanism for irrigators to collaborate to (e.g.) protect environmental and heritage features, manage surface water flows or dairy effluent, develop shared infrastructure and even develop renewable energy opportunities.

[6] The Plan 2 Farm tool developed by North Central CMA to support decision-making by irrigators regarding connecting to modernised irrigation infrastructure provides a useful starting point for development or adaptation of a business planning tool to Lake Wellington irrigators.

As part of the *Innovative and connected communities program* (Chapter 13.8), the Plan will support the development of new farm planning modules to help identify and manage cultural heritage features, reduce off-farm nutrient movement, improve energy efficiency and reduce greenhouse gas emissions.

- *Irrigation farm plan (IFP):* a detailed topographic survey will be undertaken to inform the development of the IFP. As has traditionally been the case, the IFP will address the management and movement of water around and from the property and all key risks (including nutrient and sediment movement) associated with this. The IFP may address: irrigation delivery and layout, earthworks, irrigation system design and management (including reuse), dairy effluent management systems and sediment trap locations and operation.

The concept plan and/or IFP could include plans for the management of dairy effluent.

The new farm planning framework encourages irrigators to review their plans periodically to ensure they remain relevant to their goals and strategies and that the concept plan, irrigation design and management systems are all working effectively.

Working with their advisors, irrigators will have considerable flexibility in selecting the components of the renewed farm planning framework that best relate to their operations and needs. The framework will be delivered by AgVic extension personnel and private irrigation planners and designers. Discussions with irrigators in the course of farm planning will provide extension personnel with the opportunity to direct them to other important land and water management support services offered by WGCMA, State Government agencies and industry organisations.

Development of an irrigation farm plan is a prerequisite for accessing financial incentives which are proposed to be made available under the Plan. Under the Gippsland Irrigation Development Guidelines, an irrigation farm plan is mandatory for all new irrigation developments. These guidelines will be revised to align with the renewed farm planning framework.

Engagement of irrigators in upland irrigation areas (e.g. Thorpdale potato growers) in the farm planning program will be supported by developing a farm planning module which is specific to this type of irrigation production system.

Key actions to be supported by the Plan are outlined in Table 13.1. Details on the assumptions underpinning these actions are given in Table 15.10. The financial evaluation of farm planning actions is described in Chapter 14.

Table 13.1 Key actions and targets for the farm planning program

What the Plan will support:	Implementation period (y)										Targets or outputs
	1	2	3	4	5	6	7	8	9	10	
1.1 A flexible and holistic irrigation farm planning and extension program that will: • Provide support to irrigators to undertake an "irrigation efficiency check" and implement practical, low cost actions as they develop their farm plan. • Provide farm planning extension services. • Support for farm survey and irrigation layout/design by farm planning consultant. • Support irrigators developing farm plans that, where appropriate, include collaborative, cross-property environmental and/or infrastructure works.	**Lead:** AgVic **Delivery mechanism:** extension, financial incentives										20 properties with irrigation efficiency check annually. 500 ha/y with modernised irrigation farm plans. 500 ha/y with new irrigation farm plans. Farm planning will be supported by high quality extension services and access to private irrigation designers to support farm planning.

What the Plan will support:	Implementation period (y) 1	2	3	4	5	6	7	8	9	10	Targets or outputs
1.2 Development or adaptation farm business planning tools to support irrigation farm planning. The tools will assist in the initial stages of farm planning engagement to help irrigators articulate and develop their business and farm management goals as a basis for effective farm planning. The tool will focus on defining objectives for farm business and family and understanding financial capacity for investing in IFP improvements.											Lake Wellington farm business planning tool.
	Lead: WGCMA **Delivery mechanism:** resource assessment										
1.3 Adaptation of irrigation farm planning concepts to upland irrigation settings. Guidance on irrigation farm planning will be developed for irrigators in these areas, drawing on lowland irrigation experience and dryland whole farm planning processes.											Upland irrigation farm planning guidelines linked to updated farm planning process.
	Lead: WGCMA **Delivery mechanism:** resource assessment										
1.4 Development of Lake Wellington best practice guidelines and standards for farm planning and irrigation, which draw on the insights and experiences of local farm planners, designers and extension staff and is consistent with the requirements of the *Water Act 1989*											Best practice guide to irrigation and irrigation farm planning.
	Lead: WGCMA **Delivery mechanism:** resource assessment										
1.5 Engagement with local government to ensure that statutory planning processes for irrigation farm planning are risk-based, consistent across Lake Wellington catchment and ensure high quality new and modified irrigation developments.											Consistent statutory planning work flow for new irrigation developments and works affecting floodplains. Statutory planning processes ensure appropriate referrals and evaluations are included.
	Lead: WGCMA **Delivery mechanism:** partnership development										

13.3.4 Financial incentives

The Plan recommends that financial incentives are provided for undertaking and implementing the results of the irrigation efficiency check, the development of new irrigation farm plans and the updating of existing farm plans prior to connection to the modernised SRW irrigation supply system. The level at which these incentives are provided will be set as part of the development of the Plan's initial annual implementation plan and reviewed periodically.

13.3.5 Contributions to Plan objectives and outcomes

As illustrated by Figure 13.1, the farm planning program is a key enabler of the Plan's main implementation programs. While it provides little direct contribution to achieving the Plan's aspirational objectives and outcomes, it will be a key enabler of most of these (Figure 13.3) – particularly as new farm planning tools and processes are developed to support:

- Business planning and goal setting;
- Identification and management of cultural heritage assets;
- Design and implementation of energy efficiency and renewable energy initiatives;
- Reduced off-farm movement of nutrients;
- Collaborative planning across property boundaries.

As has historically been the case, farm planning will continue to support the implementation of time and water-efficient irrigation systems which help to reduce threats from salinity and water-logging. Incorporation of energy efficiency and renewable energy initiatives may enable irrigators to access financial incentives or other support from government or industry emissions reduction initiatives (e.g. Agriculture Victoria's *Agriculture Energy Investment Plan*).

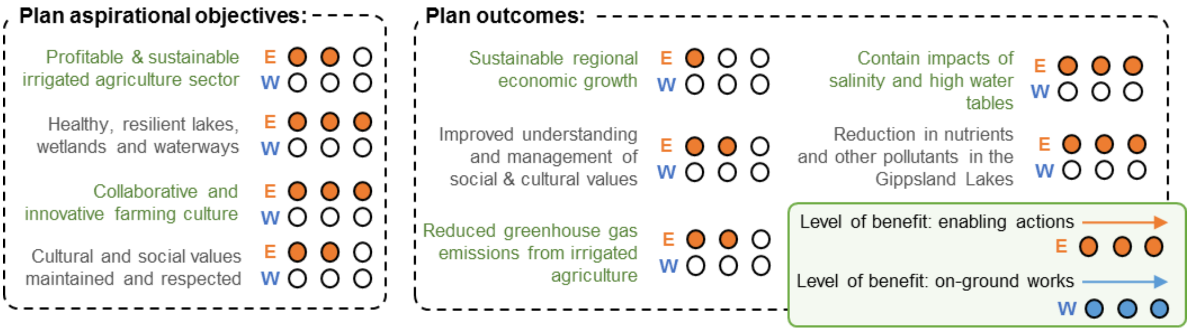

Figure 13.3 Contribution of the farm planning program to enabling and achieving aspirational objectives and outcomes of the Lake Wellington Land and Water Management Plan

13.4 On-farm irrigation and drainage program

13.4.1 Intended program outcomes

Improved irrigation and drainage infrastructure increase water use efficiency and retain nutrients on farm. Irrigation development guidelines and local government planning support high quality new irrigation development.

13.4.2 Rationale

The on-farm irrigation and drainage program will be the Plan's main delivery program. It supports the implementation of works and measures described in irrigation farm plans and, within the MID, it enables irrigators to take advantage of irrigation supply systems which have been upgraded under MID2030.

This program enables irrigators to improve irrigation water use efficiency and generate water savings which can then be used to drive on-farm production and profitability improvements. Related activities under this program also reduce labour requirements, thereby lowering costs and/or improving work-life balance for irrigators

13.4.3 Overview and key actions

Historically, this program (within the MID) has delivered works which have provided significant water savings and reduced off-farm nutrient and sediment losses. This has improved production and benefited local waterways and Lake Wellington. While the program has traditionally focussed on dairy farms within the MID, it will be expanded to include dairying and other irrigated livestock operations in areas outside the MID and irrigated vegetable-growing or (other) horticultural operations throughout Lake Wellington catchment.

The program will provide high quality extension services and, for some activities, financial incentives to support:

- Construction of irrigation reuse systems on properties with flood irrigation;
- Conversion of conventional flood irrigation systems to spray, pressurised drip or high flow flood irrigation systems (where these are appropriate to the soil type);
- Application of technologies (e.g. soil moisture sensors, controllers for irrigation system automation) and practices which improve water efficiency and/or reduce labour requirements;
- MID irrigators connecting to SRW's upgraded irrigation supply system.

The Plan supports a collaborative model of extension service provision, whereby public and private service providers and industry organisations support each other and integrate across the key dimensions of irrigation farming and irrigation land and water management – including improved irrigation water and nutrient use efficiency.

Partnerships will be developed with irrigators, industry groups and agencies to establish local, on-farm demonstrations and trials of best practice irrigation management. As applicable, these will be integrated with demonstrations and trials of best practice in nutrient and sediment management and support extension activities to improve irrigation practices. These trials' and industry engagement will initially focus on dairy production in the MID, however as irrigators in other industries and parts of Lake Wellington catchment are engaged in Land and Water Management programs, new trials and demonstrations may be implemented.

Some irrigation efficiency improvements rely on pumping of water, which increases energy demands and may lead to greater greenhouse gas emissions. Unreliable energy supplies in parts of the MID and the current high cost of energy are reported by irrigators as providing a disincentive or barrier to the adoption of irrigation efficiency improvements. The Plan supports measures to improve energy supply reliability for irrigators within the catchment, including through the development of local renewable energy generation capacity. It also supports measures to build irrigators' capacity to improve their energy use efficiency.

Planning requirements for new irrigation developments and major irrigation developments – under the Gippsland IDGs – are coordinated under this program. These will be revised to take account of the renewed farm planning framework developed for the Lake Wellington LWMP (see Chapter 9).

Under the *Water Act 1989*, the IDGs can only be used to regulate new ("greenfields") irrigation developments and irrigation redevelopments where there are changes in water use licence conditions (e.g. to increase the annual use limit or change the area to be irrigated). Many new vegetable production operations in the MID area involve redevelopment of existing dairying or other irrigated livestock production operations and do not trigger the IDGs. While most of these operations apply best practice irrigation technologies, these (re)developments are effectively unregulated.

The Plan supports amendments to the *Water Act 1989* which would allow all major irrigation developments to be referred to local government and key agencies to ensure irrigation layouts and management practices are consistent with Ministerial water use objectives and the objectives of the Plan. It also supports amendments to the *Water Act 1989* to ensure that groundwater use from a Take and Use licence is counted towards the overall annual use limit for areas which are also irrigated using surface water resources.

An increasing number of irrigators in the MID are constructing on-farm water storages to provide greater control over water availability. Some of these are inappropriately located or poorly designed, leading to failure and/or damage to nearby environmental features. The Plan – through this and the farm planning program - will encourage irrigators who plan to construct on-farm storages to do so in appropriate settings and to a high standard. It also supports the regulation of these water storages by local government[7].

The Plan also supports a review of the regulations regarding sizing requirements and operation of reuse dams to ensure they are safe, can be operated efficiently and cost-effectively[8] and that potential off-site impacts on flows and nutrient and sediment movement are appropriately managed.

Key actions to be supported by the Plan are outlined in Table 13.2. Details on the assumptions underpinning these actions are given in Table 15.11. The financial evaluation of actions under this program is described in Chapter 14.

Table 13.2 Key actions and targets for the on-farm irrigation and drainage program

What the Plan will support	Implementation period (y)										Targets or outputs
	1	2	3	4	5	6	7	8	9	10	
2.1 Provision of high quality extension services and, as appropriate, financial incentives to support Improvements in on-farm irrigation infrastructure and management practices. Activities which are supported include: • Flood-to-spray conversion; • Best practice surface irrigation (particularly high flow flood irrigation) on appropriate soil types;	**Lead:** AgVic, WGCMA **Delivery mechanism:** extension, financial incentives, on-ground works										300 ha/y flood-to-spray conversion. 200 ha/y best practice surface irrigation (high flow flood irrigation)

[7] Under Schedule 35.07 to Wellington Shire's Planning Scheme, earthworks which change the rate or flow or discharge point of water across a property boundary require a planning permit.

[8] Including, as appropriate, being powered by farm-generated renewable energy sources.

What the Plan will support	Implementation period (y) 1 2 3 4 5 6 7 8 9 10	Targets or outputs
• Irrigation outlet rationalisation (as part of connection to upgraded irrigation supply systems); • Automation of irrigation; • Soil moisture monitoring.		
2.2 Provision of high quality extension services and financial support for the construction or expansion (in appropriate settings) of irrigation reuse systems and related works to help retain nutrients and sediment on-farm.	**Lead:** AgVic, WGCMA **Delivery mechanism:** extension, financial incentives, on-ground works	700 ha/y new or expanded reuse systems.
2.3 Provision of high quality extension services and coaching for irrigators to enable on-going improvements in irrigation efficiency.	**Lead:** Agriculture Victoria **Delivery mechanism:** extension, capacity building	Irrigation efficiency and system upgrades (as per 2.1, 2.2) Extension activities, trials and demonstrations (as per 2.4)
2.4 Development of industry partnerships to establish local, on-farm demonstrations and trials of best practice irrigation management. Priorities for trials and demonstrations will be developed in conjunction with industry partners and irrigators and apply to dairy and horticulture sectors. They will be initially undertaken in the MID region and then in irrigation areas across Lake Wellington catchment, following engagement with irrigators in these areas. Demonstrations and trials will, as appropriate, integrate across on-farm irrigation and drainage and on-farm nutrient management. Demonstrations could be at paddock, farm and/or sub-catchment scale, depending on consultation outcomes.	**Key participants:** Agriculture Victoria, WGCMA, GippsDairy, AusVeg, Dairy processors. **Delivery mechanism:** extension, on-farm demonstration, partnership development, capacity building	On-farm trials. Field days. Extension publications. Improved irrigation practices.
2.5 Revision and updating of the Gippsland IDGs to set best practice standards for on-farm irrigation systems and practices for new or modified irrigation developments. *A major revision to the IDGs would only occur after regulatory/legislative change to enable them to regulate or influence major irrigation redevelopments without change to water use licence conditions. This would be as part of a state-wide process with significant input from DELWP.*	**Lead:** WGCMA **Delivery mechanism:** resource assessment	Updated Gippsland Irrigation Development Guidelines (Year 1). Fully revised IDGs following regulatory change to enable them to address irrigation redevelopments that occur without change to water use licence conditions (~Year 6)
2.6 Investigation of the issues, benefits and impacts of a proposal to increase reuse dam size limits in a Gippsland context.	**Lead:** SRW, WGCMA **Delivery mechanism:** resource assessment	Report on assessment, policy guidance on irrigation reuse dams

13.4.4 Financial incentives

The Plan recommends that financial incentives are provided for constructing or expanding irrigation reuse systems; conversation of flood irrigation systems to spray or pressurised drip irrigation systems; and best practice surface irrigation on appropriate soil types. The level at which these incentives are provided will be set as part of the development of the Plan's initial annual implementation plan and reviewed periodically.

13.4.5 Contributions to Plan objectives and outcomes

The on-farm irrigation and drainage program is one of the Plan's main implementation programs. It includes enabling activities (e.g. provision of high quality extension services) which support the achievement of the Plan's aspirational objectives and outcomes, as well as the works that directly help to achieve them (Figure 13.4). The program's key impacts are in relation to:

- Improving the profitability of irrigation;
- Reducing risks and potential impacts associated with salinity, high water tables and off-site movement of nutrients and sediment;

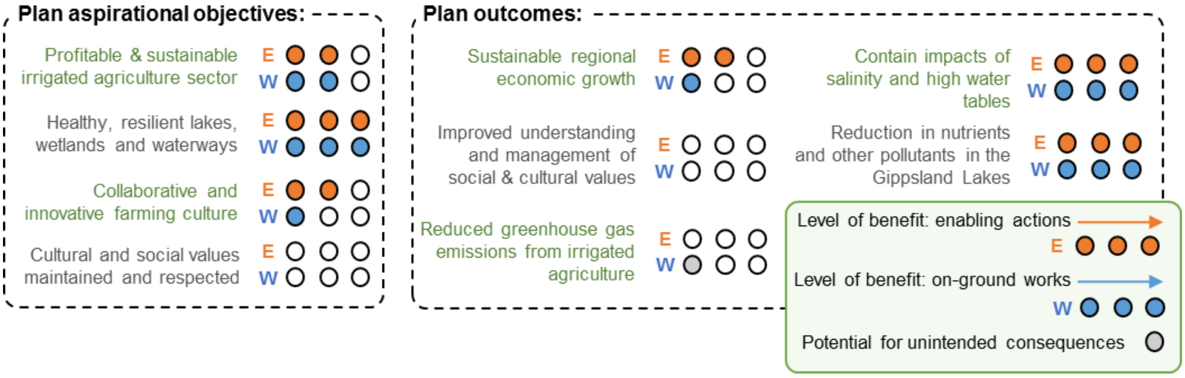

Figure 13.4 Contribution of the On-farm irrigation and drainage program to enabling and achieving aspirational objectives and outcomes of the Lake Wellington Land and Water Management Plan

The key actions under this program lead to increased on-farm energy use. With the current electricity generation mix being heavily reliant on non-renewable sources, this program potentially has the unintended consequence of increasing greenhouse gas emissions from irrigation. Activities linked to this, the farm planning and innovative and connected communities programs aim to break this nexus by improving energy efficiency and exploring local renewable energy generation opportunities.

While the program is considered to generally be consistent with the Plan's aspirational objective of healthy, resilient lakes, wetlands and waterways, the construction of reuse dams will reduce flows into waterways during small to medium rainfall events and may have unintended adverse local effects on waterway health.

13.5 On-farm nutrient management

13.5.1 Intended program outcomes

Improved nutrient and effluent management retain nutrients on farm. Efficient use of nutrients leads to improved profitability.

13.5.2 Rationale

This program is a new initiative of the Lake Wellington LWMP. It reflects the objectives of the Plan and its key role in meeting the proposed SEPP (Waters) phosphorus load reduction target for Lake Wellington. The program also makes sense from an irrigator's perspective: given the cost-price pressures they face, it is essential they maximise the effectiveness of their investments in fertiliser and use other sources of nutrients (purchased feed, dairy effluent) to best effect. By improving the efficiency of nitrogen use within irrigation farming systems, the program also seeks to reduce emissions of nitrous oxide, which is a potent greenhouse gas.

13.5.3 Overview and key actions

While the proposed SEPP (Waters) target for reduction of nutrient inputs from irrigation land and water management in Lake Wellington catchment only addresses phosphorus, this program also aims to reduce off-farm losses of nitrogen and sediments.

The nutrient management program will be underpinned by:

- *Farm planning:* to guide actions which manage off-farm movement of nutrients and sediment;
- *On-farm irrigation and drainage management:* which allow nutrients to be captured and reused on farm;
- *Trials and extension services:* the provision of collaborative, high quality extension services to support adoption of current best practices for nutrient management and to trial and demonstrate emerging practices which may further improve nutrient use efficiency and reduce off-farm losses;
- *Research and monitoring:* to better understand the sources and movement of nutrients in Lake Wellington catchment and assess the effectiveness of this Plan.

Partnerships will be developed with irrigators, industry groups and agencies to establish local, on-farm demonstrations and trials of best practice nutrient management. As applicable, these will be integrated with demonstrations and trials of best practice in irrigation management and support collaborative, industry-linked extension activities. These trials' and industry engagement will initially focus on dairy production in the MID, however as irrigators in other industries and parts of Lake Wellington catchment are engaged in land and water management programs, new trials and demonstrations will be implemented.

The Plan also supports on-going engagement by EPA in monitoring and compliance management for dairy effluent systems. This may include supporting (with Agriculture Victoria) on-farm trials, demonstrations and related capacity building activities, as well as compliance monitoring and – as necessary – enforcement through pollution abatement notices.

EPA is changing its business model from *after the fact* detection of pollution and enforcement through pollution abatement notices. This may see Codes of Practice developed for potentially polluting activities (e.g. management of dairy effluent) and more active engagement with industry to detect issues before pollution incidents occur. The Plan supports this approach and the development of a joint agency-industry position on the management of dairy effluent in Lake Wellington catchment.

Key actions to be supported by the Plan are outlined in Table 13.3. Details on the assumptions underpinning these actions are given in Table 15.12. The financial evaluation of actions under this program is described in Chapter 14.

Table 13.3 Key actions and targets for the on-farm nutrient management program

What the Plan will support	Implementation period (y) 1 2 3 4 5 6 7 8 9 10	Targets or outputs
3.1 Provision of training to irrigators to enable them to develop and implement nutrient management plans for their properties.	**Lead:** GippsDairy, WGCMA **Delivery mechanism:** Extension, financial incentives, capacity building	25 irrigators/y participate in training programs. 500 ha/y with new nutrient management plans development and implemented.
3.2 Provision of high quality extension services and financial incentives to improve the design and management of dairy effluent systems and undertake other measures which help to keep nutrients and sediment on farm.	**Lead:** GippsDairy, WGCMA **Delivery mechanism:** Extension, financial incentives	Irrigator participation in training programs. New nutrient management plans developed. Trials and demonstrations developed. Field days held and extension materials produced. 20 dairy effluent system upgrades/y.
3.3 Establishment of industry partnerships for local on-farm demonstrations and trials of best practice systems for the management of dairy effluent and of nutrients and sediments in pasture and horticultural cropping systems. Priorities for trials and demonstrations will be developed in conjunction with industry partners and irrigators and apply to dairy and horticulture sectors. Demonstrations and trials will, as appropriate, integrate across on-farm irrigation and drainage and on-farm nutrient management. Demonstrations could be at paddock, farm and/or sub-catchment scale, depending on consultation outcomes.	**Key participants:** Agriculture Victoria, WGCMA, GippsDairy, AusVeg, Dairy processors. **Delivery mechanism:** extension, on-farm demonstration, partnership development, capacity building	On-farm trials. Field days. Extension publications. Improved irrigation practices.
3.4 EPA continuing compliance monitoring to ensure that dairy effluent management systems conform to regulatory standards. *Longer-term, EPA will be adjusting its business model and moving to pollution prevention rather than response. In relation to dairy effluent, this may include development and support for adherence to an industry Code of Practice.*	**Lead:** EPA **Delivery mechanism:** compliance monitoring, regulatory enforcement	Compliance audits. Reporting on compliance outcomes.
3.5 Research to improve understanding of the sources and movement pathways of nutrients lost from irrigation farms and how these may be affected by horticultural expansion and potential new irrigation developments. The research will also consider the influence of flooding and related episodic events in lowland and upland environments. It will build on the substantial body of data from historical water quality monitoring.	**Lead:** WGCMA **Delivery mechanism:** resource assessment	Research reports and extension activities based on research findings.

What the Plan will support	Implementation period (y) 1 2 3 4 5 6 7 8 9 10	Targets or outputs
3.6 Provision of financial incentives for vegetable growers to construct silt traps to capture sediments and nutrients that would otherwise be lost from their farms.	**Lead:** AgVic, WGCMA **Delivery mechanism:** financial incentives, on-ground works	50 ha/y of irrigated land with new silt traps.
3.7 Development of an agreed agency-industry position and approach on the management of dairy effluent on irrigation farms. The position will be the subject of an industry-led communication campaign to increase regulatory compliance and adoption of best practice in dairy effluent management.	**Key partners:** WGCMA, EPA, GippsDairy, SRW **Delivery mechanism:** resource assessment, communications	Position paper. Communications campaign. Improved management of dairy effluent and reduced export of nutrients into local waterways.

13.5.4 Financial incentives

The Plan recommends that financial incentives are provided for irrigator participation in nutrient management plan training and, subject to resources, implementation of measures to reduce off-farm exports of nutrients and sediment. The level at which these incentives are provided will be set as part of the development of the Plan's initial annual implementation plan and reviewed periodically.

13.5.5 Contributions to Plan objectives and outcomes

The On-farm nutrient management program is a key implementation program and includes works that directly help to achieve the Plan's aspirational objectives and outcomes (Figure 13.4). It also includes enabling activities (e.g. provision of high quality extension services) which support their achievement. The program's key impacts are in relation to:

- Improving the profitability of irrigation;
- Reducing off-farm losses of nutrients and sediments into local waterways and wetlands and to Lake Wellington.

Actions to improve nitrogen use efficiency and effluent management under this program should also contribute to reductions in greenhouse gas emissions.

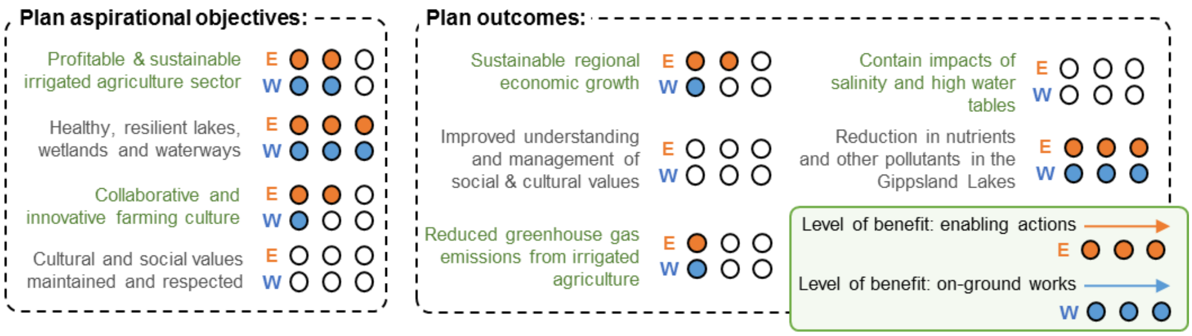

Figure 13.5 Contribution of the on-farm nutrient management program to enabling and achieving aspirational objectives and outcomes of the Lake Wellington Land and Water Management Plan

13.6 Groundwater and salinity program

13.6.1 Intended program outcomes

Waterlogging and salinity risks are mitigated through operation of the regional sub-surface drainage system. Shallow groundwater is managed sustainably and used in appropriate settings.

13.6.2 Rationale

This program continues to implement the strategy for irrigation salinity of the successful *West Gippsland Salinity Management Plan* (2005). This applies to the Macalister Salinity Management Zone (SMZ)[9], which includes the MID and its immediate environs (Figure 13.6). The irrigation salinity strategy is underpinned by several principles, as follows:

- Irrigation induced salinity will be primarily addressed by reducing groundwater recharge, where this is practically and economically feasible;
- Engineering options to reduce the water table in saline areas such as groundwater pumping will be implemented where high value assets will either not be protected by recharge control methods or will not be protected in a timely way;
- Groundwater pumping options with on-farm usage is preferred over options where the water is disposed directly to lakes and rivers;
- Any disposal of pumped groundwater to rivers and/or lakes will be undertaken to ensure there is no significant adverse environmental impacts on receiving waters or downstream diverters and will be in accordance with regulatory requirements.
- Where reducing the water table through recharge control or engineering options in saline areas will take significant time or is impractical, then salt tolerant crops and pastures will be used to improve productivity and reduce soil erosion.
- The decision to implement specific salinity control measures will take into account the social, economic and environmental costs and benefits and include the impacts on other natural resource management issues such as nutrient reduction, river health and water conservation.
- Interventions in irrigation salinity will seek to build the capacity of landowners and the community to recognise and understand the problem and aid in implementing cost-effective solutions.

As part of the Lake Wellington LWMP, this program will provide for the on-going maintenance and operation of sub-surface drainage infrastructure, which helps to protection vulnerable areas within the Macalister SMZ from waterlogging and salinity.

13.6.3 Overview and key actions

Groundwater is a significant source of water for irrigation in the Lake Wellington catchment, particularly around the Macalister SMZ (Figure 13.6). Management of the resource is complex.

Groundwater is typically taken from shallow “shoe string” sand aquifers and is used to supplement surface water supplies. During extended wetter periods, the water table in these aquifers approaches the land surface, leading to waterlogging and land salinisation. These threaten agricultural productivity, environmental features and infrastructure (particularly roads).

[9] The Macalister SMZ comprises the Boisedale, Clydebank, Heyfield, Maffra and Nambrok salinity management areas of the West Gippsland Salinity Management Plan. These were the five management areas where irrigation was the primary driver of salinity processes.

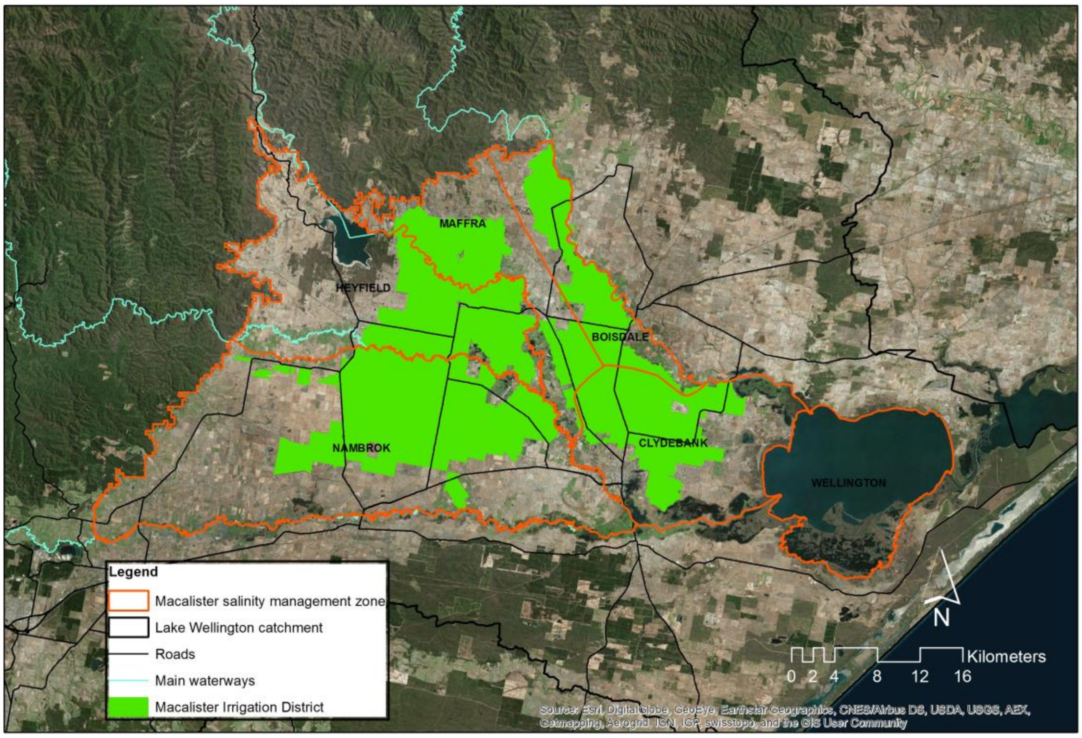

Figure 13.6 Macalister Salinity Management Zone. The SMZ comprises the five irrigation salinity management areas identified in 2005 West Gippsland Salinity Management Plan.

Since their peak in the 1990s, water tables have fallen across the MID. This reflects the influence of the millennium drought and major improvements in irrigation efficiency, with the latter supported by the West Gippsland Salinity Management Plan and, subsequently, the Macalister LWMP. While water table levels have not permanently returned to their pre-drought levels, they rise rapidly during wetter periods and continue to pose a threat in some areas.

Sub-surface drainage provided by public and private groundwater pumps in the MID has played an important role in managing salinity risks, particularly during wetter climate phases. This program aims to ensure sub-surface drainage infrastructure has the capacity and operational readiness to respond to these wetter climate phases and contain the effects of salinity and waterlogging. Achieving this objective also depends on the effectiveness of actions under the on-farm irrigation and drainage program (Chapter 13.4) and the framework for sustainable irrigation management provided by the irrigation farm plans (see Chapter 13.3).

Salinity issues are also present in isolated parts of the Lake Wellington catchment outside of the Macalister SMZ. If these or other incidences of irrigation-induced salinity develop to the point where they threaten key environmental or infrastructure assets, responses will be developed through the Plan's adaptive management processes (Chapter 15.6).

Key actions to be supported by the Plan are outlined in Table 13.3. Details on the assumptions underpinning these actions are given in Table 15.13. The financial evaluation of actions under this program is described in Chapter 14.

Table 13.4 Key actions and targets for the Groundwater and salinity program

What the Plan will support	Implementation period (y) 1	2	3	4	5	6	7	8	9	10	Lead / Delivery mechanism	Targets or outputs
4.1 Maintenance of the Macalister SMZ's public SSD infrastructure, including renewing bores and pumping systems as they reach the end of their operating lives. SRW is encouraged to: • Apply an asset management framework for the regional sub-surface drainage system; • Review energy efficiency and/or renewable energy opportunities associated with operation of SSD system and implement them, if practicable and cost-effective.	■	■	■	■	■	■	■	■	■	■	**Lead:** SRW **Delivery mechanism:** asset management, on-ground works	Macalister SMZ sub-surface drainage infrastructure maintains operational availability for use as required. Asset management framework developed and implemented. Report on energy efficiency improvement opportunities developed.
4.2 Irrigators with groundwater licences continuing to use shallow groundwater for irrigation, when it is available and of suitable quality, in accordance with local groundwater management rules.	■	■	■	■	■	■	■	■	■	■	**Lead:** SRW **Delivery mechanism:** on-ground works	Shallow groundwater within the Macalister SMZ is used for irrigation as appropriate.
4.3 SRW undertaking periodic reviews of management arrangements for the use of shallow groundwater to ensure these support effective use of the resource and management of salinity risks.			■					■			**Lead:** SRW **Delivery mechanism:** resource assessment	Reporting of periodic reviews to Lake Wellington Sustainable Irrigation Group.
4.4 The provision of high quality extension services to support farmers in areas of salinity and shallow water tables to "live with salinity". This includes providing advice to support the establishment and sustainable management of appropriate, generally salt-tolerant pastures, fodder or crops. *This action continues the Living with Salt program of the West Gippsland Salinity Management Plan.*	■	■	■	■	■	■	■	■	■	■	**Lead:** Agriculture Victoria **Delivery mechanism:** extension	On-farm trials. Field days. Extension publications. Improved production from salt or waterlogging-affected land.

13.6.4 Financial incentives

There are no activities under this program for which financial incentives are proposed.

13.6.5 Contributions to Plan objectives and outcomes

The Groundwater and salinity program is a key implementation program and includes works that primarily address the Plan's aspirational objectives and outcomes that relate to or result from the management of salinity and water logging (Figure 13.7). While operation of the groundwater pumps directly contributes to these objectives, maintenance of the infrastructure is considered to be a key enabling activity.

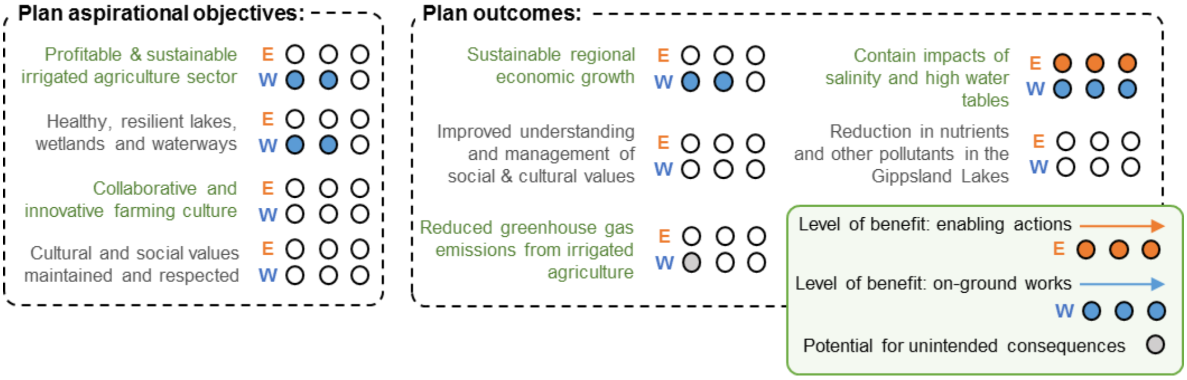

Figure 13.7 Contribution of the groundwater and salinity program to enabling and achieving aspirational objectives and outcomes of the Lake Wellington Land and Water Management Plan

Operation of the Macalister SMZ's sub-surface drainage infrastructure during wetter climate phases requires pumping of groundwater and currently has the unintended consequence of increasing greenhouse gas emissions from irrigation. Opportunities to reduce emissions - by improving energy efficiency and (potentially) using renewable energy - are supported under action 4.1.

13.7 Floodplain and off-farm irrigation drainage program

13.7.1 Intended program outcomes

The regional surface water management system reduces impacts of flooding and waterlogging.

13.7.2 Rationale

The Floodplain and off-farm drainage program primarily addresses drainage management within the MID. WGCMA's *Floodplain Management Strategy* (WGCMA, 2017) and the *Victorian Rural Drainage Strategy* (Draft) (DELWP, 2017a) address rural drainage and floodplain management issues elsewhere in the Lake Wellington catchment. The surface water management system helps to reduce the effects of flooding on farming land and infrastructure and is the primary route by which nutrients and sediments lost from irrigation farms find their way into local waterways and wetlands and, ultimately, to Lake Wellington.

13.7.3 Overview and key actions

The MID is drained by a comprehensive system of natural waterways and constructed drains. These collect and remove rainfall run-off, excess irrigation water, outfalls from irrigation channels and discharges from public groundwater pumps.

Construction of irrigation reuse systems, improvements in irrigation water use efficiency and irrigation supply system upgrades under MID2030 have reduced drain flows. These and drier climate conditions have helped to lower water tables and reduced the need for SRW to operate the sub-surface drainage system. Under non-flood conditions, drains now discharge fewer nutrients and less salt into natural waterways and Lake Wellington.

While these changes are beneficial, they also alter the flow regime of natural waterways within the MID. What, if any, environmental impact this has is poorly understood.

The Plan will continue to support diversion of drain flows for irrigation in appropriate settings. However, the relevance of drain diversion is expected to continue to decline with on-going irrigation efficiency improvements, increased irrigation tailwater reuse and further MID2030 supply system upgrades. Transfer of SRW drain heads to irrigators to support irrigation reuse will continue to be supported. The Plan supports the on-going management of the MID surface water management system by SRW and landholders to whom drain heads have been transferred.

Some Victorian CMAs are working with irrigators to reinstate natural floodplain flow pathways as a means of improving surface drainage and the health of waterways and wetlands. In conjunction with WGCMA's floodplain management program, the Plan will support the consideration of opportunities to adapt mechanisms such as Drainage Course Declarations and floodplain restoration to Lake Wellington catchment. Any actions resulting from this analysis will be developed and implemented through the Plan's adaptive management processes (see Chapter 15.6).

The Plan will support two important research initiatives to help improve the health of floodplain waterways and wetlands and manage any adverse impacts of irrigation reuse on these ecosystems:

- *Nutrient management:* research to investigate opportunities for drains and floodplain wetlands to be managed to capture or use nutrients carried off-farm during smaller flood or flow events;
- *Impacts of on and off-farm drainage management:* on-farm irrigation efficiency improvements and irrigation reuse have reduced flows into natural waterways and wetlands. This research project will explore the implications of these changes to determine if there are any adverse unintended impacts, and if so, how they might be managed.

Key actions to be supported by the Plan are outlined in Table 13.5. Details on the assumptions underpinning these actions are given in Table 15.14. The financial evaluation of actions under this program is described in Chapter 14.

Table 13.5 Key actions and targets for the Floodplain and off-farm drainage program

What the Plan will support	Implementation period (y) 1 2 3 4 5 6 7 8 9 10	Targets or outputs
5.1 Continuation of transfers of SRW drain heads to irrigators to enable tail water to be harvested and reused on farms.	**Lead:** SRW **Delivery mechanism:** planning, contributes to on-ground works	Drain head transfers to landholders – in response to irrigator requests.
5.2 Diversion of drainage water by irrigators where it is available and its quality is suitable.	**Lead:** SRW **Delivery mechanism:** on-ground works	Diversion of drainage waters in appropriate settings and as opportunities arise.
5.3 Consideration of planning and funding mechanisms to improve the function of the natural and constructed surface drainage systems and health of waterways and wetlands.	**Lead:** WGCMA **Delivery mechanism:** resource assessment, planning	Report on available mechanisms.
5.4 Research to investigate opportunities for drains and floodplain waterways and wetlands to be managed to capture or use nutrients carried off-farm during small-medium floods/rain flow events.	**Lead:** WGCMA **Delivery mechanism:** resource assessment	Research report. Extension activities based on research findings.
5.5 Research to quantify changes in streamflows resulting from on and off-farm irrigation and drainage management activities supported by the Plan and to assess their impacts.	**Lead:** WGCMA **Delivery mechanism:** resource assessment	Research report.
5.6 On-going maintenance of elements of the regional surface water drainage system that are retained under SRW operational control.	**Lead:** SRW **Delivery mechanism:** on-ground works	Function of regional surface water management system is maintained.

13.7.4 Financial incentives

There are no activities under this program for which financial incentives are proposed.

13.7.5 Contributions to Plan objectives and outcomes

The Floodplain and off-farm drainage program is a supporting program for the Plan. Supported research activities and maintenance of the surface water management infrastructure are enabling activities which support the achievement of aspirational objectives and outcomes relating to salinity and waterlogging risk mitigation and nutrient management. The surface drainage system makes direct contributions to these objectives and outcomes (as per Figure 13.8).

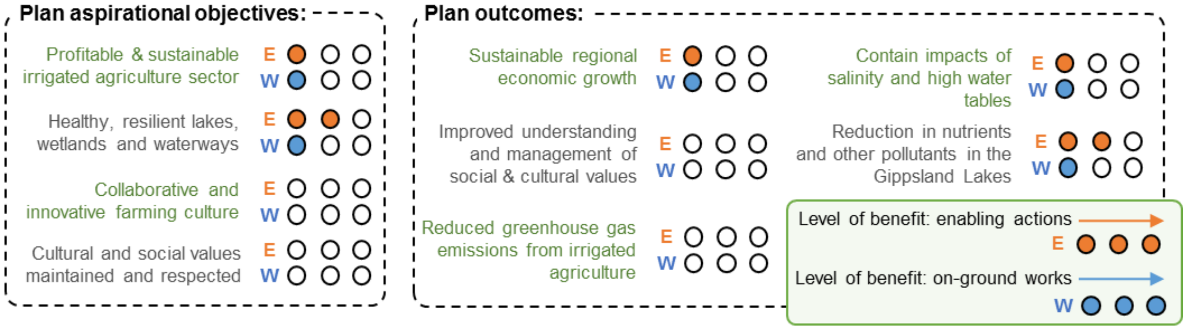

Figure 13.8 Contribution of the Floodplain and off-farm drainage program to enabling and achieving aspirational objectives and outcomes of the Lake Wellington Land and Water Management Plan

13.8 Innovative and connected irrigation communities program

13.8.1 Intended program outcomes

Energy efficiency and renewable energy opportunities are identified and implemented. Awareness of social and cultural values has increased, as has knowledge of actions to maintain and improve them. Farmer-led irrigation discussion groups are thriving. Research collaborations bring new science and technology to irrigators.

13.8.2 Rationale

The Lake Wellington LWMP identifies the need for new thinking and adaptive management to enable a future where the catchment's irrigation sector is sustainable, profitable and resilient. Shifts in land use and adoption of new technology are driving changes to farming practices and improving real-time management of irrigated land. Climate variability and longer-term climate change, consumer preferences and market forces will continue to shape irrigation industries. New policy seeks to build stronger links between land and water management and the social and cultural values of local communities and Traditional Owners.

This program consolidates the Plan's responses to the changing environment for irrigation land and water management and the need to strengthen community connections around the issue.

13.8.3 Overview and key actions

The Victorian Government has set a target for the State to achieve net zero emissions by 2050. One of the major commitments of the Victorian Water Plan, *Water for Victoria*, was for the State's water sector (CMAs and Water Corporations) to lead public sector action on emissions reductions (DELWP, 2016a).

While the commitment to net zero emissions does not extend to irrigated agriculture, land and water management programs can play an important role in reducing some of irrigated agriculture's greenhouse emissions, as well as increasing the community benefit provided by each unit of emission. More efficient use of water and nitrogenous fertilisers, better management of dairy effluent, conversion to variable speed or other, more efficient pumps and on-farm renewable energy generation may also contribute to these outcomes. Improved energy efficiency and local renewable energy generation may also help to mitigate the effects of unreliable or inadequate electricity supply experienced by some irrigators and the high cost of energy.

Opportunities to reduce emissions through improved fertiliser and dairy effluent management are already incorporated into the Plan, via the on-farm nutrient management program. However, the Plan proposes to explore other emissions reduction opportunities through this program, including in:

- *Farm planning:* development of an on-farm energy efficiency and renewable energy module for delivery with the renewed farm planning framework;
- *Energy efficiency plan:* identify and address constraints on and opportunities for the use of renewable energy and energy efficiency measures in irrigation within Lake Wellington catchment.

The Plan recognises the important cultural and social values associated with land and water in the Lake Wellington catchment. Gunaikurnai and farmers are both custodians of land in the catchment. This program will support activities which bring Traditional Owners, irrigators and other community members together to share perspectives, appreciate each other's connections to land and Country and collaborate in protecting areas with high cultural or social value.

Several initiatives will be developed to help advance these objectives, including:

- *Farm planning:* development of a cultural heritage planning and management model for incorporation in the renewed farm planning framework;
- *Cultural awareness communications, events and training materials:* which are intended to build awareness among irrigators and the broader catchment community of Indigenous cultural values associated with irrigation landscapes and how these can be maintained;
- *Collaborative management arrangements:* whereby support will be provided to irrigators and Traditional Owners to collaboratively manage Indigenous cultural features and values in irrigation landscapes.

The Plan also recognises the importance of building collaborative relationships between irrigators, which allow them to learn from each other, innovate and trial new equipment and practices. It will support the development of farmer-led irrigator discussion groups to support farm planning, irrigation efficiency, nutrient management planning and implementation.

As the Plan is implemented, WGCMA and its partners in the LWMP will seek to build connections with horticultural irrigators in various parts of Lake Wellington catchment and their industry organisations. This may lead to the development of new actions under relevant programs and/or to the adaptation of existing actions.

The Lake Wellington Sustainable Irrigation Group (LWSIG, see Chapter 13.9) will also seek to engage with relevant parties in sectors which are indirectly involved in or influence irrigation land and water management (e.g. banking, insurance, energy distribution). The engagement will involve two-way interaction to provide information about the Plan and its context and to understand participants' perspectives on the challenges faced by Lake Wellington catchment irrigators.

The LWSIG will also develop a collaborative research and technology "network" to facilitate engagement of the science and technology community in irrigation land and water management within Lake Wellington catchment. They will do this by continuing to identify research and technology priorities and opportunities (building on those expressed in this Plan) applicable to irrigation land and water management. The LWSIG will then actively engage public and private sector researchers and technologists in applying leading thinking and/or technology to key challenges and technologies for the catchment.

The scope of research to be facilitated through the research and technology network will include issues which are core to the Plan, such as irrigation water and nutrient efficiency and management of nutrient movement in irrigation landscapes. It could also include issues which are relevant to the full suite of the Plan's objectives, including the application of traditional knowledge in irrigation land and water management, applications of remote sensing technologies and "big data" in irrigation management, climate resilient farming and development of appropriate renewable energy technologies.

Key actions to be supported by the Plan are outlined in Table 13.6. Details on the assumptions underpinning these actions are given in Table 15.15. The financial evaluation of actions under this program is described in Chapter 14.

Table 13.6 Key actions and targets for the innovative and connected irrigation communities program

What the Plan will support	Implementation period (y) 1	2	3	4	5	6	7	8	9	10		Targets or outputs
Innovative irrigation												
6.1 Development of an on-farm energy efficiency and renewable energy module for delivery within the farm planning framework.			■								**Lead:** AgVic **Delivery mechanism:** resource assessment, capacity building	Farm planning module, supported by extension materials and training for farm planning providers.
6.2 Development of an irrigation energy efficiency plan for the Lake Wellington catchment. The plan will: • Review and assess any water policy or regulatory constraints on use of renewable energy in pumping; • Document renewable energy and energy efficiency opportunities appropriate to dairy and horticultural production in Lake Wellington catchment; • Describe an implementation program to take advantage of renewable energy and energy efficiency opportunities. Any implementation measures will be developed as part of the Plan's adaptive management processes.				■	■						**Partners:** WGCMA, SRW, AgVic, GippsDairy **Delivery mechanism:** resource assessment, planning	Review of policy and regulatory impediments to renewable energy use in pumping. Irrigation energy efficiency plan. The energy efficiency plan will ultimately lead to implementation of energy efficiency and renewable energy measures.
6.3 Development of a farm planning module for cultural heritage planning and management.		■									**Lead:** WGMCA, GLaWAC **Delivery mechanism:** resource assessment, planning	Farm planning module, supported by guidance for delivery.
6.4 Facilitation of irrigation land and water management research collaborations that address regional research priorities.			■	■	■	■	■	■	■	■	**Partners:** WGMCA, GippsDairy, AusVeg, AgVic, universities **Delivery mechanism:** resource assessment, capacity building	Research reports, seminars, field days, demonstrations and trials, extension materials.
Connected communities												
6.5 Development of communications and cultural awareness training materials related to Indigenous cultural values, Native Title and protection of cultural heritage for irrigation areas in Lake Wellington catchment.	■	■	■	■	■						**Lead:** WGMCA, GLaWAC **Delivery mechanism:** resource assessment, capacity building	Training materials. Cultural awareness communications and engagement activities. 10 participants/y in cultural awareness training.
6.6 Development of and support for collaborative arrangements between irrigators and Gunaikurnai to protect cultural heritage values.		■	■	■	■	■	■	■	■	■	**Lead:** WGMCA, GLaWAC **Delivery mechanism:** partnership arrangements, on-ground works	2 sites/y protected.

What the Plan will support	Implementation period (y) 1–10	Targets or outputs
6.7 Community events which recognise Indigenous and non-Indigenous cultural and social values associated with Lake Wellington irrigation areas.	**Partners:** WGMCA, GLaWAC, Local government **Delivery mechanism:** capacity building, community engagement	1 event annually.
6.8 Facilitation of farmer-led irrigator discussion groups which support (e.g.) farm planning, irrigation efficiency, nutrient management planning and implementation.	**Lead:** AgVic **Delivery mechanism:** capacity building	8 groups of ~10 people initiated and operating effectively.
6.9 Engagement with financial and other support services about irrigation land and water management issues	**Partners:** WGMCA, GLaWAC, Local government **Delivery mechanism:** capacity building, community engagement	1 event annually.

13.8.4 Financial incentives

There are no activities under this program for which financial incentives are currently proposed. Subject to funding, incentives could be developed to support collaborative management of key cultural heritage features by irrigators and Traditional Owners.

13.8.5 Contributions to Plan objectives and outcomes

The innovative and connected irrigation communities program, like the Farm planning program, is a key enabler of activity under the plan (Figure 13.9). Its main areas of focus are on greenhouse gas emissions, building connections between irrigators and Gunaikurnai and among irrigators themselves. The program also supports activities that will directly assist in advancing the Plan's cultural values objectives and outcomes (as per Table 13.6).

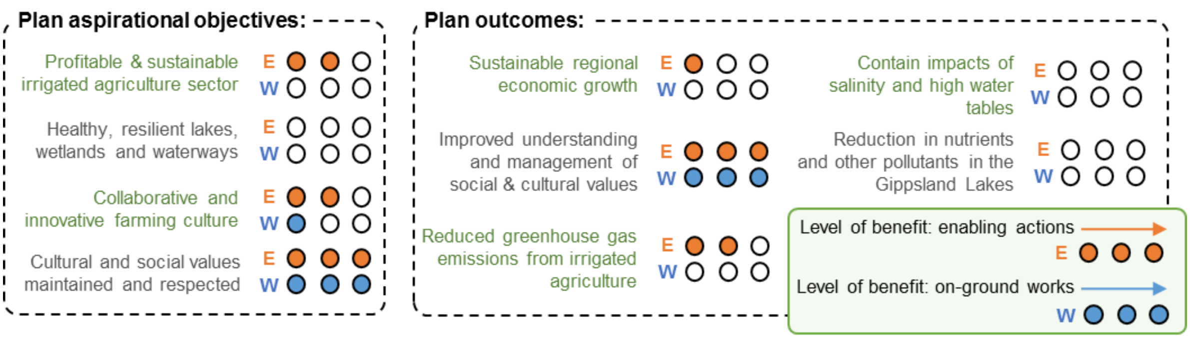

Figure 13.9 Contribution of the innovative and connected communities program to enabling and achieving aspirational objectives and outcomes of the Lake Wellington Land and Water Management Plan

13.9 Governance arrangements, roles and responsibilities

13.9.1 Lake Wellington Sustainable Irrigation Group

Program governance for the new LWMP will operate under a Lake Wellington Sustainable Irrigation Group (LWSIG; Figure 13.10). These arrangements will build on those operating for the Macalister LWMP. This group will focus on adaptive management of the Plan's programs. It will coordinate MERI processes under the Plan and drive collaborative research and innovation activities. The roles and responsibilities of key groups are described in Chapter 15.3.2.

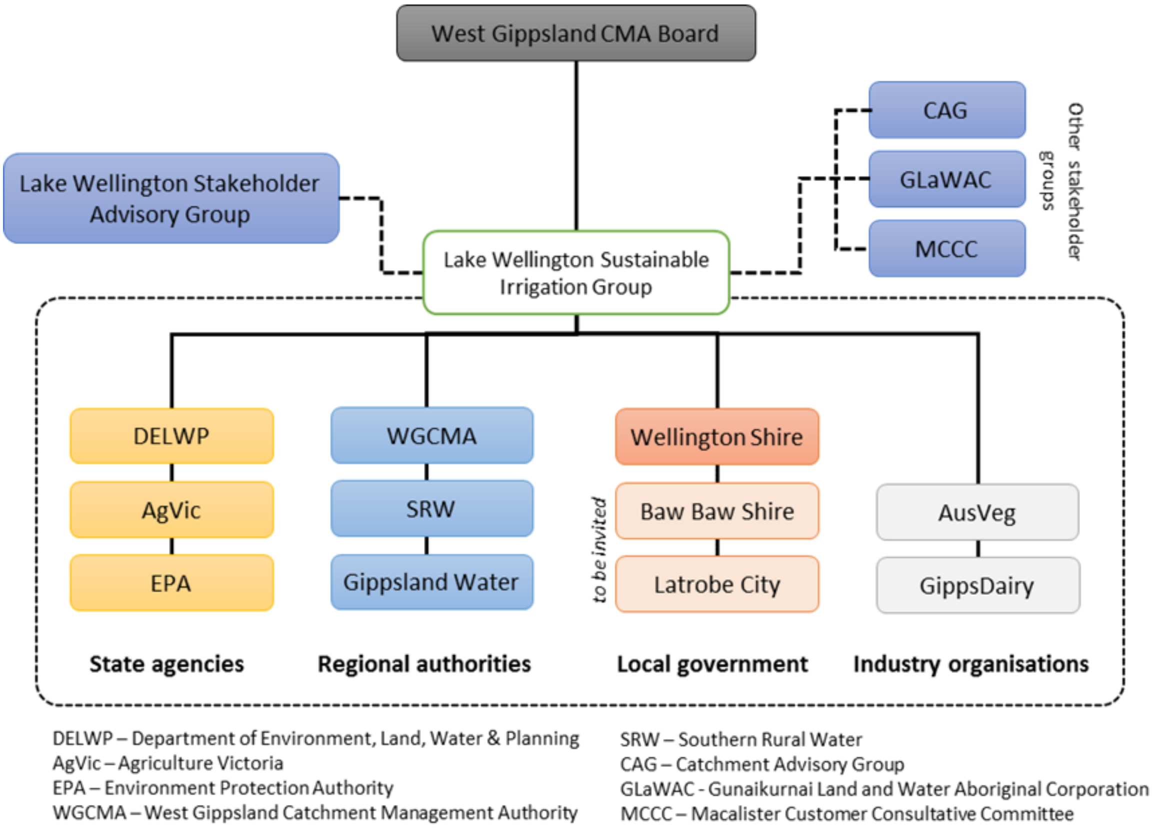

Figure 13.10 Proposed governance arrangements for Lake Wellington Land and Water Management Plan

The LWSIG will include representatives of the organisations forming the TWG which supported the development of this Plan. The group will continue to report and be accountable to WGCMA's Board. Given that the geographic scope of the Plan includes the entire Lake Wellington catchment, it is proposed that Baw Baw Shire and Latrobe City Council be invited to participate in the LWSIG (with Wellington Shire).

The LWSIG will continue to engage with the current MID stakeholder groups and will also reach out to GLaWAC to facilitate engagement with the catchment's Traditional Owners, and to industry and irrigator groups in other parts of the Lake Wellington catchment.

These engagement activities may result in changes in the make-up of LWSIG and/or the Lake Wellington Stakeholder Advisory Group (SAG).

13.9.2 Lake Wellington Stakeholder Advisory Group

The Stakeholder Advisory Group (Figure 13.10) formed to support development of the Plan will be renewed. The new membership will help to guide implementation of the Plan and ensure its programs remain relevant to the needs of irrigators. The group will initially include irrigators from the MID. Participation from horticultural irrigators in the MID and irrigators in other parts of the catchment will be sought as the Plan is implemented. Their role is described in Chapter 15.3.2.

14 Economic evaluation

14.1 Executive summary

This chapter evaluates the costs and benefits of management actions proposed for the new Lake Wellington LWMP using cost benefit analysis (CBA). It identifies the overall benefits and costs of the Plan, discusses the role of government and proposes cost-sharing.

A number of management actions were proposed by the TWG formed to support development of the new Plan. Costs and benefits were assessed for 31 management actions which were grouped as:

- Resource assessments (13)
- Planning (4)
- Capacity building (3)
- Compliance (1)
- On-ground works (10)

The management actions were all grouped into the following six programs:

1. Farm planning
2. On-farm irrigation and drainage
3. On-farm nutrient management
4. Floodplain and off-farm irrigation drainage
5. Groundwater and salinity
6. Innovative and connected irrigation communities

A "simple, proportionate CBA" was undertaken to confirm that the actions for the Plan are effective and cost-effective in managing the impacts of irrigation. This CBA assessed the total capital costs and annual operating costs of actions, but simplified the benefits. The benefits assessed were:

- Reduced phosphorus loads discharge to Lake Wellington (public benefit);
- Increased pasture productivity (private benefit);
- Labour savings to irrigate (private benefit);
- Water savings (private benefit).

In addition to reduced phosphorus loads, the other key public benefits associated with Lake Wellington LWMP include: reduction in the impacts of salinity and high water tables on regional infrastructure (i.e. roads) and buildings, a reduction in the impacts of poor irrigation practices on the Gippsland Lakes and local waterways and wetlands, and the associated benefits to the regional economy.

Consistent with DELWP's *Guidelines for Land and Water Management Plans*, reductions in phosphorus loads to Lake Wellington were estimated, but the benefits were not monetised in the CBA. Regulatory requirements were assessed against cost-efficiency criteria rather than a CBA, as they must be complied with regardless of the ratio of benefits to costs.

The overall costs and benefits for each of the Plan's management programs are given in Table 14.1.

Table 14.1 Total present value of benefits by program (discounted at 7% over 30 years)

Lake Wellington LWMP program	Costs (PV[1])	Benefits (PV[1])	NPV[2]
Farm planning	$2,187,456	$0	-$2,187,456
On-farm irrigation and drainage	$24,996,851	$49,929,648	$24,932,798
On-farm nutrient management	$22,274,337	$22,267,325	-$7,102
Floodplain and off-farm irrigation drainage	$446,636	$0	-$456,636
Groundwater and salinity	$1,197,934	$8,480,975	$7,283,041
Innovative and connected irrigation communities	$653,131	$0	-$651,131
Total	**$51,756,345**	**$80,677,948**	**$28,921,603**
Benefit cost ratio (BCR)			**1.6**

Notes:

1. PV – Present value (of future costs and benefits)
2. NPV – Net present value (the net value of present benefits and costs.

Even without quantifying the benefits associated with a reduction in nutrients to Lake Wellington, the Plan is economically attractive with a NPV of $28.5 million and benefit cost ratio (BCR) of approximately 1.6.

The management actions proposed in the Plan are estimated to be able to reduce the discharge of phosphorus from Lake Wellington catchment's irrigation by an additional 1.9 tonnes each year for ten year life of the Plan (i.e. 19 tonnes over 10 years; Figure 14.1). If the Plan is successfully implemented, this should be sufficient to offset any increase in phosphorus exports resulting from expansion in irrigation areas and more intensive use of fertilisers (see Chapter 5).

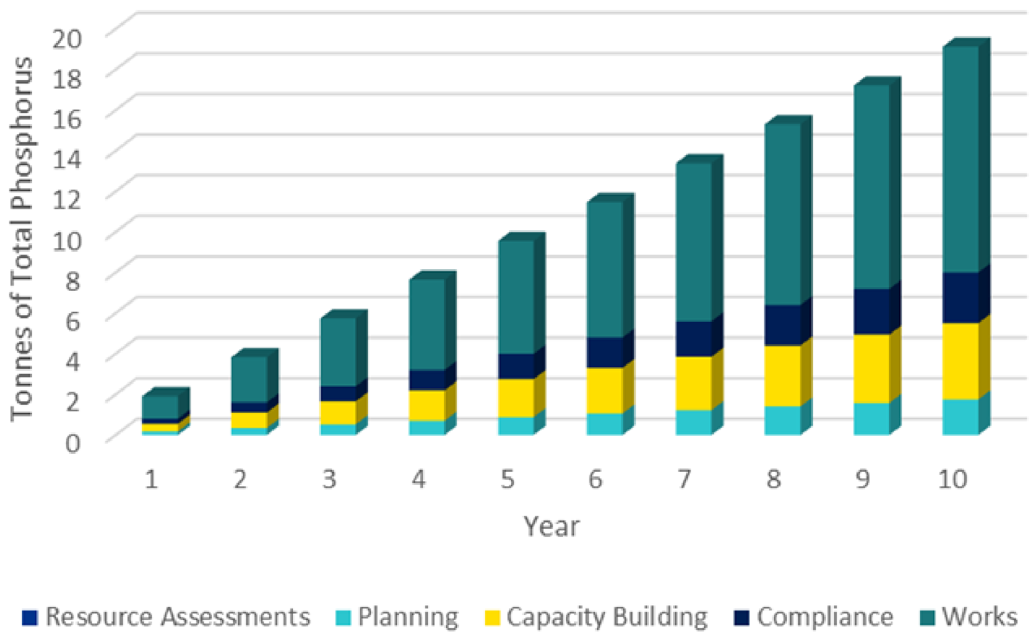

Figure 14.1 Reduced discharge of total phosphorus to Lake Wellington with assumed adoption of management actions

Government contributions to the funding of management actions in the Plan can be justified where there is evidence of market failure. There are clearly economic, social and environmental benefits of reducing nutrients to the Gippsland Lakes and there is an in-principle role for government to work with irrigators to address other negative environmental externalities associated with irrigation (e.g. salinity, groundwater accessions).

14.2 Introduction

14.2.1 What is the purpose of this chapter?

This chapter assesses the costs and benefits of specific management actions proposed for the Lake Wellington LWMP. The report identifies the overall benefits and costs for the LWMP, discusses the role of government and identifies actions suitable for cost sharing.

14.2.2 Land and Water Management Plan guidelines

The LWMP guidelines (DELWP, 2017b) set out Victoria's broad expectations for the review, renewal and implementation of irrigation land and water management plans. They outline the approach for developing regional LWMPs that are irrigator and community focussed and:

- Provide the regional strategic approach for improving sustainable irrigation in Victoria;
- Enable devolved, adaptive management of DELWP's Sustainable Irrigation Program (SIP) using modern governance arrangements;
- Consider the environmental, economic, social and cultural aspects of irrigation management;
- Establish and maintain strong engagement with irrigators, stakeholders and delivery partners;
- Set out shared regional objectives and priorities to support sustainable irrigation;
- Include targeted, cost effective actions that align with regional community and government priorities for sustainable irrigation;
- Demonstrate the connections between on-ground actions and regional objectives and targets;
- Demonstrate that the benefits of government investment exceed the costs;
- Provide a proper accountability framework for investment;
- Provide the basis for targeted, efficient and effective public performance reporting and evaluation.

This chapter demonstrates how the environmental, economic, social and cultural aspects of irrigation management are considered in decision-making. It demonstrates that the benefits of intervention exceed the costs and provides evidence for the role of government in irrigation management.

14.2.3 Prioritising management actions

All management interventions demonstrate a clear linkage to outcomes included in the program logic (Figure 15.2). The adoption of proposed management actions demonstrates the relative priority of actions within the overall Lake Wellington LWMP.

Management actions are classified under five broad headings; namely, resource assessment, planning, capacity building, compliance and on-ground works. Each type of management intervention will have very different abilities to achieve outcomes, such as the management of risks from irrigation and improvement of natural resource asset values.

When it comes to economic assessment of options, it is typical to combine various interventions (i.e. resource assessments, capacity building and on-ground works) because the overall outcome (benefit) depends on synergies between individual interventions.

14.3 Resource assessments

14.3.1 Introduction

Resource assessment includes relevant research and development, investigations and data collection, baseline trend and condition monitoring, and the use of decision support tools.

14.3.2 Research and development

Research and development (R&D) includes all research into understanding the links between various threats and their impact on resource conditions. This is an integral component of adaptive management. Specifically, it involves identifying gaps in understandings, collecting, collating and maintaining information, initiating research, understanding social drivers and understanding the implications of actions.

Improving knowledge is important across all catchment management. It is our understanding of the forces that create changes to resource conditions that allows us to strategically manage these resources. For example, developing an understanding of the biophysical effects of saline groundwater and its causes aids us in devising and targeting appropriate management actions. Improved knowledge is also required to verify assumptions between outputs of management actions and asset condition outcomes. Improving knowledge will be targeted at those areas where the returns on gaining knowledge are largest, that is, where it will provide most benefit.

R&D priorities identified for the Plan (also see Table 15.9) may be grouped as follows:

- Improved understanding of nutrient/pollutant/pathogen pathways (from farms to Lake Wellington);
- Improved on-farm systems for managing dairy effluent;
- Improved understanding and applied knowledge of best management practices (BMPs) for irrigation and nutrient management on farms.
- Increase awareness of opportunities to improve energy security through the use of renewable energy and/or energy efficiency measures.

In addition, the LWSIG will facilitate the development of collaborative arrangements for research and technology development to address emerging research priorities and technological opportunities for irrigation land and water management as the Plan is implemented. These will be incorporated into program delivery as part of the Plan's adaptive management and capacity building activities.

Costs

The estimated costs and timing assumptions for this R&D shown in Table 14.2. It may involve external costs for consultancies and/or internal costs for agency staff to undertake the required work.

Table 14.2 Costs for research and development

#	Description	Estimated cost	Year commencing [over # years]
RA1	R&D to improve our understanding of nutrient/pollutant/pathogen pathways (from on-farm to Lake Wellington)	$150,000	3 [3]

RA2	R&D to develop improved on-farm systems for managing dairy effluent	$90,000	4 [1]
RA3	R&D to improve applied knowledge of best management practices (BMPs) on irrigated farms	$150,000	2 [2]
RA4	R&D to increase awareness of opportunities to obtain energy security through the use of renewable energy and energy efficiency	$90,000	4 [2]

Benefits

Benefits will arise from R&D where the information obtained is used to influence a decision that would otherwise have been made. In simple terms, the knowledge developed from R&D requires the information to be disseminated before any benefits are realised. The dissemination of knowledge may include publishing information in a technical report or journal, or it may involve extending knowledge through workshops or field days.

No assessment of the benefits of R&D has been undertaken. The benefits of R&D are incorporated into the assessments of capacity building and on-ground works.

14.3.3 Baseline, trend and condition monitoring and evaluation

This set of actions includes all activities related to measuring physical outcomes and outputs. It can be used to understand the links and uncertainties between various threats and their impact on resource conditions. It also includes monitoring the effectiveness of works and actions on the ground and comparisons with resource condition targets.

Monitoring is important across all assets and all important threats. For rivers and streams, extensive monitoring programs are in place specifically relating to water quality parameters. For other assets, there is a need to further develop targets and indicators to monitor asset condition.

Adaptive management, the systematic process for continually improving management, policies and practices by learning from implemented outcomes, is essential for successful delivery of the LWMP (see Chapter 15 for details of the Plan's adaptive management processes). This approach will enable lessons learned to be realised during the life of the plan and enable necessary adjustments to be made in response.

The adaptive management approach (Chapter 15) will utilise monitoring and evaluation activities to form a feedback loop in order to make necessary adjustments to the Plan. This same philosophy for continual improvement underpins the objectives for the region.

The potential monitoring and evaluation identified for the Lake Wellington LWMP (see Chapter 15.5) can be grouped as follows:

- Implement a regular land use and water use survey:
  - Develop a baseline data set from where changes in catchment condition, land use, and water use can be measured;
  - Benchmark water use efficiency by irrigation system and soil type;
- Evaluating the effectiveness and efficiency of drainage and pump infrastructure;
- Evaluation of the actual benefits and costs (*ex post* evaluation) of management actions (e.g. of farm planning and tailwater reuse systems);
- Nutrient and sediment management:
  - Develop a farm scale monitoring program/guidelines for nutrients and sediments;
  - Develop a monitoring program for nutrients and sediments from other irrigated land uses in the Lake Wellington catchment;

- Validating assumptions for adoption and on-farm reductions in nutrients and sediment loads.

Costs

The estimated costs and timing assumptions for baseline, trend and condition monitoring and evaluation are shown in Table 14.3. It may involve external costs for consultancies or and/or internal costs for agency staff to undertake the required work.

Table 14.3 Costs and timing assumptions for monitoring and evaluation

#	Description	Estimated cost	Year commencing [over # years]
RA5	Implement a regular land use and water use survey	$100,000 every five years	1 [every 5 years]
RA6	Evaluating the effectiveness and efficiency of drainage and pump infrastructure	$60,000	1 [1]
RA7	Ex-post evaluation of the benefits and costs of management actions	$90,000	2 [1]
RA8	Develop a target for sustainable regional economic growth	$15,000	1 [1]
RA9	Develop a monitoring program for nutrients and sediments from other irrigated land uses in the Lake Wellington catchment	$30,000	1 [1]
RA10	Develop opportunities to manage floodplains and drainage	$50,000	3 [3]
RA11	On-going nutrient and sediment monitoring	$100,000	1 [on-going]
RA12	Develop adapt irrigation farm planning tools	$160,000	2 [3]
RA13	Develop and adapt irrigation and drainage guidelines	$50,000	3 [1]

Benefits

Benefits will arise from monitoring and evaluation where the information obtained is used to influence a decision that would otherwise have been made. Similar to R&D, this occurs when the information obtained is disseminated.

No assessment of the benefits and costs of monitoring and evaluation has been undertaken for this project. The benefits of monitoring and evaluation are assessed as part of capacity building and on-ground works.

14.4 Planning

14.4.1 Introduction

Planning includes both statutory and non-statutory land use planning. Non-statutory land use planning includes preliminary irrigation assessments, irrigation farm plans (IFP), modernised irrigation farm plans and on-farm nutrient management plans.

14.4.2 Statutory land use planning

Statutory land use planning primarily relates to planning activities conducted by local government. In its management of this process, local government may refer planning proposals to other government organisations and statutory authorities for advice. Activities subject to local government planning may include proposals for development on floodplains and to clear native vegetation.

Statutory land use planning should only be introduced where market failure has occurred, or where the risk of not implementing it could mean irretrievable damage, and where alternative instruments of achieving the same outcome are not available or satisfactory.

No major changes to statutory land use planning are recommended for the Lake Wellington LWMP. However, it is proposed that WGCMA engage with the catchment's three main local government authorities (Baw Baw, Latrobe, Wellington) to achieve a consistent approach to planning approvals for new irrigation developments and any earthworks associated with them.

14.4.3 Preliminary irrigation assessments

Pre-irrigation farm plans (called "irrigation efficiency checks" in the farm planning program, Chapter 13.3) have been introduced to help irrigators realise some of the benefits of irrigation system modernisation (via MID2030) prior to completing full irrigation farm plans.

The introduction of channel automation into the Macalister Irrigation District (MID) has brought the operating levels of channels in the automated sections back under the control of SRW. This change has exposed some gravity supply outlets that have on-farm water levels incompatible with the specified channel operating levels.

Successful gravity irrigation requires both SRW and customers to operate their respective systems within specified ranges. SRW controls the channel level, provides an outlet with specified flow head-loss characteristics and the customer controls the water level on-farm downstream of the outlet.

High on-farm water levels usually result from the cumulative effect of a range of on-farm design and maintenance factors. An irrigator would usually have to rectify several of these factors to lower on-farm water levels to allow flow rates compatible with good on-farm irrigation practice.

Many flood irrigators are unaware of their current average application rate per irrigation and the opportunities to save water and improve production by rectifying issues with their on-farm supply system. The most common factors contributing to poor supply (i.e. high on-farm water levels) are:

- Undersized farm channels
- Farm channels with excessive weed growth
- Undersized structures or obstructions located in farm channels
- Undersized bay outlets
- Structures located too high (i.e. bay outlets and farm channel culverts)
- Inappropriate irrigation bay sizes for flow rate and soil types
- Irrigation of high ground, sometimes as a result of inadequate design or construction.

An irrigation advisor who visits a property can readily identify issues with the current supply system. Assuming one full day, an irrigation advisor could undertake a walk-through of an irrigators property and produce a short 1-2-page report on "quick fixes" that could be undertaken to realise the benefits of modernised irrigation supply.

This initial farm visit by an irrigation advisor would be intended to be a pre-cursor to a full IFP.

Costs

The cost and adoption assumptions for preliminary irrigation assessments are shown in Table 14.4. these would be undertaken by Ag Vic extension officers.

Table 14.4 Costs and adoption for preliminary irrigation assessments

#	Description	Estimated cost	Adoption	Year commencing [over # years]
P1	Preliminary irrigation assessments	$1,500 per property	20 properties/year	1 [10]

Benefits

No benefits have been assessed for preliminary irrigation assessments. Benefits are achieved when advice provided by the extension officer is implemented.

14.4.4 Irrigation farm plans and modernised irrigation farm plans

IFPs involve the survey and design of properties to provide a plan for future works to address irrigation, drainage and waterway issues (see Chapter 9). Modernised irrigation farm plans are undertaken on properties that have previously undertaken a farm survey, which may have been required for an earlier IFP. Depending on the circumstances of a property, these may or may not continue to be applicable. If not, a full, new IFP may be required.

The plan includes farm layout, water delivery points, land-forming needs, and drainage design. IFPs have no direct benefit but they 'enable' farm investment to occur in a timelier and considered way. Historically, landholders are required to complete an IFP before they are eligible for further incentives (i.e. conversion to spray irrigation or constructing a tailwater re-use system).

A future with MID2030 will require substantial investment by landholders to improve their farm layouts to enable higher flow irrigation. Key opportunities for the LWMP with respect to planning and irrigation assessment include:

- Developing an IFP linked to rationalisation to show where multiple Dethridge wheels can be replaced by one automated outlet
- Undertaking an irrigation assessment to determine the difference between potential water supply flow rates and actual flow rates and identify any "low hanging fruit" opportunities to improve their irrigation system performance
- Preparing a longer-term farm plan that will provide a blue print for future irrigation system development.

The irrigation farm planning framework for the Lake Wellington catchment has been revised through development of this Plan, as described in Chapter 9.

Costs

The cost and adoption assumptions for irrigation farm plans are shown in Table 14.5.

Table 14.5 Costs and adoption for irrigation farm plans

#	Description	Estimated costs	Adoption	Year commencing [over # years]
P2	Modernised irrigation farm plan	$70 /ha	500 ha/y	1 [10]
P3	New irrigation farm plan	$120 /ha	500 ha/y	1 [10]

Benefits

We have assumed that planning per se has no immediate benefits, and that any benefits will be achieved by implementing the 'works' that are outlined in the IFP.

14.4.5 On-farm nutrient management plans

In the past, dairy effluent was viewed as a by-product of the milking process. Management techniques were centred on disposal on sacrifice paddocks or treating it in a two pond system to reduce its strength. With continuing research and a far better understanding of effluent management the industry focus has shifted away from a waste mentality to a resource utilisation approach. Today there is a far greater awareness of the importance of effluent management from both an environmental protection perspective and the industry's marketability.

Having developed a process/guidelines for producing on-farm nutrient management plans (NMPs; see RA10), this action will implement the process/guidelines so that increasingly farms adopt on farm nutrient management.

The NMP may address:

- How nitrogen and phosphorus cycle in a farm system and how they can be lost from farms into water (including faecal and sediment losses);
- What water quality means and the significance of different water bodies and catchments to water quality;
- Where the nutrient hotspots are on-farm;
- What tools are available to help measure and manage nutrient use on-farm?
- What to focus on to improve nutrient use on-farm.

Costs

The cost and adoption assumptions associated with completing NMPs are presented in Table 14.6.

Table 14.6 Costs and adoption for nutrient management plans

#	Description	Estimated costs	Adoption	Year commencing [over # years]
P4	Nutrient management plans	$70 /ha	500 ha/y	1 [10]

Benefits

We have assumed that in developing a NMP, benefits will be realised due to behavioural change (i.e. without the need for additional investment). Examples of this may include changes in the timing, location and frequency of fertiliser applications, improved distribution of nutrients across the property and better management of effluent. The potentially result in productivity improvements and reduced off-farm nutrient export. The assumed benefits of NMP are shown in Table 14.7.

Table 14.7 Unit benefits associated with nutrient management plans

#	Description	Reduction in nutrient discharge (kg)[1]	Increase in production (%)	Labour saving (%)	Water saving (ML)
P4	Nutrient management plans	0.5	5%	0%	0

Note: 1. The estimated reduction in nutrient discharged is measured relative to Lake Wellington.

14.5 Capacity building

14.5.1 Introduction

Capacity building includes all activities that provide training and upskilling, as well as those raising awareness of improved land and water management practices among irrigators.

The extension of applied R&D on demonstration farms is a key focus of capacity building activities of the LWMP. The potential capacity building identified for the Lake Wellington LWMP study area can be grouped as follows:

- Extension of applied R&D:
    - Nutrient/pollutant/pathogen pathways

    - On-farm systems for managing dairy effluent
    - BMPs on irrigated farms in the study area (horticulture and dairy).
- Awareness raising:
    - Establishing communication channels between industries and between irrigators
    - Water trading
    - Regulation / red tape associated with floodplain planning, vegetation removal, siting/capacity of reuse dams
    - Financial business management
    - Celebrating success (signage and promotion)
    - Showcase BMPs for irrigation
    - Weather monitoring, irrigation scheduling and climate change.
- Agency efficiency:
    - Combined agency approach to reporting pollution incidents
    - Train the trainers (upskilling of extension officers)
    - Greater collaboration and coordination of activities requiring multi-agency input.

14.5.2 Extension of applied research and development

The extension of applied research and development (R&D) involves activities that provide training and upskilling (e.g. workshops, and training sessions).

Costs

The costs and adoption assumptions for extending applied R&D (including agency time) is shown in Table 14.8.

Table 14.8 Costs and adoption assumptions for extension of applied R&D

#	Description	Estimated costs	Adoption	Year commencing [over # years]
CB1	Extension of applied R&D to irrigators	$5,000 per event	3 events /y	1 [10]

Benefits

The extension of applied R&D will result in some benefits where training and upskilling results in changes in behaviour without the need to for on-farm investment. Examples of capacity building where this is the case include:

- Improved irrigation practices;
- Adoption of BMPs on irrigation farms (e.g. improved fertiliser application);
- Improved effluent management.

These benefits may include:

- Water savings;
- Time savings;
- Saving money on bought in fertiliser;
- Reduced risk of nutrient export (loss) to waterways from the farm;
- Improved soil condition;
- Productivity gains from pasture responses.

The benefits may relate to all categories, but have been evaluated as a reduction in the loss of nutrients from the farm and an increase in farm productivity. The assumed benefits of extension of applied R&D are shown in Table 14.9.

Table 14.9 Unit benefits associated with extension of applied R&D

#	Description	Reduction in nutrient discharge (kg)[1]	Increase in production (%)	Labour saving (%)	Water saving (ML)
CB1	Extension of applied R&D to irrigators	0.125	5%	0%	0

Note: 1. The estimated reduction in nutrient discharged is measured relative to Lake Wellington.

Nutrient reduction

The estimate for nutrient reduction is indicative and not based on any actual data. It reflects how knowledge results in practice change without the need for further investment (e.g. through changes in fertiliser application). Knowledge may also result in reduced operating costs, however to be conservative, these have not been assessed.

Increase in pasture productivity

The estimate for the increase in pasture productivity is not based on any actual data. It was estimated based on specialist knowledge of the project team. This value reflects how knowledge can change irrigation practice, which on its own (i.e. without any additional expenditure) can increase pasture productivity.

14.5.3 Awareness raising activities

Awareness raising activities include non-training forums such as demonstration sites, field days, field trips, as well as advertising campaigns.

Costs

The cost and adoption assumptions for awareness raising activities are shown in Table 14.10.

Table 14.10 Cost and adoption assumptions for awareness raising activities

#	Description	Estimated costs	Adoption	Year commencing [over # years]
CB2	Awareness raising events	$5,000 per event	5 events /y	1 [10]

Benefits

No direct benefits are assumed from awareness raising activities.

14.5.4 Agency efficiency

An improvement in agency efficiency was raised as an area that warranted additional capacity building within the study area. An improvement in agency efficiency is required where multiple agency inputs are necessary to approve planning decisions or share intelligence relating to compliance with the Water or Environment Protection Act or the proposed SEPP(Waters). Specifically, this may relate to the issuing of irrigation and drainage development plans or non-compliance with statutory requirements.

On-going capacity building is required as part of the Plan to share knowledge, particularly where new staff are required) and to share the intelligence of agency staff as part of adaptive management.

Costs

The cost and adoption assumptions for capacity building events to improve agency efficiency is shown in Table 14.11.

Table 14.11 Cost and adoption assumptions for improving agency efficiency

#	Description	Estimated costs	Adoption	Year commencing [over # years]
CB3	Agency efficiency	$5,000 per event	4 events/y	1 [10]

Benefits

While it is probable that benefits will be realised from improved decision making (e.g. through more efficient and better decisions), no benefits have been quantified.

14.5.5 One on one extension

There are a large range of information sources accessed by irrigation landholders in the Lake Wellington region including print and non-print media, other land managers, consultants, and government agency staff.

Over the last two decades funding for one-on-one extension by the public sector has been reduced. This has occurred with the recognition that more and more applied research is delivered by the private sector. However, consistent with public benefits associated with addressing natural resource management issue, the public sector continues to provide one-on-one extension.

Costs

The cost and adoption assumptions for one on one extension are shown in Table 14.12.

Table 14.12 Cost and adoption assumptions for one on one extension

#	Description	Estimated costs	Adoption	Year commencing [over # years]
A1	Provision of one on one extension advice to irrigators	$180,000 /FTE	1 FTE /y	1 [10]

Benefits

While it is probable that benefits will be realised from improved decision making (e.g. through more efficient and better decisions), no benefits have been quantified.

14.6 Compliance

14.6.1 Introduction

Dairy farms can impact local waterways groundwater, and downstream water users if dairy effluent is poorly managed. Effluent management is the responsibility of the landholder and untreated and unmanaged discharges to waterways are illegal.

14.6.2 Increased compliance resourcing

The activity proposed for the Plan is to maintain resources directed to compliance with dairy effluent management requirements. The activity is currently business-as-usual for EPA. This may involve ad-hoc farm audits or targeted inspections. In the longer term, EPA is transitioning is approaches towards pollution prevention (rather than abatement) and will seek to engage industry through (for example) the development and adoption of Codes of Practice.

Costs

The cost and adoption assumptions for increased compliance is shown in Table 14.13.

Table 14.13 Costs and adoption assumptions for increased compliance

#	Description	Estimated costs	Adoption	Year commencing [over # years]
C1	Compliance	$170,000 /FTE	0.6 FTE /yr	1 [5]

Benefits

The benefits relate to a reduction in the loss of nutrients from the farm. The assumed benefits of increased compliance resourcing are shown in Table 14.14.

Table 14.14 Unit benefits associated with increased compliance

#	Description	Reduction in nutrient discharge (kg)[1]	Increase in production (%)	Labour saving (%)	Water saving (ML)
C1	Compliance resourcing	0.25	0	0%	0

Note: 1. The estimated reduction in nutrient discharged is measured relative to Lake Wellington.

The incremental reduction in nutrients discharged to Lake Wellington has been estimated based on the specialist knowledge of the technical working group. Relative to other management actions proposed to manage nutrient loads entering the Gippsland Lakes, the ability of greater compliance to reduce nutrient loads is considered reasonable.

14.7 On-ground works

14.7.1 Introduction

The on-ground works that are proposed in the Lake Wellington Land and Water Management Plan include:

- Tailwater reuse (W1);
- Tailwater reuse expansion (W2);
- Flood to spray (W3);
- Irrigation modernisation (W4) incorporating:
  - automatic irrigation (W5)
  - soil moisture monitoring (W7)
  - maintaining drains (W9)
- Improved effluent ponds (W6);
- Sediment traps (W8);
- Maintain groundwater pumps (W10).

14.7.2 Tailwater reuse systems

Tailwater re-use systems collect excess irrigation and irrigation induced rainfall run-off water and nutrients from irrigated pasture. Water is collected before it enters the regional drainage network and therefore the benefits are associated with the water saved and preventing the flow of nutrients to the Gippsland Lakes. The costs and benefits of re-use systems are explored below.

Costs

The costs of re-use systems include capital costs for installation, and on-going operation and maintenance of the systems. It also includes the lost production from land where the re-use is located.

The total capital cost for re-use systems are estimated at $2,000 per hectare The annual operating costs of $53 per hectare was sourced from Myers et al (2012).

The cost and adoption assumptions for tailwater reuse systems are shown in Table 14.15.

Table 14.15 Costs and adoption assumptions for tailwater reuse systems

#	Description	Capital cost	Operating costs	Adoption	Year commencing [over # years]
W1	Tailwater reuse systems	$2,000/ha	$53/ha/y	500 ha/y	1 [10]

Benefits

The benefits of tailwater re-use systems relate to:

- Reduction in nutrient discharges;
- Pasture productivity improvements;
- Labour savings;
- Water savings;

The assumed benefits of tailwater reuse systems are shown in Table 14.16.

Table 14.16 Unit benefits associated with tailwater reuse systems

#	Description	Reduction in nutrient discharge (kg)[1]	Increase in production (%)	Labour saving (%)	Water saving (ML)
W1	Tailwater re-use system	1	5%	50%	2

Note: 1. The estimated reduction in nutrient discharged is measured relative to Lake Wellington.

The key benefits associated with re-use systems are water savings (capturing and reusing irrigation and rainfall run-off), and reduced phosphorus discharge to the Gippsland Lakes.

Phosphorus retained on farm

The key public benefit associated with re-use systems is the retention of total phosphorus (TP) on farm. The amount of TP retained on farm is estimated at 4.0 kg per hectare serviced by tailwater reuse (GHD, 2005). However, subject matter specialists have conservatively estimated that this corresponds to a reduction of approximately 1 kg per hectare in Lake Wellington.

Water savings

The average volume of water saved is estimated at 2ML/ha, which is comprised of approximately 1 ML/ha of irrigation run-off and 1ML/ha of rainfall run-off (pers. comm. Gavan Lamb, then DPI).

However, this volume is likely to vary considerably depending on irrigation practices and rainfall patterns. We have demonstrated this variability in Table 14.17.

Table 14.17 Scenarios for possible water savings with tailwater reuse systems (ML/ha/y)

Scenario	Dry	Average	Wet	Total
Proportion of years	0.25	0.5	0.25	1.0
Low	1.0	1.5	1.5	1.5
Average	1.5	2.0	2.0	2.0
High	2.0	2.5	2.5	2.5

14.7.3 Tailwater reuse expansion

In certain situations, it is sensible to expand the size of an existing reuse system to capture more tailwater reuse. This may occur where changes to the farm layout means that water drains to a new part of the farm where a reuse system already exists. For example, an existing 3ML reuse dam draining 30 hectares, may be expanded to a 6ML dam that drains 60 hectares.

Costs

The costs per hectare for the expansion of tailwater re-use systems is estimated at $1,000 per hectare. The annual operating costs of $53 per hectare was sourced from Myers *et al.* (2012). These costs and adoption assumptions are shown in Table 14.18.

Table 14.18 Costs and adoption assumptions for tailwater reuse expansion

#	Description	Capital cost	Operating costs	Adoption	Year commencing [over # years]
W1	Tailwater reuse expansion	$1,000/ha	$53/ha/y	200 ha/y	1 [10]

Benefits

The benefits of tailwater re-use expansion are assumed the same as those for new reuse systems (Chapter 14.7.2). These costs and adoption assumptions are shown in Table 14.19.

Table 14.19 Unit benefits associated with tailwater reuse expansion

#	Description	Reduction in nutrient discharge (kg)[1]	Increase in production (%)	Labour saving (%)	Water saving (ML)
W1	Tailwater reuse expansion	1			2

Note: 1. The estimated reduction in nutrient discharged is measured relative to Lake Wellington.

14.7.4 Conversion of flood to spray irrigation on lighter soils

On lighter soils, conversion to a pressurised spray irrigation system is one option for reducing water use and alleviating the negative environmental impacts of irrigation.

Limited recent information is available on the costs and benefits of conversion from flood to spray. The costs and benefits presented below have been assembled from a variety of sources with varying accuracy. The costs and benefits should be considered indicative only.

Costs

The costs associated with conversion of flood to spray irrigation include both capital costs and operational costs:

- The total capital costs are estimated at $7,000 per hectare

- The annual operating costs involve increases in energy costs and increased maintenance. From the limited data available, annual operating costs were estimated at $220 per hectare.

Benefits

The benefits associated with conversion to spray irrigation include a reduction in nutrients discharged, pasture productivity improvements, labour savings, and water savings. The assumed benefits are shown in Table 14.20.

Table 14.20 Unit benefits associated with conversion of flood to spray irrigation

#	Description	Reduction in nutrient discharge (kg)[1]	Increase in production (%)	Labour saving (%)	Water saving (ML)
W3	Conversion of flood to spray	1	20%	50%	2

Note: 1. The estimated reduction in nutrient discharged is measured relative to Lake Wellington.

Phosphorus retained on farm

The key public benefit associated with conversion of flood to spray is the retention of total phosphorus (TP) on farm. The amount of TP retained on farm is estimated at 4.0 kg per hectare (GHD 2005). However, subject matter specialists have conservatively estimated that this corresponds to a reduction of 1 kg per hectare in Lake Wellington.

Productivity increases

With spray irrigators it is estimated that pasture productivity is increased by 20% due to reduced waterlogging and improvement in pasture quality and productivity.

Labour savings

We have (conservatively) estimated that landholders spend 2.5 hours/hectare irrigating via gravity flow (flood or border-check) throughout the year. If this corresponded to 10 irrigations per year, this is equivalent to 15 minutes per irrigation per hectare. With spray irrigators, it was estimated that this could be reduced by 50%, that is irrigation would be reduced to 1.25 hours/hectare.

Water savings

The average volume of water saved is estimated at 1ML/ha.

14.7.5 High flow flood irrigation (irrigation modernisation)

Modernisation of water supply in the MID means that water is being supplied at higher flow rates and larger gates are replacing inefficient Dethridge wheels. Applying water at high flow rates will reduce infiltration beyond the plant's root zone. Well-designed and managed gravity-fed surface irrigation systems have the potential to deliver on-farm application efficiencies in excess of 85% and up to 95% on the right soils.

On-farm works to enable high flow flood irrigation may include:

- Installing new bay outlets;
- Increased farm channel size;
- Landforming;
- Automatic irrigation;
- Soil moisture monitoring;
- Pipe and riser.

Costs

The costs associated with high flow flood irrigation vary considerably depending on the works that are necessary. The costs could be as low as $500 per ha and as high as $5,000 per ha. We have estimated capital costs at $2,000 per ha.

Assuming fully gravity fed systems, no new operating costs are required. Labour savings are captured as a benefit below.

Benefits

The benefits associated with high flow flood irrigation include pasture productivity improvements, labour savings, and water savings. The assumed benefits are shown in Table 14.21.

Table 14.21 Unit benefits associated with conversion to high flow flood irrigation

#	Description	Reduction in nutrient discharge (kg)[1]	Increase in production (%)	Labour saving (%)	Water saving (ML)
W4	High flow flood irrigation	0	15%	25%	0

Note: 1. The estimated reduction in nutrient discharged is measured relative to Lake Wellington.

Productivity increases

With high flow flood irrigation, it is estimated that pasture productivity is increased by 15% due to reduced waterlogging and improvement in pasture quality and productivity.

Labour savings

We have (conservatively) estimated that landholders spend 2.5 hours/ha irrigating via gravity flow (flood or border-check) throughout the year. If this corresponded to 10 irrigations per year, this is equivalent to 15 minutes per irrigation per hectare. With high flow flood irrigation, it was estimated that this could be reduced by 25%, that is equivalent to approximately 40 mins/ha.

14.7.6 Improved effluent ponds

An opportunity exists for Lake Wellington LWMP to increase intervention with regards to effluent management. Enforcement remains the responsibility of the EPA and therefore intervention should focus on encouraging the adoption of better management practices.

Research undertaken by DEDJTR (formerly the DPI Practice Change Research team [DPI 2008]) found that:

- The cost of effluent ponds and associated infrastructure can be substantial;
- Topography, soils and other farm characteristics can limit a systems effectiveness and therefore compliance with regulations;
- The lack of compliance audits limits the effectiveness of regulations (however the EPA has recently developed a Target-Risk based approach to its compliance activity and the EPA would expect this will make its approach more efficient and effective);
- The development of technology standards may support existing effluent regulations to achieve greater reductions in nutrient emissions;
- There is merit in providing technology development and positive incentives to improve compliance with regulations.

Previously government (including WGCMA) have played a role in effluent management in the MID. Government have provided extension services to assist in the development of effluent management plans, and encourage the adoption of better management practices to comply with regulation. The WGCMA have also, in the past, provided funding to the EPA for increased compliance audits.

An opportunity exists for the Lake Wellington LWMP to work with industry (dairy processors) to play a role in driving behaviour change, invest in research on technology change such as the design of effluent systems that are easier to manage.

Costs

The costs associated with improved effluent ponds and better nutrient distribution may vary considerably depending on the works that are necessary. The costs could be as low as $200 per hectare and as high as $2,000 per hectare. We have estimated capital costs at $1,000 per hectare.

The increase in annual operating costs to spread effluent and maintain the effluent system was estimated at $100 per hectare.

Benefits

The benefits associated with improved effluent systems include a reduction in nutrients discharged and pasture productivity improvements. The assumed benefits are shown in Table 14.22.

Table 14.22 Unit benefits associated with improved effluent ponds

#	Description	Reduction in nutrient discharge (kg)[1]	Increase in production (%)	Labour saving (%)	Water saving (ML)
W6	Improved effluent ponds	0.125			

Note: 1. The estimated reduction in nutrient discharged is measured relative to Lake Wellington.

Phosphorus retained on farm

The key public benefit associated with improved effluent systems is the retention of total phosphorus (TP) on farm. Subject matter specialists have conservatively estimated that this corresponds to a reduction of 0.125 kg per hectare in Lake Wellington.

14.7.7 Sediment traps

Sediment traps (or ponds) are particularly useful in agriculture for sediment control where permanent groundcover is not feasible. This is typically the situation on horticultural properties and where they should be adopted. Effectively, they help to keep soil on the property, preventing it being lost downstream. Sediment traps are useful in both grazing and horticultural enterprises. Unlike tailwater reuse systems, sediment traps are not designed for water to be stored indefinitely and reused. However, they can be built in combination with a reuse system.

Sediment traps temporarily store run-off water, which allows some of the sediment to drop out of the water and settle in the trap. The sediment can then be excavated and reused on the farm.

Sediment traps:

- Intercept overland flow and slow water velocity, allowing sediment to drop out;
- Keep soil and nutrients on the farm;
- Reduce sediment accumulation in drains and waterways;
- Improve runoff water quality.

Once a sediment trap is constructed, it requires seasonal maintenance to excavate the sediment and later to spread it on the farm.

Costs

The capital costs for sediment traps were estimated at $400 per hectare drained. Therefore, a large trap draining 15 hectares is estimated to cost $6,000 for earthworks and an outlet control structure. The annual costs to maintain the sediment traps are estimated at $100 per hectare drained.

Benefits

The benefits associated with sediment traps are a reduction in nutrients discharged. The assumed benefits are shown in Table 14.23.

Table 14.23 Unit benefits associated with sediment traps

#	Description	Reduction in nutrient discharge (kg)[1]	Increase in production (%)	Labour saving (%)	Water saving (ML)
W8	Sediment traps	1	0%	0%	0

Note: 1. The estimated reduction in nutrient discharged is measured relative to Lake Wellington.

Phosphorus retained on farm

The key public benefit associated with sediment traps is the retention of total phosphorus (TP) on farm. Subject matter specialists have conservatively estimated that this corresponds to a reduction of 1 kg per hectare in Lake Wellington.

14.7.8 Maintain groundwater pumps

Public groundwater pumps have been installed in the MID to reduce the effects of salinity on agriculture and the environment. Groundwater pumping is targeted towards protecting vulnerable assets exposed to salinity. Decision-making is based on the environmental, social and economic costs of action versus non action taking into account the impact on other natural resource management issues such as nutrient management.

The responsibility for maintaining groundwater pumps in and around the MID is jointly held by SRW and the WGCMA. The CMA provides the overall strategic direction and SRW administers the implementation of new pumps and the operation and maintenance of existing pumps. The CMA coordinates the shallow groundwater monitoring program.

Since 2005, SRW has managed and operated a network of public groundwater control pumps. The network covers four zones (Nambrok, Heyfield, Maffra/Boisdale and Clydebank) and has the potential to lower water tables over a gross area of 14,500 ha.

Since 2006 the 18 pumps have operated at 26% of full time capacity extracting an average for 2,400 ML of water and 9 tonnes of salt per year at a current operating cost of around $90,000 per year.

The actual area of influence of the pump network as currently operated was estimated at around 7,000 ha in 2001 (SKM, 2010).

Opportunities for improvements in the public groundwater drainage program include:

- Develop an asset management program to refurbish priority groundwater control pumps (see RA6);
- Encourage private groundwater pumping to minimise the need to operate the public pumps (see CB1);
- Continue to use and refine the adaptive management approach to manage the public groundwater control pumps (see RA6);

- Respond to initiatives arising from the Victorian Irrigation Drainage Program Strategic Directions 2015-20 (Water for Victoria Action 4.6).

Costs

The costs to maintain the public groundwater pumps are estimated at $100,000 per year.

Benefits

The benefits associated with maintaining groundwater pumps are an increase in pasture productivity. The assumed benefits are shown in Table 14.24.

Table 14.24 Unit benefits associated with maintaining groundwater pumps

#	Description	Reduction in nutrient discharge (kg)[1]	Increase in production (%)	Labour saving (%)	Water saving (ML)
W10	Maintaining groundwater pumps	0	15%	0%	0

Note: 1. The estimated reduction in nutrient discharged is measured relative to Lake Wellington.

Productivity increases

With the maintenance of groundwater pumps it is estimated that pasture productivity is increased by 15% on the 7,000 ha influenced by the pumps.

14.8 Administration

The programs included within the Lake Wellington LWMP need to be administered, with implementation being monitored, the Plan's MERI framework implemented and lessons learned and new knowledge incorporated into program design and delivery.

Costs

The costs to administer the Lake Wellington are the labour costs to employ people in the region. The costs, which include direct labour costs, on-costs and overhead costs are estimated at $180,000 per FTE.

Benefits

No direct benefits are assessed separately for administration. The benefits have been accounted for within capacity building (Chapter 14.5) and works (Chapter 14.7).

14.9 Adoption

The assumed adoption of the various management actions is shown in Table 14.25.

Table 14.25 Adoption of management actions

#	Adoption (year) Start	End	Farm planning	On-farm irrigation & drainage	On-farm nutrient management	Floodplain and off-farm drainage	Groundwater & salinity	Innovative & connected irrigation communities	Unit
Resource assessments									
RA1	3	6			90%	10%			
RA2	4	4			100%				
RA3	2	4		90%		10%			
RA4	4	6					50%	50%	
RA5	1	1		100%					
RA6	1	1					1		
RA7	2	1		100%					
RA8	1	1		100%					
RA9	1	1			100%				
RA10	3	3				100%			
RA11	1	10			70%		30%		
RA12	2	5	100%						
RA13	3	3		100%					
Planning									
P1	1	10	20						Properties
P2	1	10	500						Hectares
P3	1	10	500						Hectares
P4	1	10			350				Hectares
Capacity building									
CB1	1	10		2	1				Events
CB2	1	10		2		1	1	1	Events
CB3	1	10	1	1	1	1		1	Events
Compliance									
C1	1	5			2000				Hectares
On-ground works									
W1	1	10			500				Hectares
W2	1	10			200				Hectares

#	Adoption (year) Start	End	Farm planning	On-farm irrigation & drainage	On-farm nutrient management	Floodplain and off-farm drainage	Groundwater & salinity	Innovative & connected irrigation communities	Unit
W3	1	10		300					Hectares
W4	1	10		300					Hectares
W6	1	10			500				Hectares
W8	1	10			50				Hectares
W10	1	10					7000		Hectares
Administration									
A1	1	2	0.75	1.0	0.5	0.25	0.25	0.25	FTE
A2	3	10	1.0	1.0	1.0	0.25	0.25	0.5	FTE

The information shows the start year and end year for adoption and the extent of adoption.

For example, RA1, which is a $150k R&D project to investigate nutrient and pathogen pathways is assumed to be adopted over 2 years commencing in year 3 and ending in year 4. The $150k project is 90% assigned to on-farm nutrient management and 10% to floodplain and off-farm drainage.

The action W1, which is for tailwater reuse occurs from year 1 to year 10. It is assumed that 500 hectares of tailwater reuse systems are adopted each year.

14.10 Comparison of benefits and costs

The costs and benefits captured in the analysis include the following:

- Capital costs (including on-farm costs);
- Operating and maintenance costs;
- Savings in operating costs (e.g. savings in labour);
- Reduction in nutrients (phosphorus) discharged to Lake Wellington;
- Water savings;
- Improved pasture productivity.

14.10.1 Assumptions

The key assumptions underpinning the assessment, are summarised in Table 14.26. More information on these assumptions is provided in the sub sections that follow.

Table 14.26 CBA assumptions

Assumption	Description
Assessment period	30 years.
Discount rate (real)	The discount rate used is 7% in compliance with the Victorian Department of Treasury and Finance (DTF). Discount rates of 4% and 10% respectively were also tested, in compliance with DTF.
Value of water savings	$77.5 per ML
Value of labour savings	2.5 hours per hectare irrigated and $25 per hour
Value of nutrient savings	Not valued
Value of pasture productivity improvements	$3,450 per hectare

Value of water savings

In the absence of market distortions, relative prices indicate relative values. Water allocation prices vary according to seasonal conditions and can range from almost zero in extremely wet years through to $200/ML in very dry years. If we assume the following probabilities of wet, average and dry years, and associated water allocation prices then we can calculate the expected annual value of water (Table 14.27).

Table 14.27 Annual expected value of water savings

Season	Dry	Average	Wet	Total
Probability	0.25	0.5	0.25	
Value $/ML/y	200	50	10	
Expected value $/ML/y	50	25	2.5	77.5

Value of labour savings

We have also assumed an opportunity cost for the time of landholders of $25 per hour. This rate is slightly higher than the national minimum wage rate of $19.88 per hour (as of July 2017), but lower than casual labour rates, which could be in the order of $30 to $35 per hour.

Value of improvements in pasture productivity

The value of improvements in pasture productivity has been estimated using farm productivity information provided for Gippsland[10]. This average includes rain-fed production and is therefore likely to under-estimate irrigated production in the Lake Wellington catchment. For this reason, the sensitivity of the results to this value is tested

In estimating productivity benefits, we assumed:

- Stocking rate of 1.8 cows per usable ha;
- Milk solids (MS) of 468 kg/cow;
- Gross margin income of $7.33/kg MS;
- Total variable costs of $3.19/kg MS;

[10] DEDJTR, 2014, Dairy Industry Profile December 2014, located at http://agriculture.vic.gov.au/agriculture/dairy

- Gross margin of $4.13/kg MS.

The assumed dairy gross margin per hectare is $3,450/ha, which has been used to value improvements in pasture productivity.

This value compares well to the findings of a case study analysis to test the affordability of the MID2030 Program for farm businesses in the MID (RMCG 2012). This assessment collected tax return data and detailed production information for each business through face-to-face interviews.

14.10.2 Total costs

The total capital and operating costs (CAPEX/OPEX) of the programs and activities is given in Table 14.28

Table 14.28 Total capital costs and operating costs by management action (discounted at 7% over 30 years)

ID	Management action	CAPEX (PV)	OPEX (PV)	Total (PV)
Resource assessments				
RA1	Improved understanding of nutrient/pollutant/pathogen pathways (from on-farm to Lake Wellington)	$110,945	$0	$110,945
RA2	Improved on-farm systems for managing dairy effluent	$68,661	$0	$68,661
RA3	Improved understanding and applied knowledge of best management practices (BMPs) on irrigated farms in the study area (horticulture and dairy)	$122,632	$0	$122,632
RA4	Increase awareness of opportunities to obtain energy security through the use of renewable energy	$64,267	$0	$64,267
RA5	Implement a regular land use and water use survey	$160,092	$0	$160,092
RA6	Evaluating the effectiveness and efficiency of drainage and pump infrastructure	$56,075	$0	$56,075
RA7	Ex-post evaluation of the benefits and costs of management actions	$78,609	$0	$78,609
RA8	Develop a target for sustainable regional economic growth	$14,019	$0	$14,019
RA9	Develop a monitoring program for nutrients and sediments from other irrigated land uses in the Lake Wellington catchment	$28,037	$0	$28,037
RA10	Develop opportunities to manage floodplains and drainage	$36,982	$0	$36,982
RA11	On-going groundwater, nutrient and sediment monitoring	$70,236	$0	$70,236
RA12	IFP development	$126,625	$0	$126,625
RA13	IDG Review and Development	$40,815	$0	$40,815
Planning				
P1	Preliminary irrigation assessments	$210,707	$0	$210,707
P2	Modernised IFP	$245,825	$0	$245,825
P3	New IFP	$421,415	$0	$421,415
P4	On-farm nutrient management plans	$294,990	$0	$294,990
Capacity building				
CB1	Extension of applied R&D to irrigators	$105,354	$0	$105,354

ID	Management action	CAPEX (PV)	OPEX (PV)	Total (PV)
CB2	Awareness raising for irrigators	$175,590	$0	$175,590
CB3	Agency efficiency	$140,472	$0	$140,472
Compliance				
C1	Improved compliance monitoring and enforcement by the EPA	$0	$442,821	$442,821
On-ground works				
W1	Tailwater reuse	$7,023,582	$2,312,922	$9,336,503
W2	Tailwater reuse expansion	$1,404,716	$925,169	$2,329,885
W3	Flood to spray conversion	$14,749,521	$4,189,443	$18,938,964
W4	Best practice surface irrigation (high flow flood)	$4,214,149	$0	$4,214,149
W5	Automatic irrigation[1]	$0	$0	$0
W6	Improved effluent ponds	$3,511,791	$4,364,003	$7,875,794
W7	Soil moisture monitoring[1]	$0	$0	$0
W8	Sediment traps	$140,472	$436,400	$576,872
W9	Maintain drains[1]	$0	$0	$0
W10	Maintain groundwater pumps		$737,476	$737,476
Administration				
A1	Program Administration (yrs 1-2)		$976,330	$976,330
A2	Program Administration (yrs 3-10)		$3,755,206	$3,755,206
Total		**$33,616,576**	**$18,139,769**	**$51,756,345**

Notes: (1) The costs for W5, W7 and W9 have been included as irrigation modernisation (W4).

The total costs by program are shown in Table 14.29.

Table 14.29 Total present value of capital costs and operating costs (discounted at 7% over 30 years)

Land and Water Management Plan Program	Costs (PV)
Farm planning	$2,187,456
On-farm irrigation and drainage	$24,996,851
On-farm nutrient management	$22,274,337
Floodplain and off-farm irrigation drainage	$446,636
Groundwater and salinity	$1,197,934
Innovative and connected irrigation communities	$653,131
Total	**$51,756,345**

Over 90% of the total costs are associated with the on-farm programs for irrigation and drainage and nutrient management.

14.10.3 Total benefits

The assumptions used to assess the benefits associated with each management action are shown in Table 14.30.

Table 14.30 Unit benefits associated with management actions

#	Description	Benefits/ha			
		Reduction in nutrient discharge (kg)[1]	Increase in production (%)	Labour saving (%)	Water saving (ML)
Resource assessments					
RA1	Improved understanding of nutrient/pollutant/pathogen pathways (from on-farm to Lake Wellington)	-	-	-	-
RA2	Improved on-farm systems for managing dairy effluent	-	-	-	-
RA3	Improved understanding and applied knowledge of best management practices (BMPs) on irrigated farms in the study area (horticulture and dairy)	-	-	-	-
RA4	Increase awareness of opportunities to obtain energy security through the use of renewable energy	-	-	-	-
RA5	Implement a regular land use and water use survey	-	-	-	-
RA6	Evaluating the effectiveness and efficiency of drainage and pump infrastructure	-	-	-	-
RA7	Ex-post evaluation of the benefits and costs of management actions	-	-	-	-
RA8	Develop a target for sustainable regional economic growth	-	-	-	-
RA9	Develop a monitoring program for nutrients and sediments from other irrigated land uses in the Lake Wellington catchment	-	-	-	-
RA10	Develop opportunities to manage floodplains and drainage	-	-	-	-
RA11	On-going groundwater, nutrient and sediment monitoring	-	-	-	-
RA12	IFP development	-	-	-	-
RA13	IDG Review and Development	-	-	-	-
Planning					
P1	Preliminary irrigation assessments	-	-	-	-
P2	Modernised IFP	-	-	-	-
P3	New IFP	-	-	-	-
P4	On-farm nutrient management plans	0.5	5%	-	-

#	Description	*Benefits/ha* Reduction in nutrient discharge (kg)[1]	Increase in production (%)	Labour saving (%)	Water saving (ML)
Capacity building					
CB1	Extension of applied R&D to irrigators	0.25	5%	-	-
CB2	Awareness raising for irrigators	-	-	-	-
CB3	Agency efficiency	-	-	-	-
Compliance					
C1	Improved compliance monitoring and enforcement by the EPA	0.125	-	-	-
On-ground works					
W1	Tailwater reuse	1	-	-	2
W2	Tailwater reuse expansion	1	-	-	2
W3	Flood to spray	1	20%	50%	1
W4	Irrigation modernisation	-	15%	25%	
W5	Automatic irrigation[1]	-	-	-	-
W6	Improved effluent ponds	0.125	-	-	-
W7	Soil moisture monitoring[1]	-	-	-	-
W8	Sediment traps	1	-	-	-
W9	Maintain drains[1]	-	-	-	-
W10	Maintain groundwater pumps	-	5%	-	-

Notes: (1) The benefits for W5, W7 and W9 have been included as irrigation modernisation (W4).

The information in Table 14.30, demonstrates that for example; W1 - tailwater reuse, one hectare reduces TP loads to Lake Wellington by 1 kg and results in water savings of 2 ML.

The present value of benefits by action are shown in Table 14.31. Note that the benefits associated with TP reductions have not been quantified in monetary terms.

Table 14.31 Present value of benefits by management action (discounted at 7% over 30 years)

ID	Management action	Benefits (PV)
Resource assessments		
RA1	Improved understanding of nutrient/pollutant/pathogen pathways (from on-farm to Lake Wellington)	$0
RA2	Improved on-farm systems for managing dairy effluent	$0
RA3	Improved understanding and applied knowledge of best management practices (BMPs) on irrigated farms in the study area (horticulture and dairy)	$0
RA4	Increase awareness of opportunities to obtain energy security through the use of renewable energy	$0
RA5	Implement a regular land use and water use survey	$0
RA6	Evaluating the effectiveness and efficiency of drainage and pump infrastructure	$0

ID	Management action	Benefits (PV)
RA7	Ex-post evaluation of the benefits and costs of management actions	$0
RA8	Develop a target for sustainable regional economic growth	$0
RA9	Develop a monitoring program for nutrients and sediments from other irrigated land uses in the Lake Wellington catchment	$0
RA10	Develop opportunities to manage floodplains and drainage	$0
RA11	On-going groundwater, nutrient and sediment monitoring	$0
RA12	IFP development	$0
RA13	IDG Review and Development	$0
Planning		
P1	Preliminary irrigation assessments	$0
P2	Modernised IFP	$0
P3	New IFP	$0
P4	On-farm nutrient management plans	$5,269,534
Capacity building		
CB1	Extension of applied R&D to irrigators	$22,583,715
CB2	Awareness raising for irrigators	$0
CB3	Agency efficiency	$0
Compliance		
C1	Improved compliance monitoring and enforcement by the EPA	$0
On-ground works		
W1	Tailwater reuse	$6,764,205
W2	Tailwater reuse expansion	$2,705,682
W3	Flood 2 spray	$20,914,484
W4	Irrigation modernisation	$13,959,354
W5	Automatic irrigation[1]	$0
W6	Improved effluent ponds	$0
W7	Soil moisture monitoring[1]	$0
W8	Sediment traps	$0
W9	Maintain drains[1]	$0
W10	Maintain groundwater pumps	$8,480,975
Administration		
A1	Program Administration (y 1-2)	$0
A2	Program Administration (y 3-10)	$0
Total		***$80,677,948***

Notes: (1) The benefits for W5, W7 and W9 have been included as irrigation modernisation (W4).

The information presented in Table 14.31 demonstrates that more than 65% of the program benefits are associated with "works" management actions. As discussed above, the achievement of these benefits is contingent on successfully implementing many of the Plan's "enabling" activities.

The total benefits by program are shown in Table 14.32.

Table 14.32 Total present value of benefits by program (discounted at 7% over 20 years)

Land and Water Management Plan Program	Benefits (PV)
Farm planning	$0
On-farm irrigation and drainage	$49,929,648
On-farm nutrient management	$22,267,325
Floodplain and off-farm irrigation drainage	$0
Groundwater and salinity	$8,480,975
Innovative and connected irrigation communities	$0
Total	**$80,677,948**

In addition to the public benefits monetised above, the management actions proposed for the Lake Wellington LWMP are estimated to reduce the discharge by an additional 1.9 tonnes of phosphorus per year for each of the Plan's ten years (i.e. 19 tonnes over 10 years; Figure 14.2). If the Plan is successfully implemented, this should be sufficient to offset any increase in phosphorus exports resulting from expansion in irrigation areas and more intensive use of fertilisers (see Chapter 5).

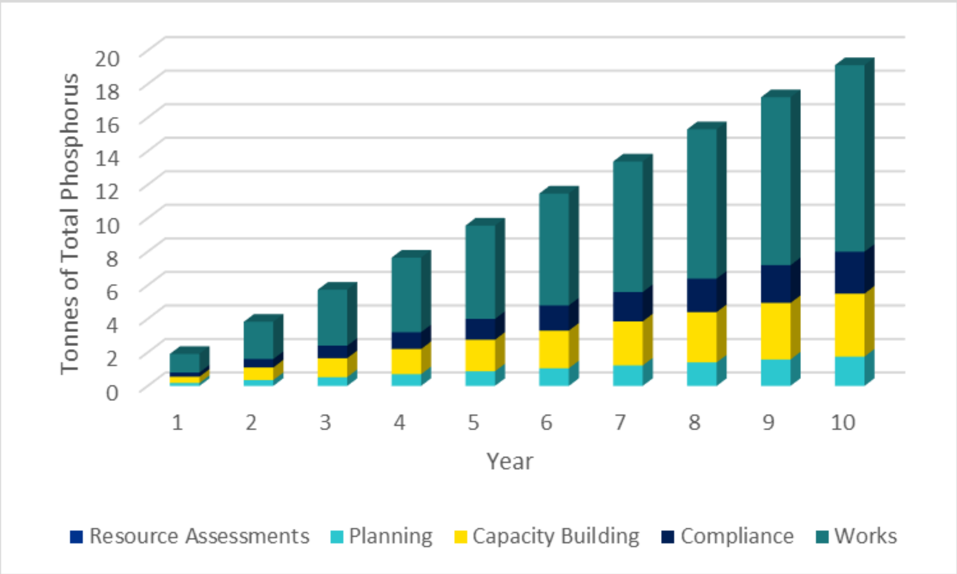

Figure 14.2 Reduced discharge of total phosphorus to Lake Wellington with assumed adoption of management actions

14.10.4 Cost benefit analysis

The cost benefit analysis for each management option is shown in Table 14.33.

Table 14.33 Comparison of benefits and costs by management action (discounted at 7% over 30 years)

ID	Management action	Costs (PV)	Benefits (PV)	NPV
Resource assessments				
RA1	Improved understanding of nutrient/pollutant/pathogen pathways (from on-farm to Lake Wellington)	$110,945	$0	-$110,945
RA2	Improved on-farm systems for managing dairy effluent	$68,661	$0	-$68,661
RA3	Improved understanding and applied knowledge of best management practices (BMPs) on irrigated farms in the study area (horticulture and dairy)	$122,632	$0	-$122,632
RA4	Increase awareness of opportunities to obtain energy security through the use of renewable energy	$64,267	$0	-$64,267
RA5	Implement a regular land use and water use survey	$160,092	$0	-$160,092
RA6	Evaluating the effectiveness and efficiency of drainage and pump infrastructure	$56,075	$0	-$56,075
RA7	Ex-post evaluation of the benefits and costs of management actions	$78,609	$0	-$78,609
RA8	Develop a target for sustainable regional economic growth	$14,019	$0	-$14,019
RA9	Develop a monitoring program for nutrients and sediments from other irrigated land uses in the Lake Wellington catchment	$28,037	$0	-$28,037
RA10	Develop opportunities to manage floodplains and drainage	$36,982	$0	-$36,982
RA11	On-going groundwater, nutrient and sediment monitoring	$70,236	$0	-$70,236
RA12	IFP development	$126,625	$0	-$126,625
RA13	IDG Review and Development	$40,815	$0	-$40,815
Planning				
P1	Preliminary irrigation assessments	$210,707	$0	-$210,707
P2	Modernised IFP	$245,825	$0	-$245,825
P3	New IFP	$421,415	$0	-$421,415
P4	On-farm nutrient management plans	$294,990	$5,269,534	$4,974,543
Capacity building				
CB1	Extension of applied R&D to irrigators	$105,354	$22,583,715	$22,478,361
CB2	Awareness raising for irrigators	$175,590	$0	-$175,590
CB3	Agency efficiency	$140,472	$0	-$140,472
Compliance				
C1	Improved compliance monitoring and enforcement by the EPA	$442,821	$0	-$442,821

ID	Management action	Costs (PV)	Benefits (PV)	NPV
On-ground works				
W1	Tailwater reuse	$9,336,503	$6,764,205	-$2,572,299
W2	Tailwater reuse expansion	$2,329,885	$2,705,682	$375,797
W3	Flood 2 spray	$18,938,964	$20,914,484	$1,975,520
W4	Irrigation modernisation	$4,214,149	$13,959,354	$9,745,205
W5	Automatic irrigation[1]	$0	$0	$0
W6	Improved effluent ponds	$7,875,794	$0	-$7,875,794
W7	Soil moisture monitoring[1]	$0	$0	$0
W8	Sediment traps	$576,872	$0	-$576,872
W9	Maintain drains1	$0	$0	$0
W10	Maintain groundwater pumps[2]	$737,476	$8,480,975	$7,743,499
Administration				
A1	Program Administration (y 1-2)	$976,330	$0	-$976,330
A2	Program Administration (y 3-10)	$3,755,206	$0	-$3,755,206
Total		**$51,756,345**	**$80,677,948**	**$28,921,603**
Benefit cost ratio				**1.6**

Notes: (1) The costs and benefits for W5, W7 and W9 have been included as irrigation modernisation (W4).

As described earlier, the results show that many of the management actions do not directly provide benefits in their own right, but rather these actions are precursors to or enablers of other “works”. The exceptions are nutrient management plans (P4) and extension of applied R&D (CB1), where it is assumed that training (and plan preparation) is sufficient to encourage behaviour change and cause benefits to be achieved.

The “works” management actions that have a negative NPV are tailwater reuse systems (W1), flood effluent ponds (W6) and sediment traps (W8) where the private benefits associated with pasture production, time savings, and water savings are not greater than the total costs.

The benefits of all o0f these actions include reductions in nutrient discharge, which are not monetised. This finding indicates that logical behaviour would suggest that implementation will not occur without a positive incentive (e.g. cost sharing).

The total benefits and costs by program are shown in Table 14.34.

Table 14.34 Total present value of benefits by program (discounted at 7% over 30 years)

Land and Water Management Plan Program	Costs (PV)	Benefits (PV)	NPV
Farm planning	$2,187,456	$0	-$2,187,456
On-farm irrigation and drainage	$24,996,851	$49,929,648	$24,932,798
On-farm nutrient management	$22,274,337	$22,267,325	-$7,102
Floodplain and off-farm drainage	$446,636	$0	-$456,636
Groundwater and salinity	$1,197,934	$8,480,975	$7,283,041
Innovative and connected irrigation communities	$653,131	$0	-$651,131
Total	**$51,756,345**	**$80,677,948**	**$28,921,603**

Land and Water Management Plan Program	Costs (PV)	Benefits (PV)	NPV
Benefit cost ratio			**1.6**

Even without quantifying the benefits associated with a reduction in nutrients to Lake Wellington, the Lake Wellington LWMP is economically attractive with a NPV of $28.9 million and a BCR of 1.6.

14.10.5 Sensitivity analysis

As is common practice in CBA, a sensitivity analysis was undertaken as part of the assessment. Key parameters sensitivity tested include:

- the discount rate, which was tested at 4% and 10%;
- the value of pasture productivity improvements;
- the value of water savings.

The rationale for testing sensitivity of results to the discount rate and other variables includes the potential for the relative performance of the overall LWMP to 'switch' and become uneconomic

Discount rate

The sensitivity of the results to discount rate are shown in Table 14.35.

Table 14.35 Sensitivity of NPV to discount rate

	Benefit cost ratio
4% discount rate	1.8
7% discount rate	1.5
10% discount rate	1.3

The results show that the Lake Wellington LWMP is robust and not overly sensitive to discount rate.

Value of pasture productivity improvements

The sensitivity of the results to the value of pasture productivity improvements is shown in Table 14.36.

Table 14.36 Sensitivity of NPV to the value of pasture productivity improvements

	Benefit cost ratio
$2,500	1.2
$3,450 / hectare	1.6
$5,000 / ha	2.1

The results show that the Plan is somewhat sensitive to the value of pasture improvements. If the value of pasture productivity improvements is reduced to $2,500 per hectare, then the BCR falls to 1.2. However, if the gross margin is increased to $5,000 per hectare (which is more likely), then the BCR is increased to 2.1. This result provides further justification of the robustness of the Lake Wellington LWMP

Value of water savings

The sensitivity of the results to the value water savings is shown in Table 14.37.

Table 14.37 Sensitivity of NPV to the value of water savings

	Benefit cost ratio
$0 / ML	1.3
$77.5 / hectare	1.6
$150 / ha	1.8

The results show that the Lake Wellington LWMP is not sensitive to the value of water savings.

14.11 Cost sharing implications

14.11.1 Cost sharing principles

Cost-sharing negotiations should proceed only after a proposed management program has passed the cost-benefit test. There is little point arguing about sharing of costs for inefficient projects. The CBA methodology for ranking projects essentially tells us whether or not a particular project is likely to increase community welfare. This is the critical first step and should not be overtaken by undue emphasis on how the project should be paid for, and by whom. The cost benefit analysis will also assist in identifying the stakeholders between whom costs should be shared.

Three sources of funding can be considered:

- Private entities or local agencies whose actions are causing the degradation that is giving rise to the need for the implementation of the plan (i.e. the 'polluters pay');
- Private entities or local agencies who would benefit from the implementation of the plan (i.e. the 'beneficiaries pay'); and
- Government.

Polluters pay

It has been a long-standing code of human conduct that if you make a mess you clean it up. This notion has been enshrined in the 'polluter-pays' principle for environmental protection. With respect to water quality, polluters are those who cause damage to the physical, biological or chemical characteristics of the waterbodies and waterways. Demanding that polluters pay is often society's policy of first choice because it is regarded as being the fairest and most equitable policy. It is also the most efficient policy when the principle can be applied to stop pollution before it occurs, or to control it within acceptable limits.

Therefore, where the polluter-pays principle is appropriate and the polluters can be identified and their pollution measured, monitored and levied, it is sensible that that polluter-pays principle should take precedence over the beneficiary-pays principle for sharing the funding of management measures. To do otherwise runs the risk that the pollution may continue unabated.

There are difficulties in applying the polluter-pays principle, which concern the identification of the polluters. It may be readily applicable when the source of pollution can be traced to a particular user of the waterbodies and waterways (so-called point-source pollution), such as wastewater treatment plants. It is much more difficult to apply when there are high costs of identifying the polluters and monitoring the damage they cause. This is particularly the case for 'non-point' pollution arising from broadacre activities.

Beneficiaries pay

The main convention by which commercial affairs are conducted is that the 'user' or 'beneficiary' of some service pays for that service. By paying prices that reflect the social value of these goods and services, an economically efficient allocation of resources can be ensured. Governments and public authorities have come to realise that it is important for the efficient use of scarce resources that the services provided by public authorities also be paid for by the users or beneficiaries of those services. Thus, the beneficiary-pays principle has been adopted by many authorities for determining who should meet the costs of the works undertaken as part of land and water planning.

A distinction can be made between direct and indirect beneficiaries (see for example, MDBC 1996), but it is appropriate that both groups pay. That is, even if the benefits are indirect or intangible, those enjoying the benefits should also contribute. This includes those, whose use of a river and its environs is non-consumptive. An example would be recreational anglers who, unlike irrigators, do not pay any charges for the use of increased quantities of water of improved quality, but benefit from the improved quality because the habitat for a sport fishery is improved.

Government Pays

Government contributions to the funding of on-ground works can be justified where there is evidence of market failure. There are clearly economic, social and environmental benefits of reducing nutrients to the Gippsland Lakes and there is an in-principle role for government to address other negative environmental externalities associated with irrigation (e.g. salinity, groundwater accessions).

From an economic and public policy perspective, government intervention is considered appropriate if each of the following conditions is met:

- There is evidence of market failure (e.g. due to externalities, public goods, or information failures)
    - The polluters are blissfully unaware of the effects of their actions on other parties (‘externalities’)
    - Enjoyment of the benefits cannot be restricted to a particular group of private entities (that is, the benefits represent ‘public goods’)
    - The costs of collecting contributions from each private beneficiary or polluter would be too large relative to the contributions required from those entities (that is, the ‘transaction costs’ are excessive when collecting contributions from the private entities).
- The total benefits of intervention exceed the total costs
- The policy tools selected form the best possible approach to address the problem.

The rationale for government intervention from an economic and public policy perspective, is evidence of a market failure (e.g. due to externalities, public goods, or information failures). In addition, the total benefits of intervention exceed the total costs, and the policy tools selected should form the best possible approach to address the problem.

The market failure most applicable to on-farm and regional opportunities for the Lake Wellington LWMP is that associated with environmental externalities (e.g. impacts due to localised salinity and nutrient discharges to the Gippsland Lakes). In some cases, information failures create the rationale for government involvement.

14.11.2 Recommendations for cost sharing

Consistent with the principles of cost sharing described above, there is a role for government, industry and irrigators to share in the costs required to deliver the Lake Wellington LWMP.

Table 14.38 Actions suitable for cost-sharing

ID	Management action	Market failure	Private net benefit	Total benefits exceed total cost	Suitability for cost sharing
Resource assessments					
RA1	Improved understanding of nutrient/pollutant/pathogen pathways (from on-farm to Lake Wellington)	Yes – information spillover (general)	No benefits are associated with the research itself	No benefits are associated with the research itself	Strategic R&D suitable for government funding
RA2	Improved on-farm systems for managing dairy effluent	Yes – information spillover (industry)	No benefits are associated with the R&D itself	No benefits are associated with the R&D itself	Applied research suitable for industry / government funding
RA3	Improved understanding and applied knowledge of best management practices (BMPs) on irrigated farms in the study area (horticulture and dairy)	Yes – information spillover (industry)	No benefits are associated with the R&D itself	No benefits are associated with the R&D itself	Applied research suitable for industry / government funding
RA4	Increase awareness of opportunities to obtain energy security through the use of renewable energy	Yes – information spillover (general)	No benefits are associated with the R&D itself	No benefits are associated with the R&D itself	Practice change suitable for government funding
RA5	Implement a regular land use and water use survey	Yes – information spillover (industry)	No benefits are associated with the survey itself	No benefits are associated with the survey itself	Applied research suitable for industry / government funding
RA6	Evaluating the effectiveness and efficiency of drainage and pump infrastructure	Yes – information spillover (general)	No benefits are associated with the evaluation itself	No benefits are associated with the evaluation itself	Applied research suitable for government funding
RA7	Ex-post evaluation of the benefits and costs of management actions	Yes – communication failure	No benefits are associated with the evaluation itself	No benefits are associated with the evaluation itself	Applied research suitable for government funding
RA8	Develop a target for sustainable regional economic growth	Yes – communication failure	No benefits are associated with the target itself	No benefits are associated with the target itself	Applied research suitable for government funding
RA9	Develop a monitoring program for nutrients and sediments from other irrigated land uses in the Lake Wellington catchment	Yes – communication failure	No benefits are associated with monitoring itself	No benefits are associated with monitoring itself	Applied research suitable for industry / government funding
RA10	Develop opportunities to manage floodplains and drainage	Yes – information spillover (general)	No benefits are associated with the R&D itself	No benefits are associated with the R&D itself	Applied research suitable for government funding
RA11	On-going groundwater, nutrient and sediment monitoring	Yes – communication failure	No benefits are associated with monitoring itself	No benefits are associated with monitoring itself	Applied research suitable for industry / government funding

ID	Management action	Market failure	Private net benefit	Total benefits exceed total cost	Suitability for cost sharing
RA12	IFP development	Yes – communication failure	No benefits are associated with the R&D itself	No benefits are associated with the R&D itself	Applied research suitable for industry / government funding
RA13	IDG Review and Development	Yes – communication failure	No benefits are associated with the R&D itself	No benefits are associated with the R&D itself	Applied research suitable for industry / government funding
Planning					
P1	Preliminary irrigation assessments	Yes – communication failure	No benefits are associated with the plan		
P2	Modernised IFP	associated with the plan itself – enabling			
P3	New IFP	activity	No benefits are associated with the plan itself – enabling activity	Suitable for government funding to address information asymmetries	
P4	On-farm nutrient management plans	Yes – communication failure	No benefits are associated with the plan		
Capacity building					
CB1	Extension of applied R&D to irrigators	Yes – communication failure	Yes	Yes	Suitable for government funding to address information asymmetries
CB2	Awareness raising for irrigators	Yes – communication failure	No	Yes, where information leads to practice change	Suitable for government funding to address information asymmetries
CB3	Agency efficiency	Yes – communication failure	No	Yes	Suitable for government funding to realise efficiencies in Program delivery

ID	Management action	Market failure	Private net benefit	Total benefits exceed total cost	Suitability for cost sharing
Compliance					
C1	Improved compliance monitoring and enforcement by the EPA	Yes – negative externalities	No	Yes, but public benefits were not monetised	Suitable for government funding for greater enforcement of regulations
On-ground works					
W1	Tailwater reuse	Yes – negative externalities	No	Yes, the additional public benefits exceed total costs	Suitable for government cost share in relation to public benefits
W2	Tailwater reuse expansion	Yes – negative externalities	Yes/No Minimal benefit or small private net cost	Yes, the additional public benefits exceed total costs	Suitable for government cost share in relation to public benefits
W3	Flood to spray conversion	Yes – negative externalities	Yes/No Minimal benefit or small private net cost	Yes, the additional public benefits exceed total costs	Suitable for government cost share in relation to public benefits
W4	Best practice surface irrigation (high flow flood)	Yes – negative externalities	Yes, private benefits exceed private costs	Yes	Suitable for government funding for extension only
W5	Automatic irrigation[1]	Yes – communication failure	Yes, private benefits exceed private costs	Yes	Suitable for government funding for extension only
W6	Improved effluent ponds	Yes – negative externalities	No	Yes, the additional public benefits exceed total costs	Suitable for government cost share in relation to public benefits
W7	Soil moisture monitoring[1]	Yes – communication failure	Yes, private benefits exceed private costs	Yes	Suitable for government funding for extension only
W8	Sediment traps	Yes – negative externalities	No	Yes, the additional public benefits exceed total costs	Suitable for government cost share in relation to public benefits
W9	Maintain drains[1]	Yes – communication failure	Yes, private benefits exceed private costs	Yes	Suitable for government funding for extension only

ID	Management action	Market failure	Private net benefit	Total benefits exceed total cost	Suitability for cost sharing
W10	Maintain groundwater pumps	Yes – negative externalities	Yes, private benefits exceed private costs	Yes	Suitable for government funding in relation to public benefits
Administration					
A1	Program Administration (y 1-2)	Not applicable	No benefits are associated with program administration	No benefits are associated with program administration	Suitable for government funding of overall Plan administration
A2	Program Administration (y 3-10)	Not applicable	No benefits are associated with program administration	No benefits are associated with program administration	Suitable for government funding of overall Plan administration

15Monitoring and adaptive management

15.1 Overview

This Monitoring Evaluation Reporting and Improvement (MERI) Plan has been developed to improve confidence and embed adaptive management processes in the implementation of the Lake Wellington LWMP. It provides the structured evaluation, reporting and improvement processes to support the Plan's implementation (Figure 15.1) and will assist the Lake Wellington LWMP by:

- Defining the program logic underpinning the Plan's targets and outcomes;
- Identifying measures and monitoring requirements by which progress towards outcomes and targets may be tracked; and
- Describing data collection approaches and processes for evaluation, reporting and adaptive management.

This MERI plan has been informed by several existing frameworks, including those developed for natural resource management programs by the Australian and Victorian Governments.

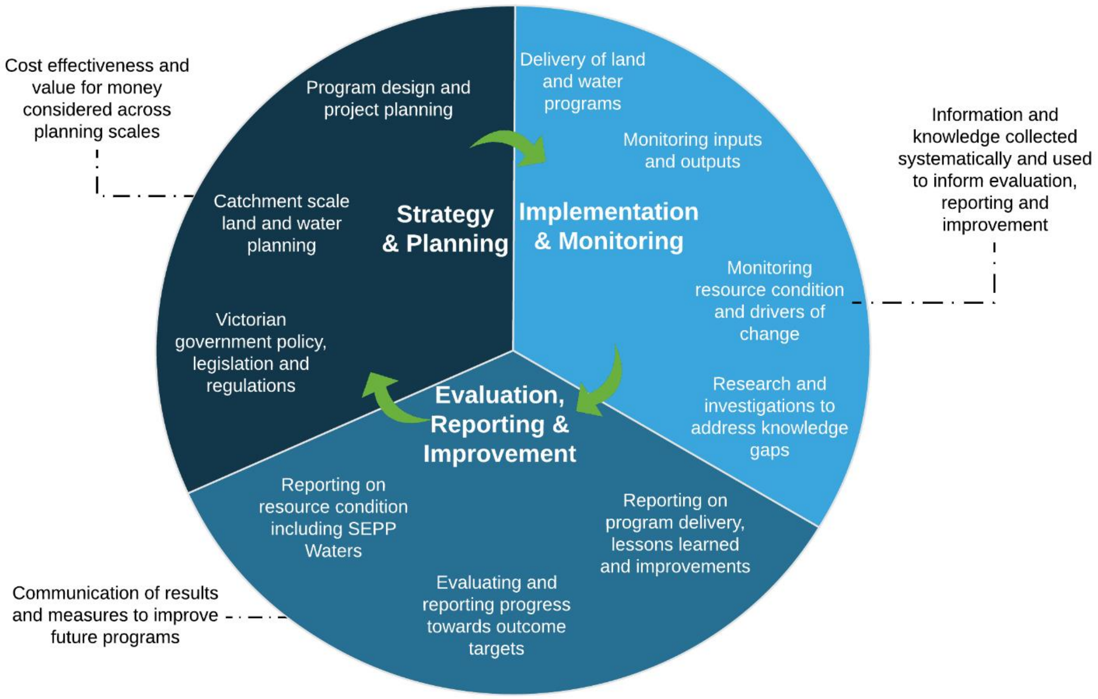

Figure 15.1 Adaptive management process for the Lake Wellington Land and Water Management Plan.

15.2 Program logic

Program logic describes the rationale for the Lake Wellington LWMP. It defines the relationships between the activities implemented through its programs, their management action targets (MATs) and the longer-term resource condition targets (RCTs) which reflect the fulfilment of the vision for the sustainable irrigation in the Lake Wellington catchment.

Elements of the program logic (illustrated in Figure 15.2) include:

- ***Vision:*** an overarching long-term aspiration for sustainable irrigation in the Lake Wellington catchment.
- ***Aspirational objectives:*** statements that provide specific detail on the vision for sustainable irrigation.
- ***Outcomes:*** statements describing what is expected to be achieved from implementation of the Plan.
- ***Resource condition targets:*** specific long-term targets for change in environmental and socio-economic conditions which will be influenced by the Plan. Two groups of RCTs are identified:

  Primary targets: these relate to the Plan's main functions of improving the quality of water entering Lake Wellington from irrigation areas and containing risks from salinity and shallow water tables (Table 15.1).

  Support targets: specific measures (Table 15.2) which demonstrate progress towards other components of the vision and aspirational objectives. Support targets are currently preliminary targets and may be revised or replaced following further analysis, as the Plan is implemented. Progress towards these targets is generally less directly influenced by the Plan than is the case for the primary targets.
- ***Management action targets:*** specific measures of the implementation of LWMP programs. Where practicable, the MATs defined for the Plan are based on DELWP's standard outputs.
- ***Foundational activities:*** activities that underpin the planning for the LWMP***.***

Assumptions link the activities and MATs to the RCTs and help to identify where knowledge gaps and uncertainties exist in the program logic and are described in Table 15.10-Table 15.16.

Table 15.1 Lake Wellington Land and Water Management Plan primary resource condition targets

Primary targets:	Rationale
Average annual phosphorus load entering Lake Wellington from irrigation areas will be reduced by 7.5 t by 2030.	This target is the proposed SEPP (Waters) phosphorus load reduction target for Lake Wellington. It links with the Plan outcome to reduce nutrients and other pollutants entering the Gippsland Lakes[1].
The area of land in the Macalister Salinity Management Zone with high water tables will not exceed the 2012 benchmark of 33,000 ha during the life of the Plan (2018-2027)	Salinity and groundwater issues within areas of the MID and surrounds are effectively in "care and maintenance". The Plan seeks to contain the extent and impact of shallow water tables and salinity to no more than the upper range recorded since the end of the Millennium Drought.

Table 15.2 Lake Wellington Land and Water Management Plan support resource condition targets

Support targets:	Rationale
The gross value of irrigated agricultural production will increase by an average of 5% p.a. during the life of the Plan (2018-2027).	Actions in the Plan support improved on-farm production and profitability and will contribute to growth and resilience in the regional economy.
By 2027, 70% of participants report increased knowledge and awareness of the Indigenous and non-Indigenous social and cultural values associated with Lake Wellington catchment irrigation areas.	This target relates to participation in targeted social and cultural awareness raising, engagement or capacity building activities, as outlined in the Innovation and community connectedness program. Surveys to benchmark understanding of social and cultural issues will need to be undertaken to verify this target.

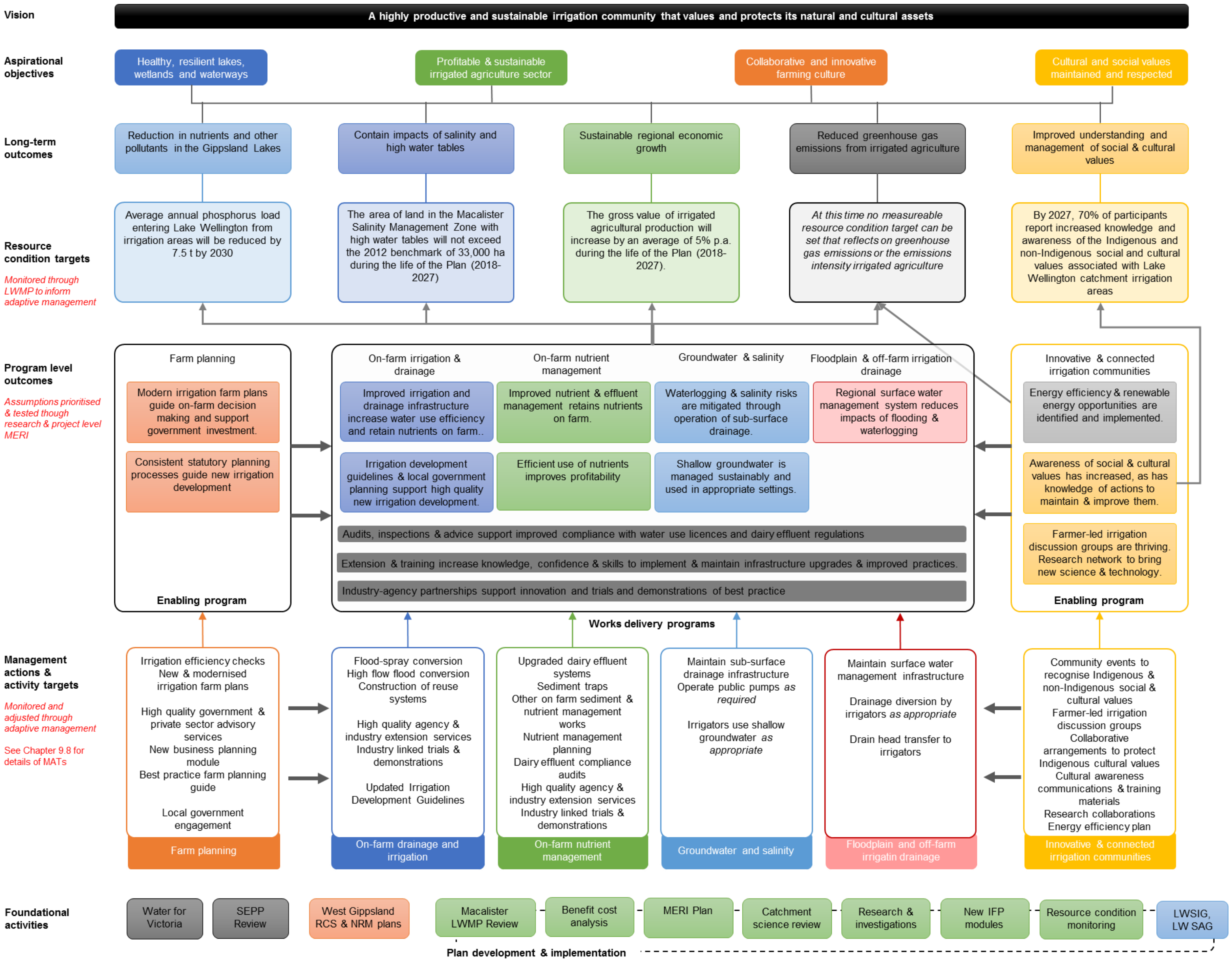

Figure 15.2 Program logic for the Lake Wellington Land and Water Management Plan

15.3 MERI requirements

There are three major aspects of the MERI plan for the Lake Wellington LWMP:

1. Evaluating progress towards the RCTs (Plan *impact*) and the *legacy* associated with management.
2. Evaluating implementation of the Plan including:
   - *Effectiveness* of the Lake Wellington LWMP, by tracking activities, achievement of MATs and adjustment of MATs through adaptive management.
   - More detailed consideration of the *appropriateness* and *efficiency* of implementation and the arrangements supporting implementation.
3. Activities and processes to support adaptive management and improvement.

15.3.1 Evaluation and reporting requirements

Evaluation and reporting will occur regularly throughout the ten-year life of the Plan (Table 15.3), follow agreed and documented MERI processes and build on the program logic. Evaluation will be guided by evaluation criteria and key evaluation questions (see Chapter 15.4). This framework will provide the basis for reporting to government and key stakeholders on progress towards targets and inform adjustments to program design and annual work programs.

Formal evaluation and reporting activities will be carried out over three time scales (annual, mid-term and final; Table 15.3). This will be supported by coordination of MERI activities, monitoring and data collection and regular progress reviews (see Chapters 15.4-15.6).

Table 15.3 Lake Wellington Land and Water Management Plan evaluation and formal reporting requirements

Time scale	Evaluation scope	Reporting requirements
Annual	Consider the activities which have been undertaken and their direct outputs. Identify new knowledge gained from implementation, research or monitoring, as well as emerging research needs and technology opportunities. Identify changes in policy and regulatory frameworks and priorities. Propose changes or adjustments to planned activities in response this knowledge.	Progress report outlining the highlights, challenges and achievements. **Audience:** LWSIG, LWSAG, WGCMA Board and DELWP, Research and Technology "virtual hub"
Mid-term	Consider implementation achievements and progress towards program goals and overall Plan outcomes. Consider how the key influences on irrigation land and water management within the Lake Wellington catchment are changing and how the LWMP should respond to this. New knowledge and information gathered through this review will assist with adaptive management by informing changes to delivery approaches and intended program outcomes.	Report on progress towards RCTs, achievement of MATs, lessons learned and improvements. Summary of the effectiveness, appropriateness and efficiency of implementation. Proposed changes to programs or MATs in response to evaluation findings. **Audience:** LWSIG, LWSAG WGCMA Board and DELWP. Summary reported to the Lake Wellington catchment community.
Final	Overall assessment of the Plan's achievements and progress towards outcomes	Overall achievements of the LWMP (MATs, RCTs and other outcomes).

Time scale	Evaluation scope	Reporting requirements
	and targets. The final evaluation will provide the evidence base of lessons learned and improvements implemented over the life of the Plan. It will provide a basis for future land and water management planning processes.	Summary of the effectiveness, appropriateness and efficiency of implementation and the degree to which legacy issues have been accounted for. Any emerging needs and priorities for future plans will be identified. **Audience:** LWSIG, LWSAG, WGCMA Board and DELWP. Summary produced for the Lake Wellington catchment community.

15.3.2 Roles and responsibilities

This MERI Plan will be supported by robust coordination arrangements, with leadership by the WGCMA and collaboration through the LWSIG.

The LWSIG will coordinate MERI processes and drive collaborative research and innovation activities. The group will report and be accountable to WGCMA's Board, who are responsible for approving decisions as outlined in Table 15.4. Reporting to DELWP will occur through the LWSIG and via the WGCMA Board.

The LWSIG will engage with stakeholder groups, as required to inform adaptive management. The Stakeholder Advisory Group (SAG) formed to support development of the Plan will be maintained to provide a formal avenue of advice and feedback. Participation from representatives of horticultural irrigators in the MID and from irrigators in other parts of the catchment will be sought as the Plan is implemented.

An annual MERI work plan will be developed to support implementation of this MERI Plan.

Table 15.4 Roles and responsibilities of key stakeholders in Lake Wellington Land and Water Management Plan MERI processes

Stakeholder	Roles and responsibilities
West Gippsland CMA Board	Review and approve reports for submission to DELWP and the community. Approve SIP investment proposal and Lake Wellington LWMP mid-term and final reviews. Consider recommendations and reports from the LWSIG.
Lake Wellington Sustainable Irrigation Group	Coordination of MERI activities, including mid-term and final review. Participate in 6 monthly informal progress reviews. Review monitoring results and contribute to evaluation processes. Contribute to annual, mid-term and final review reports. Make recommendations to WGCMA Board on adjustments to targets, LWMP programs, identify resourcing requirements and constraints based on MERI findings.
Lake Wellington Stakeholder Advisory Group	Provide local and practical advice on program design, emerging issues and community aspirations. Support the Plan's adaptive management processes.
West Gippsland CMA (chair of LWSIG)	Coordination of MERI activities. Commission resource assessment / investigations, monitoring and evaluation projects. Facilitate "virtual research and technology hub". Coordinate reporting on implementation on a 6-monthly basis (budget and outputs) and the status of management activities on an annual basis. Lead evaluation processes and development of reports. Recommend improvements to the LWSIG informed by evaluation and reporting and advice from delivery partners, contractors and stakeholders.

Stakeholder	Roles and responsibilities
Other delivery partners and contractors	Contribute to implementation of the MERI Plan and adaptive management processes.

15.4 Evaluation criteria and questions

Key evaluation questions (KEQs) drive the evaluation and reporting process and provide the basis for assessing the success of the Lake Wellington LWMP. The questions are also used to frame monitoring and data collection.

Six categories are used to frame the evaluation questions:

- ***Impact:*** measurable effects of implementation in achieving the objectives of the Plan.
- ***Effectiveness:*** success of implementation in producing the intended results.
- ***Appropriateness:*** suitability and alignment of actions to achieve the desired results.
- ***Governance and management:*** appropriateness of organisational structures and processes to support implementation.
- ***Efficiency:*** extent to which implementation has made the best use of available resources.
- ***Legacy:*** extent to which the impacts of the LWLMP will continue after funding ceases.

The evaluation framework is summarised in Table 15.5. The framework provides high level guidance for subsequent sections, including the evaluation, reporting and adaptive management processes and monitoring and data collection plan. Details of monitoring and performance measures are given in Table 15.6 and Table 15.7.

Table 15.5. Lake Wellington LWMP evaluation criteria and framework

Evaluation areas	Key evaluation questions	Type of information & evidence to support evaluation	Evaluation frequency
Impact *Plan outcomes*	1. What progress has been made towards the RCTs?	Progress towards RCTs as per their specific metrics. Supporting evidence to understand progress towards RCTs and other outcomes. Targeted R&D activities to test assumptions and improve knowledge focussed on understanding of nutrient pathways and effectiveness of actions through investigations and participator processes.	Mid-term and final
	2. What, (if any) other unanticipated outcomes been achieved?	Reports from delivery partners, Operating environment scan Agency and landholder participant interviews	
	3. To what extent has implementation contributed to the program outcomes and RCTs?	Calculated or assumed contributions of actions to outcomes used to inform ex-post evaluation. Prioritised and implemented through project level MERI.	
Effectiveness *Plan outputs*	4. To what extent have planned actions been successfully delivered?	Status of actions Reporting against standard outputs Budget performance Records of lessons learned	Annual
	5. To what extent were the MATs achieved?	Achievement of MATs	Mid-term and final review

Evaluation areas	Key evaluation questions	Type of information & evidence to support evaluation	Evaluation frequency
		Records of changes to agreed MATs and rationale for those.	
Appropriateness	6. To what extent are delivery mechanisms and policy tools appropriate to implement the plan?	Target audience for programs reached and level of uptake by target audience. Target audience reporting of program relevance. Delivery mechanisms and policy tools align with guidance from public-private benefits framework and cost-effectiveness framework for regulatory benefits.	Mid-term and final review
Governance and management	7. To what extent are appropriate organisational structures, systems and processes in place?	Terms of Reference and Agreements in place for governance groups and service delivery partners. Risk management processes in place. Financial and audit structures in place for investment.	Mid-term and final review
	8. What evidence is there of adaptive management and active implementation of MERI?	Evidence of collaborative approach to MERI through LWSIG meetings. Evidence that lessons learned and improvements are incorporated into forward planning.	Annual
Efficiency	9. To what extent has LWMP implementation used the resources allocated efficiently?	Evidence of prioritisation and targeting of investment. Evidence that economic principles underpin prioritisation and decision support tools. Extent of leveraged investment. Ex post evaluation of the benefits and costs of management.	Mid-term and final review
Legacy	10. To what extent will the impacts of the LWMP continue after the life of the plan? 11. What arrangements are in place to manage and resource the legacy?	Partnership arrangements (existing, new, strengthened). Evidence that organisations and/or agencies (especially local government, horticulture industry bodies and EPA) have developed policy/programs/tools that will support the LWMP legacy. Change in practices without LWLMP incentive or intervention.	Final review

15.5 Monitoring and data collection

Monitoring activities and data collection processes are designed to inform evaluation, reporting and adaptive management. The monitoring and data collection plan is set out in Table 15.6 and Table 15.7 and is structured according to the KEQs. These tables identify the information required to inform evaluation of: progress towards RCTs, the success and achievements of the LWLMP and the processes used to support implementation.

15.6 Adaptive management processes

The adaptive management and improvement process is an important part of the MERI cycle. Adaptive management or "learning by doing" is often an implicit aspect of implementation, with adjustments made iteratively in response to new information and knowledge. Through this MERI plan the Lake Wellington LWMP will have a more transparent and formalised adaptive management process informed by regular reviews and structured evaluation and reporting as set out in Figure 15.3 and Table 15.8.

Table 15.6. Monitoring and data collection plan – impact key evaluation questions.

Key evaluation questions	Measures and evidence		Data collection approach	Frequency of data collection
1. What progress has been made towards the RCTs?	Reduction in annual nutrient (TP) load from the MID and non-MID irrigated areas entering Lake Wellington. Reduction in annual nutrient load (TN) and sediment load (TSS) from the MID and non-MID irrigated areas entering Lake Wellington.	Flow (ML/day) Total phosphorus concentration (mg/L) Total nitrogen concentration (mg/L) Total Suspended Solids (TSS) Calculated to load measures.	Continuation of SRW's river (and drain) based load monitoring program for P in the MID. Additional river-based load monitoring for N and TSS in the MID. New monitoring program for N, P and TSS exports from other key irrigation areas in the Lake Wellington catchment.	Daily sampling, aggregated to weekly / fortnightly sample analysis. Additional grab samples taken in high flow events.
			R&D to improve understanding of nutrient/pollutant/pathogen pathways (from on-farm to Lake Wellington). Develop a farm-scale monitoring program/guidelines for nutrients and sediments.	To be determined to align with MID river-based monitoring program.
	Area with shallow water tables (<2m)	Depth to water table Salinity (EC) (provides supporting evidence for RCT)	Continuation of current depth to groundwater monitoring of bore network and salinity monitoring (sub-set of bore network)	Quarterly.
	Gross value of agricultural production (interim measure)	Gross Value of Irrigated Agricultural Production (GVIAP) produced through agricultural census.	Agricultural census data cube.	Five yearly agricultural census, with 12-month time lag between data collection and publication of census.
			Develop RCTs for secondary target outcomes for LWMP	Year 1 activity.
	Change in knowledge / awareness of indigenous and non-indigenous social and cultural values.	Participant reports of change in awareness and knowledge as per WGCMA CSKE definitions and scale.	Collected for each engagement activity (targeted to participants of engagement activity with focus on cultural/social values).	Collected in conjunction with engagement events. (Results collated annually and used to inform mid-term and final reviews).
		Case studies demonstrating change in awareness and practices (i.e. protection of cultural heritage values).	To be confirmed, but dependent on partnership arrangements being established.	Collated to inform mid-term and final reviews.
	Most significant change stories	Participant and agency examples of 'change' (practices/ works / knowledge	Systematic and participatory (with independent facilitation or training).	Tbc. LWSIG to determine if this approach is appropriate and practical.

Key evaluation questions	Measures and evidence		Data collection approach	Frequency of data collection
		/ capacity) as a result of the LWMP.		
2. What, (if any) other unanticipated outcomes been achieved?	Agency and participant workshops interviews / surveys to identify spin-offs, perverse and/or other unintended outcomes	Participant reports / case studies of positive or negative outcomes from LWLMP activities (enviro, social, economic). Agency/service provider reports of on unanticipated outcomes from LWLMP activities.	Survey of all landholder, agency and contractor participants during Year 4 to inform mid-term review or targeted in depth interviews / focus group discussions.	Year 4 and Year 9 (i.e. prior to mid-term and final review)
	Operating environment scan	Industry and economic outlook reports ABS, BOM, IPCC data and climate projections Agency and community concerns	Systematic scan of external drivers identified in the LWMP and review of emerging issues combination of website / document review and workshop process	Annual check-in through LWSIG and SAG. Systematic review as part of mid-term review and final evaluation.
3. To what extent has implementation contributed to the program outcomes (and RCTs)	Indicative measures are outlined below. These can be used and aligned with the *ex-ante* and *ex-post* benefit-cost analysis. **Resource condition** Nutrients retained, water use, emissions **Financial** Productivity, labour costs **Social** Awareness, knowledge, skills, behaviour, confidence, barriers	Targeted investigations Calculations and estimates from whole farm and nutrient management plans. Participant surveys and interviews.	Assumptions linking actions to outcomes are to be prioritised and monitored or investigated through project level MERI, which will be developed as projects are planned and implemented. Because of the importance of enabling activities (extension, advice, planning and training) the collection of participant social impact data is a priority.	Collected annually Used to inform *ex-post* economic evaluation of benefits and costs.

Table 15.7. Monitoring and data collection plan – effectiveness, efficiency, appropriateness program management and legacy

Key evaluation questions	Measures and evidence	Data collection approach	Frequency of data collection
4. To what extent have planned actions been successfully delivered?	Status of actions (i.e. traffic light report).	Captured through LWSIG meetings. Will require development of a spreadsheet or database tool to track actions.	Annual.
	Budget performance (Budget v. actual for service providers, tracking of variations).	WGCMA and service provider reporting on projects. SIP investment reporting.	Annual.
	Lessons learned.	Captured through SIP investment reporting and summarised through LWSIG process. For activities not delivered through SIP collected through survey / interviews with responsible agency.	Annual.
5. To what extent were the MATs achieved?	Planned versus actual achievement of MATs (based on DELWP standard outputs).	Reporting through SIP investment requirements.	Data collation annually and aggregated for mid-term and final reviews.
	Extent to which MATs were formally adjusted in response to MERI.	Review of progress reporting to WGCMA board and (if relevant) recommendations for adjustment to MATs. Review of SIP variations (evidence of investment being adjusted) – also captured through KEQ 7.	Mid-term and final evaluation.
6. To what extent are delivery mechanisms and policy tools appropriate to implement the plan?	Participation data for target audience i.e. # participants per # landholders/industry bodies/agencies in target audience.	Participation rates collected through activity and program registration data. Target audience defined through ABS data and local expert knowledge.	Annual
	Uptake of practices following farm planning /training and engagement activities.	Survey of all landholder, agency and contractor participants during Year 4/Year 9 to inform mid-term/final review. Consider also targeted in depth interviews / focus group discussions (also see KEQ 2)	Mid-term and final review
	Target audience reporting of program activity relevance as per WGCMA CSKE definitions and scale.	Collected for activities targeted for landholder and industry participation (engagement, planning and on-ground works).	Collected as part of implementation by service provider / delivery partner OR coordinated centrally by WGCMA.
	Policy tools align with public-private benefits framework.	Conducted by independent consultant as part of *ex post* cost-benefit analysis.	Mid-term and final review.

Key evaluation questions	Measures and evidence	Data collection approach	Frequency of data collection
7. To what extent are appropriate organisational structures, systems and processes in place?	Evidence that appropriate governance arrangements are in place for coordination and service delivery. Risk management processes in place. Financial and audit structures in place for investment.	Independent review of program management structures and processes and documentation; including risk and financial management, service delivery/contracting probity and decision making, transparency. Appreciative inquiry / group workshop process to identify strengths, opportunities and to develop design criteria for future LWMP.	Mid-term and final review.
8. What evidence is there of adaptive management and active implementation of MERI?	LWSIG established with MERI incorporated into terms of reference. MERI work plan established on annual basis. LWSIG agendas and meeting minutes direct focus to implementation of LWLMP. SIP investment reports / request for variation articulate lessons learned and improvements. *Also see KEQ 2*	Interview with LWSIG members, agency stakeholders. Review of LWSIG documentation and reports. Review of investment reports *Note: LWSIG will be the primary collaborative process for tracking implementation and enabling adaptive management.*	Mid-term and final review.
9. To what extent has LWMP implementation used the resources allocated efficiently?	Evidence of prioritisation and targeting of investment. Evidence that economic principles underpin prioritisation and decision support tools. Extent of leveraged investment (additional landholder investment as a result of program participation, industry cash / in-kind contributions, funding external to SIP secured).	Review of program guidelines and funding criteria / prioritisation approach for targeting landholder grants / farm planning and engagement programs. Review of incentive program financial reports (actual $ funded and landholder contributions). Independent review of prioritisation and decision support tools to evaluate design and application of economic principles. *Ex post* evaluation of the benefits and costs of management.	Mid-term and final review
10. To what extent will the impacts of the LWMP continue after the life of the plan?	Partnerships in place beyond life of Plan (agency) New or strengthened partnerships with and between industry and community stakeholders (horticulture, dairy, GLaWAC).	Review of partnership arrangements including LWSIG (terms of reference, industry and agency partnerships.	Mid-term and final review

Key evaluation questions	Measures and evidence	Data collection approach	Frequency of data collection
11. What arrangements are in place to manage and resource the legacy?	Landholder reports of change in practice / uptake without incentive/ intervention (emissions, nutrient reduction, irrigation efficiency).	Survey of participating and non-participating landholders during Year 4/Year 9 to inform mid-term/final review	Mid-term and final review
	Extent to which organisations / agencies have developed policy/programs/tools that will support LWMP legacy.	Interview/s with industry, agency and community partners to determine if legacy issues have been identified and accounted for in supporting policy and programs.	Mid-term and final review

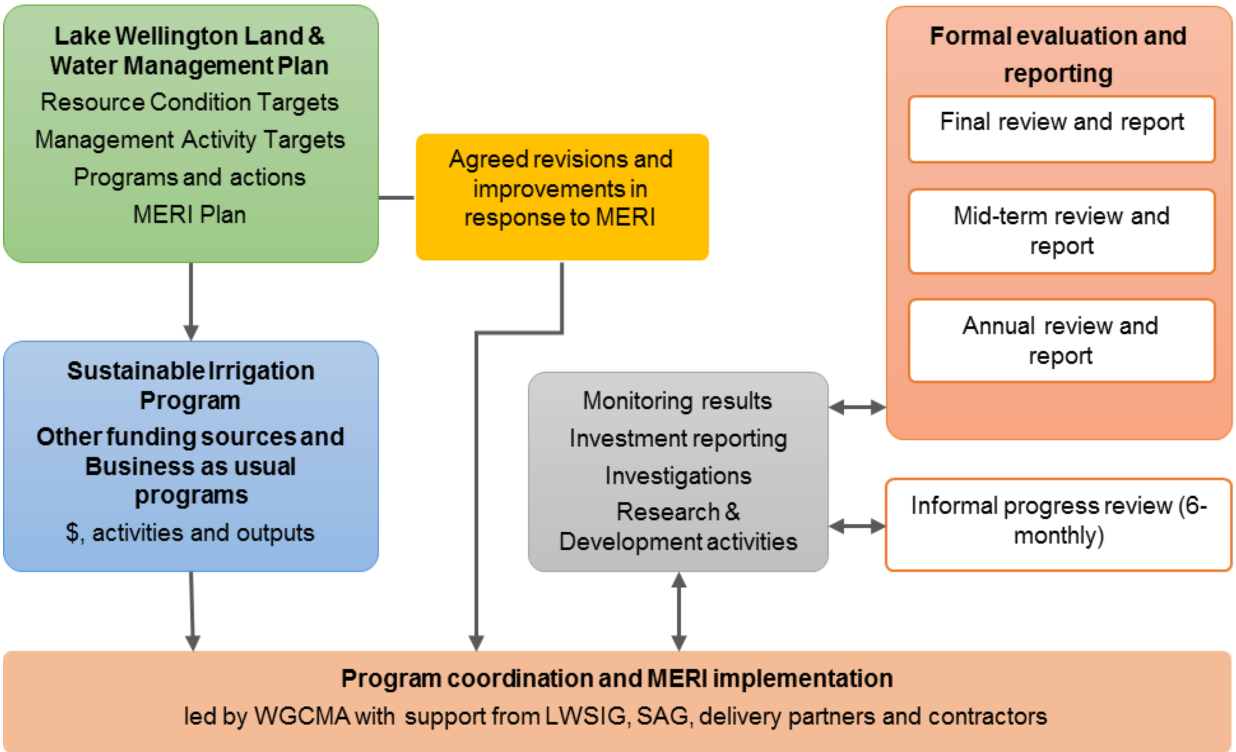

Figure 15.3. Lake Wellington LWMP adaptive management processes

Table 15.8 Adaptive management opportunities for the Lake Wellington Land and Water Management Plan

Evaluation process	Adaptive management opportunity
Progress review	Adjust delivery method within a given project or activity. Reallocate funds / reprioritise effort in response to adverse conditions or unexpected results.
Annual review	Incorporate new knowledge from monitoring and implementation into forward business plan priorities, including reprioritising effort where required. Adjust procedures, processes and contracting arrangements in response to lessons learned. Identify funding requirements / opportunities for new/unfunded actions. Identify LWMP actions requiring review/adjustment at mid-term review based on lessons learned and new knowledge.
Mid-term (and final) review	Adjust LWMP actions and develop targets where knowledge gaps from program logic/assumptions have been addressed. Identify strategic responses to address / mitigate issues arising from external drivers and pressures. Adjust delivery methods for program/projects based on review results. Request to adjust SIP funding priorities and where required seek external funding to align with LWLMP priorities. Refine governance structures, procedures and processes to ensure management is appropriate to deliver LWLMP.

15.7 Knowledge gaps

The Lake Wellington LWMP has been developed using the best available information, including a detailed review of the Macalister Irrigation District LWMP. Ten-year RCTs were developed and refined through the planning process to link the objectives and management actions and provide measures of success that can be tracked over the Plan's life.

The process of developing the Plan and program logic has identified a number of critical knowledge gaps which have been captured in research and development activities and other actions to support MERI. These are summarised in Table 15.9, Section 13 and in the main Lake Wellington LWMP document.

Table 15.9. Research, development and other actions in support of MERI and LWMP implementation

Action #	MERI or research and development opportunity
1.2	Develop or adapt farm business planning tools to support whole farm planning. The tools would assist in the initial stages of irrigation farm planning (IFP) engagement to help irrigators articulate and develop their business and farm management goals as a basis for effective farm planning.
1.3	Adapt irrigation farm planning concepts to upland irrigation settings. Development of guidance on irrigation farm planning for upland settings (e.g. Thorpdale), drawing on lowland irrigation experience and dryland whole farm planning processes.
1.4	Develop a Lake Wellington best practice guide to farm planning and irrigation, which draws on the insights and experiences of local farm planners, designers and extension staff.
2.4, 3.3	Establish industry partnerships for local on-farm demonstrations and trials of best practice systems for best practice irrigation management and the management of dairy effluent, nutrients and sediments in pasture and horticultural cropping systems.
3.5	Undertake research to improve understanding of the sources and movement pathways of nutrients lost from irrigation farms and how these may be affected by horticultural expansion and potential new irrigation developments (including significant redevelopments).
4.1	Review energy efficiency and renewable energy opportunities associated with operation of sub-surface drainage system and, if practicable, implement
5.3	Explore planning and funding mechanisms to improve the function of the natural and constructed surface drainage systems and health of waterways and wetlands. Mechanisms to consider include Drainage Course Declarations (as applied in the Goulburn Murray Irrigation District).
5.4	Research to investigate opportunities for drains and floodplain waterways and wetlands to be managed to capture or use nutrients carried off-farm during small-medium floods/rain flow events.
5.5	Research to quantify changes in streamflows resulting from on and off-farm irrigation and drainage management activities supported by the Plan and to assess their impacts.
6.1	Develop an on-farm energy efficiency and renewable energy module for delivery within the IFP framework.
6.2	Develop and implement irrigation energy efficiency plan for the Lake Wellington catchment.
6.3	Develop IFP cultural heritage planning and management module.
6.4	Facilitate irrigation land and water management research collaborations that address regional research priorities.
	Additional actions that are proposed support MERI processes are described in Table 15.16.

Further prioritisation of knowledge gaps and investigations may be required through the MERI work plan process.

The Plan will also support the development of a collaborative research and technology network to facilitate engagement of the science and technology community in irrigation land and water management within Lake Wellington catchment. As part of this MERI process, the LWSIG will continue to identify research and technology priorities and opportunities (building on those expressed in this listed in Table 15.9) applicable to irrigation land and water management.

They will actively engage public and private sector researchers and technologist in applying leading thinking and/or technology to key challenges and technologies. The scope of this work would include issues which are core to the Plan, such as irrigation water and nutrient efficiency and management of nutrient movement in irrigation landscapes. It could also include issues which are relevant to the full suite of the Plan's objectives, including the application of traditional knowledge in irrigation land and water management, applications of remote sensing technologies and "big data" in irrigation management, climate resilient farming and development of appropriate renewable energy technologies for dairy regions.

15.8 Assumptions linking programs and resource condition targets

Assumptions provide the basis for estimates of the quantum of outputs in each LWMP program and are used to link the activities and MATs to the RCTs. The broad assumptions underpinning the Plan's programs are set out Table 15.10 - Table 15.16

For the primary RCTs (reducing nutrient loads and containing the impacts of salinity and shallow water-tables) there are a mix of enabling actions and direct works and measures. The tables also identify the contribution an action makes to other RCTs.

Enabling actions aim to improve the skills, knowledge and awareness of irrigators, industry and agencies and lead to improved management practices. Works and measures include actions that directly contribute to the achievement of targets.

Table 15.10 Assumptions and links between activities and targets – farm planning program

CBA Link	Activity			Management Action Target				Link to RCTs	
	#	Description	Output Description	Type	Quantity (10 y)	Rationale	Assumptions	Primary	Additional
P1, P2, P3, CB2	1.1	Deliver a flexible and holistic irrigation farm planning and extension program.	500 ha/y with modernised irrigation farm plan	Plan - Property (irrigation), no.	100	7500 ha (75 ha per farm) = 100 plans	Program delivered Y1-10. Cost share for implementation of irrigation efficiency measures only available to irrigators with an agreed IFP. Cost share available to horticultural producers in lowland areas and upland irrigation areas, with the latter included following adaptation of IFP process to that landscape (see 1.3). Service delivered by AgVic (~0.5 FTE). Irrigation design component of IFP delivered by private providers. IFP process provides foundation for implementation of best practice farming measures to improve water and nutrient use efficiency. It is a key enabler of the on-farm irrigation and drainage and nutrient management programs.	Enabling activity	Contributes to (1) reduction of nutrient loads, (2) area affected by shallow water table (3) increased economic value as an enabling program.
			500 ha/y with new irrigation farm plan	Plan - Property (irrigation), no.	100	7500 ha (75 ha per farm) = 100 plans			
			20 properties pa with irrigation efficiency check/y	Assessment - Agronomic, No.	200	20 properties per year			
			IFP-related extension activities	Engagement event - Field Day, No. of participants	200	1 field day/y @ 20 participants			
				Engagement event - Workshop, No. of participants	100	1 workshop/y @ 10 participants			
				Assessment - Agronomic, No.	300	2 Agriculture Victoria visits per IFP @ 15 properties per y (30/y x 10 = 300)			
RA12	1.2	Develop farm business planning tools to support whole farm planning. The tools would assist in the initial stages of IFP engagement to help irrigators articulate and develop their business and farm management goals as a basis for effective farm planning.	Lake Wellington version of *Plan2Farm* type tool with localised testing.	Information management system - Decision Support, No.	1	Indirect link to RCT	Developed Y2 and incorporated into IFP delivery from Y3. Plan2Farm tool from NCCMA/GMID provides a potential model for this tool. Adapting this or similar tools to Lake Wellington landscapes and enterprises (dairy and horticulture) may be less expensive than developing a similar tool from scratch. Tool would be delivered through the updated IFP process and provide an improved basis for irrigator decision-making in implementing irrigation and nutrient use efficiency works, farm layout changes and environmental improvements.	Enabling activity	Increased economic value of irrigated agricultural production.

CBA Link	Activity			Management Action Target				Link to RCTs	
	#	Description	Output Description	Type	Quantity (10 y)	Rationale	Assumptions	Primary	Additional
							Product most likely delivered through consultancy and managed by WGCMA.		
RA3	1.3	Adapt irrigation farm planning concepts to upland irrigation settings. Development of guidance on irrigation farm planning for upland settings (e.g. Thorpdale), drawing on lowland irrigation experience and dryland whole farm planning processes.	Upland irrigation farm planning guidelines linked to updated IFP process	Publication - Written, No.	1	Indirect link to RCT	Developed Y3 and implemented into IFP deliver from Y4. Current IFP concepts have developed for lowland irrigation settings and address different issues to upland irrigation in Lake Wellington catchment. Some adaptation of conventional WFP and IFP processes would be required for these landscapes. Development and implementation of these guidelines would follow process of engagement with upland catchment irrigators by WGCMA.	Enabling activity	Contributes to (1) reduction of nutrient loads, (2) area affected by shallow water table (3) increased economic value as an enabling program.
RA12	1.4	Develop a Lake Wellington best practice guide to farm planning and irrigation, which draws on the insights and experiences of local farm planners, designers and extension staff.	Best practice guide to irrigation and irrigation farm planning.	Publication - Written, No.	1	Indirect link to RCT	Developed Y3 and available for use from then. Document would capture local experience on irrigation design and management and irrigation farm planning. It would function as a local best practice guide and support farm planning service delivery and irrigator capacity building. There is no similar best practice guide to irrigation for Lake Wellington irrigation areas. Co-investment to be sought from Dairy industry.	Enabling activity	Contributes to (1) reduction of nutrient loads, (2) area affected by shallow water table (3) increased economic value as an enabling program.
CB3, A1	1.5	Work with local government to ensure that statutory planning processes for irrigation farm planning are consistent across Lake Wellington catchment and ensure high quality new and modified irrigation developments.	Consistent statutory planning work flow for new irrigation developments	Publication - Written, No. Engagement event - Workshop, No. of participants	1 30	Indirect link to RCT 3 workshops with 10 participants at each	Commence local government engagement in Y1. Consistent statutory planning work flow developed Y2 and then revised following any major revision of IDGs. ~0.2FTE, WGCMA. Process to commence with engagement with local government to understand capacity, constraints and interest in contributing to irrigation land and water management. Consistent processes across LW catchment will help to ensure higher quality new irrigation developments, which are consistently reviewed by referral agencies.	Enabling activity	Contributes to (1) reduction of nutrient loads, (2) area affected by shallow water table (3) increased economic value as an enabling program.

CBA Link	Activity			Management Action Target				Link to RCTs	
	#	Description	Output Description	Type	Quantity (10 y)	Rationale	Assumptions	Primary	Additional
							Risk to environment from inappropriate irrigation developments and earthworks for irrigation layout modification will be reduced. They will help to enable improved environmental outcomes from LW catchment irrigation areas. Delivered by WGCMA, in conjunction with Wellington, Latrobe and Baw Baw Councils.		

Table 15.11 Assumptions and links between activities and targets – on-farm irrigation and drainage program

CBA Link	Activity		Management Action Target					Link to RCTs	
	#	Description	Output Description	Type	Quantity (10 y)	Rationale	Assumptions	Primary	Additional
W3, W4	2.1	Provide extension services and financial incentives for improvements in on-farm irrigation infrastructure and management practices.	300 ha/y flood to spray conversion.	Irrigation Infrastructure - Pressurised, Ha	3000		Delivered Y1-10. On-farm irrigation efficiency improvements increase on-farm productive capacity and reduces leakage of irrigation water to groundwater system and nutrients off-farm. They provide a high level of public benefit. Cost share may not be critical for high flow flood conversion (best practice surface irrigation), provided cost share is maintained for irrigation reuse system construction (2.2). Cost share is only provided to implement an approved IFP. Irrigation outlet rationalisation largely provides private benefit and is not suited to cost share. Technology to support irrigation efficiency improvement primarily provides private benefit and is not suited to cost share support. Assume this is targeted to lighter soils. Assumptions about benefits about on-farm irrigation infrastructure improvements are described in Chapter 14.7.	1. Phosphorus loads entering Lake Wellington are reduced.	3. Increased economic value of irrigated agricultural production.
			200 ha/y. Best practice surface irrigation/high flow flood conversion.	Irrigation Infrastructure - Gravity, Ha	2000				
W1, W2	2.2	Provide extension services and financial incentives to construct or expand irrigation reuse systems.	700 ha/y with new or expanded reuse	Water storage - Sump, No.	140	1 reuse system / 50ha as per SIP investment assumptions	Reuse systems reduce off-farm losses of water, nutrients and sediment and helps to improve the quality of receiving waters. They provide a high level of public benefit. Cost share is only provided to implement an approved IFP. Assumptions about benefits of tailwater reuse are described in Chapter 14.7.	1. Phosphorus loads entering Lake Wellington are reduced.	3. Increased economic value of irrigated agricultural production.
CB2	2.3	Provide extension services and coaching for irrigators to enable on-going improvements in irrigation efficiency	Irrigation efficiency and system upgrades	Assessment - Agronomic, No.	100	0.5 FTE per annum require approximate no. of visits for one-on one extension. 10 per year (currently doing 2 per year)	Extension service provision and capacity building is required to support irrigator participation in works programs to improve irrigation efficiency. They are a key enabler for on-ground works delivered through this program.	Enabling activity	Contributes to (1) reduction of nutrient loads, (2) area affected by shallow water table (3)

CBA Link	Activity #	Description	Output Description	Management Action Target Type	Quantity (10 y)	Rationale	Assumptions	Link to RCTs Primary	Additional
				Approval and advice - Advice, No.	1000	100 per year x 10 = 1,000 (these include enquires etc that don't neatly fit in other categories)			increased economic value as an enabling program.
				Engagement event -Meeting, No. of participants	200	10 workshops @ 20 ppl = 200			
CB1	2.4	Develop industry partnerships to establish local, on-farm demonstrations and trials of best practice irrigation management. Priorities for trials and demonstrations to be developed in conjunction with industry partners and irrigators and apply to dairy and horticulture sector.		Partnership - Agencies/ Communities, No.	2		First year commences with partnership development (dairy and horticulture), priority setting and trial establishment. Local trials support extension efforts and can integrate across farm planning, nutrient management and irrigation efficiency programs. 2.4 would be delivered in conjunction with 3.3 for trials relating to improved efficiency of nutrient use. Local trials provide a strong basis for continuous improvement in irrigation management practice	Enabling activity	Contributes to (1) reduction of nutrient loads, (2) area affected by shallow water table (3) increased economic value as an enabling program
				Engagement event - Workshop, No. of participants	200	1 / yr @ 20 ppl (*note might be crossover with other events)			
				Publication - Written, No.	1				
				Publication - Visual, No.	1	Presentation			
	2.5	Revise and update the Gippsland Irrigation Development Guidelines to set best practice standards for on-farm irrigation systems and practices for new or modified irrigation developments	Updated Gippsland Irrigation Development Guidelines	Publication - Written, No.	2	Minor refresh + major one if required	IDGs currently have limited impact on irrigation redevelopment in the MID, as most current redevelopments do not require changes to WUL, although there is a major change in irrigation land use (e.g. dairy-horticulture).	Enabling activity	Contributes to (1) reduction of nutrient loads, (2) area affected by shallow water table (3) increased economic value as an enabling program
	2.6	Investigate the issues, benefits and impacts of a proposal to increase reuse dam size limits	Report on assessment, policy guidance on	Publication - Written, No.	1		This action responds to irrigator concerns that reuse dam size limits their effectiveness. It would review the basis for regulatory and other controls on reuse	Enabling activity	Contributes to (1) reduction of nutrient loads, (2) area
				Engagement event -	20	Landholder consultation			

CBA Link	Activity #	Description	Output Description	Management Action Target Type	Quantity (10 y)	Rationale	Assumptions	Link to RCTs Primary	Additional
			irrigation reuse dams	Workshop, No. of participants			dam size and the environmental implications of any change. Depending on the outcome of the review, recommendations may be made to LWSIG to advocate for changes in controls on reuse dam size.		affected by shallow water table (3) increased economic value as an enabling program.
				Engagement event - Workshop, No. of participants	10	Agency consultation			

Table 15.12 Assumptions and links between activities and targets – on-farm nutrient management program

CBA Link	Activity			Management Action Target				Link to RCTs	
	#	Description	Output Description	Type	Quantity (10 y)	Rationale	Assumptions	Primary	Additional
P4	3.1	Provision of training to irrigators to enable them to develop and implement nutrient management plans for their properties.	# irrigators trained	Engagement event - Training, No. participants	250	Assume 25 farmers per year trained through Fert$mart or similar program	Y1-10 Delivered by WGCMA (~0.2 FTE) conjunction with Gipps Dairy (currently). Experience indicates irrigators will not participate in training without cost share support. Training leads to development and implementation of nutrient management plans and contributes to reduced off-farm loss of nutrients and improved productive capacity through improved nutrient budgeting and subsequent on-farm works. Current focus of activity is on dairy operations. The program would be adapted to horticultural operations following engagement with that industry sector. Action currently funded by Commonwealth. WGCMA and LWSIG to advocate for future funding from SIP, given the links between action and improved catchment water quality outcomes.	1. Phosphorus loads entering Lake Wellington are reduced.	3. Increased economic value of irrigated agricultural production.
			# of horticultural irrigators engaged	Assessment - Agronomic, No.	20	Assume work with 20 vegetable farms on practices			
			# of agronomists engaged in nutrient management workshop	Engagement event - Workshop, No. of participants	30	Engagement with agronomists identified as important component in delivering successful Fert$mart (or similar) - some agronomists have suggested would be valuable to deliver Fert$mart to other staff at their organisations.			
			1875 ha/y farms with new nutrient management plans developed and implemented	Plan - Property (management practices), no.	250	25/y @ 75ha each			
W6	3.2	Provide extension services and financial incentives to improve the design and management of dairy effluent systems	# dairy effluent system upgrades	Water storage - Sump, No.	200	Assume 20 per year. But in the broader catchment, there's a big pool of farms that need a lot of work. Might need reviewing.	Y1-10 Delivered by WGCMA (~0.5 FTE), with support from GippsDairy and EPA. Incentives provided for changed systems and management for dairy effluent, feed pads, laneways and other farm features which are key sources of nutrients and sediment reaching waterways (as highlighted in Chapter 4).	1. Phosphorus loads entering Lake Wellington are reduced	3. Increased economic value of irrigated agricultural production
			Extension activities	Assessment - Agronomic, No.	200	1st farm visit (20 per y)			

CBA Link	Activity			Management Action Target				Link to RCTs	
	#	Description	Output Description	Type	Quantity (10 y)	Rationale	Assumptions	Primary	Additional
				Approval and advice - Advice, No.	200	2nd farm visit (20 per y)	Changed systems and management can increase on-farm nutrient efficiency and reduce off-farm losses of nutrient and sediment. Assumptions about benefits associated with nutrient management works and measures are described in Chapter 14.7. Action currently funded by Commonwealth. WGCMA and LWSIG to advocate for future funding from SIP, given the links between action and improved catchment water quality outcomes.		
			ha of effluent management plans	Plan - Property (management practices), ha	1000	20 at 50ha each			
RA2, CB1, W8	3.3	Establish industry partnerships for local on-farm demonstrations and trials of best practice systems for the management of dairy effluent and of nutrients and sediments in pasture and horticultural cropping systems.	On-farm trials. Field days. Extension publications	Partnership - Agencies/ Communities, No.	2	Ag and horticulture	Delivered Y1-10. Extending outside MID area following engagement within irrigators, from about Y3 onwards. Delivered by AgVic (0.5 FTE) in conjunction with dairy and horticulture industry. First year commences with partnership development (dairy and horticulture), priority setting and trial establishment. Local trials support extension efforts and can integrate across farm planning, nutrient management and irrigation efficiency programs. 3.3 would be delivered in conjunction with 2.4 for trials relating to improved irrigation water use efficiency. Local trials provide a strong basis for continuous improvement in nutrient management practice.	1. Phosphorus loads entering Lake Wellington are reduced.	
				Engagement event - Workshop, No. of participants	200	1 per yr x 20 ppl x 10 yrs			
				Publication - Written, No.	10				
				Publication - Visual, No.	10				
C1	3.4	Continue a program of compliance monitoring by EPA to ensure that dairy effluent management systems conform to regulatory standards.	Compliance audits. Audit reporting. Improved compliance with EPA regulations regarding dairy effluent management.	Assessment - Surface water (inspection), No.	480	Estimate - 1 per week for 5 yrs, with longer term transition to pollution prevention.	Business-as-usual activity for EPA. Action is encouraged by the Plan, but EPA visibility in MID will increase awareness of compliance obligations and lead to improved practice. Reliance on regulatory sanctions needs to be targeted. Delivered (and funded) by EPA	1. Phosphorus loads entering Lake Wellington are reduced.	
				Publication - Written, No.	2	Report/s on compliance activities to support			

CBA Link	Activity			Management Action Target				Link to RCTs	
	#	Description	Output Description	Type	Quantity (10 y)	Rationale	Assumptions	Primary	Additional
						mid term and final reviews of Plan			
RA1	3.5	Undertake research to improve understandings of the sources and movement pathways of nutrients lost from irrigation farms and how these may be affected by horticultural expansion and potential new irrigation developments.	On-ground monitoring and research.	Assessment - Surface water, No.	1		Yr. 3-4 Reports by Day and Roberts in support of LWMP highlights lack of knowledge/understanding of nutrient pathways. Improved understanding may assist in better or more targeted management of nutrient issues. Research to build on regional water quality monitoring. Research feeds into the development and evaluation of options to reduce off-farm nutrient and sediment loss and their management once in the catchment. #5.5, 6.1, 6.2. Research outcomes inform policy development and adaptive management of LWMP.	1. Phosphorus loads entering Lake Wellington are reduced	
			Research reports.	Publication - Written, No.	1				
			Field days.	Publication - Visual, No.	1				
W8	3.6	Financial incentives for vegetable growers to construct silt traps to capture sediments and nutrients that would otherwise be lost from their farms.	Silt traps	Silt traps	500 ha irrigation land protected	Largely applicable to horticultural/ vegetable production operations	Silt traps are one of the few measures available for horticultural properties to capture sediment and nutrients moving off farm during run-off generating rainfall events. They are effective for smaller events, but not for flood conditions. Assumptions about benefits of silt traps are described in Chapter 14.7. Target is based on 50 ha/y in Y1-10 of the Plan	1. Phosphorus loads entering Lake Wellington are reduced.	
A1	3.7	Development of an agreed agency-industry position and approach on the management of dairy effluent on irrigation farms. The position will be the subject of an industry-led communication campaign to increase regulatory compliance and adoption of best practice in dairy effluent management.	Position paper, awareness raising.	Publication - Written, No.	1	Position paper, followed by communications campaign.	A consistent industry position on dairy effluent management which is regulatory compliant and consistent with good practice is lacking. This position paper will establish an agreed standard that can be supported by extension, compliance monitoring and (as necessary) pollution abatement notices.	1. Phosphorus loads entering Lake Wellington are reduced.	

Table 15.13 Assumptions and links between activities and targets – groundwater and salinity program

CBA Link	Activity			Management Action Target				Link to RCTs	
	#	Description	Output Description	Type	Quantity (10 y)	Rationale	Assumptions	Primary	Additional
W10	4.1	Maintain the MID's public sub-surface drainage system, including renewing bores and pumping systems as they reach the end of their operating lives.	Operational availability and effectiveness of regional SSD system maintained.	Pump - Groundwater, No.	18	18 pumps existing	Y1-10 Maintenance by SRW of regional SSD system to manage water tables and salinity in and adjacent to MID during wet climate phases when water tables elevated. Long-term maintenance of SSD system may need to be supported through development and implementation of an asset management framework by SRW. Assumptions about benefits of maintaining SSD infrastructure are described in Chapter 14.7.	2. Area affected by shallow water table does not exceed 2012 benchmark .	
RA4	4.1	Review energy efficiency and renewable energy opportunities associated with operation of SSD system and, if practicable, implement	Report on energy efficiency improvement opportunities	Publication - Written, No.	1		Y3 Energy efficiency review delivered by consultancy and managed by SRW.		
n/a	4.2	Irrigators with groundwater licences will be encouraged to continue to use shallow groundwater for irrigation when it is available and of suitable quality.	No specific output required for LWMP.	N/A Supporting action			Y1-10 Appropriate shallow groundwater use by irrigators is encouraged. It provides access to additional water resources and may help to mitigate salinity risks. This is business-as-usual and not a specific action to be implemented under the Plan.	2. Area affected by shallow water table does not exceed 2012 benchmark	3. Increased economic value of irrigated agricultural production
	4.3	Periodic review of the management arrangements for the use of shallow groundwater	No specific output required for LWMP.	n/a Supporting action			At ~5 year intervals through life of Plan (Y3 and Y8). Appropriate shallow groundwater use by irrigators is encouraged. It provides access to additional water resources and may help to mitigate salinity risks.	Enabling activity.	

CBA Link	Activity			Management Action Target				Link to RCTs	
	#	Description	Output Description	Type	Quantity (10 y)	Rationale	Assumptions	Primary	Additional
							This is business-as-usual and not a specific action to be implemented under the Plan. Delivered by SRW.		
A1	4.4	The provision of high quality extension services to support farmers in areas of salinity and shallow water tables to "live with salinity". This includes providing advice to support the establishment and sustainable management of appropriate, generally salt-tolerant pastures, fodder or crops.	Extension activities	Approval and advice - Advice, No.	50	Advice to ~5 irrigators/y	The action maintains support for sustainable and productive management of salt and waterlogging affected land from West Gippsland Salinity Management Plan. The action does not affect the area with shallow water tables, but contributes to these areas being agriculturally productive.	2. Area affected by shallow water table does not exceed 2012 benchmark	3. Increased economic value of irrigated agricultural production

Table 15.14 Assumptions and links between activities and targets – floodplain and off-farm irrigation drainage program

CBA Link	Activity			Management Action Target				Link to RCTs	
	#	Description	Output Description	Type	Quantity (10 y)	Rationale	Assumptions	Primary	Additional
n/a	5.1	The LWMP supports the continuation transfers of SRW drain heads to irrigators to enable tail water to be harvested and reused on farms.	No specific output required for LWMP.	N/A Supporting action			Y1-10 This is business-as-usual for SRW and not a specific action to be implemented under the Plan. Transfers of surface water drain heads to irrigators enables irrigation tail water to be harvested and reused on farms. Irrigators agree to maintain drain function following transfer of drain head.	1. Phosphorus loads entering Lake Wellington are reduced	S3. Increased economic value of irrigated agricultural production
n/a	5.2	The LWMP supports drainage diversion by irrigators in appropriate settings.	No specific output required for LWMP.	N/A Supporting action			Y1-10 This is business-as-usual for SRW and not a specific action to be implemented under the Plan. The action maintains the capacity for diversion if requested by landholders and is appropriate in the landscape setting.	1. Phosphorus loads entering Lake Wellington are reduced	S3. Increased economic value of irrigated agricultural production
RA10, A1	5.3	Explore planning and funding mechanisms to improve the function of the natural and constructed surface drainage systems and health of waterways and wetlands. Mechanisms to consider include Drainage Course Declarations (as applied in GMID).	Report on available mechanisms.	Publication - Written, No.	1		Y3 The mechanism may build on instruments in place in other regions, including Drainage Course Declarations – which apply in the GMID. A review would be undertaken in conjunction with local government, with recommendations for any further action put to LWSIG. Managed by WGCMA. Delivered by consultancy.	Enabling activity	Contributes to (1) reduction of nutrient loads, (2) area affected by shallow water table (3) increased economic value as an enabling program
RA1	5.4	Research to investigate opportunities for drains and floodplain waterways and wetlands to be managed to capture or use nutrients carried off-farm during small-medium floods/rain flow events.	Research reports.	Publication - Written, No.	1		Y4 Research to follow 3.5. Initial phase of research to comprise literature review and desk top analysis of potential impacts on off-farm measures in capturing nutrients and sediments in smaller drainage flows. Subject to findings of project, recommendations may be made to LWSIG to support further research or the development of an IFP module to support	Enabling activity	1. Phosphorus loads entering Lake Wellington are reduced
			Extension activities.	Engagement event - Workshop, No. of participants	60	Extension activities for IFP module. 3 workshops of 20 people			

CBA Link	Activity #	Description	Output Description	Management Action Target Type	Quantity (10 y)	Rationale	Assumptions	Link to RCTs Primary	Additional
							measures which could be implemented immediately. Managed by WGCMA, delivered by consultancy.		
RA10	5.5	Research to quantify changes in streamflows resulting from on and off-farm irrigation and drainage management activities supported by the Plan and to assess their impacts.	Research report	Assessment - Surface water, No.	1		Y4-5 Impacts of irrigation reuse and efficiency on catchment environmental flows are poorly understood. While these measures are anticipated to be beneficial in reducing salinity risk and nutrient losses, they may have adverse effects on flow regimes. Research would inform adaptive management of the Plan by LWSIG. Managed by WGCMA, delivered by consultancy.	Enabling activity	Contributes to (1) reduction of nutrient loads, (2) area affected by shallow water table (3) increased economic value as an enabling program.
				Publication - Written, No.	1				
n/a	5.7	Maintenance of regional surface water drainage system	No specific output required.	N/A Supporting action			This is business-as-usual for SRW and irrigators to whom drain heads have been transferred.	2. Area affected by shallow water table does not exceed 2012 benchmark.	

Table 15.15 Assumptions and links between activities and targets – innovative and connected communities program

CBA Link	Activity #	Activity Description	Output Description	Management Action Target Type	Quantity (10 y)	Rationale	Assumptions	Link to RCTs Primary	Link to RCTs Additional
RA4	6.1	Develop an on-farm energy efficiency and renewable energy module for delivery within the IFP framework.	IFP module, extension materials, training for IFP providers.	Publication - Written, No.	1	IFP module	Y3. IFP module would be rolled out from Y4. Energy supply unreliability and increased costs are significant impediments to actions which improve irrigation water use efficiency. An IFP module would provide information with which irrigators could develop renewable energy sources and/or improve energy use efficiency. Funding/co-investment would be sought under Agriculture Victoria's Energy Investment Plan. Managed by WGCMA, delivered through consultancy.	Enabling activity	3. Increased economic value of irrigated agricultural production.
				Publication - Written, No.	1	Extension material			
				Publication - Visual, No.	1	Extension material			
				Engagement event - Training, No. participants	10	Could be agency or service provider delivering - would be small number requiring training			
RA 4	6.2	Develop and implement irrigation energy efficiency plan for the Lake Wellington catchment.	Policy and regulatory impediments review	Publication - Written, No.	1		Y4-5. Development of Lake Wellington catchment irrigation energy efficiency plan. Implementation of plan from Y2 onwards. Energy supply unreliability and increased costs are significant impediments to actions which improve irrigation water use efficiency. The action would assist irrigators in implementing on farm works and measures which reduce non-renewable energy use and greenhouse gas emissions. Funding/co-investment would be sought under Agriculture Victoria's Energy Investment Plan. Focus will be on actions with short payback period in which irrigators can directly invest. Delivered by Agriculture Victoria, with support from consultancy.	Enabling activity	3. Increased economic value of irrigated agricultural production.
			Irrigation energy efficiency plan	Publication - Written, No.	1				
			# farms with renewable energy measures		25	Estimate ~5/yr - to be reviewed after first year			
			# farms with energy efficiency measures		75	Estimate ~15/yr to be reviewed after first year			
RA12	6.3	Develop IFP cultural heritage planning and management module	Cultural heritage module for IFP process	Publication - Written, No.	2	Assume extension materials and activities happen through this activity	Y2, following initial engagement with GLaWAC (6.4) IFP module developed in collaboration with GLaWAC. It would support cultural	4. Increased knowledge of indigenous and non-	

CBA Link	Activity #	Activity Description	Output Description	Management Action Target Type	Quantity (10 y)	Rationale	Assumptions	Link to RCTs Primary	Additional
				Publication - Visual, No.	2		awareness by irrigators and guide practical actions to identify and protect cultural assets within or adjacent to irrigation farms. The module would be implemented through the revised IFP process (1.1). Delivered by consultancy, co-ordinated by WGCMA in conjunction with GLaWAC.	indigenous social and cultural values	
A1	6.4	Facilitation of irrigation land and water management research collaborations that address regional research priorities.	Research partnership	Partnership - Agencies/ Communities, No.	1		Proactive facilitation of research collaborations will help to draw researchers and new technology to irrigators and irrigation land and water management. It will assist in improving the resilience and sustainability of irrigation management with Lake Wellington catchment	Enabling activity	3. Increased economic value of irrigated agricultural production.
A1	6.5	Develop communications and cultural awareness training materials related to Indigenous cultural values, Native Title and protection of cultural heritage.	Communications and engagement activities.	Engagement event - Presentation, No. of participants	90	Est 6 events x 15 ppl each	Y1 Initial engagement with GLaWAC and community to build relationships, establish scope and opportunity for cultural engagement and awareness training and develop plan for action. Y2-5 Implementation of action plan Delivered by WGCMA, in conjunction with GLaWAC (0.5 FTE	4. Increased knowledge of indigenous and non-indigenous social and cultural values.	
			Training materials	Publication - Written, No.	1				
			# participants in cultural awareness training	Engagement event - Training, No. participants	90	10 per year for 9 years			
A1	6.6	Develop and support collaborative arrangements between landholders and Gunaikurnai to protect cultural heritage values.	Development of cultural heritage module for IFPs.	Publication - Written, No.	1		Y2-10 LWSIG to explore opportunities to secure funding to provide appropriate financial incentives for effective on-ground works to protect cultural heritage features, through implementation of IFPs. Financial incentives support protective works delivered by Gunaikurnai people.	4. Increased knowledge of indigenous and non-indigenous social and cultural values.	
			#/area cultural features protected through collaborative management.	Assessment - Cultural, No.	20	20 sites assessed / protected			
A1	6.7	Support community events which recognise Indigenous and non-Indigenous cultural and social values	# events recognising Indigenous and non-Indigenous	Engagement event - Presentation,	100	Est 5 events x 20 ppl	Y3-10 LWSIP to explore opportunities to secure funding to provide appropriate financial incentives for effective on-ground works to	S4. Increased knowledge of indigenous and non-	

CBA Link	Activity			Management Action Target				Link to RCTs	
	#	Description	Output Description	Type	Quantity (10 y)	Rationale	Assumptions	Primary	Additional
		associated with Lake Wellington irrigation areas.	cultural and social values.	No. of participants			protect cultural heritage features, through implementation of IFPs. Financial incentives support protective works delivered by Gunaikurnai people.	indigenous social and cultural values	
CB2	6.8	Facilitation of farmer-led irrigator discussion groups. Discussion groups to be set up to support farm planning, irrigation efficiency, nutrient management planning and implementation.	# discussion groups operating	Engagement event - Workshop, No. of participants	80	Est 5 in MID and 3 in Upper Latrobe, 10 ppl each	Y1-10 There are only a small number of discussion groups in MID currently. Facilitating their development (through Plan extension programs) may help to accelerate implementation of various Plan actions and lead to increased community interactions, increased irrigation water and nutrient use efficiency. Discussion groups would be farmer-led and focus on issues of relevance to participants.	Enabling activity	1. Phosphorus loads entering Lake Wellington are reduced 2. Area affected by shallow water table does not exceed 2012 benchmark
A1	6.9	Engage with financial and other support services about irrigation land and water management issues.	Communications and engagement activities.	Engagement event - Presentation, No. of participants	80	Est 1 event x 8 ppl annually	Y3-10 The action has been included to extend understanding of requirements for sustainable irrigation land and water management with the catchment's finance and business support services sector. This is intended to help support irrigators interactions with the sector and help provide an external driver for the adoption of more sustainable irrigation practices. Delivered by WGCMA.	Enabling activity	1. Phosphorus loads entering Lake Wellington are reduced 2. Area affected by shallow water table does not exceed 2012 benchmark.

Table 15.16 Assumptions and links between activities and targets – actions in support of MERI

CBA Link	Activity			Management Action Target				Link to RCTs	
	#	Description	Output Description	Type	Quantity (10 y)	Rationale	Assumptions	Primary	Additional
RA5	7.1	Irrigation land use and land use change monitoring.	Spatial data and report on irrigation land use patterns and potential implications for nutrient exports.	Assessment - Geospatial, No.	2	Five year cycle for data capture	Y1-10. Data capture would only occur on 5-year cycle, commencing Y1. Reliable irrigation land use data is not available for LW catchment and there is no irrigation land use change information. This limits insights into key irrigation drivers of poor water quality conditions in LW catchment and how these may change over time. GIS-based methods for land use surveys have been developed in northern Victoria by Agriculture Victoria and would be adapted for this project. Delivered by consultancy and managed by WGCMA.	Enabling activity	Contributes to (1) reduction of nutrient loads, (2) area affected by shallow water table (3) increased economic value as an enabling program.
				Publication - Written, No.	2	To inform mid-term and final review			
RA11	7.2	Water quality monitoring to underpin research and help assess the impact and effectiveness of the Plan.	Operation of monitoring infrastructure. Periodic monitoring review reports.	Assessment - Surface water, No.	10	Within MID monitoring	Y1-10. Monitoring and evaluation of monitoring data will provide knowledge base for research into improved nutrient management. Delivered by SRW.	Enabling activity	1. Phosphorus loads entering Lake Wellington are reduced.
				Assessment - Surface water, No.	10	External to MID	Y 1-10 Monitoring is required to report on progress against SEPP target for LWMP and LWMP water quality resource condition target. Monitoring currently considers phosphorus, as per SEPP target. LWMP supports extension of monitoring to include other key water quality drivers (nitrogen, sediment). Monitoring can currently only attribute irrigation impacts on water quality to MID. LWMP supports expansion to assess impacts of irrigation in other parts of the LW catchment.		
				Publication - Written, No.	2	Mid-term and final reviews			

CBA Link	Activity			Management Action Target				Link to RCTs	
	#	Description	Output Description	Type	Quantity (10 y)	Rationale	Assumptions	Primary	Additional
RA11	7.3	Monitor and report on groundwater condition and shallow water table risks. This includes modelling and analysis of water table depth to support operation of regional SSD system.	Operation of monitoring infrastructure. Monitoring reports. Periodic monitoring review reports.	Assessment - Groundwater, No.	10	1 / year	Y1-10. Groundwater monitoring and data analysis is required to guide effective use of regional SSD system and the mitigation of risk from salinity and shallow water tables. Evaluation of monitoring information is required to determine and report on progress towards groundwater resource condition target. Delivered by SRW	Enabling activity.	2. Area affected by shallow water table does not exceed 2012 benchmark.
				Publication - Written, No.	2	Mid-term and final reviews			
RA8	7.4	Develop a target for sustainable regional economic growth	Report for adaptive management in plan	Publication - Written, No.	1		Y1. Consistent with the LWMP's vision for a highly productive and sustainable irrigation community that values and protects its natural and cultural assets is the objective to support a profitable and sustainable irrigated agriculture sector. An interim RCT has been set for sustainable economic growth to track progress towards this objective and the LWMP's vision. However, further work is required to develop a measurable target, based on measures which will be influenced by implementation of the LMWP. Delivered by consultancy and managed by WGCMA	Enabling activity	3. Increased economic value of irrigated agricultural production.
RA7	7.5	Evaluation of the benefits and costs of management actions.	Report	Publication - Written, No.	1	To inform mid-term review / adjustment of MATs / RCTs if required.	Y5. The evaluation of costs and benefits of actions in the LWMP are estimates based on available information. The purpose of this activity is to draw data from program delivery and monitoring together to undertake an evaluation of the quantifiable costs and benefits of management actions. The analysis will feed in to the mid-term review of	Enabling activity	

CBA Link	Activity #	Activity Description	Output Description	Management Action Target Type	Quantity (10 y)	Rationale	Assumptions	Link to RCTs Primary	Additional
							the LWMP. Delivered by consultancy and managed by WGCMA.		
	7.6	Independent mid-term and final review of LWLMP including review of available evidence, analysis of data, workshops and interviews with agency partners, contractors and participating landholders.	Mid-term and final review reports	Publication - Written, No.	2	Mid-term and final review	Y5, 10. An independent review will be completed at years 5 and 10. The review will form the basis of a public report on progress and support subsequent adjustments to the LWLMP programs and MATs (where required). Delivered by consultancy and managed by WGCMA.	Enabling Activity	
	7.7	Attitudes and behaviours survey of landholders and development of most significant change/case studies to support mid-term and final reviews.	Survey report/s Case studies	Publication - Written, No.	2	Survey implemented twice over life of LWLMP. Could use Assessment output instead	Y4/5 and Y9/10 Landholder survey will be used to understand the contribution of LWLMP programs (particularly planning, extension and engagement activities) towards achievement of the LWLMP RCTs. Delivered by consultancy and managed by WGCMA.	Enabling activity	
				Publication - Written, No.	20	Assume ten case studies for each mid-term and final review			
RA9	7.8	Develop a monitoring program for nutrients and sediments from other irrigated land uses in the Lake Wellington catchment.	Report describing the approach, tools needed	Publication - Written, No.	1		Y1. A method will be developed and documented to enable water quality monitoring (7.2) to monitor the amount of nutrients that are coming from irrigated land uses outside the MID.	Enabling activity	

16 Glossary

ABS	Australian Bureau of Statistics
AgVic	Agriculture Victoria
Annual use limit	Permissible amount of irrigation water that may be applied (per hectare).
BAU	Business-as-usual
Best practice surface irrigation	Forms of flood irrigation, with relatively high flow rates and which lead to reduced deep drainage and groundwater infiltration that conventional flood irrigation. High flow flood irrigation is supported under the Plan in appropriate (heavy) soil types.
BMP	Best management practice
BoM	Bureau of Meteorology
CAP	Current agricultural practice
Capacity building	An implementation mechanism for the Plan involving activities that build the management capacity of individual irrigators, the broader community or agencies involved in land and water management.
CBA	Cost benefit analysis
CMA	Catchment Management Authority
Concept plan	A key component of the revised farm planning framework for the Lake Wellington LWMP. It develops a picture of the farm in its landscape setting and identifies risks and opportunities for irrigation land and water management.
DELWP	Department of Environment, Land, Water and Planning
EPA	Environment Protection Authority
FTE	Full-time equivalent, full time member of staff
GLaWAC	Gunaikurnai Land and Water Aboriginal Corporation, the Registered Aboriginal Party for Traditional Owners in the Lake Wellington catchment.
GMID	Goulburn Murray Irrigation District
IDG	Irrigation Development Guidelines; Regional directions for irrigation development in East Gippsland, 2011. These specify requirements for new irrigation developments and redevelopments which propose significant changes to water use licence conditions.
IDP	Irrigation and drainage plan, a requirement for new or redeveloped properties subject to the Gippsland Irrigation Development Guidelines.
IFP	Irrigation farm plan, one of three main components of the revised farm planning framework developed for the Lake Wellington LWMP.
IPCC	Intergovernmental Panel on Climate Change
Irrigation efficiency check	An optional preliminary step that forms part of the updated farm planning framework for the Lake Wellington LWMP. It is designed to identify early, no regrets actions to improve on-farm irrigation and/or nutrient use efficiency.
KEQ	Key evaluation questions
LWMP	Land and Water Management Plan
LWSIG	Lake Wellington Sustainable Irrigation Group, the key governance group for the Lake Wellington LWMP.
MAT	Management action target

MERI	Monitoring, Evaluation, Reporting and Improvement
MID	Macalister Irrigation District
MID2030	Southern Rural Water's program for renewal of the irrigation water supply system in the Macalister Irrigation District
N, TN	Nitrogen, total nitrogen
NMP	Nutrient management plan
NPV	Net present value
NRM	Natural resource management
NZE	Net zero emissions
P, TP	Phosphorus, total phosphorus
Primary targets	The two primary resource condition targets of the Plan, which relate to water quality improvement and containment of salinity and shallow water tables.
PV	Present value
R&D	Research and development
RCS	Regional Catchment Strategy
RCT	Resource condition target
Resource assessment	An implementation mechanism for the Plan involving research, investigations and/or consultancies.
SAG	Stakeholder Advisory Group, landholder reference group formed to support the development of the Lake Wellington LWMP.
Secondary targets	Secondary resource condition targets for the Plan, which relate to other components of its vision and objectives.
SEPP	State Environment Protection Policy. The proposed SEPP (Waters) will replace previous SEPP (Waters of Victoria) and SEPP (Groundwater) and define beneficial uses and water quality targets for surface and groundwater. The SEPP (Waters) proposes a target for the Lake Wellington LWMP to reduce phosphorus exports to Lake Wellington by 7.5 t/y.
SIP	Sustainable Irrigation Program (of the Department of Environment, Land, Water and Planning)
SMZ	Salinity Management Zone, the Macalister SMZ comprises all five irrigation salinity management units defined in the West Gippsland Salinity Management Plan.
SRW	Southern Rural Water
Sub-surface drainage (SSD)	Network of groundwater pumps designed to lower water tables and contain expressions of waterlogging and irrigation-derived salinity.
Surface drainage	Surface water management system, designed to facilitate drainage of overland flows into watercourses.
TSS	Total Suspended Solids
TWG	Technical Working Group, which was formed to support the formulation of the Lake Wellington LWMP.
VLUIS	Victorian Land Use Information System, a key source of land use data.
WFP	Whole farm plan
WGCMA	West Gippsland Catchment Management Authority

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