# Report on the Gippsland Lakes INFFER Analysis

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## *Executive summary*

An INFFER analysis was conducted in partnership with the Gippsland Lakes Task Force (GLTF) to assess the feasibility and cost-effectiveness of achieving phosphorus (P) reduction targets. The approach used was adaptive and participatory, involving approximately 40 stakeholders and external researchers. The methods used included collation of research and other knowledge, as well as stakeholder workshops with individual follow up to agree on the scope and provide expert input on the assumptions required. Strategic guidance was provided by Chris Barry and Barry Hart on behalf of the GLTF.

The audience for the report is the Gippsland Lakes Taskforce and its stakeholders, the purpose of which is to show that INFFER provides a robust and transparent framework to develop a stronger basis for achieving cost-effective environmental outcomes from public investment. It also provides a basis for debate and discussion about agricultural trade-offs associated with achieving environmental outcomes for the Lakes.

Although climate change and the impacts of large episodic events (fire and flood) are very important, the level of detailed information from which to assess the degree of impact and costs of amelioration were insufficient to enable their inclusion in this analysis. Similarly, although the nutrient reduction targets include both nitrogen (N) and P, the knowledge base for N was insufficient and thus the analysis was restricted to P at this stage.

The most important outputs from this work were:

1. An updated spatial layer better differentiating between major land uses, which better discriminates dairying and horticultural regions. This can provide a stronger basis for more spatially detailed catchment modelling work;
2. Development/refinement of a spreadsheet tool used to integrate information to assess both the level of P reduction and associated costs as inputs to the INFFER calculation of the Benefit:Cost Index (BCI);
3. The BCI calculator to assess the cost-effectiveness of P reduction scenarios;
4. Economic optimisation analysis conducted for 10 P load reduction scenarios, which included least-cost methods to achieve specified P-reduction targets, and methods to achieve the greatest possible P-reduction for fixed budget levels;
5. Completion of two INFFER Project Assessment Forms (PAFs), assessing 20 and 40% P reduction scenarios;
6. An external review of the analysis by Tony Ladson, Dan Rattray and Darron Cook

7. This report, which incorporates comments from the external review. It outlines the methods and assumptions used and provides an overview of results and discussion

The costs used are 'back of the envelope' based on the best available information from participants and reports. They include costs of incentive payments for on-farm BMPs plus extension costs as well as legal costs involved with enforcement of regulation. The costs to farmers of land-use change have been assumed to be offset as on-going stewardship payments for the opportunity cost of lost production (annual operating profit/ha). We have included program administration costs, assumed to be 5% of the direct costs (upfront and maintenance) within the calculation of the BCI.

Overall, the analysis suggests that:

- 4% P reduction in the load entering the Lakes can be achieved with no public cost. This is due to voluntary actions of a minority of landholders. The other scenarios listed below include this amount of P reduction.

- 10% P reduction (i.e. an additional 6%) is achievable at a cost $18.8million (calculated in present value terms over 20 years). The initial up-front cost is $11.6million and the BCI is favourable at 2.3 (Note: BCI values greater than 1 indicate benefits exceed costs.)

- P reduction of 20% can also be achieved cost-effectively (BCI 1.0) at a present value cost of $80million ($54 million upfront cost assumed over 5 years followed by maintenance costs).

- It appears technically feasible to achieve 40% P reduction, but at very large cost ($1,343million over 20 years) and low BCI (0.02). As well as paying full costs of BMPs dryland beef/sheep industries and enforcement of effluent regulations in the dairy industry, major land use change of away from agriculture would be required.

The results for 10% and 20% P reduction scenarios provide the GLTF the basis to develop a stronger business case for higher public investment, including the need for greater certainty about long-term funding for maintenance costs; the choice of optimal land management strategies were sensitive to whether long-term maintenance funding was available.

The results indicate that pursuing a 40% P reduction would not be a cost-effective public investment. Subject to further scrutiny of the assumptions, this result provides a basis to discuss whether the 40% P reduction target should be retained, and/or some realism about achieving it. If it is retained, then very much greater funding will be required, as will managing the resulting social, economic and political challenges associated with large land use changes away from agriculture.

A number of additional scenarios were analysed. Projects with the highest BCI values were:

- 6% P reduction (i.e. an additional 2% above what is predicted to occur voluntarily) can be achieved through proper enforcement of existing effluent regulations (BCI 2.8, present value project cost $16.2million)

- 7% P reduction (i.e. an additional 3%) can be achieved with a budget of $2million/year for 5 years without a follow up maintenance budget (BCI 4.4, present value $9.8million)

- 9% P reduction (i.e. an additional 5%) can be reached with an annual budget of $2million/year for 5 years, followed by annual ongoing costs (BCI 2.9, present value project cost $15.5 million)

- Current incentives for the dairy and dryland grazing industries (BMPs and streambank protection but not other riparian measures) could achieve 13% P reduction (BCI 1.8, present value project cost $30.1million)

The optimisation analysis also showed that the strategies for each budget differ, depending upon whether on-going funding is required to maintain actions. For example, for fixed budgets of between $2-10 million/year budget with assured ongoing maintenance funding, the optimal management strategy always included streambank stabilisation, whereas if there was no maintenance funding beyond 5 years, the optimal management strategies focus on BMP-based incentives to the irrigated dairy industry, achieving lower P targets and higher BCI values.

Results show that given a small annual budget ($2-5million/year) with no guarantee of on-going maintenance funding, provision of incentives for irrigated dairy farming has been a sound approach by the GLTF. The work also provides an opportunity to build a case for the need for greater certainty regarding the need for long-term funding. Without this, only incremental gains can be achieved rather than larger targets.

Given the large emphasis on providing incentives to dairy farmers to improve practices, enforcement of existing effluent regulations is also important if the dairy industry is to be viewed as environmentally responsible. It is also a cost-effective public investment (BCI 2.8). Enforcement of regulations is even more important given the pressures for dairy expansion in high rainfall areas, and thus additional nutrient pressures on the Lakes and other receiving waters in Victoria.

The Gippsland Lakes INFFER analysis took approximately 100 person-days of stakeholder, consultant and researcher time, the largest component of which was consultation workshops. Given its state and national importance, and the amount of public money involved, this seems a small investment. Most assets take far less time (commonly 2-15 days) to complete an analysis.

INFFER provides the GLTF with a transparent and robust framework to justify future cost-effective public investment. It provides a strong basis to develop a business case for cost-effective environmental outcomes from public investment, as well as giving a basis for debate and discussion about agricultural trade-offs associated with achieving environmental outcomes for the Lakes.

## Introduction to INFFER

INFFER is a framework designed to assist with decision making about investment in the environment and natural resources. INFFER gives priority to highly valued natural assets, that are highly threatened or degraded, with high technical feasibility of avoiding or repairing that damage, and high adoptability of the required works by relevant land managers. It is used to develop and assess projects for assets such as natural habitat, rivers, wetlands, threatened species, agricultural land, lakes, parks and reserves. An important feature of INFFER is that it assists users to develop projects that are internally consistent—their delivery mechanisms would really deliver the required on-ground action that are required to achieve a specific, measurable, time-bound goal. Furthermore, the choice of policy responses (e.g. when it is appropriate to use extension, incentives, regulation, research, or informed no action) decided upon within INFFER are based on the relative public and private benefits of the management actions.

INFFER integrates information about asset value, degradation due to threatening processes, effectiveness of on-ground works, adoption of works by landholders, risks, costs and other factors to calculate a Benefit:Cost Index (BCI)[1], which can be used to compare alternative projects in terms of value for money. Such projects can be across different asset types, or as for the Gippsland Lakes analysis, to compare between scenarios for the same asset.

Nineteen of the 56 regional groups in Australia have used INFFER or are in the process of trialling it. State governments in Western Australia, Victoria and New South Wales have been involved in a range of INFFER assessments and its role as a guiding framework at the state level is in under consideration. INFFER is a recommended tool within Victoria's new Land and Biodiversity Policy White Paper (www.dse.vic.gov.au) and is being evaluated by the NSW government to underpin CMA Regional Catchment Stategy development. It was also the only environmental planning tool recommended by the Australian Government in the 2009 round of applications under the Caring for our Country program. A number of Non-Government Organisations are also interested in INFFER. Extensive documentation about INFFER is available (www.inffer.org).

## Background to Gippsland Lakes INFFER analysis

The work has been conducted in an adaptive partnership approach between the INFFER team and the Gippsland Lakes Taskforce (GLTF), principally through Barry Hart and Chris Barry. INFFER funded a consultant (Peter Cottingham) to co-ordinate the analysis in collaboration with the INFFER team. Reasons for conducting the work included that:

- The Gippsland Lakes are an asset of Victorian and national significance. Whilst many INFFER assessments have been conducted on smaller assets, there have been few

[1] The BCI is closely consistent with a Benefit: Cost Ratio in Benefit: Cost Analysis, except that it does not include dollar values for environmental values. Rather, it relies on a scoring system for asset value. Other variables related to the project benefits are measured as proportions or probabilities. See Appendix 2 for details.

on large, complex assets. The INFFER team were interested to test application to a large and complex asset in partnership with the GLTF.

- An environmental target (40% nutrient reduction to the lakes) has been previously agreed to and provided a testable goal on which the assessment could be conducted.
- The GLTF recognises that the current approach of encouraging best management practices (BMPs) within the irrigated dairy industry will not achieve the target and wish to think strategically about the direction and scope of future investment.
- If INFFER adds value to GLTF decision making, this will be provide additional credibility for INFFER, in addition to being of direct benefit to the GLTF.

## Methods - overview

Components of the analysis are reported below and expanded in the next section 'Scope of the analysis'. The major components of the work are described briefly as:

- Developing an agreement in January 2009 between the GLTF (represented by Barry Hart and Chris Barry), the West Gippsland CMA (Geoff Hocking), and the East Gippsland CMA (Graeme Dear) regarding roles and responsibilities.
- Appointing a private consultant (Peter Cottingham) who had a good understanding of previous work, available reports and the institutional context. It was agreed that he would complete at least two INFFER Project Assessment Forms (PAFs), the usual output from an INFFER analysis.
- Holding a project inception meeting attended by major stakeholders (2 April 2009) to agree on the definition of the asset, indicative value score, asset condition, tentative goals and scenarios for analysis. See Appendix 1 for the list of attendees and Appendix 2 for a description of the BCI. At this meeting it was agreed to hold workshops on technical feasibility and socio-economic considerations to help underpin the analysis. Stakeholders were asked to identify who should come to each workshop and this formed the basis of invitations, along with additional people who had relevant expertise.
- Conducting a technical workshop (10 June 2009) that considered previous work on nutrient reduction (including catchment-scale modelling using SedNet), best-management practices (BMPs) and their effectiveness and major knowledge gaps. Project goals were refined and improvements to the current knowledge base were suggested. These are expanded upon under the 'Technical feasibility' section below. Attendees are listed in Appendix 1.
- Conducting a socio-economic workshop (8 July 2009), mostly of agricultural extension practitioners. For each major industry (irrigated dairy, dryland dairy, beef-sheep, horticulture), people were asked to nominate relevant BMPs to reduce nutrients lost through non-point processes, and for each they had to assess % effectiveness and the farm-level adoption of each BMP under 3 scenarios (no incentives, current incentives – if applicable, full cost recovery). Attendees are listed in Appendix 1.
- Development of a spreadsheet tool (called Gippsland Lakes P Tool) to integrate the technical, socio-economic (practice change) and cost information. The new tool expanded on the spreadsheet approach developed by Ladson and Tilleard (2006).

The Gippsland Lakes P Tool was useful 1) to integrate cost information as an input to the BCI calculator; and 2) in its own right to enable scenario analysis.

- Follow up by Anna Roberts with DPI staff and CMA officers to refine assumptions used in the Gippsland Lakes P Tool. This included GIS analysis and accessing of DPI reports (Anon.2007, English *et al.* 2008, Sargant 2009, Tocker and Quinn, 2008, Cameron Gourley's Accounting for Nutrients work, David Nash's technical expert opinion) to develop an updated land use information dataset, and revision of effectiveness of BMPs.
- Preliminary calculations using the BCI calculator.
- Presentation of interim findings by Peter Cottingham to the GLTF (27 August 2009), including discussion about low BCI figures for some scenarios.
- Follow up meeting (17 September) between Barry Hart, Chris Barry, Rod Taylor (DSE), Anna Roberts, Peter Cottingham, Geoff Park and April Curatolo, to develop an understanding of the Gippsland Lakes P Tool, discussing assumptions and suggesting improvements. Additional scenarios for analysis were agreed, as was the preparation of a report (this document).
- Specialist input from INFFER, particularly in further development of the Gippsland Lakes P Tool (David Pannell, Olga Vigiak), and optimisation analysis (Graeme Doole, David Pannell) for BMP and land-use change strategies to achieve agreed scenarios.
- Opportunity for revision of assumptions in the Gippsland Lakes P tool by research, extension and CMA participants in Gippsland.
- Revision of economic optimisation scenarios (Graeme Doole, David Pannell) based on the Gippsland Lakes P Tool. Optimisation analysis to identify least-cost methods to achieve targets, plus calculation of BCIs based on the additional scenarios, showed that some strategies did have favourable BCIs (values above 1).
- Completion of INFFER PAFs for the 20% and 40% P reduction scenarios (Peter Cottingham). Completion of final report by 30 October (Anna Roberts).
- Review of analysis by Tony Ladson, Dan Rattray, and Darron Cook (November 2009).
- Results presented (Anna Roberts, Peter Cottingham) to Gippsland Lakes Taskforce (26 November 2009).
- Revision of analysis following the external review and the presentation (December 2009).

# Scope of the analysis

Based on the available research, technical and socio-economic knowledge, the scope of the project is summarised below. The accompanying PAFs (for the 20% and 40% analysis) capture all aspects required for INFFER analysis. The focus of this report is to:

- Provide explanation of how the technical, practice change and cost assumptions contained in the Gippsland Lakes P tool were decided upon.
- Report summary results of all modelled scenarios, particularly those not captured in the 2 PAFs.
- Discuss issues around the time involved in doing this analysis and how INFFER adds value to investment decision making.

## Asset

It was agreed that the asset definition would be the main bodies of the Gippsland Lakes, estuary areas at the river-lake interface and fringing variably saline lakes. It would not include consistently saline or freshwater wetlands, as saline wetlands are relatively well adapted to the changing salinity conditions that have occurred since the permanent opening of Lakes Entrance. Also, freshwater wetlands are still in a state of transition and as there are no clear management objectives for these systems, it is difficult to determine the management measures and approach to measuring success.

## Value

Putting a value on the asset and identifying the benefits of project scenarios is crucial to calculate the BCI. INFFER uses a relative scoring system (see INFFER Instruction Manual for Details) to assign a value to assets. Assets of very high national significance, such as the Gippsland Lakes, have an indicative score of 50-100. For this analysis the Gippsland Lakes have been assigned a score of 100. The BCI can be converted to a conventional Benefit:Cost Analysis if dollar values replace the score, with a score of 100 corresponding to a value of $2 billion. Details about the BCI are outlined in Appendix 2.

## Threats

The main threat being addressed by the GLTF is the frequency and severity of large blooms of potentially harmful algae and cyanobacteria. The Gippsland Lakes Future Actions Plan (Anon. 2002) is being implemented in order to achieve a 40% reduction in the average annual nutrient load entering the Lakes with the expectation that this would reduce the frequency of algal blooms in the future. The nutrient load entering the Lakes can come from numerous sources, and nutrient generation and transport rates from various land uses can be increased by large disturbances such as fire and floods. In turn, the frequency and severity of these large events are predicted to be exacerbated by climate change in the future. Given the early state of knowledge regarding the impacts of climate change, it was decided to exclude it from the analysis.

Whilst the 40% nutrient reduction target includes both N and P, most attention has focussed on P, as it is more conservative in the landscape (i.e. does not have a gaseous phase). While BMPs for N and P reduction are often similar, this is not always the case and further investigation of the relative effectiveness of BMPs on N and P retention will assist future analyses. Furthermore, future evaluations on N impacts on the Lakes should also include consideration of groundwater interactions, which to date has not been done. As the knowledge base for reducing N inputs was less robust, the analysis project focussed on P reduction only. We suggest that the GLTF re-visit the N target and consider 1) whether the information base is sufficiently strong to set it; 2) if so whether it should be the same as the P target. Other internationally important waterway assets, such as the Chesapeake Bay in the eastern USA have different N (30% reduction) and P (8% reduction targets (Anon. 2009, www.chesapeakebay.net).

## Goals

Three scenarios were identified at the inception meeting, including a ‘base case’ of the 40% P reduction target from which additional scenarios could be considered. The agreed definition was to ‘Reduce the frequency of major algal blooms to 1:10 years over a 20-year period, commencing in 2010’, expressed as ‘to achieve a P reduction target of 40% by 2030 (based on the 10-year average P load entering the Lakes)’. This is a longer time frame (20 years commencing in 2002) than intended when the Future Actions Plan was developed.

The 3 scenarios agreed at the inception meeting and then subsequently refined at the technical workshop and in consultation with Barry Hart and Chris Barry were:

1. 40% nutrient reduction target by 2030
2. Interim nutrient reduction target - 20% by 2030
3. As for scenario 1 or 2 plus control of large episodic (fire, flood) events

Large episodic events, confirmed by recent monitoring, can markedly over-shadow background events. The previous SedNet modelling (Grayson 2006), used as the basis for assessing P load generated by various land uses, considered the impacts of the 2003 fires simply, by doubling the P export from fire affected areas compared with non-affected. To consider the 2006 fires and future scenarios would require additional modelling which was beyond the scope of this study. Also, there was little information on impact and costs of management options for fire control. Thus the 3rd scenario was omitted from this study.

As the INFFER work progressed, it became clear that the costs of achieving the agreed targets were likely to be much larger than available budgets. This insight was consistent with an earlier analysis of costs, much of which was based on 1996 figures, which estimated total costs to achieve the 40% target to be well over $100 million (Ladson and Tilleard, 2006). Assessing lower targets was appropriate, both in terms of having lower (more politically realistic) budgets, and also on the basis of previous work by which suggested that 'small decreases in loads lead to more or less proportional decreased in chlorophyll, and disproportionate increases in bottom oxygen' (Webster et al. 2001). Thus there is a predicted environmental benefit in achieving even small decreases in load.

In discussion with Barry Hart and Chris Barry (17 September 2009) it was decided that some additional scenarios would be considered based on BMPs, as well as several lower budget scenarios. The INFFER team added several additional scenarios that they felt would be of interest to the GLTF. The expanded suite of scenarios therefore became:

1. 40% P reduction by 2030 (based on the 10 year average load entering the Lakes)
2. 30% P reduction by 2030 (based on the 10 year average load entering the Lakes)
3. 20% P reduction by 2030 (based on the 10 year average load entering the Lakes)
4. 10% P reduction by 2030 (based on the 10 year average load entering the Lakes)
5. $2 million/year for 5 years (followed by required funding to maintain works)
6. $5 million/year for 5 years (followed by required funding to maintain works)
7. $10 million/year for 5 years (followed by required funding to maintain works)
8. $2 million/year for 5 years (followed by no on-going funding)
9. $5 million/year for 5 years (followed by no on-going funding)
10. $10 million/year for 5 years (followed by no on-going funding)
11. Current incentives for BMPs at current incentive rates – all industries
12. As for scenario 11, but excluding riparian management
13. Current incentive rates for irrigated-dairy BMPs, full enforcement of effluent management, no riparian management
14. Enforcement of farm effluent management only
15. Streambank management – full costs assuming 50% effectiveness in P reduction
16. Streambank management – full costs assuming 20% effectiveness in P reduction
17. As for scenario 1, but a 10-fold increase in valuation of the Lakes
18. As for scenario 3, but halving the valuation of the Lakes

## Gippsland Lakes P Tool

The P management issue for Gippsland lakes is complex, including a range of actions (BMPs and land-use changes) that could be used to achieve P reductions, varying levels of effectiveness of those actions, various levels of adoption and associated costs. For this reason, we developed a spreadsheet tool to integrate the information, as a preparation for and input to the INFFER PAF process. A spreadsheet tool had been previously developed (Ladson and Tilleard 2006, based on Grayson's 2006 modelling) and this formed a useful starting basis. Each of the proposed activities to achieve load reductions is based on their effectiveness in reducing the P load (public benefit) and estimated the level of adoption without incentives, with current incentives (if currently offered) and under conditions of full cost recovery (to assess likely private benefits).

## Optimisation analysis

The Gippsland Lakes P Tool was used as a basis for an optimisation analysis to assess P load reduction (public benefits) for scenarios 1-10. The optimisation analysis was able to select the least-cost combinations of practices to achieve P reduction targets of 40, 30, 20 and 10% (scenarios 1-4), as well as to assess the most effective management actions for set budgets ($2, 5 and 10 million/year for 5 years) (scenarios 5-10). Scenarios 5-7 also allowed for on-going annual maintenance funding, whereas scenarios 8-10 assumed no on-going funding was available.

Decision variables for the optimisation were the area allocated to each land-use, incentive payment level, and the percentage of relevant land over which these incentives are offered. All decision variables are constrained to be non-negative. The incentive payment levels can either take two or three integer values. Binary variables represent the implementation of no incentives or full incentives for actions for which no incentives are currently paid. Integer variables with three possible levels define the use of no incentives, continuation of current incentives, or full incentives for actions for which incentives are presently used. The percentage of land over which these incentives are offered is constrained so that it cannot exceed the maximum area of land over which the BMP can be used minus the level of current adoption. The total area of land allocated under regulation must also be equivalent to that used currently (2,060,660 ha including native and exotic forests). Further description of the optimisation analysis is outlined in Appendix 3.

## Technical feasibility

INFFER handles technical feasibility by considering the works and actions needed to achieve the goal, associated time lags, the effectiveness of works/actions, and the risk of technical failure. Details are outlined in the INFFER Instruction Manual (available on the INFFER website).

### *Previous catchment modelling*

A number of studies based on AEAM (Grayson and Argent 2002), SedNet and sediment tracing (Wilkinson 2005, 2006, Hancock et al 2007) and SedNET/Annex (Grayson 2006) had been conducted using readily available broad land information, assumptions on delivery to streams, nutrient loads from land uses and transport and deposition along stream networks. Whilst there are some acknowledged limitations in these assumptions (see page 9 Grayson 2006 report) and considerable uncertainty in the results, the best estimates of average long term P inputs to the lakes are in the order of 329 (Grayson 2006) to 390 t TP/year (Hancock et al. 2007).

### *Land uses*

Previous modelling was based on broad land-use categories of forestry (reserve, production and plantation), grazing/pasture, irrigated, horticulture and other (residential, mining, road crossings, etc.).

At the technical workshop and through subsequent discussions, significant issues in the land use data layer used to underpin the previous modelling were identified. The most problematic were that: 1) dryland dairying was not discriminated from ‘grazing/pasture’; 2) there were important anomalies in the forest layer; 3) that topography was important to consider; 4) that horticulture (mostly potatoes in the west on steep land and irrigated vegetables in the east on flat land) were likely to have higher nutrient losses than for extensive grazing systems. It was agreed that further investigation would be useful asses if it was possible to better differentiate between land use categories.

A more representative land-use layer had been generated for each of East and West Gippsland through Land Use Impact Modelling projects (Anon. 2007; Sargant 2009). The CMAs made these available to this project and additional follow-up with local CMA and DPI extension staff sought to standardise the land-use categories between East and West. The new land-use categories were:

- Native vegetation
- Forest – production, plantation
- Irrigated dairy
- Dryland dairy
- High rainfall/mixed dairy beef
- Dryland beef/sheep
- Horticulture/cropping
- Other

Re-running SedNet reflecting the new land-use layer would have been useful, as would more detailed work better linking paddock/farm scale nutrient outputs to inputs to waterways. Neither were possible in the available time and resources available. Instead, we used existing modelling outputs and consultation with DPI and DSE personnel to split relative P contributions between old and new land classes.

### *Gippsland Lakes P Tool to assess P reduction scenarios – technical feasibility*

The Grayson (2006) estimate of 329 t P/year was adopted for the Gippsland Lakes P Tool. The main refinements in the developed spreadsheet model, compared with the Ladson and Tilleard (2006) tool, were:

- Greater scenario testing being possible, with assumptions better documented as comments within the tool.
- Allowing exploration of a broader range of BMPs (particularly for irrigated dairying), which were agreed to by stakeholders at the socio-economic workshop and refined with additional follow up.
- The % effectiveness assumptions were generated for individual BMPs from the socio-economic workshop and individual follow up with research, extension and CMA

staff. Assumptions about the % effectiveness, level of adoption and costs of individual BMPs are transparent and can be changed.

- Allowing combinations of both BMPs and land-use change options to be explored—in contrast, Ladson and Tilleard (2006) only considered BMP reduction. If the area of an agricultural land use decreases in our model, it is assumed to be replaced by native vegetation.
- Splitting the total of 107 t TP from the 'dryland agriculture' land use into the new land-use categories of dryland dairy, dryland beef/sheep, high rainfall mixed dairy/beef and horticulture.
- Assuming the contribution from horticulture was 26 t TP (from 18,300 ha land). Whilst no measurements of nutrient impacts of horticulture had been taken, and BMPs for nutrient reduction had not been developed, discussions with Rob Dimsey and Neville Fernando (DPI extension staff) were able to provide 'ball-park' estimates of P inputs, which suggested the potential for large P surpluses, and hence potential for export to waterways and the Lakes. High nutrient losses from horticulture have also been suggested by Drewry *et al.* (2006). We therefore assumed that the potential for P loss from horticulture would be equivalent to that from irrigated dairy production (total of 65 t TP from 45,890 ha land). Vegetables are grown on porous soils with good connection to the Lakes via the Mitchell River in East Gippsland. Whilst the connectivity of potato growing country in West Gippsland to the Lakes might be lower, the very high rainfall, slopes and nutrient applications suggest high potential for export to the Lakes.
- For the 81 t TP (107 t P from dryland agriculture minus 26 t P assumed to come from horticulture) remaining as the load from dryland farming, this was split across the remaining land classes of dryland dairy, high rainfall mixed dairy/beef and dryland beef/sheep. The Gippsland Lakes P Tool has 2 options – option 1 assumes that all dryland grazing contributes the same P loss/ha, while option 2 assumes that dryland dairy and high rainfall mixed beef/dairy exports are 3 times those of dryland beef/sheep. Option 2 is likely to be more realistic given that P surplus figures calculated from sheep farms in Gippsland are around 5 kg P (Gippsland Farm Monitor Report 2007), whilst for dairy farms they can be in the order of 15-24 kg P for representative farms in the Accounting for Nutrients Project (Cameron Gourley, personal communication). Option 2 partitioned 39 t P from dryland beef/sheep, which is comparable to the Ladson and Tilleard tool where dryland beef/sheep (excluding the Moe area) was assumed to have a total contribution of 34 t P (hillslope and gully combined). By contrast, option 1 suggested that 61 t P came from this land use.
- Splitting the forestry 63 t TP in proportion to the area occupied by each of native vegetation, forest - production and forest – plantation.
- Considering the TP reduction due to riparian buffering separately to other BMPs, with the P load reaching the buffer taking into account the reduction due to implementing other BMPs. We have used available GIS information to calculate the length of tributary streams in each land use category.

Although the Gippsland Lakes P Tool is useful to integrate technical, practice-change and cost information, it has limitations in assessing technical feasibility, the most important being:

- P load reduction potential is lumped across broad land use groups, whereas in reality much greater targeting of critical source areas would be possible.
- Updated soil information, which could be used to underpin catchment modelling, is available for West Gippsland, and will be available within 6–12 months for East

Gippsland. Catchment modelling based on both updated land use x soil combinations could be useful and this might change the broad P load contributions by different industries within the spreadsheet.

- The only field measurements of P losses in Gippsland have been made in the dairy industry (Nash and Murdoch 1997). There has been no attempt to quantitatively measure P losses from the dryland beef/sheep or horticulture industries.

- The tool does not represent the timing of P reductions due to BMPs or land-use changes.

- Limitations in effectiveness. Extension staff tended to be more optimistic than research staff about the effectiveness of actions because they are focussed on farm level actions and the hope that BMPs with associated incentives and extension programs might be sufficient to improve environmental outcomes, rather than in terms of the ultimate impacts on the Lakes. The impacts of BMPs on P loads to the lakes are therefore likely to be optimistic.

- The impact of fire on forestry systems is likely to dominate incremental changes from adoption of BMPs. These impacts have not been included.

- No BMPs for horticulture/cropping have been included due to a lack of information.

## Practice change

Issues of adoption/practice change or land use are considered in INFFER by the actions required on both public and private land. Questions related to whether approvals for works are required are also posed. Details are outlined in the INFFER Instruction Manual (available on the INFFER website).

The issues dealt within the Gippsland Lakes P Tool are limited to the levels of adoption of works by private landholders, with other factors being considered within the two PAFs.

*Gippsland Lakes P Tool – adoption and effectiveness considerations*

The new tool refinements include:

- Updating the maximum level of adoption through consultation at the socio-economic workshop and additional follow up with individuals.

- Considering the levels of adoption under 3 levels of incentives – zero, current incentives (if applicable), and full cost of attaining maximum adoption.

The major limitations with respect to adoption issues are that:

- Adoption levels are based on ‘best estimates’, with a lack of data available for validation. Adoption levels under the ‘no incentives’ scenario are likely to be the most reliable, and are assumed as low based on expected small or negative private benefits to individuals.

- Maximum adoption levels cannot be tested.

- Consideration of horticulture BMPs has not been included, but could be included if information becomes available.

- Forest BMPs have not been updated from the Ladson and Tilleard tool

## Delivery mechanisms and costs

Delivery mechanisms on private and public land are considered, as are socio-political risks, costs (upfront costs, on-going maintenance) and the likelihood of on-going funding. Details are outlined in the INFFER Instruction Manual (available on the INFFER website).

### *Gippsland Lakes P Tool – costs*

The most significant advances or changes to the Ladson and Tilleard tool are:

- Costs have been updated, based on consultation with local CMA and DPI staff. Total costs are discounted over 20 years using a 5% discount rate.

- Additional program administration costs have been included in addition to the direct project costs.

- Costs for BMPs have been based on information supplied by local CMA and DPI extension staff. These can be refined or updated as new information becomes available. Costs have been captured to the best of our knowledge in the time available to the project.

- Enforcement of effluent management. Costs were based on funding of compliance officers ($150,000 per year for a compliance officer who services 100 farms) plus an additional $2million fund to allow for legal costs involved in enforcement.

- Costs for land use change (e.g. away from dairy or dryland grazing to native vegetation) have been included, assumed as an on-going stewardship payment. Instead of stewardship, another option would be land buyback. We decided not to use land buyback for the INFFER analysis due to the difficulty in setting a realistic average land price, which is highly dependent upon proximity to centres of employment, more so than agricultural land capability; for example an estimate of agricultural land price in the Glenaladale area from a local Bairnsdale real estate agent was $3000/ha in November 2009. Ten years ago in the Omeo and Upper Tambo Valley area, land was voluntarily purchased for an average of $755/ha in a successful buyback scheme, showing that buyback, at least on a small scale, is feasible (Sinnett 2005). For our analysis the cost of lost production was based on the 2007/2008 Farm Monitor Project information (English *et al.* 2008, Tocker and Quinn 2008) for Gippsland for each of the dairying or grazing enterprises. For dairying it was assumed that operating profit/ha (or earnings before interest and tax) was similar across irrigated and dairy enterprises ($1990/ha) because the Farm Monitor data did not give any indication that there were profit differences between them (English *et al.* 2008). Operating profit for grazing enterprises was assumed as $150/ha (Tocker and Quinn 2008). For mixed beef/dairy enterprises, operating profit was assumed as the average of dairy and grazing enterprises ($1100/ha).

- Inclusion of calculations of cost-effectiveness of TP reduction (the % TP reduction above that gained for no investment, divided by the cost of action and multiplied by a factor) for any BMP or land use change scenario.

The major limitations with respect to the cost component are:

- Costs of land use change are both preliminary and conservative. Costs to retire land from agriculture are only based on broad, single estimates per land use of the average annual opportunity cost of lost production. They do not include options for land purchase. If changing land use to achieve large P reduction targets was seriously contemplated, then detailed consideration of whether stewardship or buyback would be required. Buyback would have large upfront costs but presumably lower ongoing maintenance costs compared to stewardship payments.

- BMP costs were obtained from DPI extension and CMA staff. A single 'average' cost has been applied to each BMP, whereas in reality targeting is possible. Costs of extension associated with incentive programs have been included for dairying.

- Streambank costs (based on Hardie 2007 and discussion with Ian Rutherfurd) have been assumed at $28,000/km (covering both sides of the river, covering fencing @ $20,000, off-stream watering @ $5,000, weed control @ $2,000 and direct seeding @ $1000) plus annual maintenance costs of $2,000/km/year. They do not include the cost of willow removal which can be up to $40,000 for severe infestations. Willow removal was assumed to be for biodiversity benefits more than nutrient benefits. Prior to the external review $20,000/km was used with no annual operating costs (these being assumed as being part of a landholder agreement). The choice between land management and streambank protection and associated BCI is highly sensitive to costs of streambank protection and so costing these for specifically for priority waterways is important.

- Riparian costs were assumed to be as for streambanks but without provision of off-stream watering or need for direct seeding. Maintenance costs were assumed to be $1000/km/year.

- No horticulture costs have been included.

- Little emphasis has been given to forestry. Profitability has not been included and other BMPs were not investigated. The P Tool could easily be updated if these were available.

## Calculation of the Benefit: Cost Index

The Gippsland Lakes P tool was used to develop the costing values (C and M values in the formula below) needed for calculation of the BCI. The BCI is calculated by the following equation:

$$BCI = \frac{V \times W \times F \times A \times B \times P \times G \times DF_B(L) \times 20}{C + PV(M)}$$

where

$V$ = value of the asset

$W$ = multiplier for impact of works

$F$ = multiplier for technical feasibility risk

$A$ = multiplier for adoption

$B$ = multiplier for adverse adoption

$P$ = multiplier for socio-political risk

$G$ = multiplier for long-term funding risk

$DF_B$ = discount factor function for benefits, which depends on $L$

$L$ = lag until benefits occur (years)

$C$ = short-term cost of project

$PV$ = present value function

$M$ = annual cost of maintaining outcomes from the project in the longer term.

Appendix 2 provides a summary description of the factors and explanation of the formula.

# Results

The parameters used to underpin the INFFER analysis are shown in Table 1. Table 2 shows % P reduction calculated from each scenario, the present value of project costs over 20 years, and the BCI. Total project costs include up-front and annual maintenance costs, to which a real annual discount rate of 5% was applied. Project administration costs were also included, assumed to be 5% of upfront and annual maintenance costs. In Table 3, land management strategies associated with optimisation (scenarios 1-10) are presented.

## P reduction with no action

From the assumptions regarding effectiveness of BMPs and the % adoption likely to occur in the absence of providing any incentives, the amount of P reduction can be calculated assuming no intervention. Assumptions suggest that 4% P reduction can be achieved with no public cost. This is due to low levels of voluntary adoption from landholders who are environmentally motivated, namely those who will adopt BMPs which have public benefits without financial incentives.

## Least-cost P reduction targets (scenarios 1-4)

Overall, the analysis suggests that:

- 4% P reduction in the load entering the Lakes can be achieved with no public cost. This is due to voluntary actions of a minority of landholders. The other scenarios listed below include this amount of P reduction.

- 10% P reduction (i.e. an additional 6%) is achievable at a cost $18.8million (Table 2, project costs calculated in present value terms over 20 years). The initial up-front cost is $11.6million and the BCI is favourable at 2.3 (Note: BCI values greater than 1 indicate benefits exceed costs.)

- P reduction of 20% can also be achieved cost-effectively (BCI 1.0) at a present value cost of $80million ($54 million upfront cost assumed over 5 years followed by maintenance costs).

- It appears technically feasible to achieve 40% P reduction, but at very large cost ($1,343million or greater over 20 years) and low BCI (0.02). As well as full paying for BMPs and enforcement of effluent regulations, major land use change (for example complete retirement of irrigated dairying plus 37,620 ha dryland grazing, or other even more costly options) would be required to achieve the target.

For the very large scale of the asset, these results are favourable and could be used to develop a strong business case for greater public investment for P targets of up to 20% P. Conducting the analysis at finer scales (e.g. single river basin level) could increase BCI figures if finer scale data were available to support the assumptions about P reduction loads. The cost of the 10% P reduction target is relatively modest ($18.8 million) compared with the 20% target ($80.2million, Table 2).

The optimal land management strategies associated with achieving the P reduction targets are shown in Table 3. For the 10% target, current incentives for pressurised irrigation conversion (on 40% of relevant land) and incentives for streambank protection (on 85% of priority waterways) are required. To reach 20% P reduction, full cost incentives for streambank protection on 90% of priority waterways, incentives for irrigated dairying farm plans and re-use systems, and proper enforcement of existing dairy regulations are needed. Reaching the 20% target is over 4 times more expensive than for 10%.

Costs rise significantly to achieve the 30% ($250 million, BCI 0.22) and 40% ($1,343 million, BCI 0.02) P reduction scenarios (Table 2), and indicate that with current technology achieving a 40% P reduction is not a cost-effective public investment. Investment into technology development to improve P impacts could well be warranted, the scope of which would need additional assessment.

To reach the 30% P reduction target, as well as actions for irrigated dairy production (Table 3), P reduction from dryland beef/sheep systems is needed through stewardship payments to maintain groundcover levels (assuming $60/ha/year payment) as well as paying full costs to protect all priority waterways. Although expensive, on the assumptions used, the 30% target appears to be achievable without land use change away from agriculture.

Achieving the 40% P load reduction target (Table 3) is very difficult. It would require paying full costs of BMPs of maintaining groundcover and controlling gully/tunnel erosion in dryland grazing industries, enforcing effluent regulations in the dairy industry and retiring large amounts of agricultural land. Based on the large P load coming from the irrigated dairy industry, retirement of irrigated dairy land (45,890 ha), plus additional retirement of 37,620 ha of dryland grazing land would reach the 40% target. The overall cost is estimated to be $1343million (BCI 0.02). Thus, whilst the 40% target appears technically feasible, the costs, socio-political risks and adoption challenges are enormous. These results, and scrutiny of their underlying assumptions,, provide a strong basis from which to assess the feasibility of the 40% P reduction target and the levels of funding required to achieve it.

The low BCI figure for the 40% scenario should not be a surprise. Benefits and costs have been previously estimated through assessment of the economic impacts of reducing algal blooms through water quality improvement practices (Olszak 2004). Olszak also showed that high costs of agricultural land use change (net present value figures ranged between $235 and 317 million) contributed to very low calculated Benefit:Cost Ratio figures (0.02-0.06).

## Budget scenarios (scenarios 5-10)

Scenarios 5-7 show results for 3 budgets of $2 million, $5 million and 10 million/year for 5 years, along with additional ongoing maintenance costs accounted for. Scenarios 8-10 are for comparable budgets for the first 5 years, but without on-going funding. The optimisation analysis shows that the optimal strategies for each budget differ, depending upon whether on-going funding is required to maintain actions. For example, a $2 million/year budget with assured ongoing maintenance funding (scenario 5, Table 3) could achieve 9% P reduction (BCI 2.9,Table 2) and the optimal management strategy includes provision of current incentives to fence off 68% of streambanks. In contrast, if there is no maintenance funding beyond 5 years (scenario 8) the optimal management strategies are greater incentives to the irrigated dairy industry, achieving a lower P target (6.6%) and higher BCI (4.3). This is also the case for the higher budget scenarios of $5million (compare scenarios 6 and 9, Table 3) and $10million (scenarios 7 and 10).

**Table 1: Parameters used to calculate the INFFER Benefit: Cost Index (BCI)**

| Parameter for BCI[A] | V | W | F | A | B | P | G | DFB | L | C | M |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Scenario[B] | | | | | | | | | | | |
| 1. 40% P | 100 | 0.50 | 0.82 | 0.4 | 1 | 0.37 | 0.5 | 0.38 | 20 | 104.70 | 115.7 |
| 2. 30% P | | 0.38 | 0.85 | 0.6 | | | | 0.48 | 15 | 137.03 | 10.54 |
| 3. 20% P | 100 | 0.25 | 0.89 | 0.7 | 1 | 0.50 | 0.6 | 0.61 | 10 | 54.01 | 2.45 |
| 4. 10% P | 100 | 0.13 | 0.92 | 0.7 | 1 | 0.62 | 0.7 | 0.61 | 10 | 11.60 | 0.67 |
| 5.$2million/year for 5 years, then annual costs | 100 | 0.13 | 0.91 | 0.7 | 1 | 0.62 | 0.7 | 0.61 | 10 | 9.71 | 0.54 |
| 6. $5million/year for 5 years, then annual costs | 100 | 0.20 | 0.90 | 0.7 | 1 | 0.62 | 0.7 | 0.61 | 10 | 21.03 | 7.61 |
| 7. $10million/year for 5 years, then annual costs | 100 | 0.24 | 0.89 | 0.7 | 1 | 0.62 | 0.7 | 0.61 | 10 | 43.24 | 13.50 |
| 8.$2million/year for 5 years, no on-going funding | 100 | 0.13 | 0.92 | 0.7 | 1 | 0.62 | 0.7 | 0.61 | 10 | 9.80 | 0 |
| 9. $5million/year for 5 years, no on-going funding | 100 | 0.13 | 0.92 | 0.7 | 1 | 0.62 | 0.7 | 0.61 | 10 | 24.67 | 0 |
| 10. $10million/yr for 5 years, no on-going funding | 100 | 0.13 | 0.92 | 0.7 | 1 | 0.62 | 0.7 | 0.61 | 10 | 49.34 | 0 |
| 11. Current incentives – all industry BMPs | 100 | 0.20 | 0.90 | 0.7 | 1 | 0.62 | 0.7 | 0.61 | 10 | 84.52 | 6.65 |
| 12. As for 11, excl. riparian | 100 | 0.16 | 0.91 | 0.7 | 1 | 0.62 | 0.7 | 0.61 | 10 | 20.85 | 0.87 |
| 13. Current incentives – irrig dairy + effluent enforcement, no riparian | 100 | 0.13 | 0.92 | 0.7 | 1 | 0.62 | 0.7 | 0.61 | 10 | 14.07 | 1.03 |
| 14. Effluent enforcement[B] | 100 | 0.13 | 0.92 | 0.7 | 1 | 0.62 | 0.7 | 0.61 | 10 | 5.18 | 1.03 |
| 15.Streambank – full costs, 50% effective | 100 | 0.20 | 0.90 | 0.7 | 1 | 0.62 | 0.7 | 0.61 | 10 | 43.93 | 1.57 |
| 16. Streambank – full costs, 50% effective | 100 | 0.13 | 0.92 | 0.7 | 1 | 0.62 | 0.7 | 0.61 | 10 | 43.93 | 1.57 |
| 17. V=1000[B] | 500 | 0.50 | 0.82 | 0.4 | 1 | 0.37 | 0.5 | 0.38 | 20 | 104.70 | 115.7 |
| 18. V=50[B] | 50 | 0.25 | 0.89 | 0.7 | 1 | 0.62 | 0.7 | 0.61 | 10 | 54.01 | 2.45 |

[A]V = value of the asset; W = multiplier for impact of works; F = multiplier for technical feasibility risk; A = multiplier for adoption; B = multiplier for adverse adoption; P = multiplier for socio-political risk; G = multiplier for long-term funding risk; DFB = discount factor function for benefits, which depends on L; L = lag until benefits occur (years); C = short-term cost of project; PV = present value function; M = annual cost of maintaining outcomes from the project in the long term; The BCI calculator and the INFFER Instruction Manual help interpret the parameters.

**Table 2: % P reduction achieved and index of P cost-effectiveness associated with investment scenarios in the Gippsland Lakes**

| Scenario | % P reduction | Present value of project cost ($ million) over 20 years | Benefit:Cost Index |
|---|---|---|---|
| 1. 40% P[A] | 40 | 1,343.0 | 0.02 |
| 2. 30% P | 30 | 249.8 | 0.22 |
| 3. 20% P | 20 | 80.2 | 1.03 |
| 4. 10% P | 10 | 18.8 | 2.29 |
| 5. $2 million/year for 5 years, then annual costs | 9 | 15.5 | 2.88 |
| 6. $5 million/year for 5 years, then annual costs | 16 | 102.5 | 0.66 |
| 7. $10 million/year, for 5 years, then annual costs | 19 | 187.7 | 0.42 |
| 8. $2 million/year for 5 years, no on-going funding | 6.6 | 9.8 | 4.38 |
| 9. $5 million/year for 5 years, no on-going funding | 7.4 | 24.7 | 1.74 |
| 10. $10 million/year for 5 years, no on-going funding | 10 | 49.3 | 0.87 |
| 11. Current incentives – all industries | 16 | 155.7 | 0.43 |
| 12. As for 11, minus riparian | 13 | 30.1 | 1.83 |
| 13. Current incentives irrigated dairy + effluent enforcement, minus riparian, no streambank | 9 | 25.05 | 1.71 |
| 14. Effluent enforcement | 6 | 16.2 | 2.75 |
| 15. Streambank (50% effective, full costs) | 16 | 60.7 | 1.11 |
| 16. Streambank (20% effective, full costs) | 9 | 60.7 | 0.71 |
| 17. As for 1, but V = 1000 | 40 | 1,343.0 | 0.17 |
| 18. As for 3 but V=50 | 20 | 80.2 | 0.52 |

[A]1) 40% P reduction by 2030 (based on the 10 year average load entering the Lakes) for least cost; 2) 30% P reduction by 2030 for least cost; 3) 20% P reduction by 2030 for least cost; 4) 10% P reduction by 2030 for least cost; 5) Most-cost effective outcome for a budget of $2 million/year for 5 years, followed by on-going costs of BMPs; 6) Most-cost effective outcome for a budget of $5 million/year for 5 years, followed by on-going costs of BMPs; 7) Most-cost effective outcome for a budget of $10 million/year for 5 years, followed by on-going costs of BMPs; 8) As for 5 but no on-going costs; 9) As for 6 but no on-going funding; 10) As for 7 but no on-going funding; 11) % P reduction which can be achieved using current incentives for voluntary adoption of BMPs (current incentives on BMPs, streambank and riparian management); 12) As for scenario 11, but excluding riparian management; 13) Current incentives for irrigated dairy BMPs plus full enforcement of effluent management in both dryland and irrigated dairy, but excluding riparian management; 14) Effluent enforcement only (full cost); 15) Streambank protection only (full costs), 50% effectiveness; 16) Streambank protection only (full costs) but assuming only 20% effectiveness instead of 50%;;

## Table 3. Optimal strategies to achieve P reduction scenarios for the Gippsland Lakes

| Scenario | Cost($million) | Strategy |
|---|---|---|
| 1. 40% P | Project costs: $99.3m cost of BMP projects plus $96.8m annual loss of profit from land-use change (cannot be achieved by BMPs alone) plus $13.4m ongoing annual costs<br>Administration costs: $5.0m up-front plus $5.5m ongoing)<br>Present value over 20 years: $1,343m | Full enforcement, effluent management, 80%; Current incentives, dryland dairy/mixed dairy-beef riparian buffering, 100%; Full cost, groundcover above 70%, 58%; Full costs, gully/tunnel erosion control, 9%; Full cost, road improvements, 100%; Full cost, streambank stabilisation, 99%.<br>Land use change out of agriculture is required (e.g. replacement of 45,890 ha of irrigated dairy and 37,620 ha of beef/sheep by native vegetation or forestry) |
| 2. 30% P | Project costs: $130.5m plus $10.0m ongoing annual cost<br>Admin: $6.5m upfront plus $0.3m ongoing<br>Present value over 20 years: $249.8m | Full cost, tailwater re-use, 30%; Current incentives, pressurised irrigation, 40%; Full enforcement, effluent management, 80%; Current incentives, irrigation farm plans, 98%; Full cost, irrigated dairy riparian buffering, 82%; Full cost, groundcover above 70%, 41%; Full cost, streambank stabilisation, 99%. |
| 3. 20% P | Project costs: $51.4m with $2.3m ongoing annual cost<br>Admin: $2.6 upfront plus $0.1 ongoing<br>Present value over 20 years: $80.2m | Current incentives, tailwater re-use, 30%; Current incentives, pressurised irrigation, 40%; Full enforcement, effluent management, 80%; Current incentives, irrigation farm plans, 98%; Full cost, streambank stabilisation, 90%. |
| 4. 10% P | Project costs: $11.6m with $0.7m ongoing annual cost<br>Admin: $0.6m upfront plus $ 0.03m ongoing<br>Present value over 20 years: $18.8m | Current incentives, pressurised irrigation conversion, 40%; Current incentives, streambank stabilisation, 85%. |
| 5. $2m/yr for 5 years, then annual costs (9%P) | $10m over 5 years including admin costs<br>Project costs: $9.2 upfront plus $0.5m on-going<br>Admin: $0.5m upfront plus $0.0m ongoing annual cost<br>Present value over 20 years: $15.5m | Current incentives, pressurised irrigation, 40%; Current incentives, streambank stabilisation, 68%. |
| 6. $5m/yr for 5 years, then annual costs (16% P) | $25m over 5 years including admin costs<br>Project costs: $20.0m upfront plus $7.3m ongoing annual cost<br>Admin: $1.0m upfront plus $0.4m ongoing<br>Present value over 20 years: $102.5m | Current incentives, pressurised irrigation, 40%; Current incentives, irrigated dairy riparian buffering, 14%; Full costs, groundcover above 70%, 41%; Current incentives, streambank stabilisation, 99%. |
| 7. $10m/yr for 5 years, then annual costs (19% P) | $50m over 5 years including admin costs<br>Project cost: $41.2m upfront plus $12.9m ongoing annual cost for BMPs<br>Admin: $2.1m upfront plus $0.6m ongoing<br>Present value over 20 years: $187.7m | Current incentives, tailwater re-use, 30%; Current incentives, pressurised irrigation, 40%; Current incentives, irrigation farm plans, 98%; Current incentives, irrigated dairy riparian buffering, 99%; Current incentives, dryland dairy/mixed dairy-beef riparian buffering, 16%; Full costs, groundcover above 70%, 71%; Current incentives, streambank stabilisation, 99%. |
| 8. 2m/yr for 5 years, no on-going (6.6% P) | $10m over five years including admin<br>Project cost: $9.3m upfront<br>Admin: $0.5 m upfront<br>Present value over 20 years:$9.80m | Current incentives, tailwater re-use, 30%; Current incentives, pressurised irrigation, 40%; Full cost, irrigation automation, 1%; Current incentives, irrigation farm plans, 98%. |
| 9. $5m/yr for 5 years, no on-going (7.4% P) | $25m over five years including admin<br>Project costs: $23.5m upfront<br>Admin costs: $1.2 m upfront<br>Present value over 20 years: $24.7m | Full cost, tailwater re-use, 12%; Current incentives, pressurised irrigation, 40%; Current incentives, irrigation farm plans, 98%. |
| 10. $10m/yr for 5 years, no on-going (10% P) | $50m over five years including admin<br>Project costs: $47m upfront<br>Admin: $2.3 m upfront<br>Present value over 20 years:$49.3m | Full cost, tailwater re-use, 27%; Current incentives, pressurised irrigation, 40%; Current incentives, irrigation farm plans, 98%. |

## BMP and effluent enforcement (scenarios 11-14)

The BCI results are sensitive to the choice of BMPs and the level of incentives paid. Scenarios 11-14 illustrate some of the possible choices; others can be explored using the Gippsland Lakes P Tool.

Applying currently available incentives (BMPs on farm, riparian and streambank management, scenario 11) across the dairy (both irrigated and dryland) and beef-sheep industries could achieve a P reduction target of 16% (Table 2), but at large cost ($156 million) and low BCI (0.4). Excluding riparian management (scenario 12) reduces the P load to 13% and the cost to $30 million, whilst producing a favourable BCI (1.8, Table 2). Ladson and Tilleard (2006) suggested that P loads to the lakes could be reduced by approximately 11% if BMPs were applied to all major land uses (range 6-18% given uncertainties). Our results are thus within the range suggested earlier, but with the additional strength of being more defensible for public investment.

Given the large emphasis on providing incentives to dairy farmers to improve practices to reduce nutrient exports in Gippsland, enforcement of existing effluent regulations is also important if the industry is to be seen as environmentally responsible. It is also a cost-effective public investment (scenario 14, Table 2, BCI 2.8). Enforcement of existing regulations is even more important given the pressures for dairy expansion in high-rainfall areas, and thus additional nutrient pressures on receiving waterways.

## Streambank protection (scenarios 15-16)

The effectiveness of streambank protection was assumed to be 50%, as used in the Ladson and Tilleard tool, based on previous work (White *et al.,* 1999, Wilkinson *et al.* 2006). As has been raised previously, there remains limited data on the rates of riverbank erosion (Hancock *et al.* 2007). For this reason, as well as assessing the impacts of streambank protection (scenario 15) we decided to include scenario 16, where the effectiveness was only 20% (Table 2). The impact on the BCI of reducing effectiveness from 50% to 20% was P reduction from 16% with an acceptable BCI (1.1), to 9% P reduction and BCI of 0.7, indicating that costs exceed benefits.

The attractiveness of streambank protection as a preferred management option is also (understandably) sensitive to costs. We assumed a cost of $28,000/km to cover both sides of the river, made up of riparian pre-management $2,000/km, direct seeding revegetation $1,000/km, provision of off-stream watering $5,000/km and on-going maintenance costs (weeds, repairs) of $2,000/km/year. We used mid-range figures from Hardie (2007) as the basis in discussion with Ian Rutherfurd (personal communication). Willow removal costs were not included (on the basis that the emphasis of the INFFER analysis was on P reduction rather than biodiversity enhancement). Inclusion of willow removal could increase costs by a further $5-40,000/km.

More detailed consideration of both cost and effectiveness assumptions could be worthwhile for fine-tuning outcomes from streambank protection, including consideration of the streams which have already been fenced off in priority areas which would be available from the CMA.

## Sensitivity of analysis of BCI to Lakes value (scenarios 17-18)

One of the most common concerns people have about INFFER is regarding the value (V) score assigned to an asset and what effect this has on the BCI result. Scenarios 1-16 have been based on a V score of 100, where a score of 100 corresponds to a value of $2 billion if BCI results were to be converted to a standard economic Benefit Cost Ratio (BCR).

Some stakeholders may argue that the Gippsland Lakes would be worth much more than $2 billion, and thus might use this as an argument to disregard low BCI results, particularly those of the 40% P reduction target. In scenario 17 we increased the assumed value of the Lakes by 10-fold, keeping other parameters the same as for scenario 1. Even with a 10-fold increase in the value of the Lakes, the 40% P target remains not cost-effective BCI 0.17).

Similarly, it could be argued that the score of 100 is too high. Keeping all other factors as for scenario 3 (20% P least cost target) but reducing V to 50 (corresponding to a value of $1billion), reduces the BCI from 1.0 to 0.5. In time, as INFFER becomes more widely used for large and important assets like the Gippsland Lakes, there will be arguments about value scores and thus it is important to be aware of the impact it can have.

Notwithstanding the above paragraph, experience in using INFFER to date, shows that the inaccuracy in valuing the asset is unlikely to be the deciding factor in whether the BCI calculation is high or low. More often, it is the low effectiveness of works, time lags, socio-political risks and high cost of required mitigation techniques that are more likely to impact on the BCI. These other factors rarely receive as much scrutiny as V, but they should do.

## Cost effectiveness of individual BMPs and land use change

Table 4 can be used to assess the relative cost-effectiveness of individual management actions (BMPs, effluent enforcement, land use change). The index of cost-effectiveness (in the P Tool) is useful for comparing the relative merits of strategies, but not for determining whether any individual strategy is worth the investment.

In all cases, cost effectiveness is higher under current incentives than paying for full costs of a BMP. Note that this does not mean that full-cost incentives could never be cost effective. They are used a number of times in Table 3 as efficient strategies to achieve effective P reductions, most commonly to achieve the more ambitious targets.

The most cost-effective strategies are those which have zero or small on-going annual costs, such as the on-farm BMPs for the irrigated dairy industry. Streambank protection, using current incentives, where the landholder agreement requires landholders to maintain ongoing costs, are comparable in cost-effectiveness to some of the on-farm BMPs. Providing on-going stewardship payments to offset the opportunity cost of lost production, such as for land retirement and reducing stocking rates to maintain groundcover are amongst those that are least cost-effective.

**Table 4. Index of cost-effectiveness for reducing P inputs (best management practices, enforcement of regulation, land use change) to the Gippsland Lakes**

| Management practice | Current incentives | Full cost |
|---|---|---|
| **Irrigated dairy production** | | |
| On-farm re-use systems for tailwater: heavy soils, flat | 0.20 | 0.08 |
| Conversion to pressurised conversion: light soils | 0.51 | 0.05 |
| Irrigation automation | Not available | 0.02 |
| Effluent management (enforcement, not incentives) | Not available | 0.13 |
| Irrigation farm plans | 0.19 | 0.13 |
| Drainage line/riparian buffering | 0.12 | 0.08 |
| Land retirement[A] | Not applicable | 0.02 |
| **Dryland Dairy/high rainfall mixed dairy-beef** | | |
| Effluent management (enforcement, not incentives) | Not available | 0.13 |
| Drainage line/riparian buffering | 0.03 | 0.02 |
| Land retirement[A] | Not applicable | 0.01 |
| **Dryland Beef-sheep** | | |
| Groundcover above 70% | Not available | 0.03 |
| Gully/tunnel erosion control | -0.01 | 0.01 |
| Drainage line/riparian buffering | 0.01 | 0.01 |
| Land retirement[A] | Not applicable | 0.01 |
| **Stream protection** | | |
| Streambank stabilisation | 0.12 | 0.08 |

[A] Land retirement assumes that 10,000 ha of land in this land class is converted to native vegetation.

# Limitations/knowledge gaps in existing data

There is a large body of research and local knowledge on the ecology of the Lakes and catchment impacts, much of which has been used to underpin the INFFER analysis. However, a number of knowledge gaps remain, some of which have important potential implications for investment decision making. These include:

- The impacts of climate change on environmental outcomes for the Lakes needs further analysis, research and discussion.
- Impacts of large episodic events, both fire and floods. Impacts from these sources can greatly supersede the agricultural contributions in some years. Better quantification of such impacts, as well as discussion about what this means for changes to current investment, is warranted.
- P – Whilst there is a large existing body of work at catchment scale (e.g. SedNet) and farm scale (e.g. Nash, Gourley), the connectivity between farm scale and delivery to the Lakes is still relatively poorly understood and simplistically treated in SedNet. There is still room for improvement in understanding how the sources of P in agricultural landscapes are connected to surface water-quality impacts and also in understanding the impacts of P forms on environmental outcomes.
- Sediment – The contributions from hillslope and gully/tunnel erosion that have been quantified with Sednet modelling could be improved by the inclusion of up-to-date soil and land use data and by considering more explicitly the connectivity between sources of sediment and stream network.
- N – Given the large N surpluses generated in the dairy and horticulture industries in particular, as well as the importance of N on environmental impacts in temperate dairying areas internationally (e.g. New Zealand, Europe, USA), research linking agricultural impacts to environmental outcomes is required. Both surface and groundwater impacts should be considered, due to connectivity between groundwater systems and the Lakes.
- In summary, finer resolution of spatial connectivity for N, P and sediment delivery from land use to impacts on the Lakes is warranted for greater confidence about the opportunities to reduce agricultural impacts on the Lakes. Given the very large sums required to achieve the more ambitious nutrient reduction targets, investment in well-targeted research to give confidence to the investment would be well worthwhile.
- Information about the effectiveness of BMPs in reducing P impacts is still relatively subjective. Further investigation could improve this, but not at the expense of failing to fill other knowledge gaps. For each land use type, scouring of DPI, DSE and CMA local information and expertise might be useful to see if there is additional unpublished, locally relevant information available.
- Riparian management – although there is some locally relevant research on the effectiveness of riparian buffering (Sharon Aarons, *personal communication*) it was only conducted at a couple of sites and is insufficient be confident about its effectiveness. Given that the costs of intervention are large, research into the effectiveness of riparian buffering for sediment, P and N trapping would appear to be a priority for additional effort. Published work suggests effectiveness is both highly variable and context specific. Studying the effectiveness of riparian buffering at representative soil x topographical x land use x land use intensity x buffer widths/management is worth considering.

- Streambank erosion – the basis for the effectiveness of streambank stabilisation is worth checking. Previous CSIRO work conducted in this catchment (Wilkinson *et al.* 2006) suggested that several hundred kilometres of streams were having the greatest impacts, with smaller gains to be made from additional protection measures. Re-assessment of priorities for streambank work may be worthwhile, as well as assessing which reaches have now been fenced out by CMA works.
- Adoption levels under zero, current and full cost recovery were gathered from expert knowledge from CMA and DPI extension staff. The uncertainties surrounding adoption levels are unlikely to be greatly improved by gathering much more detailed information. For example, adoption levels under conditions of zero incentives can be assessed according to expected private benefits. Similarly, adoption under full-cost recovery can be estimated by experienced field officers. Detailed interviewing of individual landholders is unlikely to yield much more accurate figures. One option to give greater confidence about costs required to achieve certain adoption levels would be to conduct conservation tenders (reverse auctions).
- Cost information – more local, spatially specific costs would improve the analysis. Costs associated with assessing land use change are preliminary, conservative and uncertain. No costs associated with forestry or horticulture have been included.

## *How does INFFER add value to decision-making?*

The INFFER analysis adds value to decision making through:

1. Providing a strong basis for a business case for future funding from state and national sources.
2. Highlighting that budget amount and longevity is a crucial determinant of optimal management strategy selection.
3. Providing confidence about using public money more cost-effectively through the choice of appropriate policy tools based on the public and private benefits they generate.
4. Providing a robust, transparent basis to enable strategic direction setting, debate and discussion about the future of the Gippsland Lakes and the agricultural environmental trade-offs associated with potential scenarios.
5. Building on existing biophysical research knowledge and integrating it with available socio-economic factors, consideration of institutional and political risks, costs and cost-effectiveness of actions.
6. Helping to highlight and prioritise limitations in current knowledge to inform decision making.
7. Providing internal consistency, ensuring the delivery mechanisms (works, investigations, other actions) selected will be sufficient to deliver the stated goal.
8. Helping to reduce bias in decision making by making the process fully transparent.

## Time involved

An issue often raised is that INFFER takes more time than current project development approaches. Whilst this is true, investment of large sums of public money should be underpinned by rigorous analysis. We think INFFER represents the minimum due diligence that should be conducted for major projects. Most investments made by regions in all States of Australia have poor consideration of socio-economic factors (Seymour *et al.* 2008); biophysical underpinning is strongest (and sometimes still weak overall), but it is insufficient to develop a case for cost-effective investment and delivery of sufficiently high public benefits. Treasury economists are increasingly asking for natural resource management investment to be better justified. Without a framework such as INFFER, current investments are not able to be well argued as delivering strong public benefits for the investment.

The time taken to do INFFER analyses varies, depending upon the scale/complexity of the asset, level of knowledge, access to available knowledge (expert opinion, published information etc) and the degree of co-learning and participation in the process.

The Gippsland Lakes INFFER analysis is by far the most complex and time-consuming analysis that has been undertaken to date. It took approximately 100 person-days of time (see Appendix 1 for the estimated time commitment of people in the process). Given that GLTF and major stakeholders previously had little or no exposure to INFFER, it was important for the approach to be participatory and educate stakeholders during the process. It was thus more time consuming than simply appointing a consultant to do a desktop analysis based on available literature. Actively seeking and responding to stakeholder feedback, adapting existing information (such as developing a more representative land use layer developing and refining the spreadsheet tool that served this project and is available for future assessments, conducting economic optimisation analysis) took more time than if we had simply done a desktop study using technical reports and previous research.

Examples of other completed INFFER analyses that support the view that the time taken to do an analysis can be reduced include:

- A desktop INFFER analysis of the Great Barrier Reef took 18 person-days to complete (15 days private consultant, 3 days for INFFER staff).
- Numerous small regional assets (e.g. threatened species in a local area, wetland, single large block of remnant vegetation) commonly take 2-5 person-days for analysis.
- Medium/large scale regional assets commonly take 10-15 person-days time.
- An experienced WA consultant was able to complete 2 INFFER analyses within 5 days in a CMA region in NSW where she had no local knowledge. She did this by working directly with the several key people (each for less than a day) who knew about the asset and the information available.
- There are significant learning costs that are borne when a group undertakes their first one or two INFFER analyses.

We estimate that the time to do the analysis on the Gippsland Lakes (just delivering 2 PAF outputs) without significant participation, could have taken 15-20 days consultancy time.

## *Conclusions*

The INFFER analysis suggests that up to 20% P reduction can be achieved cost-effectively (BCI values greater than 1); 10% P reduction was calculated to cost $18.8million (present value terms over 20 years), with a favourable BCI of 2.3, whereas 20% P reduction had a cost of $80million (BCI 1.0). Results provide the basis to develop a stronger business case for higher public investment, including the need for long term funding if more than incremental gains are to be made.

It appears technically feasible to achieve 40% P reduction, but at very large cost ($1,343million over 20 years) and low BCI (0.02), and requiring large land use change away from agriculture. This may stimulate discussion whether the 40% P reduction target should be retained, and/or some realism about achieving it. If retained, then much greater funding will be required, as will managing the resulting social, economic and political challenges associated with large land use changes away from agriculture.

The choice of optimal land management to achieve either least-cost P reduction outcomes is dependent upon both the level of available budget and whether long-term maintenance costs will be incurred. BMPs that do not require ongoing costs are selected in preference to those which do, particularly for budgets of less than $5 million/year. Provision of incentives for irrigated dairy farming has been a sound approach by the GLTF. The need for long-term funding to achieve 20% or greater P reduction targets provides a basis to argue for increased funding security for measurable environmental improvements.

Given the emphasis on providing incentives to dairy farmers to improve practices, enforcement of existing effluent regulations is also important if the dairy industry is to be seen as environmentally responsible. It is also a cost-effective public investment (BCI 2.8). Enforcement of regulations is even more important given the pressures for dairy expansion in high rainfall areas, and thus additional nutrient pressures on receiving waters.

Despite much biophysical research, there remain a number of knowledge gaps which meant some threats could not be included in the INFFER analysis. These included the impact of climate change, large episodic events (fire/flood), impact of N, and finer resolution regarding the spatial connectivity between P, N and sediment impacts on the Lakes. The impact of large fire/flood episodic events in particular can overwhelm benefits from managing agricultural land, and should be considered if the GLTF considers revising the P load target.

The Gippsland Lakes analysis is the most complex conducted to date. Whilst it took approximately 100 days of stakeholder, consultant and researchers time, this should be considered as due diligence, given the state and national importance of the Lakes and the amount of public money required to protect them. Most assets take far less time for analysis.

INFFER provides the GLTF with a transparent and robust framework to justify future cost-effective public investment. It provides a strong basis to develop a business case for public investment, as well as giving a basis for debate and discussion about agricultural trade-offs associated with achieving environmental outcomes.

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# Appendix 1: Involvement of people and time for analysis

This table gives an estimate of the time commitments[A] of people involved.

| Task | People involved | Time (days)[A] |
|---|---|---|
| Co-ordination | Peter Cottingham | 15 |
| Co-ordination, analysis and interpretation | Anna Roberts (INFFER/DPI) | 15 |
| Strategic guidance | Chris Barry, Barry Hart (GLTF) | 5 |
| Inception meeting | Chris Barry (GLTF), Paula Camenzuli (WGCMA), Rex Candy (EGCMA), Peter Cottingham, Barry Hart (GLTF), Geoff Hocking (WGCMA), Eleisha Keogh (EGCMA), Geoff Park (INFFER/NCCMA), Liz Radcliffe (EPA and Taskforce), Anna Roberts (INFFER/DPI), Julie Sargeant (DPI), Stephanie Spry (INFFER/DSE), Natasha Vasey-Ellis (Gippsland Coastal Board) | 14 |
| Technical workshop | Chris Barry (GLTF), Craig Beverly (DPI), Paul Bolger (GHD), Rex Candy (EGCMA), Peter Cottingham, April Curatolo (INFFER/DPI), Giles Flower (GHD), Terry Flynn (SRW), Cameron Gourley (DPI), Shayne Heywood (WGCMA), David Nash (DPI), Lachlan Newham (ANU), Geoff Park (INFFER/NCCMA), Anna Roberts (INFFER/DPI), Stephanie Spry (INFFER/DSE), Rob Stewart (DSE) | 16 |
| Socio-economic workshop | Wayne Bath (EPA), Rex Candy (EGCMA), Peter Cottingham (INFFER), Nick Dudley (DPI), Ellen Fox (DPI), Shane Heywood (WGCMA), Bridgette Keeble (DPI), Geoff Park (INFFER), Anna Roberts (INFFER), David Shambrook (DPI), Stephanie Spry (INFFER), Greg Turner (DPI). | 12 |
| Specialist input | Nick Dudley/Brett Mitchard (DPI, for land use/GIS) | 2 |
| | Julianne Sargant/Heather Adams (DPI, erosion/land use) | 1 |
| | David Pannell (INFFER/UWA) – spreadsheet tool | 5 |
| | Graeme Doole (INFFER/Uni Waikato/UWA) – economic optimisation | 3 |
| | Olga Vigiak (INFFER/DPI) | 5 |
| | David Nash (DPI) – effectiveness of nutrient reduction strategies | 1 |
| | Cameron Gourley (DPI) – nutrient surpluses and losses | 1 |
| | Ellen Fox/Gavan Lamb (DPI) – effectiveness and adoption levels from irrigated dairy systems | 2 |
| | Rex Candy – land use and cost estimates | 1 |
| | Additional involvement of people (eg. Sharon Aarons, Rick Lawson, Neville Fernando, Rob Dimsey), | 2 |
| Total | | 100 |

[A] Time estimates are best-guesses and have not been verified with participants

## Appendix 2: Calculation of the Benefit:Cost Index

Information used in the INFFER Project Assessment Form (PAF) is integrated within the Benefit:Cost Index (BCI).The information to calculate the Benefit: Cost Index (*BCI*) is collected in the course of completing the PAF. There is a spreadsheet where you can enter the required values manually and ask what-if questions about the project. The spreadsheet, called the "INFFER Benefit Cost Index Calculator (v18)", is available at www.inffer.org.

The variables that feed into calculation of the Benefit:Cost Index are mostly specified as proportions, and are included in the Index multiplicatively. Within this approach, there is no need to provide weights for each variable (as one would do in a Multi-Criterion Analysis). Indeed, given the way the formula is structured, introducing weights into the process would conflict with the logic of the approach. The BCI is broadly consistent with the "Project Prioritisation Protocol of Manoney, Joseph and Possingham (2009)[2], although the BCI is more detailed and includes more elements.

The *BCI* is calculated as follows:

$$BCI = \frac{V \times W \times F \times A \times B \times P \times G \times DF_B(L) \times 20}{C + PV(M)} \quad (1)$$

where

$V$ = value of the asset

$W$ = multiplier for impact of works

$F$ = multiplier for technical feasibility risk

$A$ = multiplier for adoption

$B$ = multiplier for adverse adoption

$P$ = multiplier for socio-political risk

$G$ = multiplier for long-term funding risk

$DF_B$ = discount factor function for benefits, which depends on $L$

$L$ = lag until benefits occur (years)

$C$ = short-term cost of project

$PV$ = present value function

$M$ = annual cost of maintaining outcomes from the project in the longer term.

Details about each of the variables is provided in the PAF Instruction Manual. Below is a brief comment about each of them.

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[2] Joseph L.N., Maloney, R. and Possingham, H.P. (2009). Optimal allocation of resources among threatened species: a project prioritization protocol, *Conservation Biology* 23: 328-338.

### *Asset value (V)*

*V* is estimated in question 1.2(b) of the PAF. It is a score that represents the value of this asset, assuming that the asset is in good condition. The scoring range is calibrated such that a score of 100 corresponds to an asset of very high national significance (such as the Gippsland Lakes).

If we were conducting a full benefit-cost analysis, we would attempt to convert the environmental and social values of the asset into dollar terms, using techniques such as choice modelling or contingent valuation. The INFFER scoring scheme is proposed as a simple alternative in the expectation that sufficient information on dollar values will not be available.

### *Impact of works (W)*

*W* represents the proportional increase in future asset value that would result if the project was fully implemented (i.e. assuming that it is fully adopted) compare to if it wasn't. It is estimated in question 2.4(b) of the PAF. *W* is measured as a proportion of the total value of the asset (in good condition). This is done to allow easy comparability across projects.

### *Technical feasibility (F)*

*F* is a proportion which represents the probability that the benefits generated would be at least as large as specified in *W*. In other words, it is the probability that benefits will not be significantly less than *W*. It is estimated in question 2.5(b) of the PAF

### *Private adoption of works and actions (A)*

*A* is a proportion representing the probability that the on-ground works and actions specified in the project will actually be adopted, assuming that the project is fully funded and the project's delivery mechanisms are implemented. It is estimated in question 3.3(b) of the PAF.

### *Preventing adoption of adverse practices (B)*

*B* is a proportion representing the probability that the project will not fail due to adoption of adverse works or actions, despite efforts by the project to prevent that adoption from occurring. It is estimated in question 3.4(b) of the PAF.

### *Socio-political risks (P)*

*P* represents the probability that other socio-political factors will **not** derail the project. This includes the risk of non-cooperation by other organisations and the impacts of social, administrative or political constraints. The latter can include resistance to the project at the political level, bureaucratic approvals that would be needed, or opposition by local government. *P* is the probability that the project will not be prevented from reaching its goal due to one or more of these factors

### *Long-term funding risks (G)*

*G* represents the probability that essential long-term funding will be available to continue to maintain the benefits generated by this project, or to complete the essential works commenced by this project. It is estimated in question 4.6(d) of the PAF.

### *Time lag to benefits (L)*

*L* is the expected time lag in years until the desired bio-physical outcomes would be achieved. It represents the earliest time when a large proportion of the benefits will occur. It is estimated in question 2.3(a) of the PAF.

### *Discount factor ($DF_B(L)$)*

Benefits that occur further into the future are a lower priority than similar benefits that occur rapidly. This is captured through the use of "discounting". The discount factor is calculated as follows:

$$DF_B(L) = 1/(1.05)^L \quad (3)$$

This assumes that the real discount rate (net of inflation) is 0.05. There is some debate about the appropriate discount rate to use for environmental projects. A real rate of 0.05 is a commonly used rate that is a little lower than rates commonly used for projects with financial outcomes, but not as low as argued for by a minority of the protagonists.

### *Up-front costs (C)*

*C* is the sum of direct costs that will be incurred within the immediate time frame of this project – say, three to five years. This is a short enough time frame to ignore discounting (recognising that this simplification introduces a very slight error). *C* is recorded in question 4.5(b) of the PAF.

### *Ongoing or maintenance costs (PV(M))*

Some costs may be incurred each year in the long term, such as monitoring and evaluation, or enforcement costs, or ongoing compensation payments. These costs, called *M*, are estimated in question 4.6(c) of the PAF.

To make them comparable to the up-front costs, we need to express them as a present value (*PV*). Calculate the PV as follows:

$$PV(M) = 10.7 \times M$$

This assumes that the discount rate is 0.05 and the time frame for paying these costs is 20 years, commencing in year 4.

*Calculating the Benefit: Cost Index*

We can now calculate the Benefit: Cost Index using equation (1). This provides an index that is comparable across projects, and provides an indication of the projects that should be higher in priority for public investment. The higher the value of the BCI, the higher the priority of the project (other things being equal).

# Appendix 3: Economic optimisation analysis

The Gippsland Lakes P tool was used as the basis of an economic optimisation analysis. The optimisation spreadsheet model contains an enormous number of alternative management strategies. This stems from the large number of possible land-use configurations and the interdependence of integer decision variables—numbers involving no decimal places—representing the level of incentives and continuous variables representing the extent of the catchment over which such incentives are used. The high number of potential strategies complicates the evaluation of least-cost strategies through simple trial and error, particularly because trial solutions are often influenced by user bias and an analyst does not know how easily more superior configurations can be identified for a given problem instance. In comparison, optimisation procedures provide a convenient means of searching large numbers of possible configurations for potential strategies that maximise (or minimise) some goal subject to constraints (Doole and Pannell, 2008).

The presence of integer decision variables and their interdependence with continuous variables in this problem mean that there are many feasible strategies for each problem scenario. This complicates solution of the model with efficient linear and nonlinear programming algorithms, which are constructed to identify the most valuable solutions in a single feasible region. When multiple feasible regions exist, each solution identified by an algorithm gives no indication of the location or in which direction superior configurations exist. Moreover, it becomes impossible to validate whether a global optima has been reached, particularly in large problems. Thus, randomness is required to propel the search for high-quality solutions and such a search will only be terminated once more valuable configurations can no longer be found (Hoos and Stutzle, 2004).

This study utilises a genetic algorithm (GA) (Mitchell, 1996), one of the most popular stochastic search methods used worldwide. A GA defines feasible solutions to an optimisation problem as members of a population that evolves over time through selection, simulated reproduction (crossover), and mutation (Goldberg, 1989; Davis, 1991). Evolution according to a measure of fitness, denoting the relative suitability of each individual, continues until an acceptable solution is identified. Randomness enters the structure of the GA explicitly when the initial population is generated and when mutation randomly changes a member of the current population to yield a new solution. The maintenance of a population of candidate solutions prevents the algorithm from becoming trapped at a set of management strategies that is valuable, but not as valuable as broadly disparate plans. The effectiveness of the GA is further enhanced here by (1) conducting small searches around new points each time they are generated to identify whether superior nearby points exist, and (2) trying to repair infeasible candidate solutions at each iteration by making small perturbations of the simulated strategy. The GA is part of the Premium Solver Platform version 9.5 (Frontline Systems, 2009) package used for optimisation in Microsoft Excel.

The use of random search procedures is valuable for the identification of near-optimal solutions in problems containing multiple feasible regions. However, a number of practical drawbacks are apparent. First, initial members of the population are generated randomly, so the components of different problem instances may be widely different. For example, in subsequent simulations involving least-cost reductions in phosphorus load of 20 and 30 per cent, the strategies used may be very different given that the solution of either problem is independent and based on random influences. Second, the simulations can typically be time-consuming. However, the use of efficient software and the presence of only a small number of integer variables in this problem reduces the solution time of one model to around two minutes. Last, there is no guarantee that superior configurations do not exist; rather, it can only be stated that identified management strategies are near-optimal. The identification of high-quality solutions is enhanced in this study through:

- Prolonging the duration of the search above standard levels;
- Requiring very tight stopping conditions, so that the algorithm only terminates once all meaningful gains have been observed;
- Running the GA more than 3 times for each problem instance to identify if alternative optima can be identified; and
- Using identified solutions as starting guesses for subsequent optimisations to test whether they can be feasibly improved.