NUTRIENT EXPORT MONITORING

Introduction

The Nutrient Export Monitoring Project was an initiative of the Office of Environment and Heritage and was one of the seven projects in the Hawkesbury–Nepean River Recovery Program. The overall program aimed to prevent an estimated 48.2 tonnes of nutrients entering the river system each year and it was anticipated that the Water Smart Farms and Nutrient Smart Management projects would achieve over 95 per cent of this reduction. To evaluate the extent of these reductions, information was needed on the quantity of nutrients moving off farms before and after the implementation of the mitigation measures. Such information has been lacking, not only for the Hawkesbury–Nepean catchment, but also on a national basis. This project has sought to fill these information gaps.

The project was funded by the Australian Government under the *Water for the Future* initiative and received $0.8 million of the total $77.4 million allocated to the overarching Hawkesbury–Nepean River Recovery Program.

Objectives

The objectives of the Nutrient Export Monitoring Project were to:

- quantify the nutrient exports (levels of nutrients entering the river system) of primary industries within the Hawkesbury–Nepean catchment. This information will provide objective estimates of nutrients entering the river system and also identify locations for investments of on-ground works for reducing diffuse nutrient loads
- evaluate the extent of nutrient reductions achieved by the measures undertaken by the Water Smart Farms and Nutrient Smart Management projects. This information will identify the practicality and cost-effectiveness of the mitigation measures and assist future decision making on rural management practices and broader scale planning for the Hawkesbury–Nepean catchment
- provide a direct measure of the performance of the Water Smart Farms and Nutrient Smart Management projects.

The Nutrient Export Monitoring Project aimed to quantify the nutrient exports of primary industries within the Hawkesbury–Nepean catchment

Methods

The Nutrient Export Monitoring Project was managed by the Water and Coastal Science Section, Scientific Services Division of the Office of Environment and Heritage. The staff engaged in the project were members of this group and were supported administratively and technically by the Office of Environment and Heritage. Project team members reported through the line management of the Water and Coastal Science Section. Figure 27 illustrates the project governance.

Figure 27. Nutrient Export Monitoring Project governance
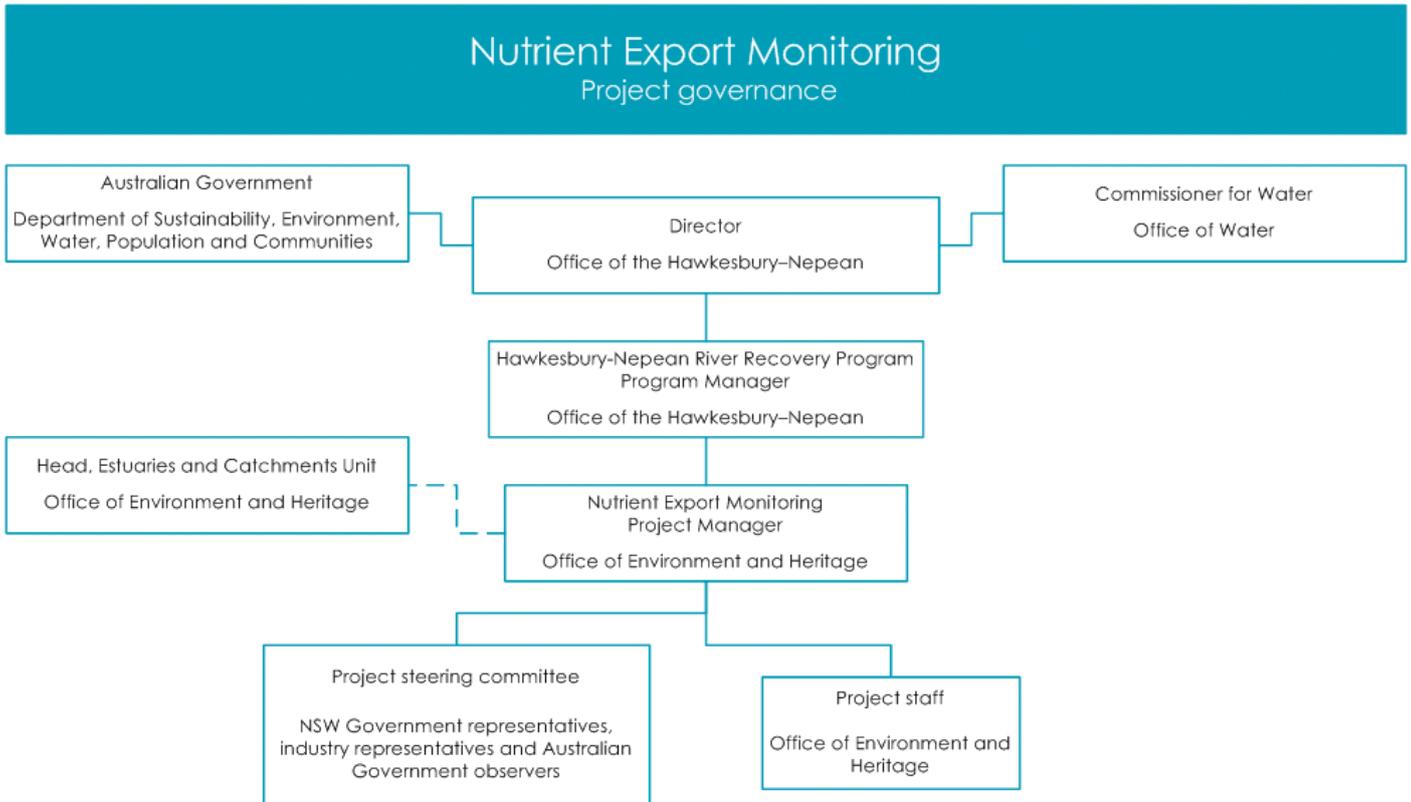
External guidance and advice was gained through the Nutrient Export Monitoring Project Steering Committee which met on a six-monthly basis. The project manager for the Nutrient Export Monitoring Project participated not only in the project steering committee meetings but also in Hawkesbury–Nepean River Recovery Program Steering Committee meetings for the overarching program. This gave strategic guidance and enabled coordination with other projects in the program. The overarching program steering committee also acted as a primary communication channel between the project team and representatives from the Australian Government.

A combination of farm-scale and broad-scale monitoring and experimentation and desktop assessments were employed to achieve the project objectives. Data collected were used in combination with existing data to derive locally specific nutrient export rates for the Hawkesbury–Nepean catchment. The export rates formed the basis for quantifying agricultural nutrient exports for the Hawkesbury–Nepean catchment below the major water supply dams, and reductions achieved through various nutrient export reduction strategies.

The farm-scale monitoring sites served additionally as case studies for the effectiveness of particular nutrient export reduction strategies and for the overall performance of the Water Smart Farms and Nutrient Smart Management projects in relation to their nutrient reduction objectives. Field experiments were used to measure the nutrient loads from particular farms that were engaged in nutrient reduction strategies. Desktop assessments, involving literature reviews and analyses of project proposal data, were used to fill remaining knowledge gaps.

Monitoring at farm-scale and broad-scale sites

Sampling was carried out at farm-scale sites on a range of different farm types and at broad-scale stream sites within the Hawkesbury–Nepean catchment. Run-off, effluent or leachate was sampled, or a combination of these was sampled depending on the site. All samples were analysed for total nitrogen and total phosphorus concentrations.

Farm-scale nutrient export rate monitoring

Farm-scale monitoring was conducted at 12 farm sites throughout the Hawkesbury–Nepean catchment. Sampling commenced at the first farm site in September 2009 and was then staggered at further sites due to availability. As shown in Figure 28, the 12 farm sites comprised:

- two extensive field vegetable sites (FV1 in the Richmond-Windsor agricultural region and FV2 in the Camden agricultural region)
- three intensive market garden sites (MG1 Rossmore, MG2 in Windsor and MG3 in Llandilo)
- three turf farm sites (T1, T2 and T3 in the Richmond-Windsor agricultural region)
- two dairy milking shed sites (D1 and D2 in the Camden agricultural region)
- one hydroponic greenhouse site (H1 in Rossmore)
- one cropping site (C1 in the Camden agricultural region).

Figure 28. Locations of farm sites

Details of the farm-scale monitoring at these sites are provided in Table F1.

|	Table F1			
	Nutrient Export Monitoring – monitoring at farm-scale sites			
Site*	**Farm type**	**Monitoring method**	**Monitoring period**	**Outcome**
FV1	Field vegetables	Automatic sampler, flow gauge and rain gauge	December 2009 to April 2010	Nutrient export rates derived
FV2	Field vegetables	Automatic sampler, flow gauge and rain gauge	April 2010 to May 2011	Nutrient export rates derived
MG1	Market garden	Automatic sampler, flow gauge and rain gauge	September 2010 to July 2011	Nutrient export rates derived
MG2	Market garden	Automatic sampler, flow gauge and rain gauge	March 2011	Nutrient export rates were not derived. Site abandoned due to flooding
MG3	Market garden	Automatic sampler, flow gauge and rain gauge	April to June 2011	Insufficient data were collected. Nutrient export rates were not derived
T1	Turf	Automatic sampler, flow gauge and rain gauge	November 2009 to November 2010	Nutrient export rates derived
T2	Turf	Automatic sampler, flow gauge and rain gauge	September 2010 to July 2011	Sampling interrupted due to irrigation works. Very little run-off generated due to unusual subsurface drainage. Nutrient export rates were not derived
T3	Turf	Automatic sampler, flow gauge and rain gauge	November 2010 to July 2011	Nutrient export rates derived
D1	Dairy milking sheds	Water level sensor and manual sampling	September 2010 to July 2011	Nutrient export rates derived
D2	Dairy milking sheds	Water level sensor and manual sampling	September 2010 to June 2011	Nutrient export rates derived
H1	Hydroponic greenhouses	Water level sensor and manual sampling	May to August 2011	Nutrient export rates derived
C1	Cropping	Rising stage sampler	February 2010 to March 2011	Nutrient export rates derived

*As illustrated in Figure 28

As shown below, the field vegetable, market garden and turf monitoring sites comprised a flow gauging weir, a water level logger, an automatic water sampler and, in most cases, a rain gauge. The automated sampler collected water samples during run-off events. The following calculations were made for each site:

- Run-off volumes for run-off events were calculated using flow rates derived from water level data.
- Flow-weighted mean concentrations for rain run-off events, irrigation run-off events and all events combined were calculated (Thornburg and Lowe, 2009).
- Site-specific run-off coefficients were calculated using rainfall and run-off data.
- Mean annual rain run-off volumes were calculated using mean annual rainfall (Bureau of Meteorology, 2007), watershed area and run-off coefficients.

Irrigation run-off volumes were extrapolated to annual volumes based on the sampling duration. Rainfall and irrigation run-off volumes were then multiplied by their respective flow-weighted mean concentrations to derive estimates of annual nutrient loads. These were then divided by watershed area to calculate total nitrogen and total phosphorus export rates.

Monitoring at the dairy sites involved collecting run-off samples from effluent when milking sheds were washed down. Run-off samples were then analysed for total nitrogen and total phosphorus concentrations and mean concentrations were derived from this data. A water level logger (which allowed run-off flow and volumes to be estimated) was installed at D1 following construction of a trafficable solids trap. Trafficable solids are the coarse solids within dairy effluent. The flow measurements and nutrient concentration data collected were used to calculate nutrient exports from this site. This nutrient export load was then divided by the number of milkers to derive per-head nutrient export rates. These export rates and mean total nitrogen and total phosphorus concentrations were later used in calculating nutrient export reductions achieved.

Monitoring system at a field vegetable site in Rossmore
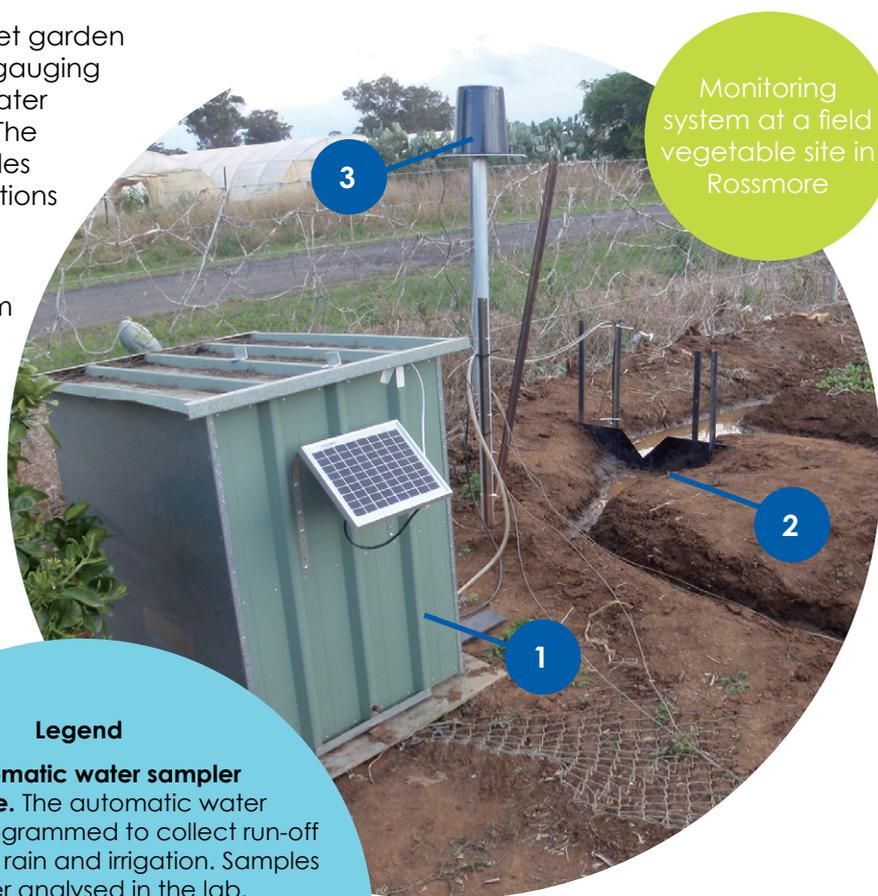
Legend

1. Automatic water sampler enclosure. The automatic water sampler is programmed to collect run-off samples after rain and irrigation. Samples are later analysed in the lab.

2. Flow gauging weir. The weir, combined with a water level logger, is used to measure the flow rate of water running off the field so that the volume of run-off over a given interval can be calculated.

3. Rain gauge. The gauge records the amount of rainfall.

At the cropping site, monitoring involved installing a rising stage sampler to passively collect run-off samples during run-off events. Rising stage samplers consisted of several sampling bottles fixed at increasing heights (stages) above the stream. This was supplemented with grab sampling (manually collecting water samples) where possible. The mean annual run-off volume for this site was calculated by multiplying the mean annual rainfall volume by the run-off coefficient for cropping reported in Novotny (2002). Mean annual nutrient loads were then calculated by multiplying the mean annual run-off volume by the mean nutrient concentrations derived from sampling at this site. These loads were then divided by land area to give nutrient export rates.

The monitoring methods at the hydroponics site (H1) were similar to those for the dairy site (D1). At H1, a water level logger was installed in a sump receiving waste leachate from the greenhouses. A pump, controlled by a float-switch, regularly pumped leachate from the sump to an adjacent pond. Grab samples were collected routinely both from the inflow to the sump and the outflow from the pond at this site. Nutrient concentration data and water level data were used to derive nutrient export rates for this site. Differences in nutrient mean concentrations were examined to determine the nutrient mitigation efficiency of the existing pond.

Broad-scale nutrient export rate monitoring

Broad-scale monitoring, involving sampling run-off from streams, was initiated in March 2009 with the aim of refining nutrient export rates for grazing and rural residential land uses. Rising stage samplers were installed at 15 stream sites throughout the catchment and sampling was initiated at a further 18 grab sampling sites, bringing the total number of sites to 33.

Sites with catchments dominated by a single agricultural land use were favoured for selection. Tree and shrub cover catchments were also sampled to help deduce nutrient export rates in agricultural catchments that were partially covered by trees and shrubs. During run-off events, run-off was passively sampled by these samplers as the water level increased in the stream. Grab samples were also collected at the rising stage sampling sites during run-off events. Run-off samples from these sites were analysed for total nitrogen and total phosphorus concentrations and these data were used to generate time-weighted mean concentrations for these sites.

The mean annual run-off volume for each broad-scale monitoring site was calculated by multiplying the mean annual rainfall volumes by typical run-off coefficients for dominant land uses (Novotny, 2002). The mean annual nutrient loads were then calculated by multiplying the mean annual run-off volumes by the time-weighted mean concentrations. These loads were then divided by land areas to give nutrient export rates.

Ultimately, a subset of these sites, where sufficient data were collected, was selected to define nutrient export rates for specific land uses. As shown in Figure 29, these comprised:

- one rural residential site (RR1 in the Camden area)
- four grazing sites (G1, G2, G3 and G4 in the Camden area)
- two tree and shrub cover sites (TS1 and TS2 in the Colo and Richmond areas).

Details of the broad-scale monitoring at these sites are provided in Table F2.

The catchment of the rural residential site partly comprised other land uses, so the loads for these other land use areas were calculated using the locally specific nutrient export rates derived as part of the project. The aerial extents of land uses within the catchment of each broad-scale monitoring site were quantified using a spatial land use dataset (Department of Environment and Climate Change, 2007) and a geographical information system (Esri, 2008). The non-rural residential loads were then deducted from the total load to give the nutrient loads for the remaining rural residential areas. This allowed nutrient export rates for the rural residential components of this catchment to be calculated.

Table F2 Nutrient Export Monitoring – monitoring at broad-scale sites				
Site*	Farm type	Monitoring method	Monitoring period	Outcome
RR1	Rural residential	Rising stage sampler and manual sampling	February 2010 to March 2011	Nutrient export rates derived
G1	Grazing	Rising stage sampler and manual sampling	February 2010 to March 2011	Nutrient export rates derived
G2	Grazing	Rising stage sampler and manual sampling	October 2009 to March 2011	Nutrient export rates derived
G3	Grazing	Manual sampling	February 2010 to March 2011	Nutrient export rates derived
G4	Grazing	Manual sampling	February 2010 to March 2011	Nutrient export rates derived
TS1	National park (predominantly)	Manual sampling	February 2010 to March 2011	Nutrient export rates derived
TS2	National park (predominantly)	Manual sampling	February 2010 to March 2011	Nutrient export rates derived

*As illustrated in Figure 29

Figure 29. Locations of broad-scale monitoring sites used to define grazing, rural residential and tree and shrub cover export rates
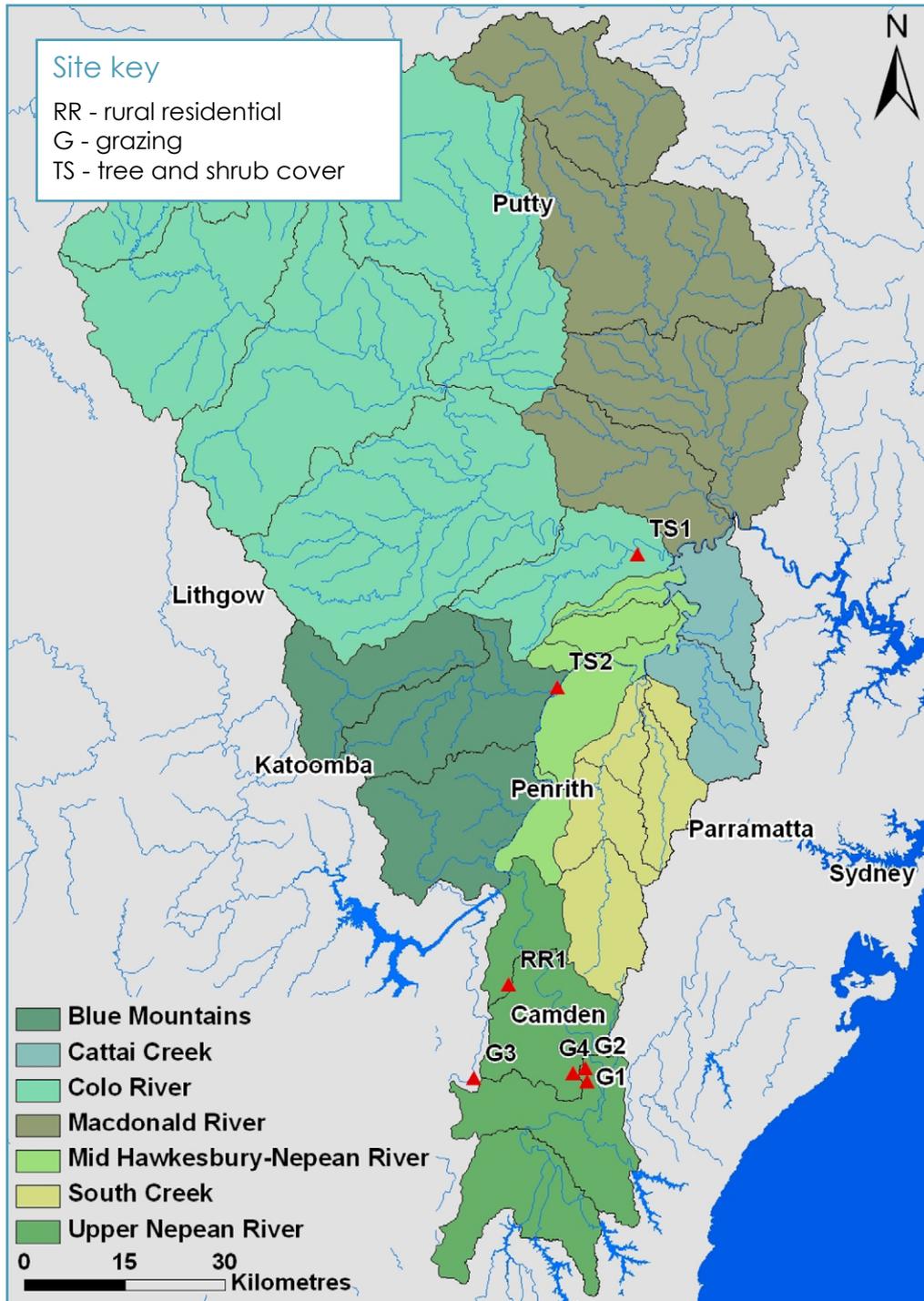
Deriving locally specific nutrient export rates for agricultural land use in the Hawkesbury–Nepean catchment

Locally specific nutrient export rates were needed to quantify:

- agricultural nutrient exports to the Hawkesbury–Nepean river system
- reductions achieved through various strategies implemented through the Nutrient Smart Management and Water Smart Farms projects.

A literature review was conducted which aimed to identify existing nutrient export rates for cropping, field vegetable production, turf farming, non-dairy grazing and dairy grazing, so as to better define representative nutrient export rates for agricultural land uses in the Hawkesbury–Nepean. Nutrient export rates derived from studies in south eastern Australia were collated. With the exception of turf, for which no previous data existed, and dairy grazing, for which only literature values were used, nutrient export rates sourced both from Nutrient Export Monitoring Project data and literature values were combined to derive median values for each of the seven land uses: field vegetables, turf, cropping, dairy grazing, non-dairy grazing, rural residential and hydroponic greenhouses. These median values were used as the total nitrogen and total phosphorus export rates for these land uses in the Hawkesbury–Nepean catchment.

Quantifying agricultural nutrient export loads for the Hawkesbury–Nepean catchment

Agricultural nutrient loads for the Hawkesbury–Nepean catchment were calculated by multiplying the aerial extent of each land use by the locally specific nutrient export rates. Land use aerial extents were defined using an existing spatial land use dataset (DECC, 2007). This dataset covered the entire project area with the exception of an area comprising part of the Cattai Creek and Berowra Creek catchments. In the areas that were not covered by this dataset, dominant land uses were digitised using aerial imagery (Esri, 2008), completing the land use dataset.

Land uses were grouped into categories: grazing, turf, field vegetables, rural residential (including hobby farms), cropping, other agriculture, urban, tree and shrub cover and other non-agricultural land uses. Aerial coverage of each of these land use categories was then summed for each of the major subcatchments within the Hawkesbury–Nepean catchment and then multiplied by nutrient export rates for each land use category.

In the case of other agricultural land uses, the medians of all agricultural land use nutrient export rates were used.

Determining the effectiveness of nutrient export reduction strategies

The range of nutrient export reduction strategies implemented through the Nutrient Smart Management and Water Smart Farms projects grew and evolved through the life of the project.

The effectiveness of the key strategies of compost application, run-off capture and reuse, effluent treatment systems, riparian stock exclusion fencing and hydroponic leachate recycling was examined as part of the Nutrient Export Monitoring Project.

Compost application was an important aspect of the Water Smart Farms and Nutrient Smart Management projects. Three rainfall simulation experiments were conducted as part of the Nutrient Export Monitoring Project in order to assess the effectiveness of this strategy in reducing nutrient exports.

The three experiments were carried out at two vegetable farm sites near Windsor, NSW. The compost applied in the experiments was derived mainly from forestry waste and was certified to Australian Standard 4454. The compost was applied as a soil conditioner and was integrated into the soil rather than applied as mulch on the surface. Methods varied slightly amongst the three experiments but generally run-off was collected from plots with and without compost applications. Volumes of run-off were quantified and samples were analysed for total nitrogen and total phosphorus concentrations. Volumes, concentrations and loads were compared between plots with and without compost applications.

The capture of run-off and nutrients in nutrient retention ponds was also a key strategy implemented by the Water Smart Farms and Nutrient Smart Management projects. In most cases the works involved constructing a new nutrient retention pond or expanding, de-silting or improving existing retention ponds. Monitoring sites were established at eight of these farms as part of the Nutrient Export Monitoring Project. These comprised two extensive field vegetable farms, three intensive market gardens and three turf farms.

These sites served as case studies for various land use types and nutrient mitigation strategies. Initially, pre- and post-implementation monitoring was to be carried out at each of these sites but ultimately the works could not be completed in time to carry out post-implementation sampling. Sampling of run-off was carried out upstream and downstream of an existing relatively ineffective nutrient retention pond at one field vegetable farm site (FV2 in Figure 28). These data gave an indication of the effectiveness of existing low-capacity ponds. Methods employed at case study sites varied greatly.

A significant number of the project proposals involved installing riparian stock exclusion fencing. To help quantify the nutrient reductions achieved through this management practice, a literature review was conducted to define typical rates of nutrient:

- deposition by cattle in riparian zones and streams
- buffering provided by buffer vegetation.

Implementation of hydroponic leachate recycling was carried out at several sites as part of the Water Smart Farms and Nutrient Smart Management projects. Effective leachate recycling retains the vast majority of leachate and associated nutrients on site. As such, the nutrient export rates derived from data collected at site H1 (see Figure 28) formed the basis for assessing the effectiveness of this strategy.

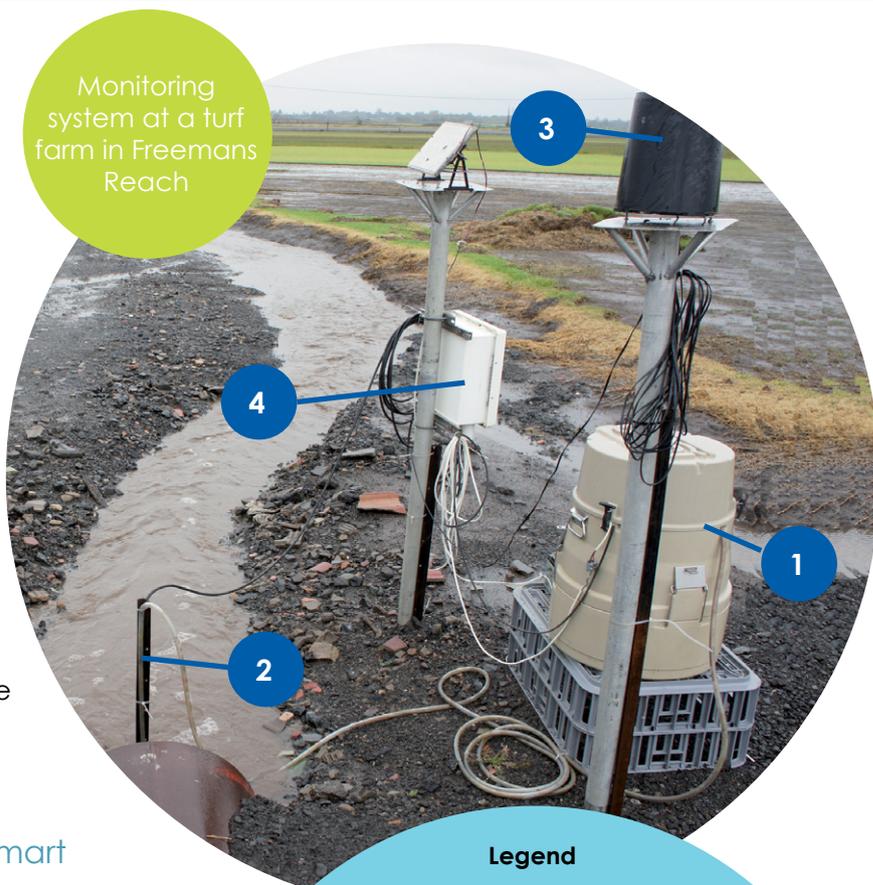Monitoring system at a turf farm in Freemans Reach

Assessing the performance of the Water Smart Farms and Nutrient Smart Management projects

There was a broad range of farm types taking part in the Water Smart Farms and Nutrient Smart Management projects and the nutrient reduction strategies employed were specific to each farm's requirements. The combinations of farm type, nutrient reduction strategies and other factors were so varied that assessments of nutrient reductions had to be tailored to each project site.

The proposals for each of the Water Smart Farms and Nutrient Smart Management sites provided much of the information used to calculate the nutrient export reductions achieved. This information included land uses, land area, management practices, pre-existing nutrient mitigation and some soil and water analysis data. At each site, nutrient loads were calculated using the locally specific nutrient export rates.

Legend

1. Automatic water sampler. The automatic water sampler is programmed to collect run-off samples after rain and irrigation. Samples are later analysed in the lab.

2. Water level sensor and sampler intake. The water level in the pipe is logged and used to measure the flow rate of water running off the field so that the volume of run-off over a given interval can be calculated. Water samples are collected from the pipe outlet.

3. Rain gauge. The gauge records the amount of rainfall.

4. Data storage and control device. Data is recorded in the data logger. The device also controls the sampler, triggering sample collection during a flow event.

All of the 12 farm-scale monitoring sites were on properties that were participating in the Water Smart Farms or Nutrient Smart Management projects or both and, where possible, site-specific nutrient export rates were used to estimate nutrient loads. Pre- and post-implementation nutrient exports were then calculated using the typical reduction rates identified in the nutrient reduction strategy assessments. The nutrient export reduction for the site was then calculated by identifying the difference between the pre- and post-implementation exports.

A number of other nutrient reduction strategies have been implemented as part of the Water Smart Farms and Nutrient Smart Management projects. These included erosion control, irrigation management and fertiliser management. In these cases, nutrient export reduction estimates were calculated using information provided in proposals and data from the literature. Nutrient reductions were calculated for each of the major land uses and nutrient reduction strategies.

Communication and engagement

Project staff undertook a range of communication and engagement activities aimed at helping the community (particularly landholders) to understand the Nutrient Export Monitoring Project. These included hosting an information stand at a farming exhibition, presenting information at industry field days, producing and distributing information flyers and fact sheets and one-on-one engagement with landholders during site visits.

Results

The Nutrient Export Monitoring Project has successfully:

- quantified the nutrient export of primary industries within the Hawkesbury–Nepean catchment
- evaluated the extent of nutrient reductions achieved by the Water Smart Farms and Nutrient Smart Management projects. It has not been possible to directly measure the performance of these projects due to project timeline delivery constraints which did not allow for pre and post-project monitoring.

The nutrient export rate data developed through this project are of particular value to catchment managers, planners and policy makers as they help to inform decisions regarding where to target nutrient export reduction measures in the future.

Technician Adam McSorley collecting a greenhouse wastewater sample at Rossmore

Communicating results

Results from the project were communicated using the following methods:

- an information flyer published in September 2010
- an information stand at the Farming Small Areas Expo 2010 held at the Hawkesbury Showground, Clarendon on 12-13 November 2010
- an information evening held on 14 September 2010 for turf farmers in Windsor, which was attended by approximately 30 turf farmers, 10 project officers and various other industry representatives
- articles in the Hawkesbury–Nepean River Recovery Program electronic newsletter (HNRRP e-news)
- two fact sheets published in September 2011. One provided a general overview of agricultural sources of nutrients and nutrient mitigation measures while the other provided technical information about nutrient exports from different agricultural land uses in the Hawkesbury–Nepean catchment and mitigation rates of various measures.

Agricultural nutrient exports

Agricultural nutrient exports were quantified for the subcatchments below the major water supply dams of the Hawkesbury–Nepean River. Agricultural nutrient exports amounted to 1159 tonnes per year of total nitrogen and 213 tonnes per year of total phosphorus (see Table F3).

As described previously, these results are based on monitoring from the Nutrient Export Monitoring Project and values derived from a technical literature review. The nutrient export values adopted in this calculation are listed in Table F4.

As anticipated in the project's first objective, this information will help identify priority locations for future works aimed at reducing diffuse nutrient loads from agricultural lands. Despite comprising only 2.5 per cent of the agricultural area of the catchment, field vegetable and turf farms constituted 42 per cent of the total nitrogen and 49 per cent of total phosphorus exports from agriculture. The South Creek, Upper Nepean River and Mid Hawkesbury–Nepean River subcatchments contained the greatest areas of these land uses and were therefore the subcatchments that contributed the greatest agricultural nutrient exports.

Table F3
Nutreint Export Monitoring – annual agricultural total nitrogen and total phosphorus loads in the subcatchments below the major water supply dams of the Hawkesbury–Nepean catchment

Subcatchment	Nutrient loads (tonnes per year)	
	Total nitrogen	Total phosphorus
South Creek	322	58
Upper Nepean River	267	45
Mid Hawkesbury–Nepean River	264	60
Colo River	152	21
Cattai Creek	104	21
Blue Mountains	21	4
MacDonald River	29	4
Total	**1159**	**213**

Table F4
Nutrient Export Monitoring – nitrogen and phosphorus export rates by land use activity derived by the project

Land use activity	Nutrient export rate (kilograms per hectare per year)	
	Total nitrogen	Total phosphorus
Field vegetables	122	22
Turf farms	53	20
Cropping	13.5	3.2
Dairy grazing	4.4	2.9
Non-dairy grazing	2.4	0.3
Hydroponic horticulture	1560	111
Rural residential	4.2	0.8

As indicated in Figures 30 and 31, the South Creek and Mid Hawkesbury–Nepean River subcatchments had the greatest intensities (exports per area of agricultural land) of agricultural nutrient exports. Nutrient mitigation measures targeting field vegetable and turf farms in these subcatchments would have the potential to achieve further substantial reductions in agricultural nutrient exports to the river.

Figure 30. Mean agricultural nitrogen export intensities for main subcatchments of the Hawkesbury–Nepean catchment
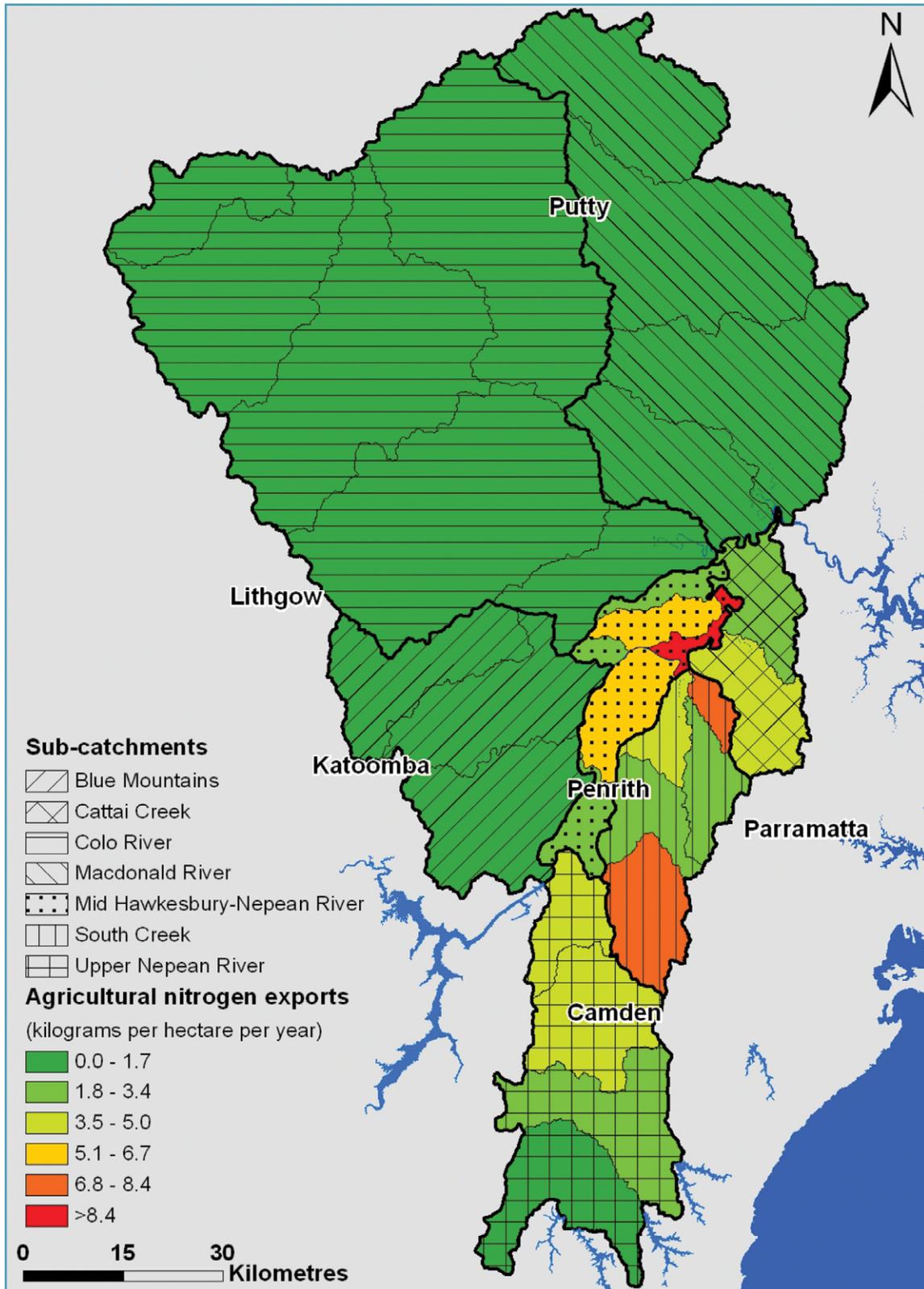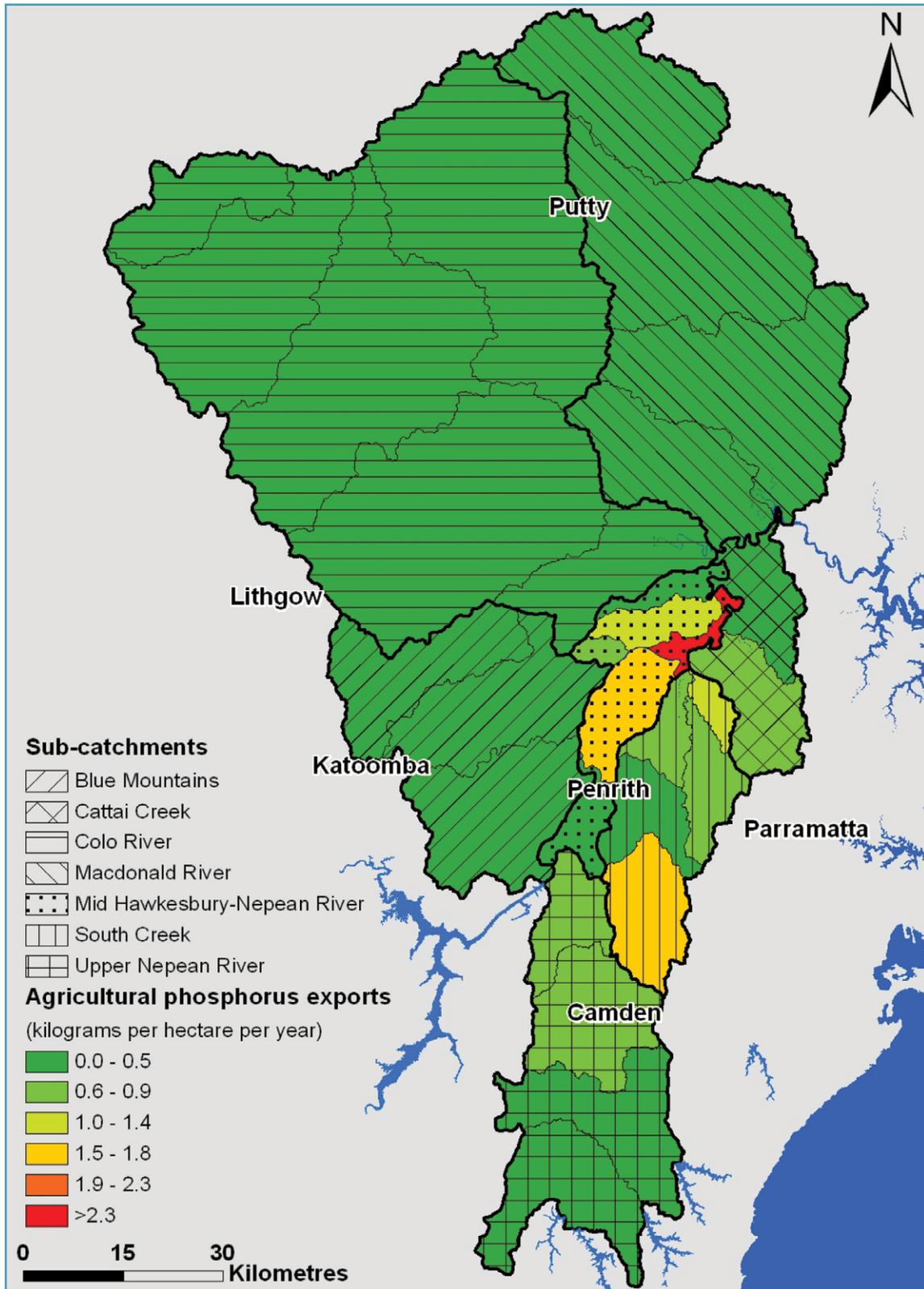
Figure 31. Mean agricultural phosphorus export intensities for
main subcatchments of the Hawkesbury–Nepean catchment

Nutrient export reductions achieved by the Water Smart Farms and Nutrient Smart Management projects

The nutrient export reductions achieved by the Water Smart Farms and Nutrient Smart Management projects were verified using the methods described on pages 108-116 of this report.

The Water Smart Farms Project achieved nutrient reductions of 15 tonnes of total nitrogen and 3.5 tonnes of phosphorus per year. As illustrated in Figure 32, these were well in excess of the project objectives of 11.8 tonnes of total nitrogen and 1.2 tonnes of total phosphorus per year.

Similarly, as shown in Figure 33, the Nutrient Smart Management Project exceeded its nutrient reduction objectives of 27 tonnes of total nitrogen and 6 tonnes of total phosphorus per year, achieving reductions of 48 tonnes of total nitrogen and 13 tonnes of total phosphorus per year.

Values adopted in these calculations for the nutrient mitigation efficiencies of some nutrient reduction practices, derived from a review of relevant technical literature undertaken for this project, are listed in Table F5. As noted previously, calculations of reductions achieved by other measures were largely based on site-specific factors adopted in project proposals.

As anticipated by the objectives, information collated by this project will provide a basis for identifying the practicality and cost-effectiveness of nutrient mitigation measures. It will also assist future decision making on rural management practices and broader scale planning for the Hawkesbury–Nepean catchment. Indeed, nutrient reduction estimates derived by the Nutrient Export Monitoring Project have subsequently been used to derive estimates of the relative cost-effectiveness of nutrient reduction activities undertaken (see Figure 34).

It is evident from Figure 34 that cost-effectiveness is influenced by both the nature of the nutrient management activity and the land use on which it is practised. This is due to the varying nutrient loads emanating from different agricultural land uses (e.g. improved fertiliser management is much more cost effective on vegetable farms than on orchards).

Figure 32. Nutrient reduction performance of the Water Smart Farms Project
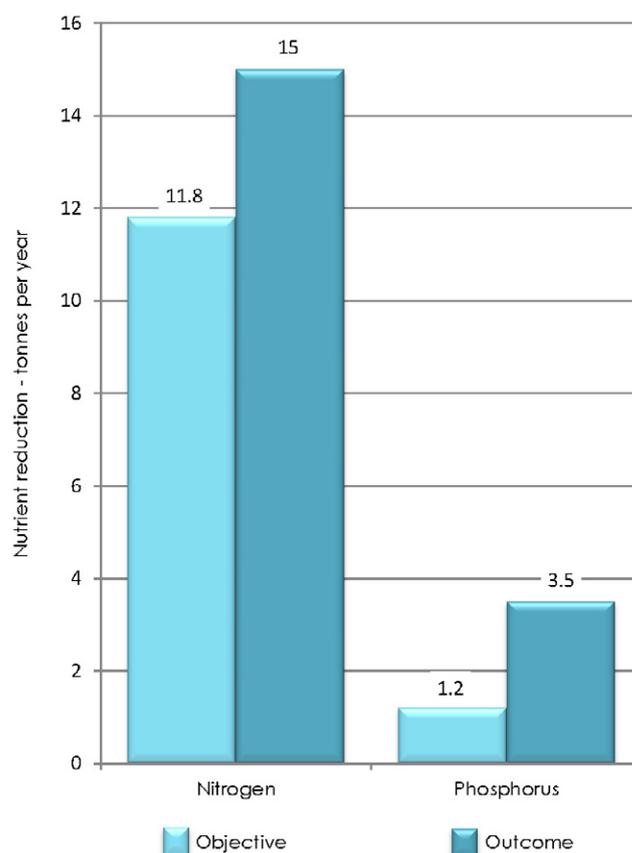
Figure 33. Nutrient reduction performance of the Nutrient Smart Management Project
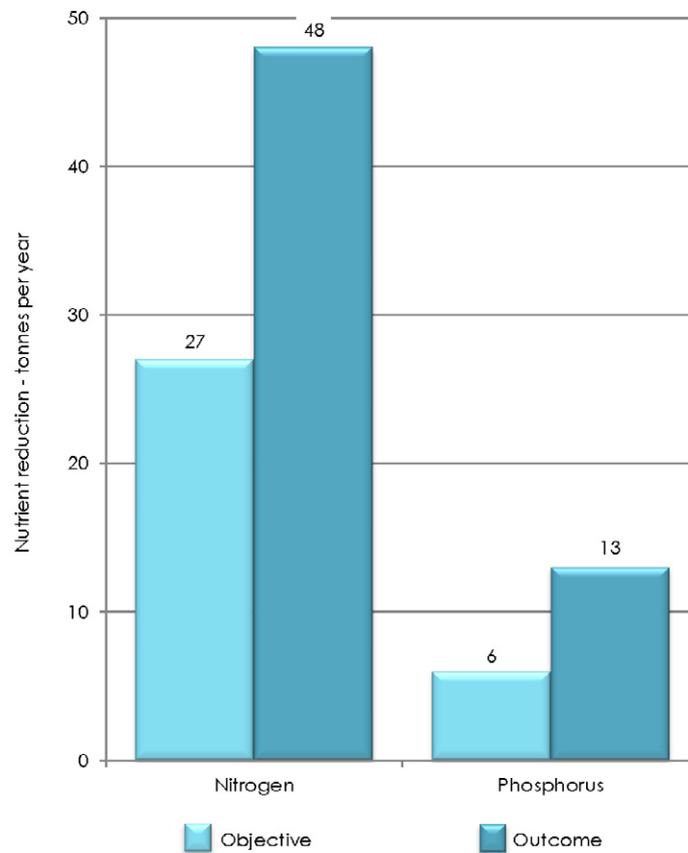

Table F5
Nutrient Export Monitoring – effectiveness of some nutrient reduction activities determined from review of relevant technical literature*

	Reduction in nutrient load (%)	
Nutrient reduction activity	Total nitrogen	Total phosphorus
Nutrient retention ponds	74	61
Riparian stock exclusion fencing and riparian buffers	50	53
Soil amendment - compost	14	49
Dairy effluent treatment ponds	39	14
Dairy effluent treatment ponds combined with land application of effluent	90	98
Mechanical soil aeration	28% reduction in run-off volume	

*Relevant technical literature: (Benham and Mote, 1999; Bjorneberg and Lentz, 2005; Bolan *et al*., 2004; Brown *et al*., 1981; Butler *et al*., 2007; Butler *et al*., 2008; Cooper and Knight, 1990; Dela-Cruz and Carpenter, 2006; Dillaha *et al*., 1989; Edwards *et al*., 1999; Evanylo *et al*., 2008; Franklin *et al*., 2006; Franklin *et al*., 2007; Lee *et al*., 2000; Lee *et al*., 2003; Line *et al*., 2000; McKergow *et al*., 2003; McKergow *et al*., 2006; McNamara and Cornish, 2002a; McNamara and Cornish, 2002b; Pit *et al*., 1999; Spargo *et al*., 2006; Sweeten and Wolfe, 1994; Szajdak *et al*., 2006; van Vliet and Derksen, 2004; van Vliet *et al*., 2006; Weaver *et al*., 2005)

Figure 34. Relative cost-effectiveness of nutrient management activities undertaken by the Nutrient Smart Management Project

Cost-effectiveness
($ per kilogram of nutrient captured or retained per year)
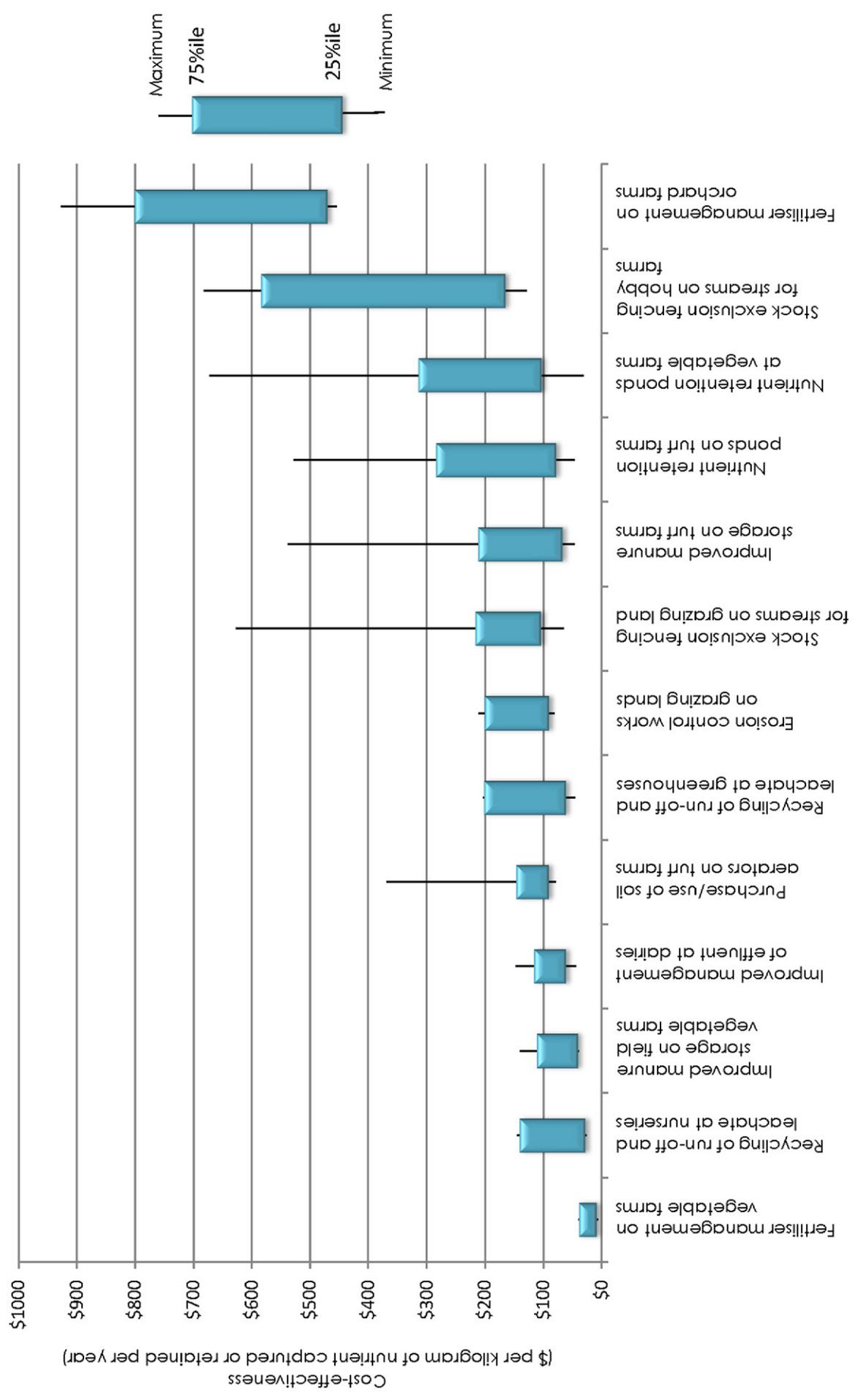
Effectiveness of the Water Smart Farms and Nutrient Smart Management projects

The scheduling of the Water Smart Farms and Nutrient Smart Management projects posed some problems for assessing the effectiveness of nutrient mitigation measures undertaken by these projects. Post-implementation monitoring was not able to be carried out at these sites because the nutrient reduction works were not implemented until the final stage of the Nutrient Export Monitoring Project.

The timeframes for monitoring and evaluating components of future similar projects should be offset from those of implementation components, so as to begin and end later. This would allow implementation components to start the process of selecting sites and determining the main types of measures that are to be implemented. Monitoring and evaluation components would then have the opportunity to monitor before and after measures have been implemented.

Local monitoring of agricultural nutrient loads was found to be beneficial and has provided new information specific to the Hawkesbury–Nepean catchment.

Learnings

Learnings resulting from the Nutrient Export Monitoring Project are:

- Monitoring nutrient exports from agricultural activities is relatively expensive and requires skill, experience and adequate time before and after on-ground works to rigorously quantify project benefits.

- Despite comprising only 2.5 per cent of the agricultural area of the lower catchment, field vegetable and turf farms are estimated to produce 42 per cent of the total nitrogen and 49 per cent of the total phosphorus exports from agricultural lands in the lower Hawkesbury–Nepean river catchment (i.e. below the main water supply dams).

- The most cost-effective nutrient management strategies implemented under the Nutrient Smart Management Project were:
  - » improved fertiliser management on vegetable farms
  - » run-off and leachate recycling at nurseries
  - » improved manure storage on field vegetable farms
  - » improved effluent management at dairy farms.

- Local monitoring of agricultural nutrient loads was found to be beneficial and has provided new information specific to the Hawkesbury–Nepean catchment. In most cases, monitoring results were broadly consistent with values reported elsewhere in the technical literature, providing greater confidence in the local use of these results to guide future regional planning and investment. In some cases, however, monitoring results from this project differed to those reported from previous studies. For example, the Nutrient Export Monitoring Project has found phosphorus export rates at field vegetable farms and market gardens to be higher than those suggested from previous investigations.

- While farmers were often enthusiastic about the project, the majority were not available to carry out practical sampling tasks. These tasks were conducted by the project team.

- To measure nutrient export loads accurately, both flow and nutrient concentrations must be measured simultaneously. However, if the interest is primarily in measuring changes in nutrient loads, it could be feasible in some cases to focus on either flow or concentration and assume that the other aspect (flow or concentration) is relatively constant or can be estimated by means other than direct measurement.