Goulburn Broken Water Quality Strategy

Issues Paper 2A
(IP2A)
Nutrients from Dryland Diffuse Sources
(Addendum)

May 1996

1. Introduction

Since the publication of Issues Paper No 2 (IP2), which investigated nutrients from dryland diffuse sources, work has been done to more accurately calculate catchment nutrient generation rates. The revised rates are in some cases substantially different from those presented in the original issues paper. This has significant implications for the conclusions originally drawn. The WQWG has decided to prepare this addendum (IP2A) to Issues Paper 2 to canvass these revised conclusions.

In addition, the preparation of this addendum allows the opportunity to address some corrections to various parts of the original issues paper and to include some further information, which has since become available.

This paper reviews Sections 4.3, 4.6, 5 and 9 of Issues Paper 2.

The work of Kelly O’Shannassy (Water Ecoscience), Peter Hopmans (Centre for Forest Tree Technology), and Michael Papworth (CNR) is providing information and comment on sections of this paper is acknowledged.

2. Catchment Nutrient Generation Rates

2.1 Estimating Catchment Nutrient Loads

Methods of estimating catchment nutrient generation rates include:

- determining land use generation rates from a combination of gauged catchment data and literature values and assigning these rates to the estimated area of land use in the catchment
- assigning ungauged catchments to similar gauged catchments and estimating loads.

Both approaches have their problems. The first requires good land use information as well as reliable land use nutrient generation rates. A problem with the second approach is that large areas of the catchment are ungauged (eg northern section of Shires of Yea and Alexandra) - what values do we assign them? There may also be errors associated with scaling up factors.

This paper attempts to estimate catchment nutrient loads using both methods. The estimates presented are just that - estimates. They will be updated as more information becomes available.

2.2 Dryland Catchment Area.

The total area of the catchment is approximately 2.4 million ha. Of this, approximately 570 000 ha is identified as the “irrigation region” of the catchment (although even this includes substantial dryland areas (71 500 ha (SIRLWSMP 1995)).

The remaining 1 830 000 ha is identified as the "dryland" part of the catchment. Table 1 shows the dryland part of the catchment split into "old" municipal boundaries. (MAP) Table 1 also estimates areas in the Upper-Mid and Mid-Lower catchment.

Table 1 - Dryland Area by "Old" Municipal Boundaries.

Municipality	Total area km2	Estimated % in catchment	Estimated % of GB catchment proportion in dryland	Area (est) in Dryland km2	Area in Mid-Upper catchment	Area in Mid-Lower catchment	Area of Farmland (km2) from ABS (Table 4 in IP2)
Alexandra	1905	100	100	1905	1905		470
Benalla (City)	16	100	100	16		16	16
Benalla (Shire)	2320	100	100	2320		2320	1230
Broadford	576	100	100	576	576		138
Euroa	1412	100	100	1412		1412	961
Goulburn	1031	100	95	1031		1031	718
Kilmore	508	50	100	254	254		235
Mansfield	3919	100	100	3919	3919		765
McIvor	1295	50	100	650		650	
Pyalong	577	100	100	577		577	
Seymour	945	100	100	945		945	623
Shepparton	917	100	30	275		275	
Tungamah	1128	100	66	745		745	897
Violet Town	935	100	100	935		935	585
Waranga	1644	66	50	540		540	
Yarrawonga	627	100	80	500		500	
Yea	1391	100	100	1391	1391		639
TOTAL	21146			17991	8045	9946	

Note small areas in the former municipalities of Whittlesea, Eltham, Healesville, Upper Yarra are ignored, as is the portion of Mansfield in Gippsland. Source of areas - Victorian Municipal Directory.

The estimated area in Table 1 is in reasonable agreement with the figure of 1 830 000 ha above.

2.3 Catchment Land Use

Determining dryland catchment land use is a frustrating exercise. The many different published catchment based land use figures conflict, do not agree and land use classifications vary. As well, the boundary of the "dryland" does not coincide with shire, parish or other reporting boundaries. The land use figures reported in Issues Paper 2 are based on, amongst other things, ABS statistics. For the year data was selected, ABS surveyed only those properties with an "estimated agricultural value of output" greater than $25000. Many farms were excluded. Therefore the total farm area reported using the ABS cannot be relied upon to provide a reasonable guide to catchment land use. (see Table 1, column 8)

The Goulburn Statistical Division covers parts of the catchment, excluding all of the Shires of McIvor, Yarrawonga and Pyalong and including parts of the Shires of Waranga and Kilmore not in the catchment.

It is concluded that it is not possible to estimate land use in this way.

In the interim an estimate of land use has been made using data gathered from a variety of sources (especially Cottingham, 1995 and DWR 1989). Land use in the dryland part of the catchment is therefore estimated to be as shown in Table 2. This also shows the land use estimates made in IP2. Note the considerable differences between the two sets of figures.

Table 2 - Estimated land use in the dryland part of the Goulburn Broken and comparison with figures shown in Table 5.4 in IP2

	Mid Lower		Upper mid		Total	
	IP2A	IP2	IP2A	IP2	IP2A	IP2
Native Vegetation (forested)	122800	294000	476800	611000	599600	905000
General agriculture (dryland-pasture and cropping)	740900	490000	344000	193000	1084900	683000
Intensive agriculture (irrigation and horticulture)	10000	7500	2000	2000	12000	9500
Plantation (pines)	6400	-	16940	-	23340	-
Urban ***	700	-	770	-	1470	-
Total	880800		840510		1721310	

(irrigated area an estimate from GMW Culture sheets - D Poulton.)

This can only be used as an estimate. Note that it is about 100 000 ha short of the total catchment area of 1.83 M ha estimated in Section 3.2. Some of this could be attributed to water bodies, roads, etc. More accurate figures should be acquired, but this exercise is beyond the scope of this paper.

Conclusions:
- Need for more accurate and reliable land use data.
- Accept the figures in Table 2 (IP2A columns) in the interim.

2.4 Nutrient and Flow Data Availability

2.4.1 Nutrients in Streams

Major data sources for nutrients in streams in the dryland part of the catchment are:
- Victorian Water Quality Monitoring Network (VWQMN)
- Major storages monitoring

The EPA also collects data at two sites on the Goulburn River. Information from these sites has not been assessed in this paper.

The VWQMN collects data on a range of parameters, including TP, TN, TKN, etc on a monthly basis at 18 sites in the dryland. (Refer to VWQMN Annual Report (Hunter and Zampatti (1994) for further information). The availability of data for rivers and streams in the Goulburn Broken catchment is shown in Appendix 1. Length of record of nutrient monitoring varies from over 5 years to 2 years. Prior to 1990 data was collected only quarterly and this information has not been used in this analysis. Not all sites are monitored for nutrients. Conclusions drawn from these short lengths of record needs to be treated with some caution as it cannot be considered representative of a range of climatic conditions. It is however the best data available.

2.4.2 Flow

Flow data is recorded at sites on a continuous basis as part of the statewide Surface Water Quantity Assessment Program and Goulburn Murray Water flow monitoring programs. This information is retrieved and cross checked before being entered on the HYDSYS database, which holds all Victorian flow monitoring information. Flows are calculated using rating curves developed from regular field measurement.

Table 3 summarises discharge and discharge generation information for gauging stations in the Goulburn Broken catchment (shaded rows indicate dryland catchments for which nutrient data is available.)

Table 3 - Runoff from gauged Catchments Goulburn Broken Catchment.

Station	Description	Area km2	Mean annual discharge ML	Discharge ML/km2
405241	Rubicon river at Rubicon	129	134000	1038.8
405218	Jamieson R at Gerrans Bridge	368	235000	638.6
405257	Snobs ck at Snobs Ck	51	32000	627.5
405256	Corduroy Ck at Eildon	41	24200	590.2
405104	Crotty ck at Narbethong	1.2	664	553.3
405219	Goulburn R at Dohertys (nr Jamieson)	694	375000	540.3
405205	Murrindindi above Colwells	108	57200	529.6
405209	Acheron River at Taggerty	619	327000	528.3
405227	Big River at Jamieson	619	320000	517.0
405215	Howqua R at Glen Esk	368	187000	508.2
405264	Big River at Frenchmans Ck	333	154000	462.5
405263	Goulburn upstream of Snake Junc	327	136000	415.9
405214	Delatite R at Tonga Bridge	368	127000	345.1
405233	Spring Ck at Strathbogie	28	9570	341.8
405217	Yea River at Devlins bridge	360	109000	302.8
405236	Island Ck at Glenburn	47	12100	257.4
405234	Seven Cks at Pollie McQuinns	154	39500	256.5
405267	Seven Cks at Euroa	332	76900	231.6
404208	Moonee Ck at Lima	94	20800	221.3
404207	Holland Ck at Kelfeera	451	93700	207.8
404203	Broken River at Benalla	1461	287000	196.4
405200	Goulburn at Murchison	10772	2080000	193.1
405231	King Parrot Ck at Flowerdale	181	34300	189.5
405244	Merton Ck at Merton	55	10200	185.5
405278	Godfrey Ck at Yarck	71	11900	167.6
405228	Hughes Ck at Tarcombe Rd	471	78100	165.8
405261	Spring Ck at Fawcett	60	9640	160.7
404206	Broken River at Moorngag	497	77900	156.7

405252	Glen Ck at Maindample	35	5430	155.1
405247	Stony Ck at Tamleugh	339	52500	154.9
405262	Creightons Ck at Creighton	86	13300	154.7
405239	Sunday Ck at Clonbinane	36	5560	154.4
405254	Tallangallook Ck at Bonnie Doon	45	6750	150.0
405274	Home Ck at Yarck	187	27100	144.9
405251	Brankeet Ck at Ancona	121	17500	144.6
405238	Mollison Ck at Pyalong	163	23000	141.1
404216	Broken R at Goorambat	1924	234000	121.6
405204	Goulburn at Shepparton	16125	1930000	119.7
405246	Castle Ck at Arcadia	164	19500	118.9
405240	Sugarloaf Ck at Ash bridge	609	66200	108.7
405245	Ford Ck at Mansfield	115	12100	105.2
405265	Mill Ck at Tallarook	30.4	3180	104.6
405212	Sunday Ck at Tallarook	337	33900	100.6
405232	Goulburn at McCoys	16806	1680000	100.0
404220	Broken River at Nillahcootie outlet	422	39100	92.7
405248	Major Ck at Graytown	282	23200	82.3
405226	Pranjip ck at Moorilim	787	62200	79.0
404218	Broken River at Nillahcootie head gauge	422	30700	72.7
405279	Wappentake Ck at Glenlea	88	4740	53.9
405230	Cornella Ck at Colbinabbin	259	11700	45.2
405280	Major Ck at Glenlea	64	2800	43.8
405229	Wanalta Ck at Wanalta	108	4310	39.9
405281	Compton Ck at Graytown	123	4620	37.6
404204	Boosey Ck at Tungamah	845	30100	35.6
404214	Broken Ck at Katamatite	270	9380	34.7
404210	Broken Ck at Rices Weir	3033	74300	24.5

Data Source: Victorian Surface Water Information to 1987. RWC.

2.5 Revised gauged catchment nutrient generation rates.

Kelly O'Shannassy from Water EcoScience has calculated catchment nutrient generation rates at 14 sites using the full amount of flow information available and the results of monthly nutrient monitoring carried out for the Victorian Water Quality Monitoring Network. The loads were calculated by multiplying monthly flows (daily flows totalled into monthly flows) by the corresponding concentration and adding the monthly load results into annual loads (see Table 4 for Summary and Appendix 2 for data). Annual loads have been averaged and divided by the catchment area to derive a catchment nutrient generation rate in terms of kg/ha/yr.

In most cases these rates differ considerably from those shown in the original Dryland Issues Paper.

Ideally nutrient generation rates would be calculated from daily flow and daily concentration data. O'Shannassy's method eliminates errors caused by underestimating flows, but nothing can be done about the monthly concentration data. Given we don't know how nutrient concentrations vary over time these revised generation rates may still be out by a considerable, unknown, factor. Cottingham (1995) investigated flow-nutrient relationships but was unable to establish meaningful relationships based on current data. This may become possible in the future as more data becomes available. Cottingham also investigated trends in nutrient concentrations. From the data available at the time of analysis no trends were detected.

Table 4 - Summary of Revised Catchment Nutrient Generation Rates.

Sino	Sub-catchment	Length of data record (years) used to calculate loads	Catchment area (ha)	Average Generated Loads kg/ha/yr		Average Nutrient Load (tonnes/yr)	
				TP	TN	TP	TN
405214	Delatite R	4	36800	0.17	2.3	6.4	84
405237	Seven Ck at Euroa	2	33200	0.13	2.63	4.3	87
404207	Hollands Ck	4	45100	0.11	1.77	4.9	80
405209	Acheron R	4	61875	0.11	2.08	7.0	128
404206	Broken R @ Moorngag	4	49700	0.11	2.15	5.3	107
405205	Murrindindi R	4	10800	0.10	2.41	1.1	26
405234	Seven Ck @ Pollie McQuinns		15300	0.09	2.81	1.4	43
405264	Big R	4	33300	0.09	1.57	2.8	52
405231	King Parrot Ck	4	18100	0.04	1.28	0.7	23
405251	Brankeet Ck	1	12100	0.03	0.46	0.4	5.6
405219	Goulburn R (upstream Jamieson)	1	69400	0.03	0.25	1.8	17.6
405212	Sunday Ck	1	33700	0.01	0.11	0.2	3.6
405246	Castle Ck	1	16400	0.01	0.11	0.2	1.7
405240	Sugarloaf Ck	1	60900	0.00*	0.05	0.1	3.2
	TOTAL		496675			36.6	661.7

* rounded. NB data for Big River from station 405264, rather than 405227 as used in IP2.

These generation rates are derived from sites which vary in terms of the length of record (Appendices 1 and 2). Accepting this, it can be seen from Table 4 that a number of catchments have relatively low nutrient generation rates (King Parrot Ck, Brankeet Ck, Goulburn River, Sunday Ck, Castle Ck, Sugarloaf Ck). This may be related to:

- the volume of runoff generated from these catchments which are mostly in the mid to lower part of the Goulburn catchment (except the Goulburn River site)
- the short length of record and the year of record
- land type (soils, geology, vegetation)
- land use
- point sources of nutrients discharging to streams or
- some other factor.

No particular catchment stands out as having a high nutrient generation rate.

The P and N export rates are in reasonable accord with the range of rates cited in the Victorian Nutrient Management Strategy and other published values (Table 6). The P and N rates for Murrindindi and Big Rivers, both forested catchments, are somewhat higher than expected. Reasons for these higher rates need further investigation.

Table 6 - Published Nutrient Generation Rates.

Land Use Type	Location	TP export (kg/ha/yr)	TN export (kg/ha/yr)	Reference
Native forest -undisturbed -disturbed	Victoria	 0.01-0.02 0.02-0.04	 0.06-0.2 0.12-0.4	Nutrient Management Strategy for Victorian Inland Waters NMSVIW
Dry sclerophyll forest	Cropper Ck, NE Vic	0.01		Flinn et al (Ortho P?)
Wet sclerophyll forest	Maroondah, Victoria	0.04		Feller, 1981
Loblolly Pine	Sth Carolina, USA	0.02		Van Lear et al, 1985
Ponderosa Pine Douglas Fir	Idaho, USA	0.05		Clayton and Kennedy, 1985
Pasture		0.03-0.4	0.1-4.6	NMSVIW
Crop Land		0.04-0.4	0.3-4.5	NMSVIW
Irrigated Land		0.3-3.5	0.9-1.4	NMSVIW

The export rates published in the "Nutrient Management Strategy for Victorian Inland Waters" are based on an extensive survey of published information (Blue Green Algae and Nutrients in Victoria A Resource Handbook - in prep.) Anomalies in the P export rates may arise because of the variations in the length of data set, although this can be overcome to a limited extent by comparing catchments for a common data set (see Section 3.5.1).

Table 7 shows catchment land use percentages estimated visually from land use maps in Water Victoria - An Environmental Handbook.

Table 7 - Catchment Land Use (estimated visually).

Sino	Sub-catchment	Dominant land uses	Estimated % land use	
			Forest %	Grazing and broad acre cropping %
405237	Seven Ck at Euroa	Pasture	10	90
405234	Seven Ck @ Pollie McQuinns	Pasture	10	90
405205	Murrindindi R	Forest	100	0
405214	Delatite R	Pasture, forest	50	50
404207	Hollands Ck	Pasture	70	30
405209	Acheron R	Pasture, forest	85	15
404206	Broken R @ Moorngag	Pasture, forest	20	80
405264	Big R	Forest	100	0
405231	King Parrot Ck	Pasture, forest	85	15
405251	Brankeet Ck	Pasture, forest	50	50
405219	Goulburn R (upstream Jamieson)	Forest	100	0
405212	Sunday Ck	Pasture	60	40
405246	Castle Ck	Pasture/cropping	0	100
405240	Sugarloaf Ck	Pasture	10	90
	TOTAL			

(pasture includes grazing/broad acre cropping.)

Most of the upper catchments have a mixture of agriculture and forest land use and the relative distribution of these can be expected to have a significant impact on nutrient exports. Further study is required to characterise catchments in terms of land use. Smart et al (1985) clearly showed the importance of delineating catchment land use. They found an exponential increase in concentrations of TP in stream water with an increase in the percentage of pasture area.

2.5.1 Annual Variation in Generation Rates

To determine if there are any major differences in between catchment generation rates the records from single years have been compared (Table 9). Loads and rates for 1994, taken to be a relatively dry year, and 1993, taken to be a relatively wet year have been calculated. At Benalla, 1994 was a relatively dry year, with rainfall, approximately 2/3 of average. Severe flooding was experienced in some parts of the catchment in October 1993.

In addition, the ratio of wet/dry nutrient generation rates have been calculated, where possible (Table 8). This indicates the relative sensitivity of each catchment to wet and dry conditions.

These wet/dry year ratios can also be used to gain a feel for catchment nutrient loads in wet and dry years.

Table 8 - Nutrient Generation Rates and wet/dry year Ratios.

		TP 93	TP 94	Wet/dry	TN 93	TN 94	Wet/Dry
404206	Broken R @ Moorngag	0.22	0.03	7.3	3.26	0.35	9.3
404207	Hollands Ck	0.17	0.02	8.5	2.31	0.22	10.5
405205	Murrindindi R	0.13	0.07	1.9	2.95	1.84	1.6
405209	Acheron R	0.15	0.08	1.9	2.85	1.53	1.9
405214	Delatite R	0.09	0.04	2.2	1.34	0.35	3.8
405231	King Parrot Ck	0.05	0.02	2.5	1.7	0.62	2.7
405234	Seven Ck @ Pollie McQuinns	0.13	0.06	2.2	3.74	1.89	2.0
405237	Seven Ck at Euroa	0.22	0.04	5.5	4.41	0.85	5.2
405264	Big R	0.09	0.04	2.2	1.8	0.88	2.0

This shows consistent wet/dry TP ratios of around 2 with the exception of Seven Cks at Euroa (5.5), Broken River at Moorngag (7.3) and Hollands Ck (8.5). The ratios for TN are more variable in the range of 1.6 to 3.8 with the exceptions again being Seven Cks at Euroa (5.2), Broken River at Moorngag (9.3) and Hollands Ck (10.5). These ratios show that the monitored catchments are consistently twice as sensitive in a wet year when compared to a dry year, with the exceptions being Seven Ck at Euroa, Broken River at Moorngag and Hollands Ck. It may also be that only these three catchments are actually showing “wet year” behaviour (they were all affected by the 1993 October flood event, especially the Broken River and Hollands Ck). It is

Table 10 - Loads and generation rates for 1993 and 1994.

			1994				1993			
Sino	Sub-catchment	Catchment area (ha)	Average Generated Loads kg/ha/yr		Load kg		Average Generated Loads kg/ha/yr		Load kg	
			TP	TN	TP	TN	TP	TN	TP	TN
404206	Broken R @ Moorngag	49690	0.03	0.35	1360	17187	0.22	3.26	10768	162190
404207	Hollands Ck	41875	0.02	0.22	828	9191	0.17	2.31	6919	96717
405205	Murrindindi R	10800	0.07	1.84	790	19886	0.13	2.95	1423	31852
405209	Acheron R	61875	0.08	1.53	4746	94934	0.15	2.85	9445	176409
405212	Sunday Ck	33700	0.01	0.11	189	3637	n/a	n/a	n/a	n/a
405214	Delatite R	36800	0.04	0.35	1522	13013	0.09	1.34	3165	49215
405219	Goulburn R (upstream Jamieson)	69400	0.03	0.25	1797	17612	n/a	n/a	n/a	n/a
405231	King Parrot Ck	18100	0.02	0.62	419	11272	0.05	1.7	955	30755
405234	Seven Ck @ Pollie McQuinns	15300	0.06	1.89	843	28910	0.13	3.74	1920	57216
405237	Seven Ck at Euroa	33200	0.04	0.85	1376	28304	0.22	4.41	7306	146511
405240	Sugarloaf Ck	60900	0.00	0.05	110	3215	n/a	n/a	n/a	n/a
405246	Castle Ck	16400	0.01	0.11	238	1748	n/a	n/a	n/a	n/a
405251	Brankeet Ck	12100	0.03	0.46	357	5607	n/a	n/a	n/a	n/a
405264	Big R	33300	0.04	0.88	1393	29285	0.09	1.8	3009	59845
	TOTAL	493440			15968	283801			49756	826013

interesting to note the change in wet/dry ratio within the Seven Cks catchment from Pollie McQuinns to Euroa. The sensitivity between and within catchments warrants further investigation.

Conclusions:

From Table 4 no particular catchment stands out as having a considerably higher nutrient (P) generation rate. A number of catchments seem to have relatively low generation rates and this may be due to a number of factors. Until data sets covering longer time frames are available it is difficult to reach any major conclusions. Further investigation may reveal reasons for intra and inter catchment generation rates.

Generation rates in 1994, a relatively dry year, are considerably less than average figures. Again no particular catchment stands out.

The "wet year" figures of 1993 show considerable differences between catchments. Whether this is due to land use differences or variations in the intensity of rainfall is unknown.

2.6 Estimating Total Dryland Catchment Nutrient Loads

2.6.1 Assigning Ungauged Areas to Gauged Catchments

On the basis of similar land types ungauged areas of the catchment have been allocated to like gauged catchments and the area represented by that gauged catchment estimated (Table 11). This method may have shortcomings associated with scaling up information from small catchments to larger catchments and results should therefore be treated cautiously. It does however, have the advantage, compared to the land use method described in Section 3.6.2, of at least using real data from approximately 500 000 ha - we are only estimating rates from 1.3 million ha.

Table 11 - Assigning Ungauged Areas to Gauged Catchments

Sub-catchment	Catchment area (km2)	Upper/Lower Catchment	Location represented	Area km2
Murrindindi R	56	U	Upper parts of the Shire of Yea	200
Seven Ck at Euroa	322	L	Upper parts of Shires of Violet Town (400), Euroa (700), Seymour (500), Goulburn (300), northern part of Yea (300) and Alexandra (300)	2500
Acheron R	619	U	Upper parts of Shire of Alexandra (1000)	1000
Seven Ck @ Pollie McQuinns	144	L	as for Sevens at Euroa	0
Delatite R	343	U	cleared portion of Shire of Mansfield (600)	600
King Parrot Ck	118	U	Upper parts of the Shire of Yea (900)and Broadford. (176)	1076
Big R	333	U	Forested portions of and Alexandra (450)	450
Broken R @ Moorngag	497	L	Upper parts of Benalla (300)and Mansfield (1000)	1300
Brankeet Ck	138	U	Some parts of Mansfield (300)	300
Hollands Ck	419	L	Upper Parts of Benalla (1100)	1100
Goulburn R (upstream Jamieson)	737	U	Forested parts of Mansfield (2000)	2000
Sunday Ck	219	U/L	Most of Broadford (500), Kilmore (125) and Seymour (245)	770
Castle Ck	288	L	Lower parts of Euroa 712, Goulburn 730, Waranga 540, Violet Town 535, Benalla 1000, Shepparton 275, Tungamah 745, Yarrawonga 500	5037
Sugarloaf Ck	487	L	Pyalong 577, McIvor 650, Kilmore 125	1352
TOTAL	4542			17685

Table 12 - Catchment Nutrient Loads using average kg/ha figures from Table 4

Sub-catchment	Area represent ed ha	TP Generation rate		TN Generation Rate	
		kg/ha	kg	kg/ha	kg
Murrindindi R	20000	0.1	2000	2.4	48000
Seven Ck at Euroa	250000	0.15	37500	2.6	650000
Acheron R	100000	0.11	11000	2.1	210000
Seven Ck @ Pollie McQuinns	0		0		0
Delatite R	60000	0.17	10200	2.3	138000
King Parrot Ck	107600	0.04	4304	1.28	137728
Big R	45000	0.1	4500	1.57	70650
Broken R @ Moorngag	130000	0.11	14300	2.1	273000
Brankeet Ck	30000	0.03	900	0.46	13800
Hollands Ck	110000	0.11	12100	1.8	198000
Goulburn R (upstream Jamieson)	200000	0.03	6000	0.25	50000
Sunday Ck	77000	0.01	770	0.2	15400
Castle Ck	503700	0.01	5037	0.11	55407
Sugarloaf Ck	135200	0.01	1352	0.05	6760
TOTAL	1768500		109963		1866745

NB Seven Creeks at Pollie McQuinns is included in Sevens at Euroa.

Using these generation rates a dryland catchment nutrient export rate for a typical year of 110 t TP and 1866 t TN is derived.

Applying the “dry” (1994) year generation rates from Table 8 a dryland catchment export rate of 51 t TP and 990 t of TN is derived (Table 13.)

Table 13 - “Dry year” Nutrient Generation Rates

Sub-catchment	Area ha	TP Generation rate		TN Generation Rate	
		kg/ha	kg	kg/ha	kg
Murrindindi R	20000	0.07	1400	1.84	36800
Seven Ck at Euroa	250000	0.06	15000	1.9	475000
Acheron R	100000	0.08	8000	1.53	153000
Seven Ck @ Pollie McQuinns	0		0		0
Delatite R	60000	0.04	2400	0.35	21000
King Parrot Ck	107600	0.02	2152	0.62	66712
Big R	45000	0.04	1800	0.88	39600
Broken R @ Moorngag	130000	0.03	3900	0.35	45500
Brankeet Ck	30000	0.03	900	0.46	13800
Hollands Ck	110000	0.02	2200	0.22	24200
Goulburn R (upstream Jamieson)	200000	0.03	6000	0.22	44000
Sunday Ck	77000	0.01	770	0.11	8470
Castle Ck	503700	0.01	5037	0.11	55407
Sugarloaf Ck	135200	0.01	1352	0.05	6760
TOTAL	1768500		50911		990249

Applying “wet” year (1993) rates from Table 8 gives a estimated dryland generation rate of 121 t TP and 2280 t TN (Table 13). This probably underestimates wet year rates as it seems unlikely that generation rates and flows would be low in the catchments with low generation rates.

Table 14 - "Wet year" Nutrient Generation Rates

Sub-catchment	Area ha	TP Generation rate		TN Generation Rate	
Murrindindi R	20000	0.13	2600	2.95	59000
Seven Ck at Euroa	125000	0.22	27500	4.41	551250
Acheron R	100000	0.15	15000	2.85	285000
Seven Ck @ Pollie McQuinns	125000	0.13	16250	3.74	467500
Delatite R	60000	0.09	5400	1.34	80400
King Parrot Ck	107600	0.05	5380	1.7	182920
Big R	45000	0.09	4050	1.8	81000
Broken R @ Moorngag	130000	0.22	28600	3.26	423800
Brankeet Ck	30000	0.03	900	0.46	13800
Hollands Ck	110000	0.02	2200	0.22	24200
Goulburn R (upstream Jamieson)	200000	0.03	6000	0.22	44000
Sunday Ck	77000	0.01	770	0.11	8470
Castle Ck	503700	0.01	5037	0.11	55407
Sugarloaf Ck	135200	0.01	1352	0.05	6760
TOTAL	1768500		121039		2283507

** the Delatite wet year rate is 0.09. For this exercise the average rate of 0.19 has been applied. In other catchments where data isn't available eg Sunday, Castle and Sugarloaf Ck a rate of 0.01 is assumed.

Summary:
Using this method, typical nutrient generation rates for the dryland catchment, using generation rates from gauged catchments, are as shown in Table 15.

Table 15 - Estimated dryland nutrient loads for dry, typical and wet years.

	TP tonnes	**TN tonnes**
Dry year	51	990
Typical/Average year	110	1866
Wet year	121	2283

These figures can only be considered preliminary estimates until better data becomes available. The wet year figure, in particular, seems low.
The wet year figure is consistent with the wet/dry ratios in Table 9. If however the wet/dry ratios are more typically in the range, 5 to 8, the wet year load could be of the order of 250 to 400 t.

The Goulburn Broken AEAM modelling process predicted dryland loads of 110 t and 1550 t for TP and TN respectively. The typical year figure for TP in Table 14 is exactly this, while the AEAM TN figure is substantially lower.

2.6.2 Land Use Generation Rates

Estimated land use nutrient generation rates have been applied to the estimated area of the particular land use in the catchment to give an indication of the key phosphorus generating land uses or land types (Table 17). This method has not been used to estimate N generating land uses because of the range of pathways N can enter waterways.

Using this method an estimate of the total phosphorus load generated from the dryland is 124 tonnes. This compares with the 110 tonnes shown in Table 15, which given the considerable uncertainties involved, is a reasonable agreement. This figure is not too different from the load, derived in Issues Paper 2, Table 5.4, of 130 tonnes of P.

Table 17 indicates that from a total dryland catchment perspective important land types are pasture (broad scale grazing) and forest. This is hardly surprising given the large areas of these land types. In the mid lower section of the catchment pasture, especially, and irrigation are the dominant sources. In the upper mid catchment pasture and forest are the dominant contributing land types.

The conclusions drawn from Table 17 will be revised over time as better, longer term information becomes available from gauged catchments.

The key nutrient sources within each of these land types is likely to be as follows:

Pasture. The key source, especially for P is likely to be sediment associated with erosion (gullies, stream bed and banks and other sources which can contribute sediment directly to streams).

Forest. Again the key source will be P associated with sediment, but the question to be answered is what is the natural background level vs an increase attributable to land use activities? Forest land use activities include timber harvesting (hardwood and soft wood), recreation, access roading. Nutrient loads resulting from wildfire may also be quite large.

Timber harvesting

The area harvested each year is estimated to be approximately 840 ha clear felled and a further 1200 ha thinned or selectively logged.

Hardwood areas logged each year in the catchment is estimated to average as follows (Table 15)(source Ross Runnells CNR):

Table 16 - Estimated Hardwood areas logged each year

Forest Management Area	Clear felled (ha)	Selective logging (ha)
Central	485 (ash and mixed species)	
Benalla-Mansfield	55	180

In addition an estimated 300 ha of softwoods are clear felled and a further 1000 ha thinned. (Simon Penfold VPC). Therefore, a total of approximately 2000 ha is disturbed by forestry operations each year.

If these areas were assumed to have a nutrient generation rate of 0.2 kg/ha/yr (there is no evidence to suggest they do) they would contribute 400 kg P/year. This is a very small proportion of the estimated forest load. Providing forest operations are carried out in accord with approved Codes of Practice they are not considered a major nutrient source from a catchment perspective. This may not be so on a local basis.

Roads and Tracks.
A major source of sediment in forested areas is roads and tracks.

Haydon et al (1991) reported on an experiment to determine the impact of vehicle use and road maintenance on erosion from unsealed roads in a catchment near Maroondah. They concluded that unsealed roads can produce high sediment loads, up to 45 to 60 t/ha/yr. This is two orders of magnitude higher than the average catchment sediment production of 0.3 t/ha/yr. Under a high use regime the level of maintenance had a significance impact on erosion rates.

Many other studies have highlighted the importance of forest roads and tracks as sediment sources. E.G. Burroughs and King (1989), Cassells et al (1982), Rieger et al (?), Langford and O'Shannessy (1976), etc.

Given the large, unquantified, length of roads and tracks in forested areas, and the intensity of their use, especially by recreationists, it is concluded that this could be a significant source of non natural P to water bodies in the forested parts of the catchment. Further work is required to confirm this.

Conclusion:

- the dominant land use contributing nutrients is pasture (broad acre grazing). In the lower catchment nutrients from irrigation also appear to be a significant source. Forest areas in the upper catchment make significant contributions.

- in the interim, the dryland catchment is predicted to yield the loads of nutrients shown in Table 14. There are considerable uncertainties associated with this estimate, which will be revised as more information becomes available.

- the dominant source of these nutrients are associated with sediment movement (ref IP2).

Table 17 - Dryland Catchment Phosphorus Generation Loads Based on Land Use Activities

Land use	Mid - Lower Catchment				Upper Mid Catchment				Total catchment		
	Area ha	Nutrient Generation Rate (kg/ha/yr)	Loads/yr (tonnes)	% of load	Area ha	Nutrient Generation Rate (kg/ha/yr)	Loads/yr (tonnes)	% of load	loads/yr	% of load	Total land use area. ha
Pasture	700000	0.06	42	74	342000	0.11	37.6	56	80	64	1042000
Cropping	40200	0.05	2	4	1500	0.1	0.2	0	2	2	41700
Horticulture	700	0.2	0	0	500	0.4	0.2	0	0	0	1200
Irrigation	10000	1	10	18	2000	0.2	0.4	1	10	8	12000
Forest	122800	0.02	2	4	476800	0.06	28.6	43	31	25	599600
Total	873700		57		822800		67		124	100	

NB These estimates will be revised over time as better information becomes available.

(c:\ip2a/dryloa.xls)

Table 17A Explanation of Adopted generation rates:

Land Use	**Mid lower catchment**	**Upper mid catchment**
Pasture	Rough "average" of , Sunday Ck (0.01) Seven Creeks at Euroa (0.13), King Parrot (0.04)	Delatite (0.17), Hollands Ck (0.11), Seven Cks at Pollie McQuinns (0.09), Broken at Moorngag (0.11)
Cropping	typical of Castle Ck	allowed a slightly higher rate in line with increased erosivity
Horticulture	Issues paper 2 value	Issues paper 2 value
Irrigation	Derived from issues paper 5, table 3.11 (rate of 1 kg/ha adopted because irrigated areas are generally close to streams)	derived from issues paper 5 and other background paper
Forest	as for pasture	Mix of Murrundindi (0.1), Acheron (0.11), Big River (0.09) and Goulburn river (0.03) values

3. Importance of in stream sediment

3.1 Background

Concern has been expressed that stream degradation issues and their impact on water quality are not being given the attention they deserve in the strategy development process, especially in the preparation of Issues Paper 2. A short review of relevant references is presented below.

3.2 Review of Importance of Sediment in Streams

Harris (in Nutrient Loadings and Algal Blooms in Australian Waters - a Discussion Paper, LWRRDC 1994)

Storm remobilisation of sedimentary materials during floods is characteristic of Australian waters.

Murrumbidgee (Murray et al. 1993. Tracing the Source of Suspended Solids in the Murrumbidgee River, Australia. IAHS - Symposium - Tracers in Hydrology. Yokomaha, Japan.)

All this... suggests that at least some mobilisation of sediment is occurring from bank erosion in the middle and lower reaches of the river. Given the silt/clay contents of the banks this must contribute to some degree to the suspended solids load.

However Pb/Cs isotope levels in suspended sediment are more consistent with contemporary basin based sheet erosion and/or rill erosion than with bank collapse.

Event based sampling suggests that upland basin rather than channel erosion may be the major source of suspended sediment to the upper third of the river during floods.

...the surface source may dominate, although some bank contribution remains likely.

But
- the background turbidity levels probably do increase downstream ... this supports the suggestion that bank erosion does contribute to suspended sediment concentrations in the downstream reaches.

Chaffey Reservoir -(Nutrient and Sediment Sources in the Chaffey Reservoir Catchment - CSIRO Div of Water Resources, Report No 94/3. January 1994).

In investigating sediment sources in the Chaffey Reservoir, it is concluded that the major source is a Tertiary basalt. But it was not possible to distinguish basalt sediment derived from surface soil erosion in the upper catchment from basaltic alluvium eroded from the channel banks close to the reservoir.

Radionuclides were used to distinguish the two sources.

Concluded that:

- radionuclide data show the sediment delivered to the reservoir consists of about 50% topsoil and 50% subsoil. Channel bank erosion in the lower catchment is probably the dominate source of subsoil.
- For high, and probably low flow conditions, water chemistry and isotope data indicate the upland Tertiary basalt is the principle source of P (as compared to other geological types in the catchment).

CMPS&F Dryland Report.

Soils associated with basalts, or its alluvial derivatives, provide P rich parent material, thus these basalt derived soils contain relatively high levels of natural P. Low P parent material produces soil with a low P content.

In the Goulburn Broken catchment some of the sediment resulting from erosion events associated with European settlement has been reworked by extensive erosion and deposited in waterways.

Soils in the following land systems have the highest levels of natural P:

- Mansfield
- Archerton
- Tiger Hill
- Wrightly
- Benalla - Benalla Alluvials
- Buller

Nutrient contributions are episodic, depending on rainfall and erosion events, particularly for P.

Erskine and Saynor - in The Influence of Waterway Management on Water Quality with particular reference to Suspended Solids, Phosphorus and Nitrogen.

Catastrophic floods or sequences of large floods in rapid succession are particularly important for generating in channel sediment. Channel erosion can account for essentially all of the suspended solids load where bank erosion and/or channel incision are active. The dominance of one sediment source over another (catchment vs instream) varies with time.

- Most of the TP load in Australian and overseas rivers is transported as particulate phosphorus by storm flows. There is a dearth of published material on P inputs to waterways from instream sources. Nevertheless, lake and river bed sediments often contain a large store of adsorbed P which can be at least partially released under anoxic conditions.
- Stream based works can also successfully reduce suspended solids loads, with dams, buffer strips and structural works being effective. Presently available information is inadequate to quantify the effects of bank protection works on reducing suspended solid loads.

- In relation to P it was found that catchment based works can reduce P loads, particularly the particulate P fraction. Buffer strips are also effective but other stream based works have not been investigated.

Wasson et al (cited in Sebire A (1991), Protecting Lake Burley Griffin Water Quality Through Erosion Control. J Soil and Water Cons 4(3), 1991.)

Developed a sediment budget for Jerrabomberra Ck, which showed that while total slope erosion is significant, most sediment is intercepted before entering tributaries connected to the main channel. They concluded “ the walls and beds of gullies and streams are important sources of sediment and there is a large amount of sediment stored in the bed of the main channel.”
(Wasson et al (1988). Sources of Sediment Reaching Lake Burley Griffin-A Progress Report. CSIRO Division of Water Resources, Canberra ACT)

3.3 Conclusion

- reworking of alluvial material from within streams during storm events may be a significant source of P
- P associated with this reworked sediment can provide internal loadings of P at critical periods of the year.
- BMPs, of any type, will be less effective in times of high flow. (Refer IP2, Sec 7.3.1)
- can’t say with any certainty that instream sources are more important than catchment sources in terms of sediment or P delivered
- however, given that bed and bank sources of sediment can immediately supply P directly to waterbodies it seems not unreasonable that these sources should be treated as a priority.

Based on this, a priority ranking of works or BMPs to reduce P loads would be:

- control of point sources of nutrients directly discharging to streams
- stabilisation of bed and banks of streams and provision of filter strips along streams
- areas above storages which could act as sediment/nutrient traps thus providing sources of internal loading:
    - urban storages
    - Eildon
    - Nillahcootie
    - Mokoan
    - Weir Pools on Broken River
    - Weir Pools on Broken Ck and tributaries
    - Goulburn Weir backwaters
- control of diffuse sources of nutrients discharging directly to streams by providing filter strips
- control of point sources indirectly discharging to streams
- control of diffuse sources indirectly discharging to streams.

This will apply over the whole catchment, although we would also need to keep in mind the objectives of the strategy, the relative costs of carrying out these works and sub catchments which produce relatively large amounts of P (if they can be identified).

4. Nutrient Control Options in the Dryland

Since Issues Paper 2 was prepared, a number of other land management activities to reduce nutrient loads have been suggested. These include:

- Rivers and streams - erosion control works carried out by waterway Management Authorities
- Forests - upgrade and relocate camping and recreation areas away from streams.
- Forests - upgrade maintenance of roads and tracks.

This section estimates the length of stream in the catchment requiring some form of treatment to prevent sediment and nutrient movement.

Nutrient control options in dryland areas revolve around controlling sediment movement into and along waterways and waterbodies. Activities which prevent sediment movement in the landscape, or provide long term storage of sediment in the landscape, are only marginally useful nutrient control options, even if they have other uses.

Techniques to minimise sediment movement into waterways include

- filter strips
- treatment of point sources directly discharging to waterways (eg an eroded gully or a source of sediment)

Land management techniques to minimise catchment sediment fluxes include establishment of perennial pasture, minimum tillage cropping techniques, treatment of soil erosion by construction of diversion or contour banks, grassed waterways, erosion control structures and the fencing of gullies.

Techniques to minimise sediment movement from stream bank and bed erosion include establishment of buffer strips to encourage revegetation, grade control structures, revetments, groynes, etc. (refer to Guidelines for Stabilising Waterways).

It is important to distinguish between buffer strips and filter strips. A buffer strip along a watercourse is an area of vegetation which provides a buffer between the actual waterway and its riparian zone. A buffer strip serves an ecological function. A filter strip is an area of vegetation along a watercourse which filters sediment (and nutrients) from surface water flows originating on adjacent land. A buffer strip can serve as a filter strip but it is unlikely a filter strip could serve as a buffer strip.

4.1 Stream length in the catchment.

To estimate the length of filter strip required in the catchment an estimate of the length of stream and its condition is required.

A very useful starting point is "The Environmental Condition of Victorian Streams" by P Mitchell. This categorises streams on the basis of their catchment size:

Minor	catchment < 5000 ha
Tributary	Catchment between 5000 and 30000 ha
Major catchment	> 30000 ha.

Stream environmental condition was assessed at a number of sites against set criteria including bed composition, proportion of pools and riffles, bank vegetation, verge vegetation, cover for fish, average flow velocity, water depth, underwater vegetation, organic debris and erosion/sedimentation. Environmental condition ratings are as follows(Table 18):

Table 18 - Stream Environmental Rating

Rating	Description
Very Poor	very degraded, often with severe erosion or sedimentation problems.
poor	significant alterations from natural state with reduced habitat value, may have erosion or sedimentation problems.
Moderate	significant alterations from natural state, still provides moderate habitat: stable.
Good	some alteration from natural state; good habitat conditions.
Excellent	site in natural or virtually natural condition; excellent habitat condition.

Stream lengths were measured from 1:250 000 topographic maps. This may underestimate stream length by an unknown factor. The length of stream in each rating category within a steam category was based on the ratings given in that stream category. Stream length and condition for the Broken and Goulburn Rivers are tabulated below (Tables 18,19 and 20) as well as estimates of the lengths of streams needing treatment. This assumes:

- all stream segments rated good and excellent do not require filter strips (this deals with forested catchments which are all assumed to have stream segments in this category).
- a percentage of segments requiring filters have side slopes > 10% (say 30%) and are therefore unsuitable as filters. Also assume that a proportion of these already have some form of buffer/filter in the form of forest or intact riparian vegetation, roads, etc (say another 30%). Totalling the two means we assume that 60% do not need/cannot be treated.
- all other stream segments do require filter strips
- in the Goulburn catchment 2/3 of the stream length is in the foothill or uplands section
- in the Broken catchment 1/3 is in the uplands section; the balance is in the plains.
- all streams need the same size filter.

Results of this analysis are shown in Tables 18 and 19 and are summarised in Table 20.

Table 19 - Stream Environmental Condition in the Broken catchment.

	Excellent	Good	Moderate	Poor	Very Poor	Total
Major	0	0	246	25	0	271
Tributary	0	30	138	63	59	290
Minor	409	0	0	387	355	1151
Total	409	30	384	475	414	1712
less 60%			-230	-285	-248	-764
to be treated			154	190	166	509
Propn in uplands 1/3			51	63	55	170
prop on plains 2/3			102	127	110	339

Table 20 - Stream Environmental Condition in the Goulburn Catchment.

	Excellent	Good	Moderate	Poor	Very Poor	Total
Major	0	193	376	151	0	720
Tributary	205	86	122	312	118	843
Minor	4506	0	1215	654	219	6594
Total	4711	279	1713	1117	337	8157
less 60%			-1028	-670	-202	-1900
to be treated			685	447	135	1267
Propn in uplands 2/3			457	298	90	845
prop on foothills/plains 1/3			228	149	45	422

Table 21 - Summary Stream lengths to be treated with filter strips.

	Goulburn	Broken	Total
Uplands	845	170	1015
Foothills	422	0	422
Plains	0	339	339
Total	1267	509	1776

The total treatable length of stream is estimated to be 1776 km (or 40% of the total length of 4439 km (sum of moderate, poor and very poor) requiring treatment. All the stream length in the uplands and half the foothills is allocated to the upper mid catchment (1226 km), with the balance allocated to the mid lower catchment (550 km).

Priorities

Assume that all other things being equal the priority for treatment will be segments rated:

1. very poor
2. poor
3. moderate.

We also need to consider at some stage the overlap between fencing of riparian verges for river management purposes and fencing of these areas as filter strips for sediment and nutrient control.

5. Economic aspects

In Issues Paper 2, the economics of nutrient reduction activities relied heavily on an ABARE publication (ABARE 1993) for costs of nutrient management options. In addition, broad estimates of the nutrient reduction performance of the option were made. Combined, these gave a ranking of the cost effectiveness of dryland nutrient reduction options in terms of dollars per kilogram of phosphorus (or nitrogen) removed per annum. The costs and effectiveness of some options have been reviewed.

*5.1 **Basic costs***

Costs can be worked on a per hectare, or per kilometre basis, depending on the control option.

5.1.1 **Filter Strip costs**:

Assuming a 30 m wide filter strip (ie 30 m on each side of a stream), 1000 m long, an area of 6 ha is enclosed by 2120 m of fencing. a 30 m buffer has been chosen arbitrally. A narrower strip would have some impact on O&M costs and will impact on nutrient reduction cost efectiveness figures.

*5.1.1.1 **Fencing:***

Table 22 - Fencing Costs

Type of fence	**Capital (construction cost)**	**O&M (excluding flood damage**
Conventional	$4000/km - $1413/ha	$50/km/yr - $18/ha/yr
Electric	$2500/km - $833/ha	$28/km/yr - $10/ha/yr

It is also possible that some fencing, especially in the flatter parts of the catchment may be subject to higher maintenance costs due to flood damage. In this situation increase maintenance costs to $1000/km every 10 years. ($353/ha); for electric fencing $635/km = $224/ha

*5.1.1.2 **Pest plant and animal(PP&A) control - ongoing maintenance**.*

Pest plant and animal management is an important, often overlooked, component of protective fencing. This will include weed maintenance eg Pattersons Curse, St Johns Wort, blackberry, gorse, as well as rabbit and fox control. This component is considered to be generally quite low in the area north of the Hume Fwy and will be considerably higher in the higher rainfall areas. Assume best practice. Costs have been derived from CNR catchment staff at Benalla.

It can be argued that this cost would have to be incurred whether or not a filter strip was installed and therefore should not be a cost against the filter strip. However, there are extra costs associated with managing a fenced off area, so it is probably fair that a proportion of this should be a cost to the filter strip - say 50%.

High rainfall areas: A five year cyclic program comprising $200/ha in the first year followed by a less expensive program ($150, $100, $100, $100) for the next 4 years.

Low rainfall areas: Assume 25% of high rainfall cost.

5.1.1.3 Water Supply

In cropping areas assume water supply will already be provided away from the fenced filter area. In higher rainfall areas there may be a need to provide alternative water supply.

Alternative water supply cost:

Assume water is pumped from a stream and reticulated to trough via poly pipe.(could go for a less expensive system eg stream access, but this would negate the purpose of the filter).

Costs per trough:

pipe	$150
tank	$200
pump	$300
installation and design	$150
Total capital	$800

assume we need 2 troughs for 6 ha fenced = $ ((800*2)/6) = $ 266/ha ($1600/km).
annual maintenance and running $95/trough/yr = $32/ha/yr ($190/km)
(haven't include replacement of pump or system after a number of years or the cost of a Diversion Licence - could assume the landholder already has one.)

5.1.1.4 Agricultural Production

Refer to North East Gross Margins 1995/96. (Murray, Simpson & Trapnell).

Gross margin/ha

Wheat Conventional tillage	$151
Wheat Minimum tillage	$167
Barley conventional	$135
Barley minimum tillage	$151
Oats	$170
Triticale	$168
Triticale minimum tillage	$183
Lupins	$47
Canola	$513
Self replacing merino flock	$149
Merino wether flock	$155
First cross ewe flock	$115
Dorset over merino ewe	$223

We'll assume a return of $150/ha. That is, for every hectare removed from agricultural production $150, of income is foregone. This may be off set by increased production from benefits associated with shelter from trees within the filter strip or a potential increase in capital value of a farm from landscape improvements, but for this exercise this is ignored.

5.1.2 Forested filter strips

(refer to Russell Washussen's pamphlet)

Blue gums (> 750 mm)
Establishment $1000/ha - year 1
$70/ha weed control year 2.
other costs

assessment year 26	$32
annual costs year 0 to 27	$19/yr/ha
thinned at year 6	$83 (non commercial)
thinning Y15	commercial

Harvest at year 27 (for our purposes say Y30) Yield $30600/ha
Thinning at Y15 yield $4730.

Could also include some agricultural benefits - estimated at 3% productivity increase (I haven't). Pines would probably give a different result.

5.1.3 Summary of costs to Install Filter Strip

Table 23A - Uplands

	Capital		O&M	
	per km	per ha	per km	per ha
Fencing (conventional)	4000	1413	50	18
Water supply	1600	266	190	32
PP&A			390	65
Lost production			900	150
Total	5600	1679	1530	265

Table 23B - Plains

	Capital		O&M	
	per km	per ha	per km	per ha
Fencing (conventional)	4000	1413	310	51
Water supply				
PP&A			96	16
Lost production			900	150
Total	4000	1413	1306	217

The ABARE equivalent figures are Capital $1460/ha ($4365/km) and $230/ha on going costs. These are quite similar to those in Table 23A and B.

Table 24 summarises costs worked out on a NPV and EAV basis, over 30 years, at discount rates of 4, 8 and 10%.

Table 24 - NPV and Equivalent Annual (EAV) Costs (30 years).

			Discount Rate					
			4%		8%		10%	
Option			NPV	EAV	NPV	EAV	NPV	EAV
Filter Strip Upland	Conventional Fence	per km	36990	2136	27078	2400	24012	2544
		per ha	6165	356	4513	400	4002	424
	Electric Fence	per km	32865	1900	23364	2075	20439	2168
		per ha	5477	316	3894	346	3406	361
Filter Strip lowland	Conventional Fence	per km	27162	1556	20214	1794	18048	1914
		per ha	4527	261	3369	299	3008	319
	Electric Fence	per km	23035	1332	16495	1465	14480	1536
		per ha	3839	222	2749	244	2413	256
Forested filter strip	Conventional fence	per km	35082	+2028	2136	192	9450	1002
		per ha	5847	+338	356	32	1575	167
River Management works		whole catchment	12.7M	0.73M	9.42M	0.84M	8.31M	0.88M

5.1.4 Total Cost of installing these filter strips.

Using the costs of filter strips derived above, and assuming the costs of filter strips in the uplands and foothills are the same, and excluding the costs of treeplanting in these strips, total costs are (using 8% discount and conventional fencing):

Table 25 - Cost of filter strips - NPV and EAV (8% over 30 years).

	Length km	NPV cost/km	EAV cost/km	Total NPV cost	Total EAV cost
Uplands	1226	27078	2400	33.2M	2.9M
Plains	550	20214	1794	11.1M	0.99M
	1776			44.3M	3.9M

There will be some overlap with the cost of river management works.

5.2 How much nutrient do filter strips have to deal with?

(This section uses the nutrient export rates from Table 17).
From Section 5.1 a total stream length of 4439 km requires treatment, but because of side slopes and existing buffers only 1776 km should be treatment. Assuming that all the nutrient load (82 t) from grazing and cropping areas is generated in areas where streams are in moderate, poor and very poor condition, only 1776/4439 (40%) of this load is “treatable” - a figure of 32.8 t.

Given an overall efficiency of 20% for filter strips (they are close to 100% effective for small events, but very ineffective for large events), and assuming 100% adoption and management (!!) they could account for 3.6 t in mid to lower catchment areas and 3 t in upper mid areas. (A total of 6.6 t, or 20% of 32.8 t).

5.2.1 Cost Effectiveness of Filter Strips

Table 26 - Estimated cost effectiveness of filter strips.

	Load treated by filters t (20%)	length of filter required km	Effectiveness of filter kg/km	Effectiveness of filter kg/ha 6 ha/km	EAV Cost of filter strip/km @ 8%	EAV Cost of filter strip/ha @8%	Cost effectiveness/km $/kg p.a.
Upper mid catchment	3.0	1226	2.5	0.4	2400	400	1000
Mid lower catchment	3.6	550	6.5	1.1	1794	299	270

This indicates it would be substantially more cost effective to undertake phosphorus reduction works using filter strips in the mid-lower catchment than in the upper mid catchment. This is due to the longer length of stream requiring treatment in upper mid catchment areas. (A slightly higher figure would be derived if the catchment nutrient generation rate of 110 t were used).

The sensitivity of these figures to the width of the strip has not been tested. As noted earlier the figures are based on a 30 m wide strip on each side of the stream.

5.3 River Management Works

The “Proposal to Form the Broken River Management Board”, prepared by Ian Drummond and Associates for the Broken River Improvement Trust costed a capital, recurrent and maintenance works program for the 4200 km sq district to be covered by the proposed Board. (Can't use Mitchell figure of stream length because this includes the Broken Ck system, which was not included in the BRMA proposal.)

The total cost of the program was $2 500 000 (= $5.95/ha) with an annual recurrent cost (following completion of all capital works) of $329 360 ($0.78/ha). Assume, for this exercise that a similar program will apply to the entire catchment, less forested upland areas. Broken catchment area = 722400 ha less forest 105400 = 617900 ha. Goulburn catchment = 1619200 ha less forest 530600 = 1088600 ha (this includes 19100 ha of redgum woodland and also includes irrigation areas not usually associated with dryland. I've taken this to be along the Goulburn River and is an area requiring treatment.). Total catchment area to be treated = 1 706 500 ha. Therefore total estimated cost of treating streams in the catchment with river management works = $10.2M. Plus O&M = $1.3 M pa. Note this is only a very rough estimate and needs further work.

These costs have been converted into NPV and EAV values, and are shown in Table 23 above.

5.3.1 How much P reduction could be attributed to river management works?

By carrying out this program of river management works assume that a load reduction is achieved of 20%, ie 20% of 124 tonnes (the Table 17 value) = 25 t.

5.3.2 Cost Effectiveness of River Management Works.

Assuming a 25 t phosphorus reduction at an EAV cost (at 8%) of $0.84 million, a cost effectiveness of $33/kg of P removed p.a. is derived. Because of the uncertainties involved in the costing and estimates of nutrient reduction, another calculation as a sensitivity test, has been made. This uses twice the cost ($1.68M), and half the reduction (12.5 t). A cost effectiveness of $134/kg P p.a. is derived.

5.4 Summary.

Compared to the cost of installing filter strips, river management works appear to be a more cost effective way of achieving nutrient reduction. However, a river management works program will include fencing of streamsides as buffer or filter strips so a similar result could occur.

6. Conclusions

Estimating the nutrient load from dryland catchments is a very difficult task. In the interim the loads are accepted to be approximately:

	TP tonnes	TN tonnes
Dry year	51	990
Typical/Average year	110	1866
Wet year	121	2283

These figures can only be considered preliminary estimates until better data becomes available. The wet year figure, in particular, seems low.

On the basis of information in Tables the key nutrient producing land types are pasture and forest. This is not surprising given the area of each land type in the catchment. Timber harvesting is only a very minor source of nutrients.

Sediment already in train in streams should be considered an important nutrient source although there is no hard information from within the catchment to confirm this. Works to stabilise sediment sources within and near streams will be an important priority.

Research to address methods of determining the relative nutrient generation importance of subcatchments and to determine the importance of instream sediment sources is warranted.

7. Bibliography

ABARE. 1993. Costs of Agricultural management practices in the Murrumbidgee value - a report to the Algal Management Working Group of the Murray Darling Basin Commission. ABARE.

Agriculture Victoria. 1995. Understanding Agriculture in your Area.

Burroughs and King. 1989. Reduction of Soil Erosion on Forest Roads. USDA Forest Service Intermountain Research Station General Technical Report INT-264.

Cassells D., Hamilton L., Saplaco S. 1982. Understanding the Role of Forests in Watershed Protection. Working Paper East-west Centre, Honolulu, Hawaii.

Cottingham P. 1995. The occurrence of algal blooms and a review of nutrients in surface waters in the Goulburn and Broken River Basins. Water Ecoscience Report No 36/95.

CSIRO. 1994. Nutrient and Sediment Sources in the Chaffey Reservoir Catchment - CSIRO Div of Water Resources, report No 94/3. January 1994).

Department of Water Resources Victoria. 1989. Water Victoria - An Environmental Handbook.

Drummond Ian and Associates. undated. Proposal to From the Broken River Management Board. Broken River Improvement Trust.

Erskine and Saynor - in The Influence of Waterway Management on Water Quality with particular reference to Suspended Solids, Phosphorus and Nitrogen

Harris J. 1994. Nutrient Loadings and Algal Blooms in Australian Waters - Discussion Paper, LWRRDC.

Haydon S., Jayasuriya M., O'Shannessy P. (1991). the Effect of Vehicle Use and Road Maintenance on Erosion from Unsealed Roads in Forests: The Road 11 Experiment. Report No MMBW-W-018. Melbourne Water.

Hunter K.M. and Zampatti B.P.. 1994. Victorian Water Quality Monitoring Network Annual Report 1993. State Water Laboratory of Victoria.

Langford J., O'Shannessy J. (1976). The Effects of Forest Operations on Soil and Water Values. In Woodchip symposium Papers, 47th ANZAAS Congress, Hobart.

Mitchell P. 1990. The Environmental Condition of Victorian Streams. Dept of Water Resources, Victoria.

Murray A., et al. 1993. Tracing the Source of Suspended Solids in the Murrumbidgee River, Australia. IAHS - Symposium - Tracers in Hydrology. Yokomaha, Japan.)

Murray L., Simpson S., Trapnell L. 1995. North East Gross Margins 1995-96. Agriculture Victoria.

Office of the Commission of the Environment. 1993. State of the Environment Report

Office of the Commission of the Environment 1991.

Reiger W., Olive L., Burgess J. Date?. Sediment discharge Response to Clear Fell Logging in selected Small Catchments Eden NSW.

Shepparton Irrigation Region Land and Water Salinity Management Strategic Plan The Second five Years (1995).

Sebire A (1991), Protecting Lake Burley Griffin Water Quality Through Erosion Control. J Soil and Water Cons 4(3), 1991

Smart M., Jones J., Sebaugh J., 1985. Stream-watershed relations in the Missouri Ozark Plateau Province. J. Environ. Qual., 14(1), 1985, pp77-82.

Standing Committee on Rivers and Catchments. 1991. Guidelines for Stabilising Waterways. Standing Committee on Rivers and Catchments, Victoria

State Government of Victoria. 1995. Nutrient Management Strategy for Victoria's inland Waters.

Washussen R. undated. Farm Planning for long term economic and environmental sustainability using forestry and Farmtree economic analysis. Benalla Farm Tree Forestry Group.

Wasson et al (1988). Sources of Sediment Reaching Lake Burley Griffin-A Progress Report. CSIRO Division of Water Resources, Canberra ACT

8. Appendix 1- Summary of Availability of Water Quality Data

Site No	**Description**	**Data Y/N**	**Quarterly data from**	**to**	**Monthly data from**
404200	Broken River - Casey Weir Tail Gauge	Y	One year only 1978/79		
404204	Boosey Ck at Tungamah	N			
404206	Broken River at Moorngag				21/8/90
404207	Hollands Ck at Kelfeera	Y	11/10/78	21/8/90	21/8/90 onwards
404208	Moonee Ck at Lima	N			
404210	Broken Ck at Rices Weir	MD BC data	earlier than Jan 83	July 89	weekly from July 89
404214	Broken Ck at Katamatite	Y			22/8/90 onwards
404216	Broken River at Goorambat (Casey Weir Head Gauge)	Y	5/7/82	22/8/90	onwards
404222	Broken River at Orrvale	N			
404224	Broken River at Gowangardie	Y	-		10/11/93
405200	Goulburn River at Murchison	Y	6/12/77	14/8/90	14/8/90 onwards
405202	Goulburn River at Seymour	Y	6/12/77	13/6/90 then discontinued	
405203	Goulburn River at Eildon	Y			7/8/90 onwards
405204	Goulburn River at Shepparton	Y	6/12/77	14/8/90	14/8/90 onwards
405205	Murrindindi River	Y	-		15/8/90 onwards
405209	Acheron River at Taggerty	Y	-		7/8/90 onwards
405212	Sunday Ck at Tallarook	Y	-		11/11/93
405214	Delatite River at Tonga Bridge	Y	-		15/8/90 onwards
405215	Howqua River at Glen Esk	N			
405217	Yea River at Devlins Bridge	N			
405218	Jamieson River at Gerrans Bridge	N			
405227	Big River at Jamieson	Y	3/10/78	16/5/90 then discontinued	
405228	Hughes Ck at Tarcombe Rd	N			
405229	Wanalta Ck at Wanalta	N			
405230	Cornella Ck at Colbinabbin	N			
405231	King Parrot Ck at Flowerdale	Y	-		15/8/90
405232	Goulburn River at McCoys Bridge	MD BC	pre Jan 83	July 89	weekly from July 89

405234	Seven Creeks downstream of Pollie McQuinns	Y	-		2/2/93 onwards
405237	Seven Creeks at Euroa	Y	-		2/2/93 onwards
405240	Sugarloaf Ck at Ash Bridge	Y	-		11/11/93
405241	Rubicon River at Rubicon	N			
405244	Merton Ck at Merton	N			
405245	Fords Ck at Mansfield	N			
405246	Castle Ck at Arcadia	Y	-		10/11/93 onwards
405247	Stony Ck at Tamleugh	N			
405248	Major Ck at Graytown	N			
405251	Brankeet Ck at Ancona	Y	-		22/11/93 onwards
405252	Glen Ck at Maindample	N			
405256	Corduroy Ck at Lake Eildon	N			
405257	Snobs Ck	N			
405261	Spring Ck at Fawcett	N			
405263	Goulburn River upstream of Snake Junction	N			
405264	Big River downstream of Frenchmans Ck	Y	-		14/8/?
405279	Wappentake Ck at Glenlea	N			
405280	Major Ck at Glenlea	N			
405281	Compton Ck at Graytown	N			

9. Appendix 2 Nutrient Generation Rates

Nutrient loads and export rates calculated from VWQMN sites in the Goulburn-Broken Basin.

Loads = kg/yr
Export rates = kg/ha/yr

	Hollands Ck		Murrindindi R		Acheron R		Sunday Ck		Delatite R	
Year	404207		405205		405209		405212		405214	
	TP	TN	TP	TN	TP	TN	TP	TN	TP	TN
1991	3744	102700	880	23834	4579	98934	*	*	12510	151667
1992	7949	110338	1300	28444	9323	143451	*	*	8363	122581
1993	6919	96717	1423	31852	9445	176409	*	*	3165	49215
1994	828	9191	790	19886	4746	94934	189	3637	1522	13013
Average	4860	79737	1098	26004	7023	128432	189	3637	6390	84119
Ha gauged	45100	45100	10800	10800	61875	61875	33700	33700	36800	36800
Av export rate	0.11	1.77	0.10	2.41	0.11	2.08	0.01	0.11	0.17	2.29

	Goulburn us Jamieson		King Parrot Ck		Seven Ck at Euroa		Castle Ck		Big R	
Year	405219		405231		405237		405246		405264	
	TP	TN	TP	TN	TP	TN	TP	TN	TP	TN
1991	*	*	514	17554	*	*	*	*	3277	63435
1992	*	*	1036	33341	*	*	*	*	3704	57156
1993	*	*	955	30755	7306	146511	*	*	3009.2	59845
1994	1797	17612	419	11272	1376	28304	238	1748	1393	29285
Average	1797	17612	731	23231	4341	87408	238	1748	2846	52430
Ha gauged	69400	69400	18100	18100	33200	33200	16400	16400	33300	33300
Av export rate	0.03	0.25	0.04	1.28	0.13	2.63	0.01	0.11	0.09	1.57

* insufficient data   pf/c:/ip2a/goulex1.xls

	Brankeet Ck		Broken R at Moorngag		Sugarloaf Ck		Seven Cks at Pollie McQuinns	
Year	405251		404206		405240		405234	
	TP	TN	TP	TN	TP	TN	TP	TN
1991	*	*	2802	117120	*	*	*	*
1992	*	*	6316	131471	*	*	*	*
1993	*	*	10768	162190	*	*	1920	57216
1994	357	5607	1360	17187	110	3215	843	28910
Average	357	5607	5312	106992	110	3215	1382	43063
Ha gauged	12100	12100	49700	49700	60900	60900	15300	15300
Av export rate	0.03	0.46	0.11	2.15	0.00	0.05	0.09	2.81

* insufficient data