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# THE ECONOMIC COST OF WETLAND DESTRUCTION

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## 1.1 ABSTRACT

Wetlands are often referred to as the ‘kidney of the river’, but what is the value of the water filtration they provide, and what is the cost of wetland destruction? This paper determines the economic value of wetlands for water filtration. It demonstrates that wetlands are of considerable economic value, even where the volume of water filtered is in excess of that required for domestic consumption.

It argues that if legislation required those who destroy natural wetlands to replace the water filtration process the wetlands once provided, it would be necessary to construct water filtration plants at significant cost.

## 1.2 INTRODUCTION

Very little information exists in Australia on the ability of natural wetlands to filter water. This factor, in combination with the interdisciplinary skills required to assess the value of this environmental service, has probably been the main reason why previous resource economists relied on questionnaires seeking peoples’ ‘willingness to pay’ to determine wetland values. Unfortunately such valuation methods are unable to capture wetland functions such as water filtration, because the public generally has little idea of what such functions are worth. This has resulted in wetlands being seriously undervalued, thereby providing misleading grounds for their destruction.

The aim of this study is to therefore to determine the value of wetlands for water filtration, and to demonstrate that there is a substantial economic cost to society of their destruction. The study is set in the Lower Murray dairy swamps in South Australia, however **the results are applicable to wetlands across Australia.**

## 1.3 BACKGROUND

The Lower Murray dairy swamps were once part of a series of fresh-water wetlands stretching along the Murray to the Coorong. Of the original 5,700 hectares of wetlands only 500 hectares remain. The destruction of this wetland area is typical of wetland losses that have occurred across the country – it is estimated that over half of Australia’s wetlands have been destroyed since European settlement (ANCA, 1996).

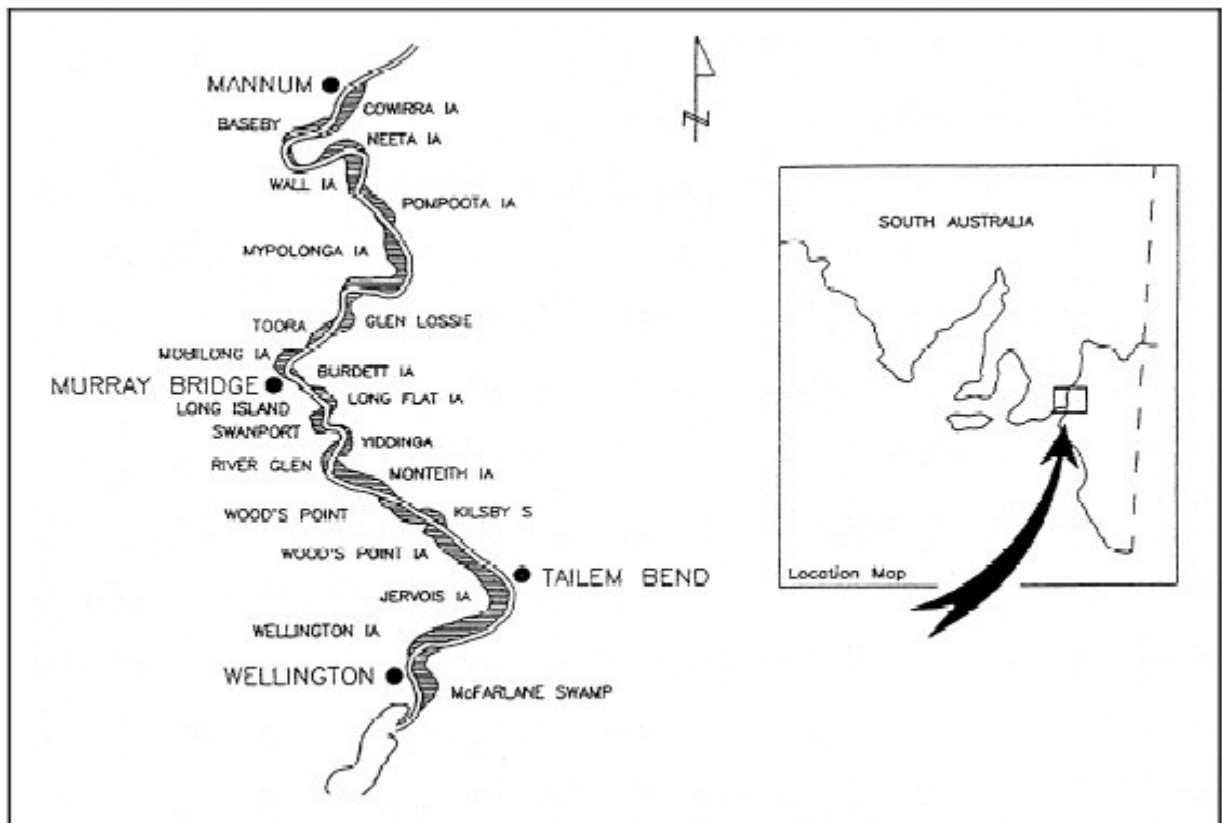
Having converted wetlands to dairy swamps and destroyed the natural water filtration process for water consumed by over 1 million South Australians it became necessary to build four water filtration plants in the location of the dairy swamps.

Politically, the return of the Lower Murray dairy swamps to wetlands is not seen as an option of high priority – wetlands are not viewed as having any great political or economic value. In contrast, the dairy industry that has developed on the wetlands has considerable commercial value; the only acknowledged drawback to the industry is the high level of effluent from the dairy pastures that enters the Murray River. An important repercussion of this effluent is its contribution to blue-green algae (BGA) outbreaks. The economic impact of BGA outbreaks is well recognised, particularly on drinking water quality and the tourism industry (Kennedy, 1997).

The figure below shows the topography of a typical reclaimed swamp, with the construction of a levee bank and irrigation drainage channels used to water dairy pastures. Excess irrigation water is then used to irrigate highland areas, while drainage water is returned to the river.

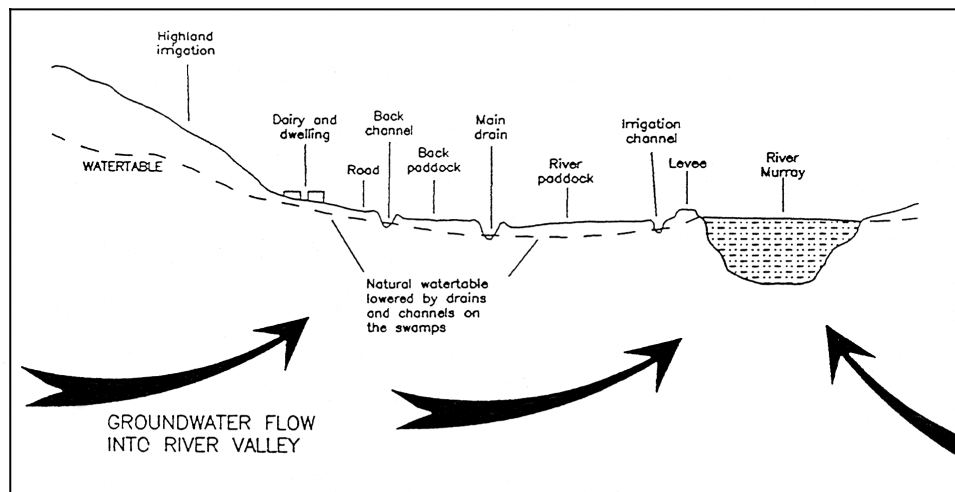
#### LOCATION OF THE STUDY AREA (SHADED AREAS = DAIRY SWAMPS)

Source (Murray and Philcox, 1995)



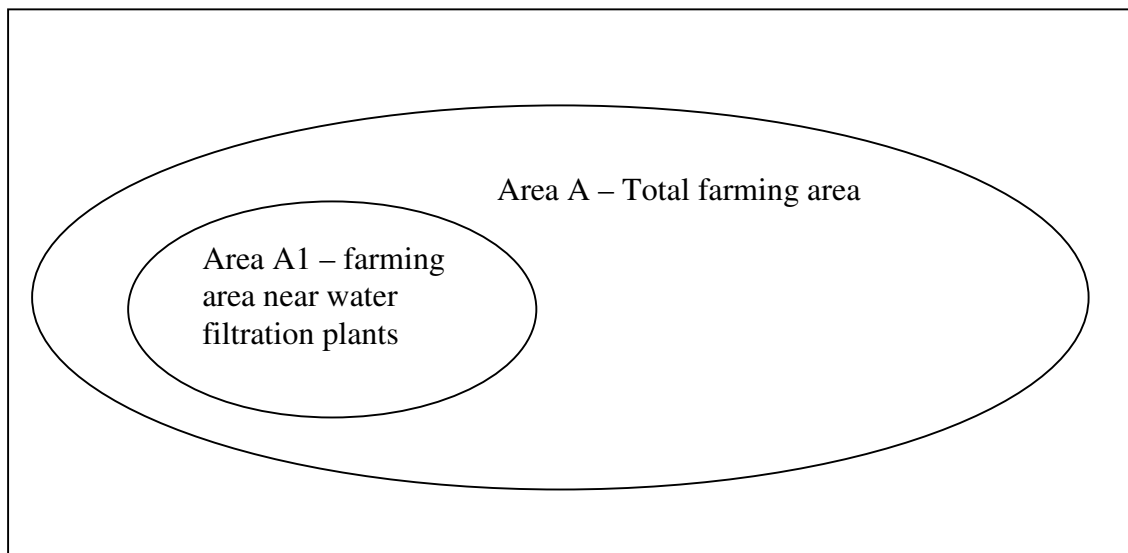
**FIGURE 1-1. TOPOGRAPHY OF A TYPICAL RECLAIMED SWAMP**

Source (Cole, 1985)



### 1.3.1 Options investigated

Three options are investigated in this study. The options relate to both a subset and the entire dairy farming area, as presented in the figure below. Area A represents the whole of the study area, which is used for dairy farming. Area A1 is a subset of area A, and represents those dairy swamps that are in the vicinity of the proposed water filtration plants<sup>1</sup>.



<sup>1</sup> The options presented in this paper focus on wetland valuation. However a consequence of returning these areas to wetlands is the removal of dairy effluent which contributes to BGA outbreaks (there are two basic approaches for attempting to reduce the probability of outbreaks of BGA: the reduction of nutrient loads into the water system, and increasing water flows at critical times (flow regulation) (Kennedy, 1997)). Details of the value of nutrient reduction associated with these options can be found in the PhD thesis from which this work is taken, Schmidt (2007).

**Option I.** examines how much of the water filtration costs could have been saved by returning dairy swamps next to the water filtration plants (Area A-1) back to constructed wetlands to undertake all or part of the filtration process. In this way, the commercial value of constructed wetlands for the filtration of domestic consumption is determined. The valuation of costs and benefits in this section requires an understanding of the commercial water filtration process, and the type and nature of the wetlands that would need to be constructed to replace all or half of the filtration system.

**Option II** determines the value of **natural** wetland for water filtration, based on the efficiency of natural wetlands to filter water in comparison with constructed ones.

**Option III** examines the conversion of the whole of area A back to wetlands for water filtration. It determines the value of natural wetlands for water filtration when the volume of filtered water is in excess of that required for domestic consumption.

### **1.3.2 Cost Benefit analysis**

The CBA methodology adopted in this study is based on that developed in Little and Mirrlees (L&M), (1976), and the Handbook of Cost–benefit Analysis, Department of Finance (DOF) (1991). The purpose of the cost-benefit model written for this analysis was to determine a value for water filtration by wetlands.

Cost–benefit analysis allows was used in this analysis because it allows for the valuation of all relevant inputs and outputs from the point of view of the farmer, the government or the community.

The main principles of cost–benefit analysis are encompassed within four key questions (DOF, 1991):

- Which costs and benefits are to be included?
- How are these costs and benefits to be valued?
- What is the interest rate at which these costs and benefits are to be discounted?
- What are the relevant constraints?

To answer these questions this analysis is undertaken from a base, historical scenario before any measures have been undertaken to either build water filtration plants or to address the problems of water pollution related to dairy farming. This base case is referred to as the ‘Status quo’. As the focus of this work is on determining a value for wetlands for water filtration, the selection of the situation as it existed at that time allows this value to be easily determined.

## 1.4 OPTION I

### 1.4.1 Methodology

In the model, wetlands are able to replace a percentage of each of the water filtration plants components at cost  $\lambda$ . To do this requires enough wetland area  $\varphi$  (ha), for a retention time of  $\zeta$  days. In this analysis,  $\zeta$  is determined to be 12 days: 10 days are required for sedimentation with a further two days required to allow one fifth of the area to dry out as part of the wetting/drying cycle (drying out a portion of the wetland allows the breakdown of vegetation and the release of carbon and nitrogen back into the atmosphere. While the literature suggests that a 10-day retention time is acceptable, sensitivity analysis has been undertaken for other retention times.

Figures from SAWater show that four of the 10 filtration plants (Mannum, Murray Bridge, Tailem Bend and Summit storage) are in the dairy swamps section of the Murray and the cost associated with these plants is \$10 million per year.

The **benefits** of replacing the water filtration plants with wetlands are therefore  $\lambda$ , i.e., the saving in the costs of building and running the filtration plants.

Thus the equation for the value **per hectare** of wetlands for water filtration,  $\psi$ , is determined by the following equation:

$$\sum_{t=1}^{25} (\alpha \lambda_t / \varphi) / (1+r)^t$$

Where:  $\varphi$  = Land area required: depends on quantity of water to be filtered, retention time, water depth, dry area;  $\lambda_t$  = total annual filtration cost (associated with these plants) in year t ( $\lambda_t$  is the cost avoided if the same quantity of water is filtered by wetlands, it is in fact a measure of the benefit of wetlands' water filtering function -  $\varphi$  and  $\lambda_t$  are related as both are associated with either a single plant or a set of plants);  $\alpha$  = filtration efficiency (%); r = discount rate.

The **costs** associated with conversion to wetlands include:

- Wetland engineering, construction and planting costs
- Purchase of water to cover evaporative losses
- Maintenance costs
- Loss of dairy income on the swamps - farmers can sell their water, and continue to farm dry stock on the highland.

Further details of all these costs and benefits are provided in the PhD thesis (Schmidt, 2007)

In summary, the NPV for the conversion of farmland to wetlands as part of the water water filtration system can be written as:

$$\sum_{t=1}^{25} ((\alpha\lambda_t) - (\chi + \tilde{\lambda}_t)) / (1+r)^t,$$

where,  $\alpha$  = filtration efficiency achieved (%),  $\lambda_t$  (filtration benefits at full filtration efficiency(\$/year)) =  $\theta_t + Bu_v + Bu_{va_t}$ ,  $\theta_t$  = annual filtration costs avoided \$,  $Bu_v$  = UV construction costs avoided (\$),  $Bu_{va_t}$  = annual UV costs avoided (\$),  $\chi$  = cost of evaporation water (\$),  $\tilde{\lambda}_t = C_{wf} + C_{gr_t}$  wetland construction and annual maintenance costs(\$),  $C_{wf}$  = cost of wetland construction (\$),  $C_{gr_t}$  = government annual repair and maintenance costs (\$).

### 1.4.2 Results

Problems of high water turbidity following drought indicate that wetlands may be able to replace half (but perhaps not all) of each water filtration plant. As indicated in below, figures in this study show that constructed wetlands are worth between \$14,100 and \$28,000 per hectare per year for their water filtration service alone, depending on whether they replace half or all of the filtration plant.

**Table 1-1. THE VALUE OF WETLANDS FOR WATER FILTRATION WHERE WETLANDS ARE USED TO REPLACE HALF OR ALL OF THE WATER FILTRTION PLANT**

Value of wetlands for water filtration \$/ha/yr	Present value per hectare \$
\$14,118–\$28,032	\$231,421–\$459,520

The figures presented in the table below take into account the costs (mentioned above) associated with conversion of the area to wetlands. They show that it would have been very profitable to include wetlands as part of the domestic water filtration system

**Table 1-2. NET RETURN FROM CONVERTING DAIRY LAND TO WETLANDS TO BE USED AS PART OF THE WATER FILTRATION SYSTEM**

	Return
<b>Benefits</b>	\$79.82 Million
<b>Costs</b>	\$40.84 Million
<b>NPV</b>	<b>\$38.98 Million</b>
<b>BCR</b>	<b>1.95</b>

## 1.5 OPTION II: THE VALUE OF NATURAL WETLANDS FOR WATER FILTRATION

### 1.5.1 Methodology

Having determined a value for constructed wetlands for domestic water filtration the next step is to determine the value of natural wetlands for water filtration when water is used for domestic consumption.

To undertake this part of the study it was necessary to examine the water filtration efficiency of constructed versus natural wetlands. Filtration efficiency depends on:

- Rate and type of water flow;
- Particle size;
- Vegetated area;
- Percentage of total river flow in contact with wetlands, and
- Number of wetlands in system

Overseas work shows large variations in filtration rates, ranging from 29 to 97% of sediment inputs to stream, however a summary of studies show average sedimentation rates in excess of 61% (Johnston, 1991). Little information exists on filtration rates in Australia, but the nature and number of wetlands suggest filtration rates at a minimum of 50% and possibly as high as 90% of that of constructed wetlands.

### 1.5.2 Results

The table below shows that natural wetlands are worth a minimum of \$7,100 per ha per year for water filtration. This figure substantially exceeds the economic return for all other land uses considered in this study (including income from dairy farming after rehabilitation of the irrigation scheme), and thus the most economically valuable use of the dairy swamp land is for wetlands for water filtration. If wetlands had been able to replace the whole filtration plant they would be worth around \$25,000 per ha/yr.

**Table 1-3. SUMMARY OF BENEFITS OF CONSTRUCTED WETLANDS FOR WATER TREATMENT \$/HA/YEAR**

<b>Filtration efficiency of natural wetlands compared with constructed wetlands</b>	<b>Replacing ½ filtration plant \$/ha/yr</b>	<b>Replacing all Filtration plant \$/ha/yr</b>
50%	\$7,100	\$14,000
90%	\$12,700	\$25,200

How do these figures compare with other studies?

- New York city spent US\$1.5 billion to protect 32,400 hectares of watershed land. This saved them building a water filtration plant costing US\$6-8 billion with annual operating costs of \$300 million. i.e., \$23,800/ha/yr. (Commission on Geosciences, 2000).
- Costanza *et al.* *The value of the world's ecosystem services and natural capital.* *Nature* (1997), showed that water supply/waste treatment is an important component of wetland value, with a value of US\$7,977/ha/yr.
- Thibodeau and Ostro (1981) valued the water supply benefits supplied by the Charles River wetlands in Massachusetts at \$35,000/ha/yr

## **1.6 OPTION III - THE VALUE OF NATURAL WETLANDS FOR WATER FILTRATION WHERE FILTERED WATER PRODUCED IS IN EXCESS OF THAT CURRENTLY REQUIRED FOR DOMESTIC CONSUMPTION.**

### **1.6.1 Methodology**

The final step in this study is to demonstrate the considerable value of water filtered by natural wetlands, even where the volume of water filtered is in excess of that required for domestic consumption (Area A). This issues is approached from two points of view:

1. Valuation is based on diminishing marginal utility: a decrease in value for excess filtered water.
2. Valuation is based on replacing the environmental service provided by wetlands (water filtration) if wetlands are destroyed.

#### **1. Valuation is based on diminishing marginal utility: a decrease in value for excess filtered water.**

While it is reasonable to assume that consumers may not value the extra water filtered by the natural wetlands to the same extent as that required for domestic consumption, the provision of additional filtered water does provide significant security for consumers in this region. On average, half of Adelaide's drinking water is sourced from the River Murray, with the other half coming from the Mt Lofty Ranges. However, in drought years, up to 90% of Adelaide's water can come from the Murray, increasing the demand for filtered water from this region. It is reasonable then to assume that population increases combined with severe drought conditions may result in the need for additional filtered water from the Murray to be available for rural users or to supplement metropolitan supply. In addition, the owners of holiday homes along the Murray draw their domestic water directly from the river, as do many farms for stock water supply. These water users will benefit directly from any water filtration undertaken by wetlands. The increase in water quality will also be beneficial for recreational activities, for example, for swimming, water skiing and boating, and thus would be valued by consumers.

Let  $\delta \times \psi$  be the value of the wetlands for water filtration for the extra water filtered where  $\psi$  = the value of wetlands for water filtration,  $\delta$  = a positive fraction (i.e. a percentage).

It would be expected that  $\delta$  would be in the range  $1 > \delta > 0$ .

The study therefore examines converting this area to wetlands using the assumed utility values associated with  $\delta$  equal to 0.25 and 0.50 (i.e. the value of wetlands for water for the supply of filtered water in excess of that required for domestic consumption is assumed to drop by either a quarter or a half)<sup>2</sup>.

### **The relationship between $\delta$ , marginal utility and price elasticity ( $\epsilon$ )**

The examples presented below shows the relationship between  $\delta$ , marginal utility and price elasticity ( $\epsilon$ ). They demonstrate that  $\delta$  in the chosen range is consistent with a realistic range of values for elasticity for a linear demand function for filtered water.

The examples demonstrate that  $\delta$  depends inversely on price elasticity of demand and the percentage increase in filtered water associated with the percentage increase in the supply of filtered water:

$$\delta = \theta [1 - (\Delta Q/Q) / (2\epsilon)]$$

where  $\epsilon$  is the price elasticity of the demand for filtered water,  $\theta = P/\psi$  and  $\psi$  is the unit value of filtered water (associated with  $Q$ ). Thus

$$\epsilon = (\Delta Q/Q) / [2(1 - \delta/\theta)]$$

#### **Example 1**

This example considers the implication for  $\epsilon$  when  $Q_2 = 4Q_1$ , so that  $\Delta Q/Q = 3$  and let  $\theta = 8$ . According to (A7-8), if  $\delta = .5$  and  $.25$ , then  $\epsilon = 2.4$  and  $1.6$  respectively. With a linear marginal utility (or demand) curve, such values for  $\epsilon$  are reasonable for small quantity  $Q_1$ .

#### **Example 2**

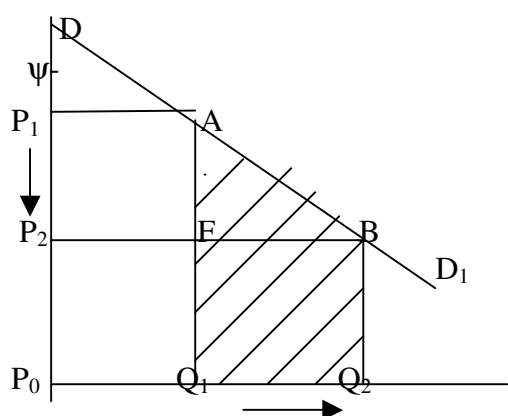
This example considers the case in which.  $Q_1 = 10$ ,  $Q_2 = 40$ ,  $P_0 = 110$ ,  $P_1 = 100$ ,  $P_2 = 70$ , i.e. the units are so chosen that the slope of the inverse form of the demand curve is  $b = dP/dQ = 1$ ,  $\psi = 105$  and  $\theta = 100/105 = 0.95$ . Note that  $P_0$  is the price at which  $Q = 0$  (see ).

The percentage change in quantity and price would therefore be 3 and .3 respectively and hence elasticity (in absolute value), being their ratio, is  $\epsilon = 3/.3 = 10$  and  $\delta = 0.95(1 - (3/20)) = 0.95(0.85) = 0.81 \sim .8$ .

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<sup>2</sup>  $\delta$  Depends inversely on the price elasticity of demand and percentage increase in supply of filtered water.

## VALUATION OF NON-MARGINAL CHANGES IN QUANTITY OF WATER PRODUCED



### 1.6.2 Results

A  $\delta$  value of 0.25 means that the value of natural wetlands for water filtration is **\$1,775/ha/yr.**

A  $\delta$  value of 0.5 means that the value of natural wetlands for water filtration is **\$3,550/ha/yr.**

If the value of natural wetlands for domestic water filtration is \$1,775/ha/yr conversion of the whole area from dairy farming back to wetlands (constructed and natural) would have provided the greater economic return.

If the value of natural wetlands for domestic water filtration is \$3,550/ha/yr, economic return is greatest if all dairy swamps are converted back to permanent wetlands for water filtration (this includes swamps that have been rehabilitated). Farmers would need to be compensated for this change<sup>3</sup>.

## 2. Valuation is based on replacing the environmental service provided by wetlands (water filtration) if wetlands are destroyed.

In the US legislation preventing the destruction of wetlands arose as a result of the US Congress 'Clean Water Act' (1972), which was designed (among other things) to minimise damage to wetlands (Bayon, 2002). This Act leads to 3 principles for assessing all developments that might impact on wetlands:

- 1) Do no harm
- 2) Minimise damage
- 3) Off-set

<sup>3</sup> Further details and a discussion of cost-sharing options between government and farmers is provided in the PhD thesis (Schmidt, 2007).

The requirement to offset damage i.e. unavoidable harm to be ‘mitigated’, has in turn lead to the development of an environmental currency ‘off-set” or “mitigation credits”, which inturn have lead to Mitigation banking. It has also created a variety of businesses specialising in enhancing or restoring wetlands in order to sell credits to needy developers.

In 1993, the Clinton administration endorsed the use of Mitigation banks, (White House Office on Environmental Policy, 1993) releasing the statement “the Nation’s wetlands perform many functions that are important to society, such as improving water quality, recharging groundwater, providing natural flood control, and supporting a wide variety of fish, wildlife and plants. The Nation’s wetlands continue to be lost at a rate of hundreds of thousands of acres per year due to both human activity and natural processes. This continued loss occurs at great cost to society.” Then in 1995, the Administration released the Federal Guidance for the Establishment, Use and Operation of Mitigation Banks (Department of Defence, 1995).

Essentially these pieces of legislation mean that if you destroy a wetland you must replace the function the wetland provides. The legal requirement that wetland functions be maintained removes the problem of relying on studies involving people’s ‘willingness to pay’ for wetlands – the cost of providing the wetland function now becomes the important factor which draws wetlands into the commercial market.

This study therefore considers the value of wetlands for water filtration if legislation required those who destroy natural wetlands to replace the water filtration process the wetlands once provided, i.e. it would be necessary to construct water filtration plants.

The methodology devised allows for variations in wetland filtration efficiency and in the amount of time wetlands are attached to the river - two important variables that make valuation of natural wetlands so difficult. The methodology uses the water filtration plant costs avoided as a reference point, and thus wetlands can be valued based on the percentage water filtration efficiency they are naturally able to achieve relative to the filtration plant. This means that wetlands that are less efficient at water filtration are worth less than those that have higher filtration rates.

The introduction of a time component into the equation makes it possible to value wetlands which are temporal in nature and are only able to filter water for certain times of the year when they are attached to the river. This methodology therefore provides an important tool for helping other researchers to determine the economic value of any particular wetland they might study.

### **1.6.3 Results**

#### **Permanent wetlands**

The table below shows the value of Permanent wetlands for water filtration based on the proportion of filtration they provide (when compared with constructed wetlands), assuming that constructed wetlands can only replace half of each mechanical water filtration plant. It

is recognised that the values for water filtration in this table are probably underestimates of the true value - construction of a filtration plant would incur fixed costs regardless of the amount or the efficiency of water filtration, and it is unlikely that fixed costs would drop in a linear fashion (as assumed in this table), and indeed may not drop at all. If we assume that the water filtration efficiency achieved is 50% then wetlands are worth around \$7,100/ha/year for water filtration.

**Table 1-4. VALUE OF PERMANENT WETLANDS FOR WATER FILTRATION BASED ON THE PROPORTION OF FILTRATION THEY PROVIDE**

<b>% Filtration achieved</b>	<b>Water filtration \$/ha/year</b>
90	12,706
70	9,883
50	7,059
30	4,235
10	1,412

The value of around \$7,100 per hectare per year must be viewed as conservative for the following reasons:

- It assumes that wetlands could only replace the primary and secondary filtration processes of each water filtration plant (for much of the year it they are able to replace all of the filtration process).
- It assumes that natural wetlands are only half as efficient as constructed ones at providing filtration benefits, while existing literature shows that they may be up to 97% as effective.
- This value is based on the costs of the water filtration plant to provide water filtration, and assumes a linear reduction in wetland value as wetland water filtration efficiency drops, i.e. if wetlands are only half as efficient at filtering water as the filtration plant, they would save only half the filtration plant costs. In fact while it might be expected that chemical and sludge disposal costs associated with the filtration plant would change with changes in filtration efficiency, the fixed costs and many of the running costs associated with filtration plants would still be incurred and thus wetland filtration values may be greater than this figure.
- The many other benefits to waterways (e.g., removing other harmful algae and other water pollutants) that are by-products of the water-filtering function of wetlands are not included (because of a lack of reliable estimates for them).

At the same time, it is recognised that even though modelling shows that wetlands are worth at least \$7,100 per ha for water filtration, there is great variability in wetland efficiencies and in wetland types across regions and therefore care must be taken when using these figures in other regions.

### Temporal wetlands

The proportion of time that temporal wetlands are connected to the river varies enormously depending on the location of the wetland, wetland depth and climatic conditions. The matrix presented in the table below shows the range of wetland filtration values that can be expected under different filtration efficiency percentages and months of connection to the river. This matrix provides an easy method for managers of temporal wetlands to determine the filtration value (\$/ha/year) of a range of wetland management options involving flooding regimes of different durations and water filtration efficiencies. The filtration ability of any particular wetland may change over time and under different flow volumes, however as long as filtration rates can be determined for these periods, the value of wetlands for water filtration can be found.

**Table 1-5. VALUE OF WETLANDS (\$/HA/YEAR) FOR WATER FILTRATION UNDER DIFFERENT FILTRATION EFFICIENCIES AND DURATION OF CONNECTION TO RIVER**

Number of months connected to river	Percentage filtration efficiency				
	10	30	50	70	90
12	1,412	4,235	7,059	9,883	12,706
10	1177	3530	5883	8236	10589
8	941	2824	4706	6588	8471
6	706	2118	3530	4941	6353
5	588	1765	2941	4118	5294
4	471	1412	2353	3294	4235
3	353	1059	1765	2471	3177
2	235	706	1177	1647	2118

Assuming that natural wetlands provide between 50% and 90% filtration values of constructed ones, we therefore expect the filtration value of Temporal wetlands to range from around \$2,900 to \$5,300 per hectare per year.

Once again the values in the table are based on the costs of the water filtration plant to provide water filtration, and assumes a linear reduction in wetland value as wetland water filtration efficiency drops. In fact the fixed costs and many of the running costs associated with filtration plants would still be incurred and thus wetland filtration values may be greater than these figures.

## 1.7 DISCUSSION

Very little information exists in Australia on the ability of natural wetlands to filter water. This factor, in combination with the interdisciplinary skills required to assess the value of this environmental service, has probably been the main reason why previous resource

economists relied on questionnaires seeking peoples' 'willingness to pay' to determine wetland values. Unfortunately such valuation methods are unable to capture wetland functions such as water filtration, because the public generally has little idea of what such functions are worth. This has resulted in wetlands being seriously undervalued, thereby providing misleading grounds for their destruction.

The methodology developed in this study addresses this lack of knowledge by focusing on the value of the water filtration process itself. It looks at the actual costs involved in building and running water filtration plants and thus determines the cost to the public of mechanically filtering water. The study then examines how much of these costs could be saved by utilising constructed wetlands to undertake all or part of the filtration process. In this way, the commercial value of wetlands for water filtration is determined.

The results from this study show the significant value that wetlands have when their worth is based on the cost of replicating their filtration function; constructed wetlands are worth over \$14,100/ha/yr, natural permanent wetlands are worth over \$7,100/ha/yr, and natural temporal wetlands are worth over \$2,900/ha/yr. These values are consistent with those obtained from other international work.

Further, the study shows the considerable value of wetlands for water filtration even where the volume of water filtered is in excess of that required for domestic consumption (i.e. diminishing marginal utility).

Significantly, if we compare the values determined in this study for Managed (temporal) wetlands (ranging from around \$2,900 to \$5,300 per hectare per year) with those obtained by using 'willingness to pay' or 'choice modelling' techniques of between \$82 and \$300 per hectare per year, it is clear that the values determined in this study for filtration value alone are easily in excess of the values currently attributed to wetlands based on peoples willingness to pay. This suggests that choice experiments are unable to capture the value of resources where legislation fails to make people accountable for their environmental impacts. The reasons for this failure relate to the public nature of ecosystem services – the public enjoys the services for free and therefore has no idea of the economic value of the services when they are asked to assess them. This problem is perhaps best summarised by Diamon and Hausman (1994) "We do not expect that public policy would be improved by using choice methods to affect the levels and patterns of spending for school education, foreign aid, Medicare, construction of safer highways, medical research, airline safety, or police and fire services. Yet people have concerns for others in all of these areas that parallel their concern for the environment."

However, as long as people are willing to identify and pay for their desired wetland attributes, then the benefits (net of additional cost for improving various wetland attributes) should be considered in conjunction with the value of wetlands for water filtration determined in this study. It is expected that the water filtering use of wetlands and their other environmental uses are complementary and not mutually exclusive.

This study highlights the need for resource economists need to pay more attention to valuing wetlands as a series of key processes and to working in conjunction with researchers from other disciplines to understand such things as filtration and the impact of wetting and drying cycle. In support of this notion, Barbier *et al.* (1997) state that “regardless of the method selected to value wetlands, an interdisciplinary approach will be needed at virtually all stages in the assessment, and this should particularly involve collaboration between economists and ecologists.”

## **1.8 POLICY IMPLICATIONS**

The results from this study indicate that if wetlands were used as part of the drinking water filtration process they could provide an extremely valuable service to the community. The set of factors that have caused the valuation of wetland functions to be overlooked – the ‘invisibility’ of the functions performed, the complex nature of these functions, and the need for more interaction between economists and others involved in the research and development process – means that the government is poorly equipped to make investment decisions where wetlands are concerned. This has probably been partially or predominately responsible for the lack of legislation which ensures accountability and safeguards against ill-judged wetland destruction. This also highlights the difficulty of ensuring the allocation of money for environmental projects where the benefits are not clearly visible or understood by the public.

The difficulty for the government is the decision to allocate substantial funds to projects that do not show immediate or visible results. The government thus has to decide if it is willing to spend significant amounts of money for environmental benefits.

Following the example set in the United States, Australia must consider the introduction of legislation to prevent wetland destruction. Once established, the legislation needs to be supported by the establishment of a wetland mitigation banking system whereby businesses (or individuals) who enhance or restore wetlands are provided with wetland ‘credits’ that they are able to sell to needy developers. Such a system would help to ensure the protection of the important functions wetlands provide, (a very valuable one of which is water filtration), and could halt the destruction of wetland areas. It would provide the incentive to rehabilitate degraded areas, and not only yield environmental benefits but have tangible economic benefits, based on market prices.

Other important implications for this work include the urgent need for wetlands to receive sufficient water during drought conditions to maintain their very valuable water filtering function, and the need for Governments to consider ecosystem service payments for landholders who manage/preserve wetlands, until a mitigation banking and credit trading system is established.

Municipal water managers might also like to consider the use of wetlands as part of future water filtration systems.

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