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**THE IMPORTANCE OF RIPARIAN VEGETATION IN IMPROVING WATER QUALITY**

**RESEARCH REPORT NO. 2**

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# ESTABLISHING THE POTENTIAL FOR OFFSET TRADING IN THE LOWER FITZROY RIVER RESEARCH REPORTS

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**Any comments will be gratefully received and should be directed to Associate Professor John Rolfe**

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## Abstract

Non-point source water pollution of waterways is a significant environmental problem throughout the Fitzroy Basin. Grazing being the major land use (i.e. about 88 percent of the land area in the region), it is also the major source of pollutants, including sediment and nutrients (mainly nitrogen and phosphorus). The effect of livestock grazing, and the need for the restoration of the riparian vegetation zones along the waterways to reduce nutrient and sediment inputs is being recommended. Maintaining riparian zone vegetation is also crucial for the water quality of the catchment as well as the GBR lagoon. Riparian buffer zones can improve and maintain water quality by filtering sediment, nutrients, organic mater, and pesticides from surface and groundwater flow, through the processes of deposition, absorption, plant uptake, and denitrification. It can effectively reduce the amount of sediment reaching streams and rivers.

A relatively large body of studies exists that support the use of riparian buffer strips to manage nutrients and sediments. While it is well recognized that buffer zones have great potential to improve water quality and enhance riparian biodiversity, however how best to realize this potential is still a matter of considerable debate. In many occasions, a patchwork of policies and initiatives featuring either a regulatory or market-based or a mixture of regulatory and voluntary approaches have developed to encourage the protection/establishment of riparian buffer zones. In this report, the importance of riparian zones in reducing sediment and nutrient loads into the receiving waters are described and a review of on-ground initiatives in the region is made.

## 1. Introduction

Many streams in Queensland have poor or reduced levels of water quality. This is an issue of concern because of the impacts on environmental health of the associated ecosystems within streams, in estuaries and coastal zones, and for some streams, on the Great Barrier Reef lagoon. In recent years a focus on the health of the Great Barrier Reef and the potential impacts of terrestrial pollution has generated substantial interest in opportunities to improve water quality from inland streams (PC, 2003 and SQCA, 2003).

Contributions to reduced water quality in the Fitzroy basin have been reviewed by Rolfe *et al.* (2004), where they report that agricultural land use is likely to be the major contributor to increased sediment and nutrient loads in the river system. Across the Burdekin and Fitzroy systems, agriculture (beef cattle and dryland cropping) account for about 80 percent of pollution loads to the Great Barrier Reef lagoon (PC, 2003). Cattle grazing can affect water quality in a number of ways, including:

- woodland removal and vegetation clearing, particularly in riparian areas,
- overgrazing, soil disturbance and stream bank erosion by cattle,
- cattle access to waterways/riparian strips, and
- applying fertilizers and herbicides to pastures.

(PC, 2003: 104)

Key mechanisms to reduce water quality impacts from grazing and dryland cropping areas include protection of riparian areas and improvements in ground cover. The protection of riparian areas would mean that these zones would tend not to be sources of sediments and nutrients, and may also act as filter and buffer strips where sediments and nutrients are entering streams from grazing and farming lands. Improvements in ground cover on grazing and farming lands are also important mechanisms for reducing sediment and nutrient losses to waterways and can be achieved through actions such as reduced stocking rates (on grazing lands), avoiding over-grazing, excluding livestock from water bodies, creating filter strips to trap nutrients and sediments, improved property management planning, and minimum tillage (on farming lands).

In the project that this report forms an output, the focus is on exploring options for market based instruments to improve water quality in the Fitzroy river system. The high contribution of agriculture to water quality impacts, and the previous focus of regulatory effort on other contributors (industrial and urban sources) means that most opportunities to improve water quality will be associated with agriculture. The purpose of a market-based instrument would be to relate incentives for improved water quality more directly to land managers and ensure that improvements in land management are achieved at lowest cost.

In this project, a choice existed between two broad mechanisms for minimising water quality impacts from agriculture: riparian protection and improved ground cover. Improved ground cover is a very important mechanism for improving water quality because it stops sediment and nutrient movement at the source. It may also be associated with relatively low opportunity costs in many cases. However, appropriate levels of ground cover vary by land use, soil type, land condition, land slope, vegetation cover and rainfall patterns. There are also difficulties in developing an adequate monitoring system or predicting how sediment and nutrient movement varies according to ground cover. These factors may make it difficult to develop standard improvements or minimum conditions in ground cover that are easily definable to landholders.

Improvements in riparian protection are more easily defined as an action to landholders because the location (waterways) and area involved (width of riparian strip) can be easily described. The linkages between riparian buffer strips and water quality is expected to vary according to factors such as soil type and management actions (e.g. access by stock), but would not be expected to be as complex as the improved ground cover action. Consequently, ‘improvements in riparian vegetation’ has been selected as the key management action of interest for this research project.

In this report, the relationship between riparian vegetation and water quality impacts in the Fitzroy basin are explored. The purpose of the report is to collate relevant information so that the key factors for landholders and policy makers in enhancing riparian vegetation in the basin can be identified. These factors will then be used in the subsequent design of a choice modelling experiment.

## 2. Definitional Issues

The riparian zone is any place/land along a riverbank, stream, creek or water body where land and water meet. Naturally it is a vegetated filter strip between terrestrial and aquatic systems. According to Narumalani *et al.* (1997), riparian buffer zones are “permanently vegetated areas located between pollutant sources and water bodies … which allow runoff and associated pollutants to be attenuated before reaching surface and underground water sources via infiltration, absorption, uptake, filtering, and deposition" (p: 394). However, it is important not to consider this as just a narrow strip of land covered with vegetation and trees. Besides providing material fluxes between terrestrial and riverine ecosystems, riparian zones are considered as wildlife corridors for maintaining biodiversity.

Depending on the nature of the land (e.g. floodplain and valley) and the adjacent land use (e.g farming, grazing, urban settlement and forestry), the width of riparian zone varies from a very narrow to a wide landscape with a varying degree of vegetation and tree covers. According to Apan *et al.* (2002), “[r]iparian landscapes include land areas adjacent to a river or stream. They are unique environments because of their positions, structures and functions in the landscape. Riparian areas are important pathways for the flow of energy, matter and organisms through the landscape and act as ecotones between the terrestrial and aquatic zones and corridors across regions. They are valuable natural resources that could serve a wide variety of productive, protective, and aesthetic functions” (p: 43).

Due to its important role in providing many services, riparian zone is fragile and vulnerable to both over-use and mis-use. That’s why it needs special care and management. Riparian zones need to be restored and managed for its important contribution in reducing erosion, improving water quality, maintaining river course and stock management, controlling nutrients, decreasing algal growth, increasing fish stocks, providing landscape refuse and maintaining biodiversity.

Riparian zones play an important role in Australian waterways. However, status and condition of the riparian vegetation vary among state to state within Australia. The status of riparian vegetation within the Great Barrier Reef catchment is still only partly studied (Furnas, 2003). There have been detailed surveys of riparian vegetation in several catchments. According to Furnas (2003), "[t]he results show that a significant proportion of the riparian vegetation along both large and small watercourses has been thinned or reduced in width. The degree of disturbance is often greater along smaller frontage in catchments. Most eroded soil initially enters river systems through these small, seasonally flowing streams. The enormous number of small streams in all catchments makes management practices such as fencing streams to exclude cattle, very difficult and expensive" (p: 124).

## 3. Riparian Vegetation and Water Quality Impacts in the Fitzroy Basin

In terms of area, cattle grazing is the principal land use and comprises about 88 percent in the Fitzroy Basin area (Jones *et al.,* 2000) and 94 percent of the area used for agriculture (Furnas, 2003). As it occupies such a large area in the basin, it is the dominant land use which has the most impact on water quality both in the catchment and the GBR lagoon. Stock can have both direct and indirect effect on the riparian ecosystem, directly through impacting on the geomorphology of habitats as well as on vegetation and water quality and indirectly through altering habitat structure and patterns (Jansen and Robertson, 2001). Scrimgeour and Kendall (2003) comment, "[l]ivestock grazing can profoundly alter the abundance and composition of stream communities through interactive effects on nutrient loadings, bank stability, channel morphology, substratum size composition and riparian vegetation" (p: 348).

Many improved pastures for grazing have been established through extensive clearing of native vegetation throughout the region since European settlement[1]. It has been estimated that the average clearing rate for the Queensland was 577,000 hectares (0.33 percent of Queensland's land area) per year between 1999-2000 and 2000-01, with approximately 94 percent of woody vegetation change attributed to clearing for pasture,

[1] EPA (1999) estimates that more than 50 percent of the Queensland's original 117 million hectares of woody vegetation have been cleared primarily for agricultural purposes since European settlement.

and about 16 percent of the total clearing in Queensland occurred in the Fitzroy catchment (PC, 2003).

Being grazing the dominant land use in the Fitzroy catchment, run-off resulting from cattle grazing areas is the primary influence on water quality in the Reef. Davidson (2003) recognizes that "[d]ue to the vast areas involved in pastoralism, most of the collective sediments and nutrients reaching the coast come from cattle grazing lands in the drier catchments of the Burdekin and Fitzroy rivers" (p: 38). According to Science Panel estimates, agriculture including grazing contributes around 80 percent of the pollution loads to the GBR lagoon (PC: 2003). Modelling by Moss *et al*. (1993) suggest that around 73 percent (51400 tonnes) of the nitrogen discharged annually from the GBR catchments is sourced from grazing lands and around 21 percent (14500 tonnes) from cropping lands (quoted in PC, 2003).

Therefore, maintaining riparian zone vegetation is crucial for the water quality of the catchment as well as the GBR lagoon. Riparian buffer zones can improve and maintain water quality by filtering sediment, nutrients, organic mater, and pesticides from surface and groundwater flow, through the processes of deposition, absorption, plant uptake, and denitrification. It can effectively reduce the amount of sediment reaching streams and rivers[2] (Ducros and Joyce, 2003).

The riparian vegetation plays a significant role in relation to soil erosion, channel stability, wildlife and fish habitat, and water quality. Vegetations in riparian areas also have important roles in regulating the upstream-downstream movement of matter and energy by filtering or stopping the movement of sediment, water and nutrients. Specifically, riparian vegetation has an important filtering role for dissolved nitrogen, phosphorus and toxins moving along the slope of discharge. For instance, Correll and Kingston (1992) found that riparian forest bordering agricultural fields removed over 80 percent of the nitrate and total phosphorus in overland flooding, and about 85 percent of nitrate in shallow groundwater drainage from the cropland (reported in Apan *et al.*, 2002).

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[2] Although much of it largely depends upon the physical environment and vegetation cover in the riparian area.

Riparian vegetation once covered large areas of the GBR catchment. Removal of vegetation in general is considered as the primary cause of erosion and nutrient loss in the GBR catchment (Davidson, 2003). Studies show that the riparian zone forms an important sediment sink, where fluvially transported sediment can temporarily be stored. Good riparian vegetation coverage is beneficial in reducing sediment, nutrient and pesticide runoff into creeks and streams (Askey-Doran *et al.,* 1996 reported in Jones *et al.,* 2000); that is why it is considered as most contributing factor in trapping runoff from the catchment to the GBRMP (Jones *et al.,* 2000). A study in Australia shows that approximately 90 percent of sediment transported overland to waterways may be trapped by a buffer strip of vegetation and grasses (Askey-Doran *et al.,* 1996 reported in Jones *et al.,* 2000). Another experimental trial in the wet tropics show that grass strips of sufficient width can trap up to 80 percent of eroded soil entering the riparian zone (Furnas, 2003).

Improved land management practices, specifically immediate minimization of vegetation clearance and maintenance/conservation of existing (remnant) vegetation are essential if water quality of the GBR is to be maintained and protected (Haynes and Michalek-Wagner, 2000). Although a number of land management strategies along the riparian zone are in place at the farm level, the fact remains that appropriate land management throughout the GBR catchment remains a great challenge (*ibid*). Not only vegetation clearing on agricultural lands is till being carried out at rates that are up to an order of magnitude higher than any other Australian State (*ibid*), there exists a poor ground cover in remnant vegetation (Taylor and Jones, 2000; CRC, 2003). CRC (2003) states that 63 percent of the original extent of native vegetation has been cleared as of 1999 and the average rate of clearing is between 0.5 and 0.75 percent of the catchment annually. About 80 percent of the Dawson and 50 percent of the Comet/Nogoa/ Mackenzie have poor to very poor riparian coverage (Taylor and Jones, 2000). Presence of stock was found at 71 percent of sites in the Comet, Nogoa and Mackenzie and 87 percent of sites in the Dowson area of the Fitzroy catchment (*ibid*). Studies show that stock access to riparian zone and clearing of vegetation are the major contributor to poor riparian condition and bank stability (CRC, 2003).

## 4. Ground Cover and Water Quality Impacts

Restoration and proper maintenance of riparian zone provides benefits for water quality, the physical condition of the stream, and aquatic and terrestrial ecology. Erosion can seriously affect the productivity of grazing lands in particular. The movement of sediments, nutrients and organic matter may also adversely affect water quality in streams.

Poor/impounding vegetation cover, particularly in the riparian lands, can affect water quality in rivers as well as downstream estuarine and coastal waters. Good management of riparian land can decrease the amount of soil and nutrients moving from farming field and upslope of the riparian land into the stream. By trapping soil and nutrients, water quality can be improved and the loss of in-stream habitat through siltation can be prevented. According to Qureshi and Harrison (2001), poor vegetation makes riparian areas prone to erosion, bank slumping and weed and pest invasion, adversely affecting water quality and riparian biota and leading to increased downstream flooding and sedimentation.

Riparian vegetation has been shown to have a mitigating effect on pollution for receiving bodies of water. The effectiveness of narrow vegetated buffers in mitigating the effects of reduced water quality is well documented in the literature (Thibault, 1997). Cooper *et al.* (1986) found that a riparian forest buffer of only 16 m wide effectively removed most of the nitrate from ground water. Peterjohn and Correll (1984) found similar results. Gilliam *et al.* (1986) studied the sediment transport from soil erosion of agricultural fields and found that 88 percent of the sediment eroded from these fields over a 20-year period had been deposited in the riparian zone (reported in Thibault, 1997).

Eighty-nine percent of the nitrogen in runoff was removed by a riparian forest in Maryland (Peterjohm and Correll, 1984 quoted in Thibault, 1997). It was ascertained that the nutrient removal by reducing diffuse-source pollution in riparian forests is ecologically significant to receiving waters. Lowrance *et al.* (1984) considered riparian zone to be important in maintaining stream water quality. A study shows that it can act as a filter for $NO_3$-N, Ca, Mg, K, and $SO_4$-S (Lowrance *et al.,* 1984).

## 5. Riparian Vegetation, Water Quality and Agricultural Productivity

Sediment and nutrient losses have been identified as a threat to the productivity of agricultural farms and the quality of river waters. Soil degradation concerns farmers because it decreases crop yields and thus returns to agricultural production. Soil degradation concerns society because it reduces water quality through runoff and sedimentation. Both on-site (i.e. private) and off-site (i.e. social) effects are important.

Erosion/suspended sediment may reduce not only on-farm productivity, but also can contribute to a host of off-farm problems. Soil carried as sediment can clog irrigation systems, damage aquatic ecosystems by covering up fish breeding areas, and increase the costs of treating water.

Erosion reduces productivity by causing loss of topsoils that are often shallow and which contain most of the nutrients in the soil profile. Higher rates of run-off from eroded surface, waste valuable moisture – the principal factor limiting productivity in arid lands. By removing sediment, nutrients and organic matter, run-off can have an adverse effect of water quality (NRM, 2001).

## 6. Extent of Riparian Buffer Zones

The condition and extent of riparian vegetation along Australia's rivers and streams varies greatly. Qureshi (1999) summarizes a wide variety of literature on riparian zones width requirements, concluding that the minimum width recommended varies from 6 to 30 m (quoted in Qureshi and Harrison, 2001). The optimal or adequate width of riparian buffers remains an issue of controversy, and will vary with the circumstances. Castelle *et al.* (1994) found buffer widths of three to 200 m effective, depending on site-specific conditions (reported in Narumalani *et al.*, 1997).

According to Qureshi and Harrison (2001), "[t]he appropriate design and width of riparian vegetation buffers in north Queensland is a matter of considerable debate, in part due to the multi-purpose nature of these strips, e.g. dense grass can control runoff problems but only large trees will bind banks and reduce summer water temperatures. Conservation agencies would like the buffers to be wide and well wooded, but farmers are loath to take prime land out of cropping" (p: 103-4).

Deciding on the width of the stream corridor is perhaps the most important decision a land use planner or resource manager could face in designing the riparian zone management plans. Because external stresses on the corridor, such as the input of dissolved substances, are uneven along its length, good design and management practices often require uneven corridor widths. In most situations, the determination of the optimum width for particular management objective is not trivial – various factors such as land use, slope, rainfall, stream order, existing riparian vegetation, landform and geology, must be thoroughly considered.

## 7. Management and Restoration of Riparian Vegetation: Limitations of Regulation

There is an extensive body of literature on the need for the maintenance and establishment of riparian vegetation zone in the catchment (Qureshi and Harrison, 2001), but little literature on how to maintain or restore it. Buffer zones can be restored through command-and-control approach, such as regulations. However, for environmental regulations to be effective, they must be palatable to land owners. Regulations restricting its development would not be perceived as obtrusive. Land users that traditionally disturb the land right to the stream edge will deem the maintenance of a buffer area as a loss in potential income or value. In this situation regulations stopping land development would most likely require some sort of compensation. This can prove to be complicated and expensive. Also, the lack of acceptance of the regulations increases the risk of infractions that may result in the need for mitigation efforts (Thibault, 1997: 44).

The establishment and maintenance of vegetated riparian buffers along the riverbanks has been mandated by the state government legislation in Australia. However, as discussed in the first report of this research project (Rolfe *et al.*, 2004), private costs on the part of the landholders are higher than the private benefit in maintaining the buffer zones along the watercourses. On the other hand, social benefits are considered to be higher than the social cost. This kind of externalities leads to a case of market failure.

As discussed in the first report (Rolfe *et al.*, 2004), the regulatory approach to restore riparian vegetation has had some success, but is difficult to enforce, lacks local support, leads to inequitable distribution of benefits and costs, and does not halt the incremental decline of riparian vegetation. Experiences elsewhere show that market-based instruments are seen as the alternative option to restore and management of riparian zone vegetation. The *Reef Water Quality Protection Plan* also emphasizes on the adoption of market based instruments because "[e]ffective use of economic instruments can produce a double dividend; both better environmental outcomes as well as superior economic performance" (SQCA, 2003: 16).

In many countries, a patchwork of policies and initiatives featuring a mixture of regulatory and voluntary approaches has developed to encourage buffer zone establishment (Caruso, 2000).

Market-based instruments offer a complementary approach that can address these limitations of command-and-control approach. It has the potential to create incentive mechanism among landholders to restore riparian vegetation zone along the riverbank. It is seen as a powerful driver for change throughout the GBR catchment to "establish conservation agreements and covenants to ensure protection and management of remnant bushland, riparian vegetation and wetlands that can produce water quality improvement outcomes for the Reef" (SQCA, 2003:15). According to Qureshi and Harrison (2001), "[w]hile there would be considerable social benefits, farmers would be loath to give up crop land. Typically, legislative acts available to protect natural resources do not have the capacity to force farmers to implement revegetation option. …landholders may be convinced to change their riparian land management by moral suasion and financial subsidy, avoiding the long lead-time, enforcement cost and social disharmony of compulsion by legislation or regulation" (p: 111).

## 8.0 Designing Incentive Programs to Engage Landholders in Protecting/Establishing Riparian Vegetation in the Fitzroy Basin.

There are three categories of land tenure along the streams and rivers in the Fitzroy Basin: private property used for grazing and cropping, State Forests used for production forestry and some grazing, and Crown Land used for a variety of purposes, including support of traveling stock and for recreation. Most riparian areas/lands are privately owned which makes it difficult/costly for them to introduce measures such as fencing as a solution to the impact of livestock on riparian condition. Restoration of riparian vegetation on private properties becomes the responsibility of landholders. This creates an externality as explained in the first report (Rolfe *et al.*, 2004).

Therefore, it is important to consider how farming and grazing management practices could be altered, specifically an incentive mechanism could be introduced to improve riparian ecosystem and thus improve the water quality through reducing loads of nutrients and sediments in the Fitzroy Basin.

### 8.1 Review of On-ground Activities to Establish the Riparian Vegetation and Improve the Water Quality

There are some on-ground initiatives in the Fitzroy Basin to improve the riparian conditions and thus the water quality. Among them the significant one is the devolved grant scheme, titled *Fitzroy Basin Best Management Practices Devolved Grant,* run by the Fitzroy Basin Association (FBA) to establish and protect the riparian vegetation in the basin. The Devolved Grant provides funding support for on-ground projects aimed at improving riparian and groundcover condition across the whole Fitzroy Basin. The FBA also completed a devolved grant scheme for the Fitzroy region titled *Increasing Adoption of Best Management Practices in the Fitzroy Basin Region* in 2001-02. This scheme focused on protecting remnant riparian vegetation by providing incentives for the implementation of best management practices (BMPs) on private and public lands in the greater basin area with the exemption of the area covered by the Lower Fitzroy Devolved grant scheme (Greening Australia, 2003).

Currently the FBA is implementing its second phase of the devolved grant scheme, titled *Fitzroy Basin Best Management Practices Devolved Grant*[3]. To date a total of about 200 projects has been approved through the devolved grant involving a dollar value of about $1.5 million from the Natural Heritage Trust (NHT) fund and about 3

[3] Another devolved grant scheme, titled *Lower Fitzroy River – Incentives for Strategic Community Action to Improve Catchment Health,* developed by a coalition of Livingstone and Fitzroy shire councils and Rockhampton city council with a similar focus to the FBA devolved grant was implemented in the Lower Fitzroy region during 2001-02 (LFRCAP, nd).

million from landholders' (normally in-kind) contribution[4]. These funding supports are provided for fencing off riparian areas and provision of off-stream watering, and management of strategic weed and erosion control based on the *Property Resource Management Plan* designed for each individual property.

While the devolved grant schemes are seen as a positive contribution on the part of the landholders towards the sustainable management of natural resources in the region, however, this may not be the most cost-effective approach to achieve the outcome. Furthermore, this approach does provide little or no incentive to landholders to invest on technological innovation and adopt cheaper and better technology. And here lies the essence of a market-based instrument at the property level to achieve the desired level of pollution reduction at the lowest possible cost.

## 8.2 Quantifying the Impact of Land Use Changes on the Water Quality

Another important issue is the linkages between different types/areas of riparian vegetation and the subsequent impact on water quality. Studies about the quantification of the impact of establishment/protection of riparian vegetation on the improvements in water quality are not conclusive (Clausen *et al.*, 2000; Dosskey, 2001). In reviewing a large body of scientific literature on riparian buffer, Dosskey (2001) concludes "consensus of experimental research on functions of buffers clearly shows that they can substantially limit sediment runoff from fields, retain sediment and sediment-bound pollutants from surface runoff, and remove nitrate N from groundwater runoff. Less certain is the magnitude of these functions compared to the cultivated crop condition that buffer would replace within the context of buffer installation programs" (p: 577).

However, recent advancement in modeling the impact of land use and other changes on the water quality is able to provide information about the degree to which establishment of riparian buffer can enhance water quality in streams/rivers or catchment scale. Two such models, namely *Sednet* and *EMSS*, are currently being used in predicting pollution loads in different catchments in Queensland.

[4] Personal communication with the FBA official on April 2, 2004.

The CSIRO, together with the National Land and Water Resources Audit (NLWRA) has developed a model named *SedNet* or *Sediment Network* model (CSIRO, 2002). It was used to assess the movement of sediment and nutrient across Australia for the NLWRA. Using the GIS maps and other information, such as soil type, land use, geology and river and gully networks, the *Sednet* can be used to assess the water quality for regional catchments and to identify the most cost-effective places (i.e. hotspots) to control the major sources of sediment and nutrients that cause the quality of water within a catchment. The *SedNet* has been used to identify sediment and nutrient hotspots in the Burdekin catchment and describe how best they can be managed (Prosser *et al.,* 2002).

The second one is the *Environmental Management Support System* or *EMSS* developed by the CRC for Catchment Hydrology. The EMSS uses the lumped conceptual catchment scale model to estimate daily runoff and pollutant load of total suspended solids, total phosphorus and total nitrogen from 175 catchments within the 23,000 km$^2$ area in the south-east Queensland region (Chiew *et al.,* 2002). The model estimates are sensitive to changes in climate, storage operations, land use and land management practices, including point and non-point source loadings and treatments. The main use of the EMSS is to estimate present runoff and pollutant loads and to predict the impact of changes in land use (there are nine land use categories used in the EMSS) and land management practices on runoff and pollutant export loads to the receiving water.

Therefore, using these models it is also possible to quantify/predict the impacts of establishing more riparian protection zones on receiving water bodies. Specifically, how much reduction of pollution loads can be achieved from establishing buffers on the grazing fields along the waterways.

## 8.3 Identifying the Attributes

Another important aspect is the identification of the key factors that could be involved in the process of establishing/protecting riparian buffer zones on grazing fields.

A provisional list of attributes that landholders might consider in establishing/ protecting riparian zones as important is as follows:

- Width of strip
- Exclusion of cattle (whole or part)
- Supply of water points off-stream
- Management of weeds and fire
- Length of agreement (five, five + years)
- Vegetation type (grass, grass + woody, grass+ tree, grass+woody+tree)
- Vegetation density
- Runoff characteristics
- Soil water retention
- Soil denitrification potential
- Slope type
- Stocking rates
- Soil condition (silty clay loam, sandy loam)
- Pasture management (poor, moderate and good)

**Conclusion**

Restoration and maintenance of riparian vegetation is recognized as being an important aspect of combating dryland salinity, declining water quality, soil erosion and loss of riparian habitats. Riparian habitats have significant effects on material fluxes between terrestrial and riverine ecosystems. It is also a powerful indicator of catchment health. Thibault (1997) states that "[m]aintaining these buffer areas [land along stream edges] has been shown to have important positive effects, such as, preserving stream water quality, wildlife habitat, and serving as a natural aesthetic amenity…" (p: 37). If left unabated, the continuous misuse of the riparian environment could bring further ecological problems and economic losses. Hence, there is a need to effectively manage these areas through restoration, rehabilitation, conservation or preservation programmes.

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