NEFA BACKGROUND PAPER
The Need for Stream Buffers
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The riparian zone is the interface between a stream (and other waterbodies) and land through groundwater, subsurface flows and flooding. The riparian zone can be considered to encompass the entire extent of a stream's floodplain. Riparian vegetation has a direct influence on streams and is influenced by streams.

Hansen *et. al.* (2010) note:

> *The riparian zone (riparia) is the interface between aquatic and terrestrial environments (Naiman and Décamps, 1997) and it mediates the flow of energy, and physical and biotic vectors between the two (Lake, 2005, Naiman et al., 2005). Consequently, riparia are often environments of exceptionally high diversity. The importance of intact riparian zones is universally acknowledged as critical to aquatic-terrestrial ecosystem function and ultimately, to waterway health.*

Riparian vegetation is enhanced by increased soil moisture, increased humidity and nutrients from flood events. They provide resources for a broad range of fauna, especially during droughts. Numerous species are primarily associated with riparian habitats for at least part of their life-cycles, this includes a multitude of plants and invertebrates, most frogs and tortoises, some lizards and birds, and a few mammals (ie Platypus, Water Rat and Fishing Bat). Riparian vegetation also regulates the health and functioning of aquatic ecosystems, is the basis of aquatic food chains in upper catchments, and provide the branches and logs that structure many instream habitats for numerous aquatic invertebrates and many fish.

The health of streams is directly related to the health and functioning of riparian vegetation. Riparian buffers serve several functions:

- shading of streams and minimising fluctuations in water temperatures
- reducing the volumes of overland flows entering streams
- trapping sediments and associated pollutants moving from upslope towards streams
- maintainenance of stable stream banks and channels;
- providing wood, leaf litter, fruits, flowers, insects and other resource inputs to streams;
- maintenance of habitat requirements for many aquatic and terrestrial species; and,
- provide corridors for the movement of a suite of terrestrial species.

The key threatening process declaration under the *Fisheries Management Act 1994* for 'degradation of native riparian vegetation along New South Wales water courses' states:

> *1. Riparian vegetation refers to the vegetation fringing water courses and can be defined as any vegetation on land which adjoins, directly influences, or is influenced by a body of water. Riparian habitats thus include land immediately alongside large and small creeks and rivers, including the river bank itself; gullies and dips that sometimes run with surface water; areas around lakes; wetlands on river floodplains that interact with the river in times of flood.*
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> ...
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> *4. Degradation of riparian vegetation has a major influence on stream ecosystems by;*

- *Increasing the amount of sediment and nutrients reaching streams as runoff, and increasing light penetration of the water body. These inputs have the combined effect of smothering benthic communities and increasing harmful algal growth.*
- *Reducing the inputs of organic carbon, via leaves, twigs, and branches. Terrestrially derived carbon inputs are the major energy source in most stream ecosystems.*
- *Reducing the amount of large woody debris entering the aquatic ecosystem and thereby negatively impacting on habitat and spawning sites of several vulnerable and endangered species listed under the Fisheries Management Act, 1994.*
- *Destabilising river banks.*
- *Reducing the amount of overhanging riparian vegetation resulting in a loss of shade and shelter for fish.*

Hansen *et. al.* (2010) consider"

> *Disturbance and modifications to catchments through clearing vegetation for agriculture and grazing of livestock have resulted in extensive degradation of riparian zones and their adjacent waterbodies. This is predominantly through increased transfer of nutrients, sediment and pollutants into streams, exacerbated bed and bank erosion, and loss of in-stream and terrestrial biodiversity via degradation of riparian and aquatic vegetation and loss of important habitat structure such as large wood.*

From their review of the importance of the riparian zone to freshwater fish, Pusey and Arthington (2003) note:

Given the number and importance of links between riparian and lotic ecosystems, it is not surprising that spatial and temporal variation in fish assemblage composition and characteristics (i.e. species richness, abundance, biomass) have been linked to variation in riparian cover ... or that fish communities are adversely affected by riparian destruction and recover only when riparian integrity is re-established ...

Pusey and Arthington (2003) identify a large variety of known and potential impacts on fish as a consequence of changes to riparian vegetation, summarising in part that:

Impacts associated with changes in light quality range from increased egg and larval mortality due to increased ultraviolet (UV) B irradiation and a decreased ability to discriminate between potential mates to increased conspicuousness to predators. ... The interception of terrestrial sediments and nutrients by the riparian zone has important consequences for stream fish, maintaining habitat structure, water clarity and food-web structure. Coarse organic matter donated to the aquatic environment by the riparian zones has a large range of influences on stream habitat, which, in turn, affect biodiversity and a range of process, such as fish reproduction and predation. Terrestrial matter is also consumed directly by fish and may be a very important source of energy in some Australian systems and under certain circumstances.

It has been long recognised that the necessity is to establish riparian buffers along streams, and they have been required to be applied in various forms to public lands in NSW since 1975 (see **The Battle to Protect Soils and Streams**). Croke and Hairsine (1995) considered that *"Streamside Reserves must be … retained along all rivers, streams (permanent and temporary), drainage lines, swamps, springs, wetlands and bodies of standing water"*. Hansen *et. al.* (2010) recognise *"Maximising lateral and longitudinal extent of intact riparian zones, starting in the headwaters, provides the best protection for the waterway".* There is no maximum width for riparian buffers, though there are minimum widths below which the likelihood of significant impacts should be considered unacceptable.

Regrettably, while there have been a variety of studies that help inform the design of riparian buffers, there has been insufficient studies to assess the effectiveness of various buffer widths in protecting various values in Australia. From their review of the scientific literature Hansen *et. al.* (2010) concluded that research *"is inadequate and thus hinders development of meaningful management guidelines for maintaining or restoring aquatic-terrestrial ecosystems"*, lamenting *"the opportunities to gain new information from existing management programs are frequently overlooked"*. Given that NSW Government agencies espouse "adaptive management", the failure to rigorously assess the effectiveness of buffer strips in over 40 years since the Standard Erosion Guidelines were first adopted is reprehensible.

Unfortunately, because logging has been constrained in riparian zones in the past they are now sought after for logging by the timber industry. Management of riparian zones is therefore a political issue. Ecological requirements are usually severely compromised by the quest for resources.

Headwaters

It is along the smallest streams and drainage lines where most of the interaction between terrestrial and aquatic environments occurs. Small headwater streams generally drain catchments smaller than two square kilometres and can constitute over 75% of the stream length in a drainage basin (Barmuta *et. al.* 2009).

Lowe and Likens (2005) consider:

> *Everywhere on Earth, streams and rivers occur in hierarchical networks resembling the branching pattern of a tree, with smaller branches joining to form larger branches as water travels from uplands to lakes, estuaries, and seas. The finest branches of these networks, beginning where water flowing overland first coalesces to form a discernible channel, are called headwater streams. ... because of their small size, these streams are often missing from maps that guide the management of natural resources.*
>
> *...*
>
> *There is growing evidence that the water quality, biodiversity, and ecological health of freshwater systems depend on functions provided by headwater streams, which are similar in their importance to the fine branches of the human respiratory system in the lung.*
>
> *...*
>
> *Headwaters are a source of life. They are critical habitat for rare and endangered freshwater species, and guardians of many downstream resources and ecosystem services on which humans rely ...*

Small headwater streams are where most of the inputs of energy, sediments, nutrients and pollutants from the adjacent terrestrial environment occurs. These streams are often ephemeral or intermittently flow, yet they can harbour endemic invertebrates - many with highly restricted distributions (Barmuta *et. al.* 2009).

Barmuta *et. al.* (2009) consider:

> *For forested headwaters in upland areas, the streams tend to be steep, with a stair-step longitudinal profile, and the catchments are subject to unpredictable land-slips or debris flows. Hydrologically, the permanent streams tend to derive a greater proportion of their modal flows from groundwater than downstream segments, and they tend to be shallow with slow water velocities (Gomi et al. 2002). Because of their small size and large contact with the adjacent terrestrial habitat, flows are responsive to runoff events ...*
>
> *...*
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> *In forested areas, the riparian vegetation usually forms a closed canopy, and most of the energy for the in-stream food web is provided by allochthonously-derived inputs of leaf litter (often termed CPOM: coarse particulate organic matter), and leaching of this material yields large quantities of dissolved organic matter (DOM) which can be augmented by direct inputs from interflow, groundwater or overland flow. The DOM pool can be up to 10 times greater than the pool of particulate organic matter and it provides energy and nutrients to in-stream biofilms that form the basal food resource for many invertebrate consumers ...*

Hansen *et. al.* (2010) state:

> *The best opportunity for mitigation of catchment-scale disturbances is by the protection or rehabilitation of headwater systems due to their demonstrated capacity*

> *for greatest regulation of water quality and highest contribution to regional biodiversity”.*
> ...
> *Erosion in headwater areas makes a disproportionately high contribution to waterway sedimentation and elevated nutrient levels (Lowe and Likens, 2005, Naiman et al., 2005). Ephemeral streams also contribute large amounts sediment and nutrients that are mobilised during storm events (Wenger, 1999, Fisher et al., 2004)*

Davies and Nelson (1993) note that *“the role of first-order streams in sediment transport from hillslopes experiencing accelerated erosion has long been recognised”.* concluding that *“enhanced fine sediment movement in streams as a result of logging is most likely to occur owing to disturbance of headwater stream channels”*.

Croke and Hairsine (1995) note *“in general it is agreed that buffer strips should extend to the springhead or runoff confluence point of any sub-catchment and should be well upstream of any existing channel or streambed, since flow will occur at a higher point in the catchment once the forest has been cleared.”*

Despite the headwaters of catchments warranting the greatest protection, in current practice buffer strips along streams increase in size with stream size. Bren (1999) notes that the problem with this is that *“compared to more rigorous methods this under-protects the stream head, but overprotects divergent areas downstream. A method based on a constant ratio of upslope contributing area to buffer area gave the widest buffers at the stream head and buffers of diminishing width as one moved downstream.”*. Bren notes that having relatively wider buffers for the smaller headwater streams *“makes sense hydrologically but is probably politically unacceptable.”*

Buffer widths

Vegetation growing along streams does physically affect streams by binding streambanks and stabilising channels, while providing shade to cool the streams and regulate in-stream primary productivity. Detritus from the vegetation is the primary contributor to aquatic food webs. Branches and logs are important for flow mediation and sediment deposition, while providing important habitat requirements for many species. Periodic pulses are provided by material washed in from floodplains. Many species living in riparian habitats in turn rely upon aquatic invertebrates for a large part of their diets.

In relation to stream bank stability, Wasson (2000) found that “*channel size is related to riparian vegetation. From this it follows that riparian vegetation should be protected wherever it still exists, and that channel widening may be arrested (and perhaps reversed) in some circumstances by revegetation”*.

In relation to the need for shading, Hansen *et. al.* (2010) note “*Aquatic organisms may be highly temperature sensitive. Elevated in-stream temperatures directly affect aquatic biota through ecosystem respiration, which reduces dissolved oxygen availability and pH, (Davies et al., 2004, Rutherford et al., 2004). Some taxa are extremely sensitive to elevated temperatures, for example, mayfly larvae have upper lethal limits of around 22°C ... Changes in thermal regime can impact fish reproduction and increased temperatures can also reduce their tolerance to other toxicants”*

While limited buffers can directly protect stream bank vegetation, wider buffers are needed to limit pollution of waterways by nutrients and sediments.

Direction of runoff onto undisturbed vegetation and the maintenance of undisturbed filter strips along streams are the principal means of slowing runoff and trapping mobilised sediments and nutrients before they reach a stream. They are thus the principal means of mitigating the unavoidable impacts of logging and roads on water quality. Outside of saturated areas the undisturbed soil allows increased infiltration of water and thus sediment deposition and the roughness of the ground litter and vegetation slows surface-flows and act as sediment traps. The vegetation can uptake, assimilate and remove many of the nutrients.

If an infiltration area is logged, disturbed by machinery, subject to burning or grazed by livestock then the effectiveness of such zones is greatly reduced and sediment can more easily pass directly into streams and thus increase stream turbidity and sedimentation. Heron and Hairsine (1998) note that *"Infiltration rates are likely to be highly variable in riparian zones due to the combined effects of vegetative growth and soil properties, as influenced by land management."* Croke *et. al*. (1999) found that *"severe disturbance of the filter strip by successive passes of a bulldozer reduced sediment trapping to 40%".*

Currently in NSW buffers are applied from the top of the creek bank, as it is during high flow conditions that overland flow is most pronounced and buffers are most needed to absorb sediments and nutrients. As recognised by Cornish (1975), rather than *"permanence of flow" "the high peak flow situation (with the coincident likelihood of higher surface runoff) is more in need of strip protection".*

As noted by Cornish (1975) *"the effective width of a filter strip is of direct relevance to the absorption of sediment from upslope".*

At a macro-scale, buffer widths need to be increased along with increasing catchment area, increasing rainfall intensities and increasing slopes to maintain relative effectiveness. At a micro-scale, the widths of buffer zones need to be increased along with decreasing soil storage capacity, increasing soil moisture content, reduced evapotranspiration of vegetation, and reduced ground cover within the buffer. The condition of the slopes draining into buffers also has significant effects, increasing buffer widths are required with increasing levels of disturbance.

Davies and Nelson (1994) found that *"All effects of logging were dependent on buffer strip width and were not significantly affected by coupe slope, soil erodibility or time (over one to five years) since logging. All impacts of logging were significant only at buffer widths of <30 m."*

At buffer widths of 10-30 m Davies and Nelson (1994) found that the most significant impacts were increases in superficial silt and decreases in populations of macroinvertebrates and Brown Trout, with declines in abundance of 80% and 54% respectively at buffer widths <30 m.

Davies and Nelson caution that their assessment was undertaken during low flow conditions and that *"it is possible that larger buffer widths may be needed in some or many situations to protect streams from enhanced sediment and/or nutrient loads associated with substantial storm events."* They cite research by Gowns and Davis which found that even with 100m buffers the macroinvertebrate composition in buffered streams was intermediate between unlogged and clearfelled streams, suggesting *"that even logging with 100-m buffers may still cause community responses at the species level."*

Munks (1996) reviewed the available literature to recommend buffer widths for various functions.

Munks (1996) Recommended buffer widths for various functions of riparian vegetation

Function of the Riparian Vegetation	Recommended Buffer Width (from edge of bank)
Water Quality, Sediment, Pollutants etc.	20-50m (streams) 40-100m (rivers)
Bank Stabilisation	10 m + (rivers and streams)
Provision of habitat for terrestrial animals	50-60 m (rivers)
Provision of food, habitat and protection of stream fauna	30-100 m (streams)

Based on her review Munks (1996) recommend minimum buffer widths for streams.

Table 3.5. Munks (1996) recommended <u>minimum</u> buffer widths for streams:

Type of River or Stream	Minimum width from stream bank*
Main Rivers	40 m
Creeks and streams from the point where their catchment exceeds 100 ha	30 m
Small streams with a catchment of 50 to 100 ha	30-50 m
Small streams, tributaries, gully and drainage lines which only carry surface water during periods of heavy rainfall	30 m

* If the slope of adjacent land running down to the stream is greater than 10%, the recommended width is increased to 50m.

Munks (1996) also considers that *"adequate widths of riparian vegetation for fauna protection needs to be species-specific."*

Hansen *et. al.* (2010) undertook a meta-analysis of >200 riparian studies and recommended riparian buffer widths of between 30 and 200 m dependant on land use intensity and the management objective. Hansen *et. al.* (2010) considered forestry operations and grazing at low stocking rates (<5 Dry Sheep Equivalents/ha/annum all stock) as being relatively low impact. Though the impacts of logging operations vary with the logging intensity, slopes and soils.

Hansen *et. al.* (2010) Minimum width recommendations for Victorian riparian zones based upon available scientific literature and adjusted using expert opinion, where appropriate, to account for known differences between Victorian and international systems. All widths are in metres.

Landscape context /Management Objective	Land Use Intensity High	Land Use Intensity Moderate	Land Use Intensity Low	Wetland/lowland floodplain/off-stream water bodies	Steep catchments/cleared hillslopes/low order streams
Improve water quality	60	45	30	120	40
Moderate stream temperatures	95	65	35	40	35
Provide food	95	65	35	40	35

and resources					
Improve in-stream biodiversity	100	70	40	Variable*	40
Improve terrestrial biodiversity	200	150	100	Variable*	200

* Variability in width is related to the lateral extent of hydrological connectivity and thus, any recommendation will be site specific.

In forestry planning stream buffers are usually applied to act as sediment and nutrient filters for subsurface and overland flows (i.e. Barling and Moore 1994). They are more effective for removing sediment than nutrients from the flow and are more effective at removing coarse rather than fine sediments (i.e. Barling and Moore 1994). They are also most effective when the flow is shallow, slow, and enters the strip uniformly along its length (i.e. Barling and Moore 1994). Barling and Moore (1994) note that *"in hilly terrain flow rapidly concentrates, producing higher flow velocities and larger flow depths that can rapidly submerge the vegetation and significantly reduce the effectiveness of the filter strip"*.

When water flows become concentrated, usually on roads and snig tracks, it becomes hard to control the deposition of sediments and nutrients. Bren and Leitch (1985) found that spreading outflow from a road evenly over a 5m wide and 5m long area of undisturbed ground *"did not have any effect. Scrutiny of the individual storm records indicated that a possible effect was discernible only for very small storms"*, an outcome which they in part attributed to the area quickly becoming *"covered with a layer of fine sediment which blocked points of infiltration entry into the soil"* and the tendency of the water *"to flow along preferential paths, thereby reducing the opportunity for infiltration".* Bren and Leitch (1985) concluded that "*if infiltration of the outflow of road culverts is to be obtained then special measures to distribute water adequately over the slope and to maintain infiltration pathways may be necessary."*

Lacey (1998) assessed sediment accumulation at traps located 5 m below cross bank outlets on snig tracks and found it *"to be of a similar magnitude to that of the on-track traps"* at all of his Orara West sites and one of his four Doyles River sites. In other words, in the majority of cases re-direction of silt laden water over short infiltration slopes had no effect. Lacey attributed this to a fire 2 months before logging at Orara West removing ground litter and vegetation and *"some ground disturbance by logging machinery"* at the Doyles River site.

Croke *et. al.* (1999) found in the Eden area that, for every 5 m of hillslope below a cross bank overland flow was reduced by 336±189 litres. Based on this they constructed a lookup table to identify *"the probability of road/track runoff reaching the stream network".* For example, for a 1 in 10 year storm event generating 27 mm of runoff with cross banks spaced at 20 m intervals, at least some 75 m of available hillslope length would be required below the outlet to ensure that runoff does not enter the stream.

Such studies emphasise the need to maximise buffer width and minimise concentrations of flows in the general logging area before they enter riparian buffers.

Barling and Moore (1994) identify *"The most commonly recommended buffer width for streams in forested areas is 30 m; however, there have been no Australian studies to determine the effectiveness of, or appropriate widths for, buffer strips in forestry operations"*.

Croke and Hairsine (1995) categorised streamside buffers as Streamside Reserves (no logging or machinery disturbance) and Filter Strips (logging, but no machinery disturbance), and made recommendations for their minimum widths along streams and around wetlands based primarily on controlling overland flows of sediments. All their buffers are classed as Streamside Reserves except for those on drainage lines.

Table 3.6. Croke and Hairsine's (1995) recommended "Minimum Streamside Reserve and Filter Strip Widths according to stream type"

Type of River or Stream	Minimum widths
Rivers, Lakes and Streams used for water supply	100 m
Creeks and streams from the point where their catchment exceeds 100 ha	40 m
Small streams with a catchment less than 100 ha	30 m
Temporary streams flowing more than 1 in 5 years and carries water for some time (weeks) after rainfall.	20 m
Drainage lines carrying water only during or immediately (hours, days) after rainfall	10 m
Permanent springs, swampy ground, wetlands and bodies of standing water	30 m

Croke and Hairsine (1995) note that Streamside Reserves must be:

> *"extended beyond the minimum widths wherever necessary according to a field assessment of the size and flow of the stream or spring, the size and nature of the soak, swampy ground or body of standing water; the nature of the surrounding topography and soil type, the intensity and magnitude of the harvesting operation; the riparian habitat value; and the proximity and physical design of any water supply take-off and distribution system."*

Croke and Hairsine consider that extensions of Streamside Reserve widths must *"be determined according to soil type, hazard class slope, and other climatic and geomorphic variables relevant to the region"*.

Croke and Hairsine (1995) also emphasise that *"It is crucial when defining buffer strips in the field that all sources of runoff generation are included within the buffer strip zone. It is essential to incorporate the 'saturated zone', which is the area along the stream or drainage line that is permanently saturated (eg swampy ground) or becomes saturated (eg seepage area) with the onset of rain".* They consider that *"this is recognisable through the existence of saturated soil or presence of a vegetation associated with frequently saturated soil".*

Barmuta *et. al.* (2009) caution:

> *Riparian buffers can get breached during intense rainfall events, and the changes to the catchment's flow paths from some harvesting operations or cultivation regimes can result in notable biotic and abiotic effects in spite of riparian protection ... Moreover buffers are inevitably breached by roads, tracks and both anthropogenic and natural drainage lines, which can sometimes result in more sediment being*

delivered to a 'buffered' stream than in nearby 'unbuffered' streams (Gomi et al. 2006d).

In north-east NSW riparian buffers are now specified by the Environment Protection Licence (EPL 1999). These have been developed in an ongoing battle between the EPA and the Forestry Corporation (see **The Battle to Protect Soils and Streams**), which has seen the Forestry Corporation vigorously opposing the implementation of best practice. The outcomes are particularly bad for headwater streams.

EPA's 1999 minimum filter strip width for mapped and unmapped drainage lines, prescribed streams and watercourses in public native forests (metres - measured along the ground surface).

Stream Order	Inherent Hazard Level 1	Inherent Hazard Level 2	Inherent Hazard Level 3
Unmapped	10	10	15
1st order	10	15	20
2nd order	15	20	25
3rd order or greater	20	25	30

EPA's 1999 minimum filter strip width for mapped and unmapped wetlands and swamps in native forests (metres - measures along the ground surface).

	Total Area of Wetlands or Swamps (ha)	
	0.01 - 0.5 ha	**Greater than 0.5 ha**
Wetlands or Swamps	10	40

Stream mapping from aerial photographs does not identifiy many smaller streams, and some larger ones, particularly in steeper forested landscapes – these are the unmapped drainage lines referenced by the EPL. These constitute a significant proportion of the headwater streams identified as being particularly important for catchment health. The EPL requires the exclusion of logging from within 10 metres, and the exclusion of machinery from within 5 metres, of unmapped drainage lines. An additional 10 m wide protection zone is applied in which machinery disturbance is meant to be minimised. The Fisheries Licence also protects these in the vicinity of records of threatened fish, when Fisheries bother to report their presence to the Forestry Corporation (see **Protecting Threatened Fish**).

While the EPL riparian buffers are theoretically minimums, in practice they usually become maximums. There is never any attempt to expand them in particularly fragile and vulnerable catchments as identified as necessary by numerous authors (i.e. Croke and Hairsine 1995).

The riparian buffer widths of 10-20m (mostly 10m) applied by the EPL for unmapped and 1st order streams are significantly less than the 30-50m identified by Munks (1996) for small streams, tributaries, gully and drainage lines in catchments less than 100 ha, or the 35-40m (up to 200m to improve terrestrial biodiversity) identified by Hansen *et. al.* (2010) for steep catchments and low order streams, or even the 20-30m for erosion control identified by Croke and Hairsine (1995) for temporary and small streams in catchments less than 100ha. .

In May 2004 the Forestry Corporation was successful in getting the Environment Protection Licence amended to have the effect of excluding "non-scheduled" forestry operations from requiring licences. Since then the Forestry Corporation have been refusing to obtain licences for over 90% of their logging operations, meaning they are no longer subject to the EPLs (see **The Battle to Protect Soils and Streams)**.

Most particularly, the Forestry Corporation now refuse to apply riparian buffers to unmapped streams in most operations. When the Forestry Corporation was granted exemption from the EPL for most of their operations in 2004 they obtained a major resource windfall by allowing themselves to log the banks of the unmapped streams and increasing disturbance to drainage depressions. These riparian buffers are now routinely logged despite their overwhelming importance for catchment health.

The Battle to Protect Soils and Streams

Logging impacts on streams

Protecting Streams

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