LOGGING INDUSTRY RESEARCH ORGANISATION
NEW ZEALAND

ISSN 1171-6932

REPORT

Vol. 18 No. 10 1993

THE IMPACT OF RIPARIAN BUFFER STRIP CHARACTERISTICS ON FOREST HARVESTING

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ABSTRACT

A paper planning exercise was carried out to evaluate the impact of fixed width riparian buffer strips on harvesting plans. In three different catchments, the width and the percent of the total stream length required for the riparian buffer strip were varied to provide different scenarios. No site specific information was taken into consideration when applying the buffer strips, and no management practices were specified for the strips.

The following trends were established. The area required for riparian buffer strips was determined by the stream density of the catchment. As the restrictions increased:

- *the area affected by the buffer strips increased proportionally*
- *the roading requirements increased steadily above the initial requirement*
- *the setting area (coup) size and the average haul distance decreased*
- *no clear trend could be determined for the number of landings required*

INTRODUCTION

A buffer strip along a watercourse can significantly reduce the instream and downstream impacts from harvesting operations (Graynoth, 1979). Riparian buffer strips are not limited to sediment/nutrient interception but serve many other functions, such as providing aesthetic qualities, maintaining instream values and allowing diversity of biota within our plantation forests (Fenton, 1992).

A number of countries have imposed fixed width riparian buffer strips for their forested land use. They are also used in specific cases in New Zealand. The loss of productive area is one of the forest industry's most widely proclaimed concerns in relation to the demand for broad generalised riparian buffer strips. The physical dimensions of riparian buffer strips can have a direct influence on the harvesting plans.

This study uses the paper planning approach to evaluate the effect of imposing fixed width riparian buffer strips on harvesting. The paper planning exercise has been shown to be very effective as a research tool (Reutebach and Murphy, 1986). No site specific information is

Table 1 - Catchment characteristics

Project Catchments	Owera	Whakauru	Graham
Total Catchment Area (ha)	296	302	202
Total Stream Length (m)	14080	7870	11630
Stream Density (m/ha)	47.6	26.2	57.6
Initial Productive Area (ha)	280	300	175

taken into account, such as the ecological value of the stream, the slope of the bank or the soil type, when applying the buffer strips.

In each area the physical dimensions of the riparian buffer strip were altered to provide five different restriction combinations. For each combination, a harvest plan was generated so that the area in buffer strips, the roading density and the number of landings, their setting size and average hauling distance (AHD) could be calculated.

CASE STUDY

Project Areas

The following areas were chosen because they represent a cross-section of the type of catchments that are in plantation forests throughout New Zealand.

Coromandel - Part of the Owera River Catchment. This area is located in Whangapoua Forest on the Coromandel Peninsular. The watercourses are generally narrow and steep sided, with a mix of remnant native bush and scrub. It is moderately steep forest with clay soil which will require a mixture of cable hauler and ground based extraction systems.

Central North Island - The central part of the Whakauru Stream Catchment. This area is located in Kinleith Forest near Tokoroa. The soils are deep free draining pumice, and much of the area has already been cleared over the past four years. The stream flows along a deeply incised valley cutting west off the Mamaku Plateau. Bordering the main valley is gently rolling hill country suitable for ground based extraction.

Nelson/Marlborough - Part of the Graham Stream Catchment. This area is located in the Rai/Whangamoa Forest just south-east of Nelson. The area is on Pelorus steep soils and the stream drops steeply from its native bush covered headwaters located in the Mt. Richmond State Forest Park, to the radiata pine covered mid-lower slopes into the Whangamoa River. It has been partly logged using both ground based and highlead systems. Contour tracking is used for some of the ground based extraction.

The total catchment area, the stream length and the initial productive area were measured directly from the 1:5,000 and 1:10,000 topographic maps, and are shown in Table 1.

Project Design

In defining buffer strip requirements for a given site, the following important variables should be taken into account (Hicks and Howard-Williams, 1990) :

- the length of watercourse requiring protection within the area under consideration

- the required width of the strips
- the desired height clearance over the strip
- the vegetation management practised within the strip

To try and establish some basic trends for the effects on harvesting, the following restriction parameters were chosen :

Length - a buffer strip extending for either 30% or 75% of the total stream length. This was applied from the lower main waterways in the catchment and then extended, as required, into headwaters and minor side catchments.

Width - a 20 or 40 metre strip width on each side of the stream centerline. These values were chosen to reflect some of the current overseas restriction requirements.

Height restrictions were not considered since they will only have a significant impact if the buffer strip was ruled to be a strict "no-go" area. The ability to road across streams at appropriate points has not been excluded, but avoided if possible. No assumptions were made about the management practices required within the strip. PLANS[1] harvest planning software was used to draw up a harvest plan for each combination. All the results presented were measured from these plans.

RESULTS

Area Affected by Restrictions

Table 2 shows the portion of the initial productive area affected by the riparian buffer strip restriction imposed.

It includes both the land converted into buffer strips, and sections of forest that will become inaccessible due to the restriction. Logging machines, new roads, major road upgrades, and landings have been excluded from the riparian buffer area. The loss of productive land due to permanent roading has not been included. The stream density varies considerably between the catchments (Table 1), and the area required for riparian buffer strips varies accordingly.

Table 2 - Affected Area

Riparian Restrictions		Productive Area Affected					
Length	Width	Owera		Whakauru		Graham	
(%)	(m)	(ha)	(%)	(ha)	(%)	(ha)	(%)
0	0	0	0	0	0	0	0
30	20	16.7	5.9	8.6	2.9	10.7	6.1
30	40	33.4	11.8	16.9	5.6	21.3	12.2
75	20	38.0	13.5	22.5	7.5	31.8	18.3
75	40	80.1	28.4	44.5	14.8	60.4	34.7

Roading

In preparing the initial plans (no riparian restrictions) for each area, an attempt was made to :

- use existing roads and tracks, with appropriate realignment and widening as required
- concentrate roading along main ridges, benches and generally in areas with a low gradient
- avoid roading beside watercourses, and through areas of unstable soil or morphology

[1] Preliminary Logging ANalysis System produced by the USDA Forest Service - PNW Research Station, Portland, U.S.A.

This approach will help reduce potential adverse impacts and ensure reduced construction and maintenance costs (Vaughan, 1990). Road crossings of buffer strips has been minimised and the use of existing roads within the buffer strips was only allowed if minimal earthmoving was required to bring them up to logging standard.

Road requirements measured for each restriction level examined during this study are shown in Table 3. Boundary roads were split equally between adjacent forested catchments.

Setting Parameters

All planning was based on conventional style ground-based and cable (highlead/skyline) extraction. Areas identified for ground based extraction did not differentiate between skidder, tractor or tracked skidder. Cable areas were examined with a medium powered skyline machine having a 21 metre high tower and a maximum reach of 600 metres.

Double handling on cable settings was included where the hauler was located on an acceptable pad and logs were transferred by ground based means to a suitable processing site.

Methods such as long reach multispan systems or helicopter logging were not included in this analysis. The total number of landings required, the average setting size and the AHD obtained from the planning exercise are shown in Table 4.

Table 3 - Roading requirements

Riparian Restriction		Roading Requirements					
Length	Width	Owera		Whakauru		Graham	
(%)	(m)	(km)	(m/ha)	(km)	(m/ha)	(km)	(m/ha)
0	0	9.3	33.2	8.9	29.7	5.2	29.7
30	20	9.3	33.2	9.1	30.3	5.2	29.7
30	40	10.7	38.2	9.1	30.3	5.2	29.7
75	20	11.3	40.4	9.5	31.7	5.8	33.1
75	40	11.5	41.1	9.6	32.0	5.8	33.1

Table 4 - Setting parameters - number, size and AHD

Riparian Restriction		Average Setting Parameters								
		Owera			Whakauru			Graham		
Length (%)	Width (m)	Sites No.	Size (ha)	AHD (m)	Sites No.	Size (ha)	AHD (m)	Sites No.	Size (ha)	AHD (m)
0	0	30	9.4	187	38	7.9	153	18	9.7	189
30	20	30	8.8	187	39	7.5	147	18	9.1	187
30	40	33	7.5	177	39	7.3	146	18	8.5	185
75	20	38	6.4	152	41	6.8	142	24	5.9	155
75	40	40	5.1	136	39	6.6	140	22	5.2	150

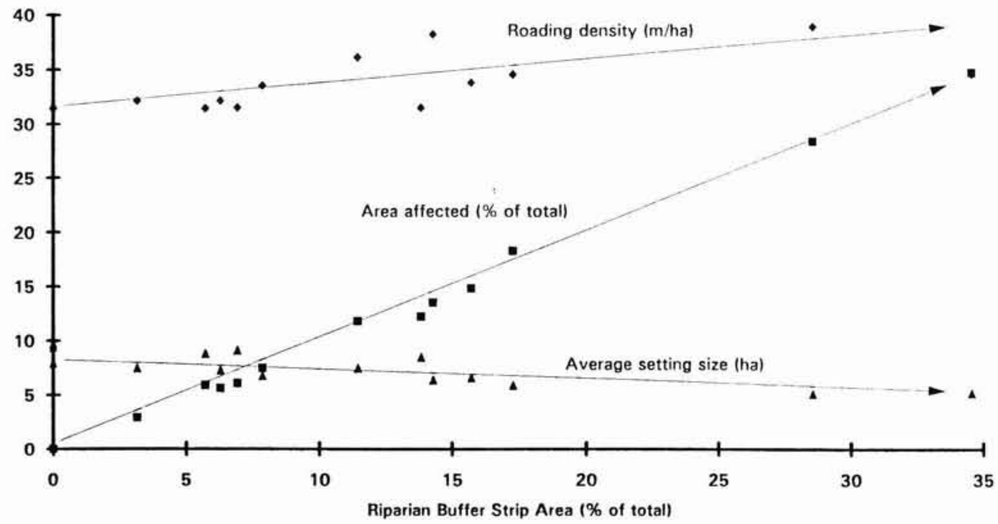

Figure 1 - Trends established by regression analysis

Regression Analysis

Regression analysis was used to construct predictive equations for the affected area, the roading and the setting size. The most appropriate prediction variable (AREA) for all these equations was found by multiplying the required riparian buffer strip % length and width by the stream density of the catchment.

Affected area (% of total)
= AREA
($P<0.0001$, $r^2=0.99$)

Roading density (m/ha)
= IRD + 0.17 x AREA
($P=0.0067$, $r^2=0.55$)

Average setting area
= ISS - 0.118 x AREA
($P=0.0002$, $r^2=0.67$)

where :
AREA = Stream density (m/ha) x Width (m) x Length (%) / 5000
IRD = Initial Roading Density (m/ha)
ISS = Initial Setting Size (ha)

IRD and ISS were obtained from the initial unrestricted plan. Their average values were 30 m/ha and 8.8 ha respectively (based on these case studies).

The regression analysis results have been combined to produce a simple spreadsheet model. How to use the spreadsheet model and what you can expect to obtain from it is explained in Appendix 1.

DISCUSSION

Affected Area

From Figure 1 we see that the affected area increases proportionally with the buffer strip length and width requirements, and catchment stream density. Very little area outside the buffer strip becomes unharvestable in the catchments due to the restrictions. If the ability to cross streams through riparian buffer strips with roadways was prohibited, then much more area, especially on steep difficult sites would be affected.

The term "affected area" was carefully chosen because the actual impact on forest harvesting depends very much on the management practices required within the buffer strip. If no harvesting is allowed within the strip, then the reduced harvestable area is equal to the riparian buffer area, and compounded by the additional roading and landings required.

However, the strip might be just an area of awareness, or an area of limited machine activity in which case little productive potential is lost.

In the case of a strict no-go riparian buffer strip, there are cost implications beyond the land out of production and additional roading costs. Increased access difficulty will mean sections of the forest will become uneconomic to harvest. There are additional costs such as weed/pest control and taxes/rates on non-productive land.

To use the parameter "percent of total stream length" as a control mechanism is only workable if the length of stream is known (i.e. on a map as in this case study). It cannot be applied to a general river definition such as that of the Resource Management Act[2]. Rivers are so diverse, to apply such a definition to determine the total river length would require a very long and comprehensive catchment study.

Roading

The increasing levels of riparian protection along the streams required changes to the logging layout over portions of the planning area, and these changes were often associated with additional roading requirements (Figure 1). Increased roading requirements seldom coincided with existing roads or tracks, and often crossed the steeper headwalls of sub catchments to access adjacent unroaded ridges. The additional roading required to meet various riparian commitments was often characterised by :

- higher environmental/site impacts
- higher construction and maintenance costs
- higher risk of failure

Careful consideration must be given to what we are trying to achieve with riparian buffer strips before applying them, or formulating regulations. For example, if we are only interested in sedimentation of streams, riparian buffer strips could be very effective for the non-point source sedimentation interception and protecting stream banks, but the additional roading may cause more concentrated point source sediment runoff (Mosley, 1980). There is a need for developing some mechanism to balance the gains from riparian buffer strips against increased risk of sedimentation associated with additional roading.

It is important that careful planning ensures roads are constructed on the best locations to meet the harvesting needs. Then, unless significant changes to harvesting systems occur, and the roads are relatively well maintained, the environmental impact during subsequent rotations will be dramatically reduced.

Setting Parameters

Planning to meet increasing buffer strip requirements reduced the average setting size (Figure 1). Additional landings were often required, and where this occurred AHD reduced significantly. We can note that during this project the unrestricted plans were all associated with the least number of landings, largest average setting size, longest AHDs and least roading requirements.

The ground based settings are less affected by increasing restriction levels than cable settings. It is easier to manipulate ground based layout to fit in with buffer strip requirements, particularly on easy topography. Some landings on all the plans serve both ground-based and cable extraction. On the difficult sites, cable setting areas are generally larger than those for ground-based extraction.

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[2] RMA (1991) river definition "means a continually or intermittently flowing body of fresh water and includes a stream but does not include any artificial watercourse".

The productivity and performance of cable settings is very dependent on deflection. Deflection may be severely limited on many sites if skylines cannot be anchored through and beyond riparian zones. The implications of this are lower payloads and/or increased downtime, and increased site disturbance due to logs dragging along the ground.

Further Considerations

The effect of differing management practices on the effectiveness of buffer strips (sediment trapping, protection of instream biota, aesthetic values, etc.) still needs to be established. The result of such work will greatly influence the overall discussion, and in particular the industry's acceptance of using riparian buffer strips. Many of the current concerns are perceived and subjective and work is required to recommend guidelines based on measurable and objective data.

Gilliam et al (1992) stated close agreement for riparian buffer strip requirements can be found for a given location between local authority and forest industry staff during site visits. A co-operative approach involving industry, environmental agencies, local authorities and researchers should therefore begin dealing with some of the issues highlighted during the development of this project. Collaborative research should continue on a site specific/case study basis to address the performance of, and possible management alternatives within, riparian buffer areas. It would provide the basis for New Zealand guidelines regarding the placement and dimensions of buffer strips.

Guidelines for the implementation of riparian buffer strips should focus on recommending practical techniques that will effectively reduce adverse impacts on identified significant values.

CONCLUSIONS

The development of this project has highlighted the following points in relation to fixed width riparian buffer strips:

- The area required for riparian buffer strips was determined by the stream density of the catchment.

- As the restrictions increased, the area affected by the buffer strips increased proportionally, the roading requirements increased steadily above the initial requirement, the setting area (coup) size and the AHD decreased.

- The overall impact of riparian buffer strips is very dependent on the management practices required within the strip. The impact can be minimal if it is designated a zone of awareness, or severe if the buffer strip is decreed a "no-go" zone.

- The cost of having riparian buffer strips is not limited to loss of productive land but includes rates/taxes on unproductive land, weed/pest control costs and inconvenience.

- Generalised riparian buffer strip requirements are likely to result in additional roading and landings. These will often be in more difficult locations, have higher adverse environmental impacts and be more costly to construct and maintain.

- Smaller setting areas may reduce cable deflection and can lead to greater site disturbance, as well as lower productivity due to reduced payload capability.

- Riparian buffer requirements should not be based on a percentage of the total stream length unless the streams in a region are well defined.

- Good road planning for the first rotation harvest and re-establishment should ensure less environmental impact from the subsequent rotations.

- There is a need for further research on a site specific or case study basis to speed up the change from perceived, subjective control to measurable, objective control.

- Ideally the use of riparian buffer zones should aim to avoid or minimise the adverse impacts on identified values.

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Appendix 1 - Riparian Buffer Economic Model

From the regression analysis of the results presented in the report, a short spreadsheet model has been generated. For a given catchment,

The following variables are required:

* catchment size (ha)
* total length of stream (km)
* length and typical width of road, OR an estimate of roading density
* buffer strip requirements (three variable constraints can be specified per catchment)

The spreadsheet will then calculate:

* final roading density (this includes the additional roading required because of the buffer strip restrictions)
* area taken up by these roads
* area that will be taken up by the buffer strip
* total area out of production due to roading and riparian buffer strips (as an area and a percent of the total)

The sample spreadsheet

The spreadsheet will allow any or all of the variables to be changed, to gauge the impact of altering them. In the example shown on the attached spreadsheet, each of the three catchments has a size of 300 ha. The first two have identical stream and roading characteristics, but differing buffer strip requirements which increased the total area out of production from 5.6% to 18.7%. In the third catchment the length of roading is not known, so it has been estimated at 4% (of the total area). There is also a variable buffer constraint, 40 metres in width along 75% of the total stream length, 15m width along 20%, and a 10m width along the remaining 5%. The spreadsheet estimates that 31.7% of this catchment will be affected by roading and buffer strips requirements.

Riparian Buffer Strip Economic Impact Model

Variables	*Catchments* 1	2	3	*Comments*
Catchment Area (ha)	300.0	300.0	300.0	total catchment area
Stream Length (km)	7.9	7.9	12.0	definition of stream not critical, but be consistent between catchment
Length of Roading (km)	8.9	8.9	0.0	total length of permanent roading within the catchment
Typical Road Width (m)	8.0	8.0	0.0	width out of production due to roading
OR Estimate Road Density (%)				
High = 7, Med = 4, Low = 2	0.0	0.0	4.0	enter only if road length and width is not known
Therefore Road Density is (%)	2.4	2.4	4.0	
Buffer Strip Requirements				
A Length (%)	30	75	75	percent of total stream length requiring....
Width (m)	20	40	40	....this many metres of buffer strip width on each side
B Length (%)	0	0	20	Note: width is to each side from centre of stream
Width (m)	0	0	15	the percentages should not add up to over 100 per catchment
C Length (%)	0	0	5	three different strip conditions per catchment can be put in
Width (m)	0	0	10	
Results				
Final Roading Density (%)	2.5	2.9	4.9	includes the increased roading due to the buffer requirements
Roading Area (ha)	7.4	8.7	14.7	area out of production due to roading requirements
Riparian Buffer Area (ha)	9.5	47.4	80.4	area taken up by the riparian buffer strip
Total Area Affected (ha)	16.9	56.1	95.1	total area affected by roading and riparian buffer strip requirements
" " " (%)	5.6	18.7	31.7	