APPENDIX 6

Hydrological response to timber harvesting and associated silviculture in the intermediate rainfall zone of the jarrah forest

PROGRESS REPORT ON SPP 2000/03

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by

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Introduction

There has been a large number of studies of catchment hydrology in the forests of south-western Australia and these studies have provided an adequate understanding of hydrologic processes and the impact of forest management on catchment hydrology. A review of these studies was undertaken as a part of developing the Forest Management Plan (1994-2003) and changes in practice were adopted as a result. The current practices represent a conservative, precautionary approach to the management of forests to ensure the protection of potable water supplies. Nevertheless, there have been no catchment studies on the hydrologic impacts of the current silvicultural practices in jarrah forest.

This project aims to investigate the hydrologic impacts of timber harvesting and the associated silvicultural treatments in the intermediate rainfall zone (IRZ, 900 – 1100 mm/year) of the jarrah forest. The results of the project will also address part of Ministerial Condition 12-3 attached to Forest Management Plan 1994-2003, which states that CALM shall monitor and report on the status and effectiveness of silvicultural measures in the IRZ to protect water quality.

Methods

Experimental treatment

The study is based on a before and after/control and impact design in which two catchments have been treated, and one catchment remained untreated as a control. The study is located on three second-order catchments that form part of the Yarragil Brook catchment area in the IRZ of the jarrah forest about 20 km SE of Dwellingup. 4X (2.73 km^2) and 6C (4.58 km^2) catchments were subjected to a timber harvesting operation and associated silvicultural treatments and Wuraming catchment (4.4 km^2) remained untreated as a control. Timber harvesting was conducted from Dec 2000 to Feb 2001, and the subsequent silvicultural treatments from April to May 2001.

The timber harvesting treatment applied to 4X was the standard phased-logging prescription and follow-up silviculture for second order catchments in the IRZ (hereafter termed the standard treatment-catchment). The standard prescription includes the retention of at least 30% of the catchment at a basal area of at least $15 m^2 ha^{-1}$ for a period of at least 15 years after harvesting the remainder of the catchment. The standard post-logging treatment involves the removal of trees not marked for retention (cull trees) by notching with herbicide in thinned areas or by pushdown in shelterwood areas within a 4m radius of each crop tree. 6C was treated with a more intensive prescription than the standard (hereafter termed the intensive treatment-catchment), by omitting the requirement to retain 30% of the catchment with a basal area of >$15m^2ha^{-1}$. The follow-up silviculture in 6C was also more intensive than that for 4X whereby all cull trees were notched or pushed down.

Hydrological measurement
Monitoring of groundwater levels, stream flow and stream salinity has been ongoing for at least the previous 14 years in the three catchments. Stream discharge and conductivity have been monitored continuously at automated stream gauging stations at the catchment outlets. Groundwater levels have been monitored approximately monthly since mid 1999 in a network of bores in the three catchments - six in 4X (two valley and four hillslope), 18 in 6C (six valley and 12 hillslope) and ten in Wuraming (five valley and five hillslope). Prior to 1999, bore water levels were measured less frequently, but usually at least twice annually -once in late autumn/early winter in the usual period of minimum groundwater levels, and again in late spring/early summer in the usual period of maximum groundwater levels. Water collected as grab samples or by an automatic water sampler immediately upstream of the weir at the catchment outlet have been analysed for turbidity.

Forest density measurement
To assess changes in overstorey density, resulting from the timber harvesting operation and associated silvicultural treatments, measures of crown cover, crown density index, basal area, and stocking were taken before and after the treatments in the three catchments. A description of the techniques used to take each of these measures, except for stocking, is given in Stoneman *et al.* 1988. Stocking was assessed by allocating each tree, which was included in the basal area sweep and whose diameter over bark was measured at 1.35 m above ground, into one of the size classes: < 15 cm, 15-45 cm, 45-60 cm, >60 cm.

In the treatment catchments, the forest density measurements were taken along transects, permanently marked at 100m intervals. There were nine transects 200 m apart in the standard treatment-catchment, and eight transects 300 m apart in the intensive treatment-catchment. The transects were orientated north-south and spanned the catchments. Crown cover was measured at 20m intervals and the other measures at 100m intervals. In the control catchment, all measures were taken at permanently marked points on a 50 m by 100 m grid. This resulted in 625 records of crown cover, and 127 records of the other measures in the standard treatment-catchment, and 759 records of crown cover and 156 records of the other measures in the intensive treatment-catchment. In the control catchment there was a total of 927 records of each of the forest density measures.

Rainfall measurement
Monitoring of rainfall has been ongoing for the last 17 years in each of the standard and intensive treatment-catchments by automatic rain gauges recording at 5-minute intervals.

Data analysis

Groundwater level

To assess changes to groundwater levels in response to the treatments, linear regressions of annual minimum bore groundwater levels for the pre-treatment period were determined in pair-wise combinations between each bore in the treated catchments with each of the control catchment bores. The regressions were based on bore records from 1988 to 2000, however, some records were not available for some bores in some years hence there were between 4 and 10 data points in the regressions. For each treatment bore, the linear regression of the paired combination with the highest R^2 (all $R^2 \geq 0.93$) was used to predict the annual minimum water level in that treatment bore from the annual minimum water level occurring in the corresponding control bore after the treatment, i.e. the minimum bore water level expected in the treatment bore as if no timber harvesting or associated silvicultural treatment occurred. The difference between the predicted water level and the observed treatment bore water level is attributed to the treatment. In 2001 and 2002, the two years following treatment, the water level in most bores in all three catchments continued to decline throughout the year (Fig. 1). To enable the regression analysis to be applied to these bores, the "minimum" water level is considered to have occurred on 30/06, the median date on which the minimum groundwater level occurred in all bores in 2000. Minimum groundwater levels were used in the analysis because they are less subject to between-year changes in response to variable weather patterns than maximum groundwater levels.

For two hillslope bores in 4X, there were insufficient records to enable a regression against control bores. Hence a (secondary) regression was determined between these bores and two other bores in 4X (both $R^2 = 0.99$, n=6, 1989 –2002) for which there were good (primary) regressions with control bores ($R^2 = 0.95$, n=10, 1988 –2000; $R^2 = 0.99$, n=6, 1989 –2000). For these two bores, the primary and secondary regressions were used in a stepwise manner to predict the water levels in the treatment bores from post-treatment control bore minimum water levels.

Streamflow, stream salinity and stream turbidity

In 2001 there was no streamflow in the intensive treatment-catchment or in the control catchment and an insignificant few hours of stream flow in the standard treatment-catchment. Presently (August 2002) the streams are flowing in the treated catchments and since the analysis of stream discharge is based on annual totals, the stream responses are not reported here.

Vegetation

Pre and post-treatment overstorey density has been assessed but the data have not yet been analysed and so are not reported here.

Results

The total rainfall at the study sites in the first year following treatment was 515 mm. This was substantially lower than the average of 913 mm for the preceding 16 years (Fig. 2).

The groundwater hydrograph of a hillslope bore in the intensive treatment-catchment shown in Fig. 1 is representative of the hydrographs of hillslope bores in the three catchments. Two trends are evident in this hydrograph - a long-term progressive fall in groundwater levels, and the absence of a late spring/early summer peak in water level in 2001. Groundwater levels in all bores in the three catchments have continued to fall since the treatments were applied.

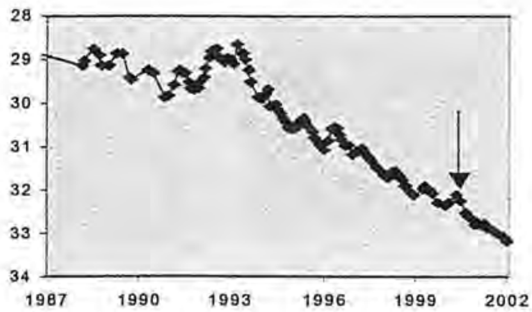

Fig 1. Groundwater levels in a hillslope bore in 6C catchment. Arrow indicates time of treatment.

Table 1 shows the average change in groundwater levels in boreholes in the treated catchments, relative to the groundwater levels in boreholes in the control catchment, following timber harvesting and associated silviculture. It was anticipated that timber harvesting would result in rises in groundwater level. However, the following results generally show the opposite trend, that is, small declines in groundwater level in boreholes in the harvested catchments relative to groundwater levels in boreholes in the control catchment.

In the first winter following the treatments, groundwater levels fell relatively more in both the standard and intensively treated catchments than in the control catchment. However, the magnitude of the average fall was small and ranged between 0.03 m in the valleys of the intensively treated catchment, and 0.15 m in the valleys of the standard treatment-catchment. Groundwater levels fell more in the standard than in the intensive treatment-catchment, however, the magnitude of the difference in average responses between the two catchments was small, i.e. about 0.12 m in the valleys and almost no difference on the hillslopes.

In the second winter following treatment, the difference in response between the two treated catchments, was greater than after the first winter. Groundwater levels in the standard treatment-catchment continued to fall relative to the control, and the magnitude of the fall was greater in the valleys (0.36 m) than after the first winter following treatment (0.15 m). In the intensive treatment-catchment, groundwater levels fell by a further 0.05 m in the valleys but rose by about 0.19 m on the hillslopes.

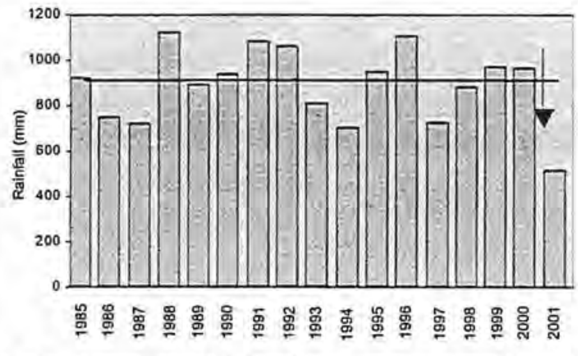

Fig 2. Annual rainfall (bars) and average annual rainfall for the period 1985 to 2000 (line) at the study site. Arrow indicates time of treatment

After two winters following treatment, the largest cumulative response in each of the catchments was an average fall of about 0.5 m in the valleys in the standard treatment-catchments and a rise of about 0.1 m on the hillslopes in the intensive treatment-catchments.

Table 1. Average change in groundwater levels in treated catchments, following treatment in the summer of 2000/01, relative to the control catchment

	No of bores	Bore location	Change after first winter		Cumulative change after second winter	
			Average (m)	Range (m)	Average (m)	Range (m)
Standard treatment	2	Valley	-0.15	-0.13 to -0.16	-0.51	-0.25 to -0.78
	4	Hillslope	-0.10	+0.01 to -0.14	-0.22	+0.45 to -0.36
	6	All	-0.11		-0.32	
Intensive treatment	6	Valley	-0.03	+0.19 to -0.14	-0.08	+0.41 to -0.55
	12	Hillslope	-0.08	+0.26 to -0.75	+0.11	+0.58 to -1.11
	18	All	-0.06		+0.05	

Discussion

The atypically low rainfall in the first year following the timber harvesting and associated treatments had a greater effect on the water balance, and consequently groundwater level, in the catchments than the treatments. There was a small net fall in groundwater levels, and of a similar magnitude in the valleys and hillslopes, in both treatments.

In the second year following treatment, some trends in groundwater response have become apparent. The standard treatment continued to have less influence on groundwater recharge than climate and groundwater levels have continued to fall. The falls were greatest in the valleys. In contrast, groundwater levels have risen about 0.1 m on the hillslopes in response to the intensive treatment. However, the magnitude of these changes is much smaller than the changes in groundwater level in response to the timber harvesting and associated silvicultural practices of the early 1980's (Borg *et al.* 1987) where average groundwater levels rose more than 1.7 m in the valleys and hillslopes in the first two years following treatment.

Conclusion

Timber harvesting was expected to result in rises in groundwater level. However, the results have generally shown the opposite trend, that is, small declines in groundwater levels in the harvested catchments relative to groundwater levels in the control catchment. Since the results presented here are very early in the expected response of groundwater level to timber harvesting, and are influenced by the very low rainfall in 2001, it is important that monitoring continue for at least another three years and the results be evaluated at that time.

Reference

Borg, H., King, P.D. and Loh, I.C. (1987) Stream and groundwater response to logging and subsequent regeneration in the southern forest of Western Australia. Interim results from paired catchment studies. Water Authority of Western Australia Report No. WH 34.

Stoneman, G.L., Rose, P.W. and Borg, H. (1988) Recovery of forest density after intensive logging in the southern forest of Western Australia. Department of Conservation and Land Management, Technical Report No. 19.