NIWA
Taihoro Nukurangi

The effect of vegetation change on water yield for the Orari River at Gorge catchment, Canterbury: Phase 6

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Prepared by:
Maurice Duncan

For any information regarding this report please contact:

Maurice Duncan
Hydrologist
Applied Hydrology
+64-3-343 7863
Maurice.Duncan@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
PO Box 8602
Riccarton
Christchurch 8011

Phone +64 3 348 8987

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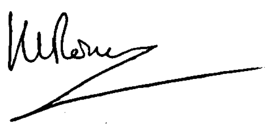	Approved for release by:	Helen Rouse

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Executive summary

The Orari River catchment is under pressure from abstraction leading to low flows. The Orari-Temuka-Opihi-Pareora Zone Committee are concerned that afforesting the predominantly short grassland hill country upstream of the Gorge water-level recorder, located where the Orari River emerges on to the Canterbury plains, will further reduce low flows. Thus, reducing the security of supply for consent holders and in-stream environmental values.

This report investigates the sensitivity to afforestation of the low and mean flows coming from the catchment upstream of the recorder. The results of this investigation may be used to set limits on the amount of new afforestation in the Orari River catchment to limit potential reductions to the 7-day mean annual low flows (7-day MALF).

This report uses methods that have been subjected to rigorous critical review to calculate the effects of staged forest development in selected sensitive catchments, and to estimate the area of short grassland in the catchment that could be afforested without reducing 7-day MALF by more than 5 per cent.

This report is the sixth in a series of reports on specific catchments. The calculation methods used here are identical to those of earlier studies, except that the land cover was taken from the more recent Land Cover Data Base Version 4.

This study found the upper Orari catchment could have 20 per cent and 30 per cent of its catchment area converted from short grassland to a staged forestry development before reducing the 7-day MALF flows more than 5 per cent and the mean flow by 10 per cent respectively. The upper Orari can be considered to be a flow sensitive catchment.

The average security of supply of allocated water was reduced from 357 days per year to 353 days per year when 25 per cent of the catchment was afforested.

An investigation of the source areas of low flows and mean flows in earlier studies showed the 7-day MALF was sourced primarily from the high yielding (high rainfall) areas, with the mean flows being sourced more evenly over the catchment. In the upper Orari River catchment upstream of the Gorge the pattern is also apparent but less pronounced as only of the 31.5 per cent of the catchment area is high yielding and produces 51 per cent of the 7-day MALF and 34 per cent of the mean flow. Only 2.3 per cent of the high-yielding low flow source area is in the area suitable and available for afforestation.

1 Introduction

The concern about forest plantations replacing pasture and tussock is because water yields from closed canopy forested catchments are much lower than those from pasture catchments. This has been shown in many New Zealand catchment studies (Duncan and Collins 2013). The principle mechanism is that rainfall is intercepted by tree leaves or needles and evaporates and so does not contribute to soil water where it would be available for transpiration or to contribute to runoff. A second mechanism is that tree roots are commonly deeper than grass roots and so can exploit a larger soil volume for transpiration. This soil volume has to be substantially filled with water before the land can contribute to groundwater or runoff.

In a contract for Environment Canterbury (ECan) by NIWA (Duncan 2003a), a method was developed to estimate the effects on low flows of replacing a range of vegetation types with plantation forestry. That study showed that a change from short grassland to plantation forestry was likely to reduce low flows from the area planted by 41 per cent, taking into account the staged nature of plantation forestry development within a catchment.

This level of flow reduction was then applied to several flow-sensitive catchments to estimate the effects of afforestation of 5 per cent, 10 per cent, 15 per cent and 20 per cent of each catchment on the mean annual low flow (7-day MALF) – the afforestation being within that part of the catchment supplying water at time of low flows (the 7-day MALF discharge area). This estimate was considered to represent the "worst case scenario" where all afforestation took place in the low flow water-producing part of the catchment. This report is the tenth in a series aimed at understanding the effects of land-use change on flows on which to base policy. For a complete understanding of the background and issues, the series of reports needs to be understood, because this current report builds upon them rather than repeating them. Duncan (1996) comprehensively reviewed the New Zealand literature on the hydrological effects of land use change as well as suggesting ways of identifying catchments whose flows were sensitive to land use change. Duncan (2000) examined hydrological data from Canterbury catchments (Kakahu, Ashley and Hawkins) where there was land use change, to assess their value for estimating the effects of land use change in Canterbury. The report concluded that the Kakahu, Ashley and Hawkins data sets were consistent with the other New Zealand data and did not justify developing a separate "Canterbury" land use change model. It also reviewed the value of various rainfall to runoff models for assessing the effects of land use change on hydrology. Duncan (2003a) reviewed the vegetation characteristics that impact on water yield and described in detail the vegetation cover of relevant New Zealand paired catchment experiments. The study included a field visit to help categorise Canterbury hill country vegetation types in terms of their effects on water yield and looked at the effects of evenly staged afforestation because previous studies had concentrated on a comparison of water yield between mature plantations and other land covers. The study finished with an example using the Waipara River at White Gorge where the effects of staged partial afforesting of the 7-day MALF source areas on flows were estimated. Duncan (2003b) extended the Duncan (2003a) study to a further six catchments.

A study (Duncan 2004), known as the Phase 1 report, reviewed the methodology from the 2003 reports for estimating the effects of planting forestry in flow-sensitive catchments to reflect more accurately the basis for land use controls that will allow plantings scattered throughout the catchment. As a result of that review the mean flow or annual yield reduction to be expected for a whole catchment for conversion of short grassland to staged plantation forestry (all forest ages represented) was confirmed as 41 per cent, but the mean annual low flow reduction was changed to

37 per cent (Duncan 2004). That study applied the methods to seven catchments. The Phase 2 study (Duncan and Image 2004) extended the analysis to a further seven catchments and updated the Phase 1 analysis. Since then, the methods used in the Phase 2 analysis have been applied to a further 30 catchments over two studies (Phase 3 - Duncan and Dey 2006 and Phase 4 - Duncan et al. 2008).

Since the Phase 3 report (Duncan and Dey 2006) an Environment Canterbury Hearing Panel has considered the Officer reports and public submissions on those parts of Chapter 5 of the Natural Resources Regional Plan (NRRP) addressing land-use change effects on hydrology. In response to submissions reviewing the science behind the issue, the effect on mean flow of closed canopy forest, replacing short grassland, has been revised to a 50 per cent reduction. This translates to a 37 per cent reduction in mean flow (or annual yield) for staged plantation forestry and a 33 per cent reduction in low flows for staged plantation forestry.

The work reported here applies the same methods as used in Phase 1, 2, 3, 4 and 5 studies, but assumes the revised 37 per cent reduction in mean and median flows and 33 per cent reduction in low flows. Flow reductions are given as flow changes and as percentage changes. The flow reduction data are also used to determine the change in reliability of supply. The only other difference between this study and earlier studies is that land cover was taken from the more recent Land Cover Data Base 4 (LCDB4) (Landcare Research 2015) coverage that was not available when the previous studies were done. LCDB4 defines more land cover categories than earlier LCBD versions and was derived from imagery acquired in 2012/2013. Appendix 1 contains the study brief.

In common with previous studies this study uses the concept of a “staged forest development” when considering the effects of afforestation on flows. This involves taking into account the reduced evaporative water demand when land is bare after harvest, and while the trees grow until they can be considered to have complete canopy cover. If the time from planting to harvest is 28 years then each 1/28 of the land to be afforested is given the evaporative demand of the forest for each year of the forest planting to harvest cycle (Duncan 2003a).

2 Methods

The methods used herein have been refined after rigorous critical review of the methods used in earlier studies (Duncan 2003a, b). The essence of the reviews, the responses to them and the changes made to the methods in response to the reviews are contained in Duncan (2004a). There was further review as a result of the NRRP hearings (Duncan 2007).

The methods were as detailed in the Phase 1 report (Duncan 2004a). However, the methods were automated for all subsequent reports including this report. The flow reduction factors used for this report differ from the earliest reports (see Section 1) and are 37 per cent for mean and median flows and 33 per cent for low flows. The Phase 4 report (Duncan et al. 2008) details the effects of these changes for the catchments assessed in that report.

2.1 Assumptions

The specific assumptions used in calculation the effects of afforestation on water yield were:

- The forest is a staged forest development with a 28 year rotation.
- The flow reduction factors were 37 per cent for mean and median flows and 33 per cent for low flows.
- The land suitable for commercial forestry had >700 mm annual rainfall, slope <35 degrees and an altitude <750 m.
- Within the area suitable, the land available for afforestation had the following LCDB4 land cover categories:
    - Tall tussock grassland
    - High producing exotic grassland
    - Low producing grassland and
    - Depleted grassland.
- The area of simulated afforestation was 5 per cent, 10 per cent, 15 per cent, 20 per cent or 25 per cent of the total catchment area, planted on the area suitable for commercial forestry for the 7-day MALF, and 10 per cent, 15 per cent, 20 per cent, 25 per cent and 30 per cent for the mean flow.
- The reduction in the reliability of supply caused by the afforestation is calculated for the mean, median and low flows. The calculation for the low flow is based on the minimum flow (the flow at which all abstractions must stop except for that required for domestic, stock and fire-fighting purposes) plus any abstraction allocation.
- For the calculation of reliability of supply the reduction in flow for each level of planting for the mean and 7-day mean annual low flow was applied to the median and minimum + allocation flows respectively.

For consistency with earlier reports the criteria used for land suitable for commercial forestry were the same as that used for the earlier reports. Advice from the forestry industry (Peter Weir, NZ Forestry Owners association pers. comm.) suggests that the annual rainfall limit is too low (more rainfall is needed for viable forest), the slope limit is too low (trees can be planted and harvested on steeper terrain) and the altitude limit too high (trees should not be planted at such high elevations). In the upper Orari catchment the main constraint on the area suitable for commercial forestry used in this report is altitude. Thus any revised criteria are unlikely to increase the area deemed suitable for commercial forestry.

3 Results

Tables showing flow reductions for 7-day MALF and mean are summarised in this section. Also note that flow figures have been calculated with full precision but presented in the tables rounded to three significant figures in keeping with the precision with which they are measured. The percentage flow change figures in the tables are presented to one decimal place to aid understanding of the tables. However, the percentage figures should be rounded to the nearest whole number for use in setting policy, to be consistent with the precision of the data behind these percentages, e.g., thus a flow reduction values of 5.4 per cent could be regarded as reducing the flow by more than 5 per cent.

Readers need to appreciate that the approach used does not take into account variations between sites or between years. The between-year variation is not important for information for policy decisions that require an average value. There will be variation between sites, but the use of an average reduction figure and the exclusion of catchments with well-sustained flows from these studies will minimise that variation.

3.1 Orari River at the Gorge

The Orari River catchment upstream of the Gorge water-level recorder, with an area of 522 km^2 has only 34 per cent of the catchment area is suitable for commercial forestry. This is mainly because the large area of land at elevations >750 m in the head waters of the catchment (Figure 3-1) is not suitable for commercial forestry. The area available for forestry is further limited to 32 per cent of the total catchment area from the point of view of this study by the land cover categories not listed in Section 2 (exotic forest, gravel or rock, native forest, deciduous forest, fern land sub-alpine scrubland, manuka or kanuka, matagouri, lakes and landslides). Therefore, the effect of forestry planting on flow reductions (Tables 3-1 and 3-2) or on reliability of supply (Table 3-1) was not calculated for planting areas in excess of 30 per cent of the total catchment area. Of the 16,500 ha that could be afforested, 10,300 ha were classified as low producing grassland, 3,000 ha was high producing grassland and the balance tall tussock grassland.

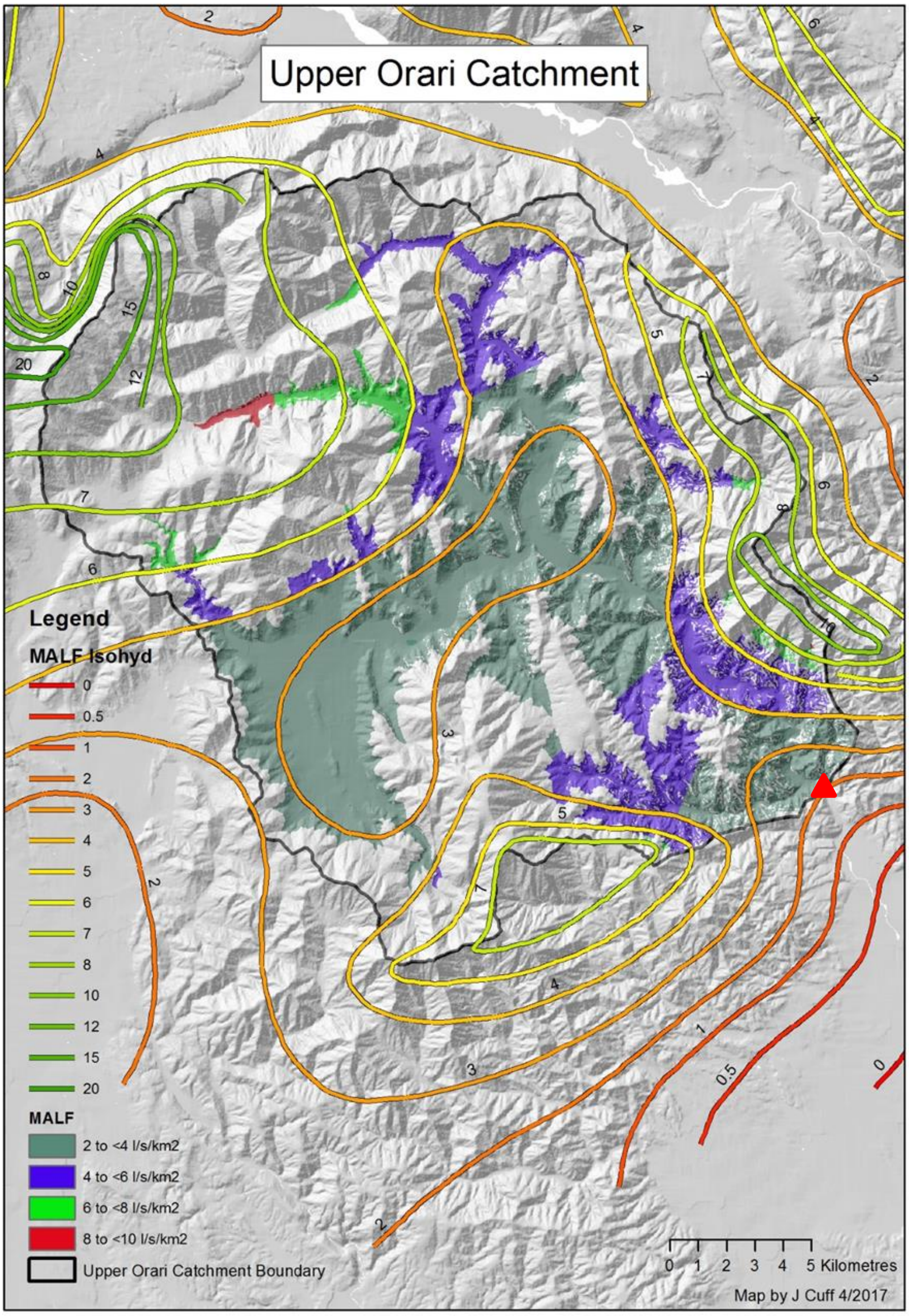

Figure 3-1: The Orari River catchment upstream of the Gorge water-level recorder (▲) showing the areas suitable for forestry in colour. The remaining area is too high, too steep or has too low rainfall to be suitable for afforestation. Colours indicate the low flow yield of the various potential forest areas. Also shown are the 7-day MALF isohyds.

Table 3-1 and Table 3-2 show the effects of planting short grassland in forest on a range of flows[1].

Table 3-1: The effects of planting short grassland in forest on mean flow: Orari River catchment.

	Area (km²)	Total flow (L/s)	Flow reduction 10% planted (L/s)	Flow reduction 15% planted (L/s)	Flow reduction 20% planted (L/s)	Flow reduction 25% planted (L/s)	Flow reduction 30% planted (L/s)
Total available	165	2650					
Catchment total	520	9010	311	467	623	779	934
Estimated new flow			8700	8540	8400	8230	8080
Percent reduction			3.5	5.2	6.9	8.6	10.4

Table 3-2: The effects of planting short grassland in forest on the 7-day mean annual low flow: Orari River catchment.

	Area (km²)	Total flow (L/s)	Flow reduction. 5% planted (L/s)	Flow reduction. 10% planted (L/s)	Flow reduction. 15% planted (L/s)	Flow reduction. 20% planted (L/s)	Flow reduction. 25% planted (L/s)
Total available	165	606					
Catchment[2] total	520	2750	31.9	63.8	95.7	128	160
Estimated new flow			2718	2686	2654	2622	2590
Percent reduction			1.2	2.3	3.5	4.6	5.8

Table 3-3 shows the changes in reliability of supply. The water supply becomes unreliable when flows fall below the prescribed minimum flow plus the actual take. On the advice of ECan, the proportion of the allocation that is assumed to be taken is the sum of the stock-water allocation, 50 per cent of the irrigation allocation and the public water supply allocation. The most left-hand numerical column in Table 3-3 shows the flow for each flow statistic. The next column shows the number of days per year the flow is equalled or exceeded under the current land cover, and the columns to the right, the decrease in the number of days per year the flows would be equalled or exceeded should that percentage of the catchment be afforested. For the calculation of the reliability of supply of the median flow and minimum plus allocation flow, the percentage flow reductions applied were those for the mean flow and 7-day MALF respectively. Readers need to note this table and all others of its kind in this report give only the average number of days per year the flow would be equalled or exceeded and the average change in reliability of supply. In drought years, the reduction in reliability of supply may be several times that shown by the average.

[1] Readers are reminded that in these tables the percentage reduction values should be rounded to whole numbers, but are presented with one decimal place so the calculations can be followed

Table 3-3: Reduction in reliability of supply for mean, median, 7-day MALF and takes: Orari River catchment.

Flow Statistic	Flow (L/s)	Exceedance (d/y)	Reliability reduction 5% planted (d/y)	Reliability reduction 10% planted (d/y)	Reliability reduction 15% planted (d/y)	Reliability reduction 20% planted (d/y)	Reliability reduction 25% planted (d/y)
Mean	9010	113	3.2	6.3	9.6	12.8	16.0
Median	6320	183	5.5	10.9	16.6	22.1	27.7
MALF	2750	334	1.5	3.1	4.6	6.1	7.6
Min. + allocation	2160	357	1.0	2.0	2.8	3.4	4.0

Table 3-4 and Figure 3-2 show the proportion of the 7-day MALF and the mean flow coming from each 7-day MALF isohyd band. Usually mean flows are supplied by each 7-day MALF band more in proportion to the areas they occupy than 7-day MALF flows, which are much less than the proportion of the areas they occupy in the low MALF bands and much more in the high MALF bands. In the Orari River catchment upstream of the Gorge the pattern is also apparent, but less pronounced, as only of the 31.5 per cent of the catchment area is high yielding and produces 51 per cent of the 7-day MALF and 34 per cent of the mean flow.

The high 7-day MALF producing area is that with a water yield greater than 6 L/s/km^2 (Figure 3-2). Figure 1 shows that very little of the high 7-day MALF producing area is suitable for afforestation, i.e., is above the 6 L/s/km^2 isohyd. Only 2.3 per cent of the total catchment area both meets the afforestation suitability criteria and has a land cover suitable for afforestation. Accordingly, afforestation of the suitable and available high 7-day MALF producing area is unlikely to adversely affect the 7-day MALF.

Table 3-4: The proportion of the 7-day MALF and the mean flow currently mapped as coming from each low flow isohyd band: Orari River catchment.

7-day MALF band ($L/s/km^2$)	Area (km^2)	Area proportion (%)	MALF (L/s)	MALF proportion (%)	Mean flow (L/s)	Mean flow proportion (%)
2 to <4 $L/s/km^2$	197	37.9	558	20.3	2840	33.2
4 to <6 $L/s/km^2$	159	30.6	778	28.3	2750	32.1
6 to <8 $L/s/km^2$	96	18.5	667	24.2	1850	21.6
8 to <10 $L/s/km^2$	40	7.6	356	12.9	876	10.2
10 to <12 $L/s/km^2$	11	2.1	124	4.5	248	2.9
12 to <20 $L/s/km^2$	17	3.3	267	9.7	0	0
20 to <25 $L/s/km^2$	0	0	2.88	0.1	0	0
Total	520	100	2750	100	9010	100

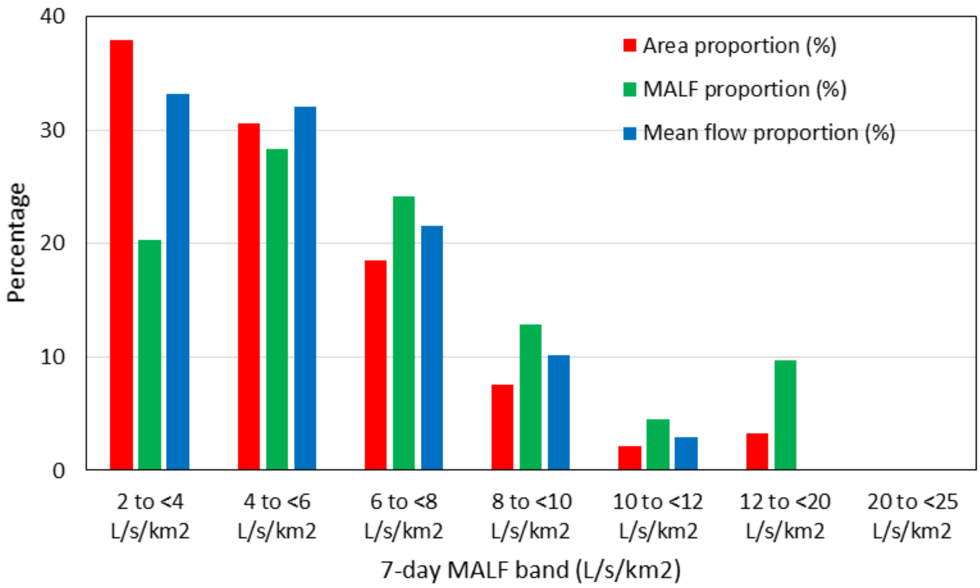

Figure 3-2: The proportion of catchment area, 7-day MALF and mean flow from each 7-day MALF isohyd band: Orari River catchment.

4 Summary

Tables 4-1 and 4-2 summarise the results[3].

For the Orari at Gorge catchment afforestation of ~22 per cent total catchment area spread evenly over the area suitable and available for forestry would reduce the 7-day MALF by 5 per cent (Table 4-1), and reduce the mean flow by ~7.5 per cent.

Table 4-1: Summary of the 7-day MALF reduction estimates when evenly staged forest replaces short grassland.

Catchment	7-day MALF (L/s)	MALF loss due to forest planting				
		5% forest %, (L/s)	10% forest %, (L/s)	15% forest %, (L/s)	20% forest %, (L/s)	25% forest %, (L/s)
Orari	2750	1.2 (31.9)	2.3 (63.8)	3.5 (95.7)	4.6 (128)	5.8 (160)

Table 4-2 summarises the mean flow reduction estimates when evenly staged forest replaces short grassland.

Table 4-2: Summary of the mean flow reduction estimates when evenly staged forest replaces short grassland.

Catchment	Mean flow (L/s)	Mean flow loss due to forest planting				
		10% forest %, (L/s)	15% forest %, (L/s)	20% forest %, (L/s)	25% forest %, (L/s)	30% forest %, (L/s)
Orari	9010	3.5 (311)	5.2 (467)	6.9 (622)	8.6 (780)	10.4 (808)

Table 4-3 shows the average current reliability of supply for abstractions and the average reduction in the reliability of supply when evenly staged forest replaces short grassland.

Table 4-3: Summary of the reduction in the average reliability of supply of the minimum flow plus allocation for abstractions when evenly staged forest replaces.

Catchment	Current reliability (days)	Average reliability of supply reduction (days/y) due to forest planting				
		5% forest (d/y)	10% forest (d/y)	15% forest (d/y)	20% forest (d/y)	25% forest (d/y)
Orari	357	1.0	2.0	2.8	3.4	4.0

[3] Readers are reminded that in these tables and others the percentage reduction values should be rounded to whole numbers, but are presented with one decimal place to be consistent with the tables in Section 3. Thus a 4.6% reduction should be interpreted as a 5% reduction

5 Discussion

This report examines the effects on 7-day MALF, mean flows and security of supply of replacing up to 30 per cent of a catchment area in short grassland cover as defined in Duncan (2003a) with a staged forest development for the Orari River at Gorge catchment. The methods used herein have been refined after rigorous critical review of the methods used in earlier studies (Duncan 2003a, b). The essence of the reviews, the responses to them and the changes made to the methods in response to the reviews are contained in Duncan (2004a). In response to submitters to the NRRP hearing the flow reduction factors were reduced (see Sections 1 and 2).

5.1 Security of supply

The reduction in security of supply caused by afforestation of 5-25 per cent of the catchment was calculated for four flow parameters: mean, median and 7-day MALF flows, and minimum flow plus allocation. The current level of availability of the 7-day MALF +allocation was 357 days per year. However, the calculation masks a wide inter-annual variation; during a drought year the availability is likely to reduce substantially and the reduction in security of supply caused by afforestation will be greater in a drought year.

5.2 Sources of flow for mean and 7-day MALF flows

From inspection of Figure 3-2 it can be deduced that the 7-day MALF flows and mean flows are predominantly sourced from different parts of the catchments. The mean flow appears to come from all over the catchment more or less in proportion to the area covered by each isohyd band. In contrast 7-day MALF flows are mainly sourced from the higher yielding isohyd bands where the contributions to the total MALF are higher than the proportional areas of the isohyd bands. In the lowest yielding part of the catchment both flow measures yield less than would be expected from their areas. The implication is that if short grassland is converted to a staged forest development where the new forest is not distributed evenly over the catchment then the effect on stream flows will be different even if the same proportions of the catchment are converted to forestry. Concentrating the forest in the low flow producing areas with high specific discharges as was reported in Duncan (2003a) reduced 7-day MALF flows more than distributing the same proportion of forest evenly over the portion of the catchment suitable and available (this study). It would also have a greater effect than concentrating the forest in the low flow areas producing the lowest specific discharges. The same principle applies to mean flows.

Figure 3-2 shows that the area suitable for commercial forestry is predominantly in the part of the catchment where low flow yields are lower than elsewhere in the catchment, so there is little likelihood of commercial forestry being planted in the low flow yielding part of the catchment where water yields are high, that could bring into question the results in this report.

5.3 Agreement of isohyd map generated flows and recorder flows

When estimating the effects of the afforestation, the catchment water yield obtained from the isohyd maps is scaled to agree with the water yield provided by ECan hydrology staff. The isohyd map total is obtained by multiplying the mean value of adjacent isohyds by the area between the isohyds and summing for the catchment. It is these mean values that are scaled. For the Orari catchment there was a reasonable agreement between map and hydrological record values with the 7-day

MALF having a better agreement than the mean flow. There may be very good reasons for this behaviour, such as losses to ground water in the lower parts of the catchment, or springs re-emerging in the lower parts of the catchment. The author is not familiar enough with the catchment to make a judgement about the differences. Table 5-1 lists the pairs of water yield values and the scaling parameters for the catchment. Readers will have to judge for themselves as to whether the computations are appropriate or not. However, as the study results are in terms of percentage change in yield and as each inter-isohyd mean is scaled by the same value this issue should not affect the results of the study. Readers should note that the need for scaling factors is primarily a function of interpretation of the isohyd maps rather than any inaccuracy in the maps. The isohyd maps are primarily based on data from 1982 to 2002. The maps were partially revised in 2008, whereas the hydrological statistics are based on data from September 1982 to June 2016 (Jen Dodson, ECan Pers. Comm.). The map data is consistent with that of the earlier studies.

Table 5-1: Scaling factors used to equate water yields from maps with water yields supplied by ECan hydrological staff (some numbers have been rounded).

Catchment	Map MALF (L/s)	Schedule MALF (L/s)	Ratio	Map Mean (L/s)	Schedule Mean (L/s)	Ratio
Orari	2672	2752	0.97	9886	9008	1.1

5.4 Afforestation thresholds

In previous studies (Duncan 2004b, Duncan and Dey 2006) catchments that had their 7-day MALF flows changed by less than 5 per cent when 20 per cent of the short grassland in the catchment was converted to forest were declared in the report to be insensitive to afforestation and so there would be no restrictions on afforestation in the catchment. In those studies, and in the current study, there were a number of catchments that had their 7-day MALF flows reduced by more than 5 per cent when 25 per cent of the short grassland was afforested. If the objective of the policy in the NRRP is to sustain the ecological values in the streams by maintaining the current 7-day MALF then a restriction on the allowable proportion of forestry should be put on all catchments based on the proportion that causes the 7-day MALF be reduced by 5 per cent.

The current Land and Water Regional plan controls on forestry in flow sensitive catchments are given in Appendix 2. For the 520 km^2 Orari Catchment at the Gorge, Rule 5.73, bullet 3 applies: *“In any catchment greater than 50 km^2 in area the new area of planting, together with all other new areas of planting in the same flow sensitive catchment since 1 November 2012, will not cumulatively cause more than a five percent reduction in the seven day mean annual low flow, and/or more than a 10 per cent reduction in the mean flow.”*

6 Conclusions

The methods used here for determining and presenting the effects of afforestation of short grassland on 7-day MALF and mean flows have been revised in response to rigorous critical review.

This study found the Orari River at Gorge catchment could have ~22 per cent and 30 per cent of its catchment area suitable and available for forestry converted from short grassland to a staged forestry development before reducing the 7-day MALF flows more than 5 per cent and the mean flow by more than 10 per cent respectively.

The average reliability of supply of the Orari at Gorge catchment was 357 days per year before afforestation and 354 days per year after 25 per cent afforestation. However, in a drought year availability is likely to be reduced substantially and the reduction in security of supply caused by afforestation will increase materially.

Mean and 7-day MALF flows are predominantly sourced from different areas of the catchment. Mean flows are sourced more or less evenly throughout the catchment whereas 51 per cent of the low flows are sourced from the high yielding and generally higher elevation parts of the catchment comprising 32 per cent of the catchment area. Thus, afforestation strategies to reduce effects on 7-day MALF flows may have a greater effect on mean flows. The effect of forest distributions different from the evenly spread distribution assumed for this study is likely to vary.

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Appendix A Scope of work

Project brief

Calculation of the effect of forestry planting on water yield for in the Orari River at Gorge catchment, Canterbury.

Scope and nature of services

To estimate the effect of forestry planting in the Orari River catchment on the 7-day MALF and mean flows at Gorge/Silverton.

To identify the level of afforestation which would cause a reduction of the 7-day MALF by more than 5 per cent and the mean flow by 10 per cent.

Tasks

Using the same methods as previous studies e.g., Duncan et al. (2008) to estimate the effect of forestry planting scattered throughout the catchment on the 7-day MALF and mean flow for the Orari River at Silverton Catchment. Afforestation to be limited to areas with average annual rainfalls <750 mm/y, slopes<35 degrees and elevations less than 750 m above mean sea level.

Identify the area of afforestation which would result in a reduction of the 7-day MALF by more than 5 per cent and the mean flow by 10 per cent.

Identify the low flow producing parts of the catchment that would be especially sensitive to the effects of afforestation.

Outputs

A written report that:

- clearly states any assumptions used in the analysis
- describes the results of the analysis of the effects of forest planting on the 7-day MALF and mean flows for the Orari River at Gorge/Silverton
- identifies the proportions of the catchment that result in a reduction of the 7-day MALF by more than 5 per cent and the mean flow by 10 per cent
- identifies (spatially) the low flow producing areas that are likely to be sensitive the effects of afforestation.

The report may also include recommendations for further work.

Information and assistance to be provided by Environment Canterbury

Environment Canterbury will supply to the Consultant the following Orari River catchment information:

- Catchment boundary with a grid reference for the location of the flow recorder site that defines the downstream end of the catchment.
- The catchment area to the flow recorder site.

- An orthophoto of the catchment showing the catchment boundary and streams.
- A map of the 7-day MALF isohydes and areas suitable for forestry with catchment boundary and streams.
- A map of the 7-day MALF isohydes and grid with catchment boundary and streams.
- A map of the mean flow isohydes and areas suitable for forestry with catchment boundary and streams.
- A map of the mean flow isohydes and grid with catchment boundary and streams.
- A map of ground covers, e. g., herbs, water, woody, bare ground with catchment boundary and streams.
- Current estimates of the 7-day MALF and mean flow at the recorder site.
- A set of tin layers for the 7-day MALF and mean flow data.
- The minimum flow for the flow recorder site.
- The area between adjacent pairs of 7-day MALF and mean flow isohydes for the catchment.
- Identification of the area between each adjacent pair of isohydes that is suitable for forestry (i.e., that is not currently on forest, has an average annual rainfall <750 mm/y, slopes <35 degrees and elevation less than 750 m above mean sea level).
- For the areas identified as suitable for forestry the area of each vegetation class as identified by the most appropriate land cover database.
- Spreadsheet with work sheets for;
    - MALF and mean flow area for the whole catchment by isohyd.
    - Mean flow catchment summary: Columns for mean flow band, band area and specific discharge for each band.
    - MALF catchment summary: Columns for mean flow band, band area and specific discharge for each band.
    - Mean flow and cover. Columns for mean flow band, cover class in each band and area for each cover class in each band.
    - MALF and cover. Columns for MALF band, cover class in each band and area for each cover class in each band.
    - Mean flow cover pivot table with columns for Mean flow band, Cover class name, Data (sum of area and per cent total area for each cover class), and numerical values for those items.
    - MALF cover pivot table with columns for MALF band, Cover class name, Data (sum of area and per cent total area for each cover class), and numerical values for those items.

Appendix B Land & Water Regional plan controls on forestry in flow sensitive catchments

Policy 4.75

Flow Sensitive Catchments

Reduced effects arising from the interception of rainfall run-off on surface water flows in the flow sensitive catchments listed in Sections six to 15 is achieved by controlling the area, density and species of trees planted, except where tree-planting is required to control deep-seated soil erosion.

Regional Rules

Rule 5.72. The replanting after harvest of areas of plantation forest within any flow-sensitive catchment listed in Sections six to 15 is a permitted activity, provided the following conditions are met:

- The total area of replanted forest does not exceed the area of forest and replanting of the forest occurs in the same location, or the area as used for a rotation forestry operation, that existed at 1 November 2010; and
- Any replanting occurs within five years of the removal of the previous forest cover.

Rule 5.73. The planting of new areas of plantation forest within any flow-sensitive catchment listed in Sections six to 15 is a controlled activity, provided the forest planting meets the following conditions:

- Existing areas of exotic tall vegetation, other than plantation forest, that is greater than 2 m tall and occupies more than 80 per cent of the canopy cover and existed at 1 November 2010 may be planted in plantation forest; and
- In catchments less than or equal to 50 km^2 in area the total area of land planted in plantation forest does not exceed 20 per cent of the flow sensitive catchment or sub-catchment listed in Sections six to 15; and
- In any catchment greater than 50 km^2 in area the new area of planting, together with all other new areas of planting in the same flow sensitive catchment since 1 November 2012, will not cumulatively cause more than a five percent reduction in the seven day mean annual low flow, and/or more than a 10 per cent reduction in the mean flow.

The CRC reserves control over the following matter

- The provision of information on the location, density and timing of planting.

Rule 5.74. The replanting after harvest of areas of plantation forest that does not meet the conditions of Rule 5.72 or the planting of new plantation forest that does not meet one or more of the conditions of Rule 5.73, within any flow-sensitive catchment listed in Sections six to 15 is a restricted discretionary activity.

The exercise of discretion is restricted to the following matters

- The actual or potential adverse environmental effects of forestry planting on the surface water flows in the catchment, including water allocation status, minimum flow or flow regime, in-stream values and authorised takes and use of the water; and

- The actual or potential adverse environmental effects of forestry planting on groundwater recharge; and
- The benefits of the forestry for slope stability, erosion control, noxious plant control, water quality, carbon sequestration and biodiversity protection; and 4. The spacing and density, and species of the planting.