Development of a System to Optimise Water Recharge and Timber Production from *Pinus pinaster* Aiton Plantations on the Gnangara Water Mound

Scott Wood  
*University of Notre Dame Australia*

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**Publication Details**  
1. Introduction

i) Background and outline of the study

The Western Australian Government on the advice of the Department of Conservation and Land Management (CALM) decided in 1996 to progressively liquidate the 21,500 hectares of *Pinus pinaster* Aiton plantation resource 20 kilometres north of Perth, which had been established over the previous 80 years. The plantations are located on the Gnangara Water Mound, which currently provides 40% of the water consumed in the Perth region (Figure 1).

![Figure 1. The location of the *P. pinaster* Aiton plantations in relation to the Gnangara Water Mound](image-url)
The area of plantations of *Pinus pinaster* Aiton on the Gnangara mound is made up of three recognised plantations; Gnangara, Pinjar and Yanchep plantations (Figure 1).

The decision to liquidate the stands and cease replanting was brought about by a number of factors including the perceived increasing conflict between timber and water production on the Gnangara Water Mound, the increasing incidence of wildfires resulting from arson and the demonstrated capacity to grow *P. pinaster* Aiton more efficiently on cleared agricultural land at other locations. (Shea. S.R. Pers Com.) It is expected the harvesting of all of the plantations will be completed between 2004 and 2029.

The existence of the plantations on the Gnangara Water Mound became a concern from the mid 1970s because of increasing awareness of the conflict between extraction of water for domestic use, the extraction of water by the pine plantations and projected shortages of water to Perth consumers because of drought. The increase in water use from the Gnangara Mound for domestic consumption also resulted in conflicts with conservation values. Rare and endangered subterranean species that occur in the Yanchep cave system are thought to be dependant on the maintenance of groundwater levels for their survival (Wilkens, H., Culver, D. C. & Humphreys, W.F. 2000).

The plantation silvicultural systems were progressively modified from the mid 1970s in an attempt to ameliorate these conflicts (Butcher 1979). The basal area was reduced to attempt to achieve a rotational average of 11 m$^2$ basal area. The future land use of the Gnangara Mound has become a major planning issue for the Western Australian State Government involving several different State Government Agencies. The Gnangara Sustainability strategy 2009 has recently been published (Department of Water 2009).
The decision to liquidate the plantations has also enabled the Government to allocate 160,000 cubic metres of logs per annum over a 25-year period to Wesbeam Pty Ltd for the production of Laminated Veneer Lumber (LVL). This was possible because it was previously seen as an under utilised resource (Professor Dr Syd Shea 2008, Notre Dame University Fremantle former Executive Director CALM pers. comm.). This resulted in 2004 in the construction of a factory producing LVL with a work force of approximately 140 people. It was necessary for the Western Australian Government to legislate an Agreement Act in order to secure the investment required. The government passed legislation (Wood Processing (Wesbeam) Agreement Act 2002) which has provided an opportunity to utilize the pine resource for a high value product but it has also constrained the rate and method by which the plantations can be liquidated.

The requirements to meet both the log resource contracts and maximise water recharge to a significant groundwater resource provide a unique opportunity to scientifically evaluate the impact of significantly different harvesting regimes on the costs and benefits to water, timber production, conservation assets and potentially other land uses. To accomplish this, an integration of the large amount of forest growth and hydrological data and the utilisation of operational research methods to develop temporal and spatial harvesting regimes, which would optimise the water, timber and conservation resources of the area was required.

Normal pine plantation management in Western Australia is aimed at optimising wood production. It involves establishment, two to four thinning operations, clear falling and replanting over a 30 to 40 year cycle. This normal harvesting schedule does not necessarily allow for optimisation of land use for other values like water recharge. To achieve a greater water recharge outcome significant departures from normal harvesting schedules may be required.
Previously the Forest Products Commission (which succeeded CALM and is now the State Government Agency responsible for forest management in Western Australia) has concentrated on evaluating a limited number of harvesting scenarios, which involve maximising the wood production. Theoretically, if wood fibre production was the only consideration, the optimum harvesting regime would involve the retention of trees throughout the total area for as long as possible at densities that optimised wood production. Even a harvesting regime that maximised wood fibre production would not necessarily be the optimum regime for the production of logs to be utilized for laminated veneer lumber. In addition to timber production the government is seeking to balance the water usage from the area to meet both the demand for water for the metropolitan area and that required for conservation habitat in the Gnangara region.

The need to seek increased water production from any potential source has been driven in part by an apparent change in climate. Average annual rainfall since 1969 has been reduced by approximately 100 mm per annum to an average of 720mm between 1969 and 2007 at Wanneroo compared to average rainfall of 820mm over the period from 1914 to 1968 (Water Corporation 2008).

**ii) Need for and significance of the study**

This study is essential to determine if it is possible to vary the rate and method of harvesting the plantation to increase water yield while at least maintaining timber yield at levels that meet the legal obligations of the State Government to supply timber of specified dimensions to the Laminated Veneer Lumber Plant. This plant commenced operations in 2004 and has legal rights to 4 million cubic metres of timber up to the year 2029.
The techniques, which have been developed, should also have direct relevance for the new Maritime Pine plantings occurring in the lower rainfall zone of Western Australia. These are located on cleared agricultural land and the objective of these plantings is to increase water consumption in order to minimise salinity and water logging. Measurement techniques for leaf area available to this study and a thorough understanding of leaf area dynamics and its relationship to water use and growth developed in this thesis are likely to be the most transferable aspect of the research which has been undertaken in this study.

The overall objective of this thesis was to investigate and compare the options that are available to optimise the yield of water (ceasing or reducing the decline of groundwater levels) and timber by analysing the effect of different pine harvesting regimes on the principal products derived from the area - water and timber. A conceptual approach to the study is illustrated in Figure 2.
Factors affecting growth
- Growth stages
- Silviculture effects
- Limiting factors

Water use
1. Understanding stand canopy/leaf area growth
2. Leaf area to water use relationship
3. Age changes in water use
4. Challenges in water use calculations
5. Water use models
6. Comparative water use studies by various land uses

Ranking of priorities for treatment

Constraints and their relaxation
Scenario choices to test boundaries

Linear programming and model development

Wood and water outcomes

Figure 2. Conceptual approach to the study

Specifically the thesis provides for:–

1. A synthesis of the large amount of data on factors affecting growth and development of *P. pinaster* Aiton and the relationship between leaf area and groundwater recharge.

2. The provision, to managers, of a range of options for harvesting the plantation resource with a comparative assessment of each regime on timber production and groundwater recharge.
iii) Issues being analysed and investigated in the study

The overarching research questions for this study were:

- What is the optimum harvesting regime that provides the best water recharge outcome within the timber volume constraints that apply because of contractual commitments that are supported by legislation?
- Whether and how much additional groundwater recharge can be achieved by the progressive relaxation of the volume constraints and the manipulation of the timing and spatial harvesting strategies?

The following specific Modelling and Scheduling Questions were addressed:

- The Wood Processing (Wesbeam) Agreement Act (2002) contains constraints, which limit the options of what stands can be removed over the period of the contract. However, it may be necessary to depart from the contract schedule to achieve a larger water outcome. Before this can be considered, an evaluation of what the impacts of a relaxation of those constraints on water yield and timber outcomes is required.
- What series of scenarios can be used to test and compare different wood outcomes and their impact on water availability?
- Which scenario gives the best water outcome?

Other factors affecting the Gnangara Mound ground water system need to be understood so that sensible recommendations can be made. For example, are pruning, burning of litter and native bush prescribed burning significant factors affecting ground water recharge?

An attempt has been made to qualify and quantify the effect of these factors on ground water recharge. However, the time frames and expertise required in making specific recommendations were beyond the scope of this thesis. Some attempt, however, has been
made to make general recommendations on these external, but relevant, issues to allow the effect of harvesting regime options to be placed in the context of other management options.

There were a number of detailed factors that needed to be evaluated to achieve the objectives of this study.

• The impact of different spatial and temporal harvesting regimes on groundwater recharge in different locations on the Gnangara Water Mound.

• A general understanding of the water inputs and outputs of the Gnangara Mound and how all land use changes have impacted upon this.

• The future climate regime. There has been a decline of rainfall since 1969. The period between 1914 and 1968 is recognized as much wetter than the period from 1969 and 2007. The total cumulative reduction of rainfall is 3 metres since 1969 (on average approximately 100 mm less per year) at Wanneroo when this period is compared to the average rainfall that had occurred between 1914 and 1968. (Figure 3)
The decline in rainfall emphasizes the need to recognise that there are other factors, in addition to the pine plantation on Gnangara Mound, that have contributed to the decline in groundwater levels. For example, “The decline in water tables has occurred over a very long time period, and that during this time, both private and public use has increased very substantially” (Peer Review Group 2002 p.2) and “that the current groundwater levels are the consequence of a combination of factors, which include climate, abstraction and land use, over a long period of time” (Response to Peer Review Panel Comments 2002 p. 2). This confirms that it would be incorrect to attribute the decrease in groundwater levels to a single factor alone.