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Surrey Hills, northwest Tasmania – the birthplace of industrial-scale eucalypt plantations in Australia

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Introduction

In Australia, eucalypts were not favoured for plantations on a large commercial basis until relatively recent times. This was primarily due to the ready availability of eucalypts from natural stands and the development of very successful regeneration techniques.[1] Also there had always been doubt that eucalypt plantations could be established to provide, and indeed replace, native forests as a source of sawlogs within a commercial timeframe. Eucalypt plantations were more prevalent overseas and by the end of 1990 it was estimated that over 10 million hectares, equivalent to about six per cent of the native forest area in Australia, were planted worldwide to supply products such as pulpwood, firewood, mining props and the like, with the exception of sawlogs.[2] These regions lacked native eucalypt predators and generally had the benefit of much lower labour costs.

One of Australia's first large eucalypt establishment programs took place from the 1920s to the 1960s in Western Australia. Approximately 8,300 hectares of *Eucalyptus astringens* (Brown Mallet) were sown for tannin extraction and eventually tool handle production. However, just over 2,000 hectares failed.[3] Australian Paper Manufacturers (APM) was next, with relatively significant programs near Coffs Harbour in New South Wales and the Gippsland region in southern Victoria; the intention being to manage them intensively on a short rotation basis for pulpwood production. The former project started in the late 1950s with *E. grandis* (Flooded Gum) planted to produce pulpwood for a planned pulp mill that was never built. A little over 5,000 hectares were successfully established before the project was discontinued in 1982 and the land and plantations sold to the NSW Forestry Commission in 1984.[4] The latter program started in 1960 in the Strzelecki Ranges where predominantly *E. regnans* (Mountain Ash or Swamp Gum) was planted. At 8,000 hectares it was the largest eucalypt plantation program prior to the 1980s, but market considerations then forced an almost complete cessation, although a very small planting program of *E. globulus* spp *globulus*[5] (Tasmanian Blue Gum) and *E. nitens* (Shining Gum) was maintained by APM.[6] Even though experimental plantings of *E. globulus* began as early as 1974 in Western Australia, [7] Bunnings Tree Farms started their own program in 1980 by planting 28 hectares of *E. globulus*. By 1995 the plantation estate owned or controlled by this company was well over 19,000 hectares.[8]

More recently, the 1997 'Plantations for Australia – The 2020 Vision', a strategic initiative of industry and Commonwealth, State and Territory governments, led to significant eucalypt plantings. Predominantly *E. globulus* was planted in Western Australia, the Green Triangle region of south-east South Australia and western Victoria, and primarily *E. nitens* in Tasmania. Funding for this was mainly via private capital sources through Managed Investment Schemes (MIS). [9] For a decade from the mid-1990s the annual planting rate of eucalypts reached extraordinary levels, with large amounts of retail investment money used to purchase cleared land and establish the plantations.

The overarching aim of the 2020 Vision was a national target to treble the area of commercial tree crops by 2020. Under this policy, eucalypt plantations increased from a low base in 1997 of 250,541 hectares[10] to around 980,000 hectares in 2011 at an annual average planting rate of about 52,000 hectares.[11]

The Surrey Hills Estate

There was, however, a very significant but much lesser known eucalypt plantation project that started in north-west Tasmania in the 1950s. This program could arguably be considered the birthplace of industrial-scale eucalypt plantations in Australia because it is where standard silvicultural and tree breeding techniques, that were used during the recent MIS boom, were first pioneered and refined. Founded on a large private property known as Surrey Hills, approximately 60,000 hectares in size and located about 40 kilometres south of Burnie on Tasmania's north coast, the project can lay claim to having created the largest private forest plantation, softwood or hardwood, in Australia.

Figure 1: Map of Tasmania showing location of Surrey Hills

Surrey Hills is located on a broad basaltic plateau in a subalpine zone starting from approximately 550 metres above sea level and rising to about 750 metres. Whilst rainfall is abundant (over 2 metres a year falls in the southern half), the area can receive persistently inclement weather at any time of the year. Within this relatively narrow altitudinal zone there is great variability in the climate and the risk of severe frost damage is high, particularly in areas where cold-air drainage is poor. On very cold sites seedlots can vary in survival rate from good to complete failure.[12] It is for this very reason that the plantations on Surrey Hills are almost exclusively made up of *E. nitens*, a relatively

cold-tolerant species found naturally in Victoria and NSW, rather than the more common *E. globulus* found in the majority of eucalypt plantations on the mainland and a species virtually restricted to Tasmania.[13]

Establishing new plantations on a large commercial scale requires knowledge, infrastructure and capital together with:

- the confidence the species will survive in the local climate;
- a source of high quality seeds to grow trees to meet market requirements;
- a nursery facility capable of producing large numbers of high quality seedlings;
- a knowledge of the most suitable silvicultural techniques;
- an understanding of the nutritional issues;
- access to a research program aimed at continually improving practices and product; and, most importantly;
- confidence to tie up large amounts of capital for a relatively long period before harvest.

The owners of the Surrey Hills estate understood all these factors. After a period of shoe-string budgets, but highly creative management, they invested in a large and innovative research program; built and operated large and innovative nurseries; built a state-of-the-art fibre technology laboratory, and set up a well-founded tree improvement program. They planted seed orchards and encouraged their forestry staff to research and develop silvicultural practices appropriate for the challenging physical environment. They also invested a large amount of their own capital.

The irony of this story, however, is that the motives for establishing plantations at Surrey Hills, on such a large scale, did not originate from a deliberate plantation strategy. Instead it developed because of the difficulty of regenerating the natural forests and the subsequent slow growth of the young trees. This raised questions about Surrey Hills' ability to meet the long term wood supply for the pulp and paper mill in nearby Burnie, owned and operated by Associated Pulp and Paper Mills (APPM), the same company that owned the Surrey Hills estate.

The Regeneration Dilemma

In 1945 APPM employed Reg Needham, their first professionally trained forester, to manage the '1926 Concession'[14] and freehold forests to supply timber for the APPM pulp and paper mill in Burnie.[15] After growing up in Hobart he graduated from Creswick, and his first forestry job was in Victoria with the then Victorian Forests Commission. Whilst posted at East Gippsland he fought the 1939 'Black Friday' wildfire, mainly on horseback. Needham saw firsthand the effects of uncontrolled hot fires, lit by farmers late in the season to promote green pick in the elevated subalpine country. He saw their fires coalesce during blow-up conditions into a raging inferno that was impossible to contain, particularly when associated with high fuel levels.[16]

On his return to Tasmania, Needham sought to bring order to the management of the *E. delegatensis* (White-top Stringybark or Alpine Ash) native forests on Surrey Hills which had been exposed to rough bush cattle grazing at various intensities for the preceding 90 years. Needham first inspected Surrey Hills in January 1946 on horseback.[17] He was immediately concerned about the destruction of young eucalypt seedlings through unregulated grazing and the associated burning practices of the graziers. Their indiscriminate burning during the summer months had the potential to become wildfires in very hot conditions and could destroy large areas of *E. delegatensis* forests. Needham also reported that these fires promoted a dense understorey of pepperbush (*Tasmannia lanceolata*) when the persistent fires weakened the older trees and opened up the canopy:

> …for more than 50 years Surrey had been continually burned to provide sweet food for stock. The timber regrowth came up in the open spaces, but was killed by the light fires which do no

> harm and the more fire resistant species such as peppertree scrub, sweet box, heaths and other similar species have withstood the fires and flourished. Now in places the peppertree scrub etc on areas near the plains where most of the burning originated is so dense that it is extremely difficult to walk through, and impossible to ride through.[18]

In 1954 Needham decided to discontinue the practice of grazing rights over runs at Surrey Hills to protect forest regeneration by cancelling all grazing leases. However, this proved difficult to police and they encountered a good deal of trouble with straying stock, so much so that a public pound was set up near Waratah and a ranger based there to act as a pound-keeper to remove illegal cattle.[19]

Systematic harvesting operations commenced on Surrey Hills in the mid 1950s within the main commercial forest types – *E. delegatensis* grassy woodland; *E. delegatensis* with a pepperbush understorey; and a mixed forest of *E. delegatensis* and myrtle (*Lophozonia* (*Nothofagus*) *cunninghamii*) understorey. Burning as a regeneration treatment was only effective on areas with sufficient fuel to create an intense fire. Under the climatic conditions prevailing at Surrey Hills, however, a successful burn could only be achieved in periods of high fire danger, unless removal of the understorey was carried out in advance, to enable the fuel to be dried and concentrated on the forest floor at a time when the surrounding forests were relatively non-inflammable.

Associated Forest Holdings (AFH) was formed in 1957 as a fully owned subsidiary of APPM to take over all forestry operations in the north-west including regenerating areas harvested on Surrey Hills. Although AFH actively carried out regeneration burns on their coastal forests, there were fire control difficulties that they did not think could be overcome within the subalpine forests. They also noticed that *E. delegatensis* seedlings grew vigorously in areas that had not been burned for five years. Needham himself observed that areas rooted up in the early 1950s with exposed mineral soil, provided good germination conditions for young *E. delegatensis* seedlings in these grassy areas.[20] Notwithstanding the issues of severe frosts and fires, rabbits and native mammals also ate everything and caused considerable damage to young eucalypt seedlings. A poisoning program using compound 1080 (sodium fluoroacetate) became a high priority to protect seedlings from browsing by herbivorous animals.

Eucalypt regeneration on sites with a peppertree understorey was not successful and AFH recognised the need for some treatment prior to logging. After various tests in the early 1950s they mounted a Land Klearing Blade with adjustable teeth or feet on a bulldozer.[21] This was used as a pre-logging treatment to push over the peppertree scrub, expose the soil, drive over it and produce a light disturbance of the ground for a seedbed. It became known locally as 'pepper dozing'. Encouraging regeneration results were observed and it was decided to carry out this operation prior to felling. Very good regeneration usually appeared within two years and rotting peppertree scrub on the ground gave fair protection from frost and game.[22] In the first 10 years over 2,500 hectares was pepper dozed and annual reports recorded favourable eucalypt regeneration. Once regeneration was evident, harvesting of the merchantable trees utilising a seed tree retention system followed.

But there were problems with pepper dozing. It principally relied on seed from the seed trees and the main commercial eucalypt species on Surrey Hills, *E. delegatensis*, produced irregular seed supply. A very good seed year was rare, and sometimes no seed was available at all for periods of up to four years. In periods when trees carried little or no mature seed, regeneration was unsuccessful unless seed was artificially supplied immediately after the treatment.[23] The proportion of land effectively regenerated was unreliable with many areas poorly stocked. In well stocked areas the overall growth rate was poor and growth that did occur was spread over far too many stems. This regeneration was susceptible to heavy attacks by insects and browsing mammals.

Figure 2: Failed regeneration after pepper dozing. *Photo:* RK Orme

The lack of systematic surveys of regeneration to provide monitoring and feedback also hindered any progress and improvement.[24] There was also considerable debate over silvicultural techniques with the Tasmanian Forestry Commission as it favoured burning after logging followed by the sowing of seed.[25] Needham on the other hand had strong views against burning which were shaped by his experiences with fire management in Victoria, especially during the 1939 conflagration. It did not help the Forestry Commission's argument or confidence when a regeneration fire of theirs escaped and damaged large amounts of established regeneration on Crown Land in the Mt Tor region, adjacent to Surrey Hills.

AFH focused its attention on various management options in response to the regeneration problem. One idea was to improve the yield of existing regeneration by introducing non-commercial thinning on a trial basis.[26] However this was not a sustainable solution. Another was to plant eucalypts but the thought of spending a lot of money on planting trees seemed nonsensical at that time. After several failures the idea was dropped. However, APPM had employed a plantation superintendent, Dick de Boer, for its *Pinus radiata* plantation program[27] in September 1950.[28] With his European training and rubber plantation experience in Indonesia he persisted in trialling eucalypt plantings on Surrey Hills, despite being instructed not to, and eventually succeeded to the point where he was allowed to continue experimenting. Through his persistence and experience de Boer was the pivotal figure in laying the foundation for the eucalypt program on Surrey Hills and without him AFH may not have become the leaders in eucalypt plantation development in Australia.

In 1969 de Boer instigated an AFH funded co-operative project with the Tasmanian Forestry Commission to investigate the best techniques to employ in regenerating high elevation eucalypt forests. A joint eucalypt regeneration survey of Surrey Hills and adjoining Crown concession areas was carried out in 1970 by Keith Orme, a Tasmanian Forestry Commission research forester, who

studied the effectiveness of regeneration after pepper dozing and made comparisons with successful regeneration of eucalypts after fire.[29]

At the same time the parent company, APPM, was actively engaged in pulp mill investigations with the aim of establishing a new world class pulp mill in northern Tasmania, and it was important that satisfactory long term arrangements were put in place for an ongoing wood supply. Following the work by Orme, changes to AFH's regeneration policy in the 1970s at first focused, reluctantly, on introducing fire to achieve better results but, instead of relying on natural regeneration, it soon included ideas of planting trees on a large scale – but the capability to do so was missing.

Experimental and trial plantings – the search for the ideal species

Orme's study had highlighted that a total dependence on natural seed shed after any form of site preparation was unreliable and led to many failures. This, combined with a slow growth rate recorded for native forest regeneration, led to the realisation that the future supply of timber was an acute issue for the company and provided the impetus for it to become much more strategic and focused on developing techniques to improve the yield of the forests. This is where eucalypt plantings became more prominent, although the potential costs made AFH cautious. Orme's work introduced new and expensive considerations such as nursery stock, control of browsing animals and insects and how to cope with severe and regular frosts.[30]

Initially AFH believed it was unrealistic to consider a complete change from natural regeneration techniques to a total reliance on plantations for Surrey Hills. No species had yet been found that was suitable to grow at a big scale on Surrey Hills. All they had were around 18 hectares experimental plantings of mainly *E. globulus* and *E. delegatensis* established over the previous 20 years using various methods of cultivation. Many of these earlier plantings suffered damage through susceptibility to cold, weed competition, browsing by animals and insects and a lack of suitable species.[31]

In the early 1970s, a decision was made to modestly expand eucalypt plantings and to initially focus on species comparisons for a small plantation program to supplement native forest regeneration. In 1971, as an adjunct to the primary focus of his study, Orme also established a trial of a variety of eucalypt (and coniferous) species on Surrey Hills, to test their potential at a higher altitude. As well as identifying species that could be used as an alternative to *E. delegatensis* if its regeneration continued to be an issue, he also wanted to get a measure of the growth rates that could be expected from the species when they were grown under intensive forest management at that altitude.[32] At the same time – for two years beginning in June 1970 – AFH contracted a research scientist for similar studies, namely growth rates of *E. delegatensis* at various elevations, and the work created considerable interest within the company.[33]

Small-scale trial plantings, including various combinations of row-by-row mixed species continued over the next 10 years. They highlighted the practical problems that occur due to differing rates of growth for different species. Different planting techniques using ploughed ridges were also introduced to try and protect seedlings from the severe frosts. Trials using existing plantings were expanded to determine the optimum period for planting. Provenance trials using some of the species were also introduced. Although largely unpublished, the early findings and successes of many of these trials enabled AFH to embark on annual planting programs in the order of 200 hectares in the early 1980s.

One of the more critical problems faced at that time was the observed explosion of insect numbers. Native forestry operations were concentrated on Surrey Hills in forests that were growing towards their climatic limit and the subsequent proliferation of young regeneration created optimum

conditions for phytophagous insects to survive, propagate and feed on the young trees, particularly in areas of high rainfall. In natural regeneration this process serves as a form of natural thinning. In eucalypt plantations, where initial stocking is controlled, insect attacks can lead to complete failure.

In the early 70s relatively little was known about the life cycles of forest insects in Australia and their impact on eucalypt regeneration.[34] Research in the 1960s in southern Tasmania provided valuable information on the biology of the main leaf beetle pest and its impact on the growth of eucalypt regeneration.[35] However intensive studies were required before any control measures could be effective and this commenced in 1973 with the support of an entomological PhD student, David de Little, funded by a company grant to the University of Tasmania. De Little's work so impressed AFH management that he was offered employment in 1975 as well as the opportunity to complete his research project.[36] He quickly began a detailed general insect survey of *E. regnans*, *E. obliqua*, *E. delegatensis* and *E. globulus* plantations at different altitudes between sea level and 600m as well as *E. delegatensis* natural regeneration at Surrey Hills. The aim of these surveys was to determine the abundance and distribution of insects injurious to young eucalypts, and their natural predators, parasites and parasitoids, and to evaluate the susceptibility of different eucalypt species and treatments at different altitudes.

Eucalyptus nitens – the out of favour saviour

By 1975 AFH started to seriously face the challenge of how to successfully establish eucalypt plantations in the climatically harsh subalpine country of Surrey Hills with suitable species. Of all the species trialled, only one showed promising results. This was *E. nitens*, introduced from Victoria where it only had a limited distribution. However, it took a lot of convincing and time before it was readily accepted as the preferred species to plant on Surrey Hills.

Interest in *E. nitens* was first recorded in the mid-1960s after Needham had inspected *E. nitens* native forest at Errinundra, Victoria, and was impressed with prospects for growing the species in Tasmania for sawmilling.[37] In 1966 a batch of seed was procured and seedlings were planted at Tewkesbury and at Highclere, some 10 kilometres north of Surrey Hills. The plantings at Highclere turned out poorly, but the Tewkesbury planting was successful without being influential.[38] In January 1974 a series of *E. globulus* and *E. nitens* trials were established at various locations in north-west Tasmania including southern Surrey Hills. None of the trials had much influence on company policy for plantation species as they each had their own site-specific problems (severe frost, woody weeds, atypical soil etc.), despite promising early results from the *E. nitens* plantings. Later that year excess *E. nitens* seedlings from the January plantings were planted in gaps of *E. delegatensis* regeneration and as enrichment plantings at log dumps at the southern end of Surrey Hills. They grew spectacularly, particularly with the shelter of the existing regeneration. Around this time de Boer became familiar with the work on *E. nitens* by Victorian forest researcher Dr Leon Pederick. Pederick made available various seed-lots, representing a faster growing 'juvenile persistent form' for trial plantings.[39] This led to further experimental plantings of *E. nitens* and included a 13 acre (5.2 hectares) trial at two sites of 22 provenances planted in December 1974 and January 1975. De Boer was one of the first employees to recognise the value of *E. nitens* as a viable plantation species for Surrey Hills:

> Experiments with fast growing and frost resistant Eucalypt species on the higher elevations are still in progress. So far only one species E. nitens or shining gum, introduced from Victoria where it only has a limited distribution, has shown promising results.[40]

However the APPM Research Department, headed by Charles Turner, opposed the planting of *E. nitens*, and preferred *E. globulus* as the species of choice. His opinion was mainly influenced by very

good growth rates of *E. globulus* on the coast and its excellent performance in pulping tests.[41] This is despite one of AFH's managers writing, in early 1978, that:

> E. nitens in Walters Road [altitude of 560m] bedazzled all. It appears as though we have found a useful species for altitudes intermediate between E.globulus and E.delegatensis. Major problem is of-course seed supply.[42]

Another problem with *E. nitens* at that time was that it lacked convincing evidence of satisfactory wood quality. In 1980 wood sampling of native forest and plantation *E. nitens* in Victoria was carried out and the results reassured the company that the wood quality made from *E. nitens* was acceptable as a species to supply fibre for the making of fine printing and writing papers.[43]

The planting trial at Walters Road was very significant in the acceptance of *E. nitens.*

Figure 3: 6 year old *E. nitens* at Walters Rd on Surrey Hills. The best seedlot grew 11m mean height in 6 years in a sheltered situation – March 1981. *Photo:* G.H. Dean

E. nitens was free planted in natural gaps – that is, spacing between trees and planting pattern was irregular. Growth results were reported as excellent, showed strong frost resistance and saplings responded dramatically in height and diameter to shelter:

> The early growth rates are thus, not surpisely [sic], unprecedented on Surrey Hills and survival has been excellent.[44]

Despite early plantings of *E. globulus* on Surrey Hills suffering badly from frost, efforts continued to establish it in the Hampshire area, just north of Surrey Hills and now regarded as unsuitable for that species. But success was sporadic at best and management needed to be convinced that only a minor proportion of the land available on Surrey Hills was suitable for *E. globulus*.

Meanwhile de Boer, who had a strong interest in science, encouraged visits from CSIRO scientists who became collaborators on a long series of trials. These regular visits were a source of ideas and

expertise which were critical in the development of plantations and the training of staff. One of the significant benefits of this collaboration was evident in the establishment of provenance trials on Surrey Hills of *E. nitens* and other species including *E. globulus* ssp *globulus* and *E. globulus* ssp *bicostata* with a more rigorous experimental design compared to those used previously and with more seedlots than previous trials. These provenance trials still drew criticism from CSIRO personnel because the number of trees in each plot was considered to be too many whereas the prevailing theory was that statistical efficiency would be a lot higher with only 4-6 tree plots, or even single tree plots. However the original design of 36 trees per plot came from a specific request by AFH management that the plots should be large enough to allow people inspecting these trials to get a general feel for the appearance of the seedlots. This is a case where an additional but smaller demonstration trial would have been useful.[45]

Each trial on Surrey Hills was showing that *E. nitens* grew well and could survive the cold whereas *E. globulus* grew very poorly. Research forester, Geoff Dean[46] recorded the following from one of the trials:

> Eucalyptus nitens has shown some promise as a possible major species for regeneration in this area [Surrey Hills]. The aim of these trials is to test the suitability of E. nitens and to investigate the variability within the species as it would affect choice of seed supply, possible breeding strategies…[47]

In another trial, *E. delegatensis* was planted at southern Surrey Hills and the frost damage was so severe that only a single tree survived – it did not go unnoticed that it happened to be a *E. nitens* seedling which had been included by chance.[48]

Soon after the results from these trials had become clear, Dean took Turner to Walters Road. Evidently he acknowledged the success of *E. nitens* growth by saying "I will never criticise *E. nitens* again.*"*[49]

In time 300m above sea level came to be regarded as a working upper limit for success of *E. globulus* and ended attempts to plant the species above it.[50] As late as May 1979 *E. delegatensis* was the preferred species on sites over 500m altitude,[51] despite the failure of routine plantings and a cultivation trial of that species prior to that date. The reality facing AFH was that *E. nitens* and not *E. globulus* showed an ability to grow in the cold climate and the growth or survival of *E. globulus* at lower and more humid elevations was impeded by *Mycosphaerella* leaf disease. This was the catalyst for the company to make the decision to plant *E. nitens* in preference to *E. globulus* and *E. delegatensis* on Surrey Hills.

The quest for genetic improvement and the leaders in eucalypt plantation silviculture

In 1975 the small eucalypt planting program doubled to 400 hectares per year. This rather small scale reflected concerns at a number of levels. The establishment of the plantations was costly; there were inadequate seedling protection programs to combat insect attacks and mammal browsing; and there was a lack of knowledge on nutritional requirements to ensure successful growth rates. Native forest regeneration of harvested areas was still considered to be unsatisfactory and a decision was needed on whether or not AFH should focus solely on planting trees to ensure a future crop.

Once AFH had confidently selected *E. nitens* as a preferred species[52] for a plantation program on Surrey Hills after many trial plantings, it turned its attention to developing a tree breeding program. The company decided to try and improve wood property traits such as pulp yield and basic density as well as the conventional tree breeding efforts that focused on growth rates. This was unusual at

the time. Although their economic importance was well understood, the former were difficult and expensive traits to measure, requiring specialist laboratory facilities, while growth rates were easily measured in the field. The strong relationship between AFH's foresters and staff at the pulp and paper mill in Burnie overcame the hurdle of including wood property traits in the breeding program but apart from this, the breeding program followed contemporary standards. Quantitative methods were used to analyse collected data and to estimate breeding values for each tree in the breeding program. Tree breeding is a slow process because of long generation times. Therefore it was essential to find ways of efficiently transferring gains resulting from intense selection in the research phase to the operational program. This was done through establishment of seed orchards to produce improved bulk seed for operational planting. The best trees were propagated by grafting so that genetically identical seed orchards could be established at several different localities as an insurance policy to produce sufficient quantity of high quality operational seed. A broader collection of grafted selections were planted out in breeding arboreta where staff, following a planned mating design, could use artificial cross pollination to produce seed for the next generation of breeding trials.

A three hectare *E. nitens* seedling orchard was established in 1981 at northern Surrey Hills. It consisted of 35 families from five provenances. An *E. nitens* progeny trial was also established at West Takone (about 20 kilometres north-west of Surrey Hills) consisting of 49 families from six provenances. All provenances and families in the seed orchard were represented in the trial. In that year the company's nursery at Ridgley raised a total of 797,000 eucalypt seedlings. Three quarters were *E. nitens* and the balance consisted of *E. globulus* and *E. regnans.*[53]

In 1984 various grafting techniques were tried with *E. globulus* and *E. nitens* in an effort to produce clonal stock for seed orchards, the idea being that highly desired genotypes could be replicated many times to improve the overall quality of the seed. Another way to utilise the benefits from tree breeding was thought to be through cloning of desired genotypes for direct operational deployment, where vegetative reproduction, usually by cuttings or tissue culture, can induce uniformity and capture genetic gains from preferred genotypes.[54] If it could be done, cloning held the potential to make very large gains in the operational program relatively quickly. It was successful operationally with tropical eucalypts, but temperate eucalypts were much more difficult, especially *E. nitens*. AFH actively pursued cloning research and developed some 20 hectares of clonal trials in order to develop commercial techniques for clonal forestry.[55] However low rooting success and relatively high propagation costs made operational clones into plantations uncompetitive against open pollinated seed orchard deployment strategies.[56]

Many changes to nursery and plantation silvicultural practices, including fertilisation, weed control and control of insects and other pests, came about from operational staff trialling various techniques and equipment as they sought to optimise productivity and minimise costs. This constant review not only helped to reduce the establishment costs of eucalypt plantations to compare favourably with the establishment costs of natural regeneration, but also provided a strategic focus for the research unit. For example de Boer, who managed the research and operational parts of the business, initiated numerous trials on weed control techniques, focused particularly on dealing with aggressive competitors such as white grass (*Poa labillardierei*) and 'lily grasses' such as *Lomandra longifolia* (Common Sagg or mat-rush) and *Diplarena moraea* (White Flag Iris). He was always trialling different machines, ploughs and techniques such as V-blading and scalping burnt off grasses.[57]

This led to a continual increase in plantation establishment on Surrey Hills from an estate of around 1,800 hectares in 1983 to a total of 22,000 hectares a decade later - the largest single plantation estate in Tasmania at that time.

A change of focus - the beginnings of an industrial-scale plantation estate, improved infrastructure and the advantage of tacit knowledge[58]

By the mid 1980s AFH had established a successful tree breeding program[59] and in 1991 commenced deployment of improved genotypes into plantations. The next step in the value chain was to harness these gains with state-of-the-art facilities and build on their scientific approach to underpin that journey. This was not such a difficult task as APPM was a very progressive company and had a culture of excellence which flowed through to AFH - it was a culture born out of the ideas and entrepreneurship of the early leadership of the Collins House group of companies from which APPM originated. Staff training was supported, and expected, with formal short courses, library facilities and study tours, usually associated with a specific project. Membership of technical associations was strongly encouraged and with this came associations with CSIRO and universities, as well as participation in industry conferences and exposure to visiting experts. APPM was relatively small in size and in order to remain economic and meet prevailing environmental standards, it was therefore obliged to develop a strong record of innovation in research and was well-known internationally within the industry.[60] Many nursery practices, first and second rotation site preparation techniques, fertilising, and pest management techniques came about from ideas and prior experience from a series of plantation managers, other operational staff and researchers. There was an unbroken line of succession from de Boer to the present time where the outgoing plantation manager was replaced by their deputy. This led to the retention of a remarkable amount of tacit knowledge in the organisation which was handed from one manager and staff member to the next.

In 1983 mining giant North Broken Hill Limited[61] bought out its other partners in APPM and established its own subsidiary forestry company called North Forest Products (NFP). NFP immediately undertook a major review of the entire business in Tasmania and reassessed the company's plans for its pulp and paper milling sector, land base available to them and their operational and research results to that time. As a result the company decided to:

- Adopt as a goal the development of a substantial eucalypt tree farming resource in northern Tasmania.
- Substantially increase its annual planting rate.
- Transfer focus from pine to eucalypt.
- Within the eucalypts, concentrate on *E. nitens* and *E. globulus*.[62]

As part of focussing on eucalypt plantings, NFP set a challenge for the research branch to not only grow a species that could survive the cold and grow quickly, but could produce high yielding fibre. With the selection of *E. nitens* the first two objectives were met, but only rudimentary information was available for its wood properties. Consequently NFP undertook a major expansion of its eucalypt research capability that eventually became the largest such research undertaking in Australia's private forestry sector. This created confidence to fully invest in eucalypt plantations to replace reliance on native forest regeneration.

In particular, the company sought to further improve the genetic quality of their plantings by advancing existing breeding and cloning research and began an in-house tree improvement program. This was unique in Australian forestry at that time for *E. nitens* [63] and *E. globulus* and NFP became leaders in genetically improved seed and clonal propagation of both species.[64]

Confidence in the *E. nitens* planting program had been dented in 1982 when a freeze event on Surrey Hills killed large areas of plantings. A forester employed by NFP was encouraged to carry out a study into the frost resistance of *E. nitens*.[65] His work led to a more thorough collection of single-tree seedlots from *E. nitens* trees in mainland natural forests and the commencement of significant base population breeding trials.

Also in 1983 the close working collaboration between the company and CSIRO brought to the attention of NFP staff, a clonal eucalypt program in Brazil. This initiated a fifteen year program to investigate the opportunities for clonal propagation by both cuttings and tissue culture of *E. nitens, E. globulus* and some associated hybrids with a view to operational clonal deployment.[66]

In September 1993 North Broken Hill Peko Limited[67] sold their pulp and paper business, including the Tasmanian pulp and paper mills, to Amcor. They retained the Tasmanian forestry business including the freehold land, the plantation program and the eucalypt research centre that had been established in 1985. Up until then all measurement of wood properties had been carried out in APPM's laboratory in Burnie but with the separation of the forestry business, a new wood fibre laboratory was needed and was opened in Ridgley in 1995. NFP then had aims to be a globally significant supplier of wood fibre suitable for graphic paper production. To underpin this, the plantation program across all of its freehold land in the north-west of Tasmania was increased to around 3,000 hectares per year.

The new fibre technology laboratory, built at a then cost of $2 million, had five main working areas: wood preparation; wood testing; wet lab - pulping and pulp evaluation; paper testing; and chemical laboratory and microscopy.[68] This laboratory was one of only two such laboratories in Australia and was the only one to be fully accredited by the National Association of Testing Authorities. Through its kraft pulp yield evaluation capability, NFP was able to differentiate its pulpwood resource on pulp yield and sell export woodchip shipments based on a guaranteed pulp yield.[69]

APPM originally established nurseries to raise bare-root seedlings for the *P. radiata* plantation program to supply seedlings from 1953 onward.[70] Attempts were subsequently made to grow bare-rooted eucalypt stock but the very fine seed of *E. nitens* made the results extremely variable. *E. globulus* was somewhat more successful, probably due to its much larger seed mass.[71] So, unlike *P. radiata,* growing eucalypt planting stock in a container nursery proved to be a much more reliable production system.

Back in 1973 about 325,000 eucalypt seedlings had been grown in veneer and paper tubes.[72] Unique nursery techniques were developed over the next 25 years to produce a range of seedling types ideally suited to planting on a variety of sites under different climatic conditions, particularly the harsher and colder sites on Surrey Hills. By the 1980s there were two cycles of container grown eucalypt seedlings produced at the company's Ridgley nursery each year. The first crop was established in paper pots in late spring to early summer and, once large enough to handle the shock, transplanted into a field nursery where it was progressively root pruned, undercut and wrenched[73] to produce a very hardy lignified seedling ('½:½' stock)[74] suitable for autumn and winter planting on Surrey Hills and other sites.[75] When these seedlings left the container nursery for the field nursery,[76] the space was then refilled with a new crop of paper-potted container seedlings. These spent the rest of summer and winter in the container nursery and were dispatched in spring directly to plantation coupes suitable for these less robust seedlings. That freed up the nursery for the cycle to start again.

By the mid-1980s the Ridgley nurseries were producing four million seedlings per year, just meeting the company's demand for seedlings. However as the annual plantation program continued to increase it became necessary to get some seedlings grown under contract at external nurseries. These seedlings were considerably more expensive. This, combined with the availability of modern container nursery technology, led to a decision to build a new container nursery with an annual production of around seven million seedlings. A greenfield coastal site was purchased at Somerset near Burnie and construction commenced in 1996 and the first seedlings were dispatched in 1997. By the late 2000s its capacity had been progressively increased through four consecutive expansion projects and it produced around 20 million seedlings in its busiest year. [77] With the shift of nursery

production to Somerset the container nursery at Ridgley and the field nursery at East Ridgley were closed. The technology used at Somerset (fertigation[78] and cell sizes), enabled the production of container seedlings equal to the old '½:½' type.

Postscript – the MIS era and beyond towards a new era

In August 2000 North Limited[79] was taken over by a much larger mining company, Rio Tinto Limited. They immediately announced, after a review of North's assets, that the forestry business would not be retained and in May 2001 the listed Tasmanian company Gunns Limited took ownership. NFP was renamed Gunns Forest Products and the next decade saw a massive increase in the land base and plantation establishment program. Up until that change of ownership all regeneration and then plantation development had been funded entirely by the company. In fact, one of the benefits of North Limited being primarily a miner was the access to free cash flow from mining activities to fund the plantation development program. The expansion in the Gunns era, however, was fuelled by investment money that poured into a company-run MIS. Gunns was a late starter in MIS, which began in the 1990s, offering their first project in 2000. In 2001 their estate was insignificant, but ownership of NFP changed that in an instant. It also added enormously to the credibility of their offering and woodlot sales accelerated. It could be reasonably argued that they survived long enough to see the collapse of all their main national MIS competitors (e.g. Timbercorp, Great Southern, Forest Enterprises Australia, and Willmott) before they too called in the administrators in September 2012. This was mainly because the freehold wood that came from the NFP acquisition just over a decade earlier had initially protected them against the impacts of the global financial crisis of 2008.

In 2014 a company called New Forests, the Australian domiciled Timber Investment Management Organisation (TIMO), purchased, on behalf of an investment fund they manage, around 175,000 hectares of Gunns' land, including approximately 100,000 hectares of plantation. It was mostly made up of the old freehold ex-NFP estate, including Surrey Hills. TIMOs have until recently typically contracted a third party forest manager to operate their estates but in this instance New Forests created a new entity, Forico Pty Limited (Forico), to manage the newly acquired estate. Most of the remaining Gunns' staff, many of whom had been there when it was owned by NFP, were retained. As a contemporary forest manager, Forico is a plantation only business, and manages the non-plantation elements of Surrey Hills for their environmental values. In addition, despite being only 18 months in office, Forico is showing significant reinvestment in the estate with a recommission of the Surrey Hills Mill, replanting of fallow plantation land, environmental works including ecological burning and weed management, and strong plans for a rebirth of the research and development investment.

Conclusion

Whilst in the early days the apparent inexhaustibility of the natural resource impeded large-scale development of eucalypt plantations in Australia, attention to innovation and targeted research, together with rapidly changing environmental and social values, has shown what can be achieved. The cumulative result of extensive trials and observations that started in the 1950s, cutting edge research, a major tree breeding program and investment in state-of-the-art facilities, enabled a relatively small company in north-western Tasmania to convert a large parcel of land, almost worthless in productive terms once the original forest was harvested, into a world class source of papermaking fibre. Without the research, the future forest would have yielded only about 2-3 cubic metres per hectare per year instead of at least five times that amount, with the added benefit of higher quality wood fibre.

AFH's eucalypt plantation program was unique in Australia. What set it apart from other major projects was that it had a much harder task to be successful – it had a legacy parcel of land covered in native forest, woodlands and grasslands with good soils and rainfall but an otherwise hostile climate. They had to find the right species to grow successfully and develop the appropriate silviculture techniques to make it work. Extensive eucalypt species trials were planted to determine which species was best suited to not only cope with the extreme climate at Surrey Hills, but could also provide high quality wood fibre to its international market. Once *E. nitens* had proved capable of withstanding most of the frosts and grow under a constant cold and wet climate, a regular plantation establishment program had begun at around 400 hectares per year and by 1981 over 1,000 hectares had been established specifically on Surrey Hills. The other programs elsewhere in Australia had a relatively clean slate – they chose species already extensively used and proven in plantations around the world and acquired favourable land for growing trees rapidly, typically already cleared and pastured.

Today the Surrey Hills estate has gone from a failed attempt at livestock farming by the Van Diemen's Land Company in the early 1830s to being the largest, and one of the most productive, single eucalypt plantation estates in Australia, supporting nearly 30,000 hectares of plantations. The unique culture of the parent companies, APPM and NFP, also contributed to the success of eucalypt plantation development on Surrey Hills. It is unlikely that it would have happened without it. Around 45 years of corporate encouragement and commitment to excellence all along the value chain, up to the change of ownership in 2001, differentiated this program from the others.

Clearly, by the early 1980s, compared to APPM, APM had established a larger area of eucalypt plantations, spread over two states. On the other hand, APPM kept scaling up their annual eucalypt program as confidence built and impediments were overcome by research and observation, to the point that, by 2011 and under Gunns' ownership, the total Tasmania eucalypt estate had grown to 170,000 hectares.[80] Australia-wide, they then managed an estate of around 288,000 hectares. It all began on Surrey Hills and this surely warrants its recognition as the birthplace of industrial-scale eucalypt plantations in Australia and undoubtedly set the benchmark that other major programs have subsequently followed.

NOTES

[1] Harvesting of native forests had been occurring for over 100 years by the time of WWII, and whilst adequate regeneration had established without much scientific knowledge in the more open forest types, there had always been problems with regeneration in the wet forests. It wasn't until the late 1950s when research findings from studies by Max Gilbert and Murray Cunningham identified the key factors for the successful regeneration of wet eucalypt forests in Tasmania and Victoria that there was a greater level of confidence and success in regeneration techniques adopted by foresters in those forest types. See Gilbert, J. M. (1959) Forest succession in the Florentine Valley, Tasmania. *Papers and Proceedings of the Royal. Society of Tasmania* 93:129-151; Cunningham T. M. (1960) *The natural regeneration of Eucalyptus regnans*, University of Melbourne School of Forestry, Bulletin No 1, Melbourne.

[2] Pandey, D. 1992. *Assessment of Tropical Forest Plantation Resource*. Institutionen för Skogstaxering 1992, Swedish University of Agricultural Sciences. Umea, Sweden;
Ball, J.B. (1995). Development of Eucalyptus Plantations - an Overview. *Proceedings of the Regional Expert Consultation on Eucalyptus,* Bangkok, Thailand 4-8 October 1993. Vol .I. pp.15-27 – via http://www.fao.org/forestry/4603-0c162e555bb41fe8fe9cf076acda4216d.pdf Sourced 1/9/15.

[3] Department of Conservation & Land Management (1995) *Dryandra Woodland Management Plan 1995-2005*. Lands and Forest Commission, Perth, 106 pages.

[4] Mann, M. J. (1990) A.P.M. Forests plantation projects: The first forty years. In J. Dargavel and N. Semple (eds) *Prospects for Australian forest plantations*. Centre for Resource and Environment Studies. ANU, Canberra, pages 157-66.

[5] In this paper it will be referred to as *E. globulus.*

[6] Mann, M. J. (1990) *Op cit.*

[7] David de Little, pers comm. De Little saw first hand these early trial plantings near Denmark W.A. which were not very successful as they had been planted on ex-*E. marginata* (Jarrah) sites instead of ex-*E. diversicolor* (Karri).

[8] Anderson, C. (1995) Bunnings Treefarms – Eucalypt Plantation Managers. IFA Newsletter 36(2):25-7.

[9] See http://www.agriculture.gov.au/Style Library/Images/DAFF/__data/assets/pdffile/0009/2398185/plantations-australia-2020-vision.pdf

[10] National Forest Inventory (2000) National Inventory Tabular Report – March 2000. Bureau of Rural Sciences, Canberra via http://data.daff.gov.au/data/warehouse/brsShop/data/12941_npi4.pdf. Accessed 1 September 2015.

[11] Gavran, M. (2012), *Australian plantation statistics 2012 update*, ABARES technical report, Canberra, June via http://data.daff.gov.au/data/warehouse/aplnsd9ablf002/aplnsd9ablf0022012/AustPlantationStats_2012_v.1.0.0.pdf. Accessed 1 September 2015.

[12] A more detailed description of Surrey Hills and its environmental history is found in Onfray, R. (2012) Cultural artefacts or 'neglected old parks': the colonisation of rainforests in north-western Tasmania. In Stubbs, B.; Lennon, J.; Specht, A. and Taylor, J. (eds) *Australia's Ever-changing forests VI. Proceedings of the Eighth National Conference on Australian Forest History*. Australian Forest History Society Inc, Canberra, pp 125-48.

[13] *E. globulus* has a natural distribution which includes southern Victoria, particularly the Otway Ranges and southern Gippsland. There are also isolated occurrences on King Island and Flinders Island in Bass Strait and on the summit of the You Yangs range near Geelong.

[14] The '1926 Concession' was part of a pulpwood concession system initiated in Tasmania for a specific purpose – that of encouraging the establishment of the pulp and paper industry to use the forest resources of the State. Successive Acts of Parliament which established concessions between 1926 and 1968, varied considerably, most significantly in terms of method and in the allocation of rights and obligations.

[15] Reg Needham was born in Tasmania in 1913 and moved with his family to Victoria in 1925. In 1930 he topped the examination for entry to the Victorian School of Forestry at Creswick at the end of 1932.

[16] Needham recalled his experiences working in Victoria in an unfinished and unpublished memoir titled "A Forester Remembers", written just prior to his death in July 1991.

[17] Needham, R. H. (1946) Wood Supply - Surrey Hills. Unpublished internal memo dated 15 January 1946. Needham was accompanied by Luke Etchell, who was his guide for the inspection. Etchell was a stockman on Surrey Hills and worked as an overseer for some of the larger grazing leases for over 50 years. He was well known in western Tasmania and regarded as one of the best bushmen and wallaby snarers at the time. He died in 1948 aged 80.

[18] Needham, R. H. (1946) *Ibid*. This detailed report summarises Needham's first inspection of Surrey Hills on horseback over three days and provides a valuable insight into the state of Surrey Hills at that time.

[19] Needham, R. H. (1951) Unpublished internal document dated 15 February 1951.

[20] Needham, R. H. (1960) Problems associated with regeneration of *Eucalyptus gigantea* in the Surrey Hills area. *Appita* 13(4): 136-40

[21] The Land Klearing Blade was the first adjustable tooth blade used around the world for land clearing, heaping of debris and rock removal. American logger Ted Flynn designed it in 1949. He also designed and built other bulldozer inventions, most notably a bulldozer for the US Forest Service in 1939 that "proved to be a machine of vital importance during WWII. Small enough to be carried by planes it was leap- frogged over the Japanese lines in the South Pacific and air-dropped to clear landing strips in the jungle in the enemy's rear" – See J. A. Miller (ed) (1963) From bulls to bulldozers: a memoir on the development of machines in the western woods from letters of Ted P. Flynn. Forest History (Fall edition):14-17 accessed from http://www.foresthistory.org/publications/joffh/bulldozers.pdf. Accessed on 28 August 2015.

[22] Needham, R. H. (1960) *Op cit*

[23] de Boer, D. (1973) Eucalyptus growth and establishment. Unpublished AFH internal report.

[24] Dean, G. H. (2010) Early eucalypt plantations in Ringwood/Surrey Hills. Unpublished report.

[25] The Tasmanian Forestry Commission possessed a strong burning culture within its cadre of professional foresters. Gilbert's work in the Florentine Valley advocated the importance of fire to ensure successful eucalypt regeneration and this was applied religiously as part of their silvicultural works. They found it hard to believe that AFH would not use fire at Surrey Hills to help promote regeneration. In fact co-author David de Little recalls a story when the Forestry Commission had missed out on employing him in 1975 where they said "so you're going to work for that funny company in Burnie" implying that not adopting the accepted method of regenerating eucalypts using fire as well as experimenting with plantations was 'lunacy' – David de Little, *pers comm*.

[26] AFH (1972) Review of Company Operations. Unpublished internal document

[27] AFH had also planted pines (principally *Pinus radiata*) as another approach to the regeneration problem and this was more successful. Pine plantations expanded to about 12,000 hectares, mostly outside of Surrey Hills and thus didn't directly assist with the regeneration problems on Surrey Hills itself. But pine could be grown anywhere in the world and there were never any certain commercial advantages in planting and using pine. Technology and economics in fine papermaking had shifted away from softwood towards the exclusive use of hardwoods, such as eucalypt fibre.

[28] Dirk 'Dick' de Boer (his name in Dutch was Ing. D. de Boer to recognise his profession as Engineer) was initially posted at Guildford to promote the establishment of pine plantations. When he started there were two experimental plantations totalling less than 25 hectares. By the time he retired in 1983 AFH had about 11,000 ha of pine plantations and 3,300 ha of eucalypts. The development work initiated and supervised by de Boer formed the basis for the rapid expansion of the eucalypt plantation program. This included nursery design and techniques, tree breeding and seed production, plantation establishment and maintenance and insect and game protection.

[29] Orme, R. K. (1971) The regeneration of commercial eucalypt forests on Surrey Hills, NW Tasmania. Unpublished Master of Science thesis, University of Tasmania, Hobart. Orme was a key figure in the early development of *E. globulus* and *E. nitens* plantations in Tasmania and in the early 1970s was a visionary on how the next generation of wood could be supplied from plantations. He collected seed for the *E. globulus* provenance trials and promoted the idea worldwide of co-operative trials of *E. globulus.* He promoted eucalypt plantations to sceptical audiences around Tasmania, demonstrating the success of plantings in Spain, Portugal and France.

[30] Frosts or freeze events were a major management consideration. It was not uncommon for Surrey Hills to experience major 'freezes' where the surface soil froze and temperatures remained below zero for 2-3 days. Computerised automatic weather stations were installed at two sites on Surrey Hills in 1995 and measured frosts. Data from these stations were analysed over a twelve year period and frost events were recorded at an average of 120 days per annum (one frost every 3 days on average).

[31] Dean, G. H. (1998) Internal document on eucalypt tree farm policy background for CEO talk, North Forest Products, 15 April 1998.

[32] Species trialled included *E. delegatensis, E. regnans, E. fastigata, E. globulus, E. nitens, E. dalrympleana, E. cypellocarpa, E. bicostata, E. maidenii, E. subcrenulata, E. johnstonii, E. gunnii, E. urnigera, E. perriniana,* and *E. viminalis* – Ian Ravenwood *pers comm.*

[33] R.H. Needham (1972). AFH letter to Dr Truda Howard, 22 May, 1972.

[34] de Boer, D. (1975) Re-afforestation of eucalypts in Tasmania. Presentation to Appita Burnie local branch, unpublished internal document**.**

[35] Greaves, R. (1966) Insect defoliation of eucalypt regrowth in the Florentine Valley, Tasmania. Appita 19:119-26

[36] Crisp, E.V (1975) Internal memo to RH Needham dated 3 July 1975. After commencing employment, de Little continued part time with his PhD studies. De Little went on to become the first member of the forestry research group when it was officially formed in July 1985 and separated from AFH. He was the inaugural Research Manager and reported directly to the Executive Forester for APPM, based in Launceston. After the sale of the pulp and paper mills to Amcor in 1993 and the introduction of a new wood fibre laboratory at Ridgley, de Little became part of a new research management group called North Eucalypt Technologies

[37] In 1954 Burnie Board and Timber, another subsidiary of APPM, opened an integrated sawmill adjoining its pulp and paper mill at Burnie to produce billets, woodchips and prime sawn boards. The Company believed that better quality logs from its freehold and Concession forests should be utilised to produce sawn timber. The sawmill also gave far better utilisation of unsplittable pulpwood in head logs. This mill is a great example of APPM/AFH innovation that was ahead of its time in terms of a company running a sawmill integrated with a pulp mill.

[38] It was believed that this initial batch of seeds from the Errinundra population was representative of the slow growing 'early adult form' of the species (see Tibbits (1986a) Eucalypt plantations in Tasmania. Australian Forestry 49(4):219-25). Much later in 1991, it was found to be sufficiently taxonomically different to be ascribed specific status and renamed *E. denticulata*. See Cook, I.O. & Ladiges, P.Y. (1991) Morphological variation within *Eucalyptus nitens* s. lat. and recognition of a new species, *E. denticulata*. Australian Systematic Botany 4:375-90.

[39] Tibbits, W. N. (1986a). The reason for highlighting this point is to contrast with the early failure of 1966 batch of seeds thought to be *E. nitens* – see endnote 38 above.

[40] de Boer, D. (1975) *Op cit*

[41] Dean, G. H. (2010) *Op cit*. *E. nitens* also didn't look like a commercial species in its first year. When Forest Superintendent Ted Crisp was shown the first large-scale planting of *E. nitens*, at 1 year old, he said "well you can forget about nitens because it looks more like blackberries." He was referring to the fact that after one year they look more like shrubs with little indication of apical dominance. However it was the second year that made all the difference – David de Little, *pers comm*.

[42] Hills, R. (1978) Notes on Field Trip to Surrey Hills 29 March, 1978. Unpublished internal document.

[43] Dean, G. H. (2010) *Op cit*. The investigation and report was carried out and reported in the APPM Research Unit by Charles Turner and staff.

[44] Dean, G. H. (1978) Walters Road – E. nitens planting. Unpublished internal document, August 1978.

[45] Geoff Dean, *pers comm.*

[46] Geoff Dean started at AFH as a forester in 1972 and worked under de Boer. He was a key researcher in the quest to achieve higher yields of pulp from the trees through AFH's tree breeding program.

[47] Dean, G. H. (1978) Dudfields Road provenance and species trials. Internal memo dated August, 1978

[48] Geoff Dean, *pers comm.*

[49] Geoff Dean, *pers comm*.

[50] Dean, G. H. (2010) *Op cit*

[51] Dean, G. H (1979) *Op cit*

[52] When AFH finally got approval to purchase a kilogram of *E. nitens* seed, Geoff Dean worked out it was more expensive than gold on a weight for weight basis – David de Little, *pers comm*.

[53] AFH 1981-82 Annual Report. Unpublished internal document

[54] Dean, G. H. *et al* (1990) *Breeding eucalypts for manufacture of pulp and paper.* Proceedings of 23rd Forest Products Conference, CSIRO, Clayton 19-22 November, 1990. Volume II

[55] Tibbits, W. N. e*t al* (1989) Improving short rotation, fast growing, cool temperate eucalypts through controlled pollination, hybridization and vegetative propagation. *Commonwealth Forestry Conference Session 6 – Temperate plantation management,* September 1989, 17 pages.

[56] Hamilton, M. et al (2008) Achievements in forest tree improvement in Australia and New Zealand: Genetic improvement of *Eucalyptus nitens* in Australia. *Australian Forestry* 71(2):82-93.

[57] Many years later subsequent plantation managers carried on this tradition. Second and third rotation site preparation and cultivation techniques, such as complete de-stumping, mound ploughing using skidders and spot cultivating with 22 tonne excavators with Wilco and Bandicoot attachments, were refined by the company when most MIS companies were planting their first rotation.

[58] Tacit knowledge, as opposed to formal, codified or explicit knowledge, is the kind of knowledge that is difficult to transfer to another person by means of writing it down or verbalising it.

[59] 88 tree breeding trials containing well over 100,000 trees had been planted – Tibbits (1986a)

[60] A lot was learnt from these experiences and for example when the new nursery was built in the mid 1990s the project manager described the process used as 'stealing ideas shamelessly'.

[61] The company changed its name to North Broken Hill Peko Ltd in December 1988 after it merged with Peko-Wallsend. In November 1994 the company changed its name again, to North Ltd.

[62] Whyte, I. N. (1990) APPM's Tree-farming program: past, present and future. In J. Dargavel and Semple, N.(eds) *Prospects for Australian Forest Plantations.* Centre for Resource and Environmental Studies. ANU, Canberra, pp. 167-181.

[63] The company's tree breeding program for *E. nitens* is today the longest running tree breeding program in Australia. Between 1975 and 1986 twelve first-generation progeny trials were established - see Hamilton, M. et al (2008) *Op Cit* for a summary of Gunns breeding program.

[64] Whyte, I. N. (1990) *Op cit.*

[65] Wayne Tibbits was employed as an operational forester in North-east Tasmania and after completing his post doctoral study in 1986, was transferred to the research centre at Ridgley – see Tibbits, W. N. (1986b) Frost resistance in *Eucalyptus nitens* (Deane & Maiden). PhD Thesis, University of Tasmania.

[66] De Little, D. W. (2004) Historical review of cloning R&D for temperate commercial eucalypts in Australia. Paper presented at Clonal Workshop, CRC for Sustainable Production Forestry, Lismore and Mt Gambier.

[67] North Broken Hill Limited became North Broken Hill Peko Limited in December 1988 following the takeover of Peko-Wallsend Ltd in August 1988.

[68] French, J. and Dean, G. (1997) Design of a laboratory for pulp fibre assessment. *Appita* 50(2):98-102.

[69] Ravenwood, I. C. (2010) The integration of fibre technology, tree breeding and the Somerset nursery – an overview. Unpublished internal report. May 2010. 9 pages.

[70] In 1950 APPM decided to embark on a small pine plantation scheme at Surrey Hills after establishing trial plots in 1948 elsewhere – see Needham (1990) The Origins and History of Associated Forest Holdings: to 1975. Unpublished document, August 1990.

[71] There are approximately 1 to 2 million seeds per kilogram of cleaned *E. nitens* seed, depending on the seed size. A kilogram of cleaned *E. globulus* will have around 300,000 seeds.

[72] AFH 1972-73 Annual Report. Unpublished internal document.

[73] These techniques basically toughen up open rooted seedlings and make them easy to lift, bundle up for transport and plant, increasing survival rates in the field. Root pruning is where a tractor is fitted with blades that run down the rows and cut off long lateral roots. Undercutting involves fitting a blade that runs along under the seedlings about 15cm below the soil and prunes off long vertical roots. Wrenching involves a device that grabs the seedlings and lifts them a bit to loosen the soil around the seedlings.

[74] Pine stock was grown open-rooted in the nursery because it was easier to sow its relatively large seed. Eucalypts had a much smaller seed and were germinated in seedling trays and pricked out into paper pots at the cotyledon stage. Because of the relatively small size of the potted eucalypt seedlings and their softness, the window for planting was limited to late spring and early summer. When pine planting ceased in the mid-1980s and was replaced by a much larger eucalypt planting program, it meant there was a much smaller planting window. 'Half/half' eucalypt stock was developed to extend the eucalypt planting season by transplanting the paper-potted seedlings to an open rooted nursery bed in the ground for further growth and development. This produced larger, tougher stock that could be planted from late autumn right through the winter with the softer, smaller potted stock planted directly into the field from mid-spring. This was crucial for successfully establishing eucalypt plantations on Surrey Hills.

[75] Les Baker joined AFH in 1980 as a plantation forester working directly under de Boer. He became Plantation Superintendent following de Boer's retirement in 1983. He developed the seedling ½:½ system. Les also introduced the container system at the Ridgley nursery and was instrumental in the annual scale-up of the eucalypt plantation establishment program. As Operations Manager Baker managed the construction of the Hampshire Chip mill and the Burnie port export facility which opened in 1995.

[76] In 1985 the field nursery was at West Ridgley but was later re-established at East Ridgley on a much more level block purchased from a local farmer – Ian Ravenwood, *pers comm.*

[77] Ian Ravenwood was employed with AFH at Ridgley in July 1985 primarily to assist with the clonal and tree improvement research program. During this time he coordinated the establishment of main base population trials for *E. nitens* and *E. globulus*, controlled the development of propagation glasshouses and tissue culture laboratories, as well as organising office accommodation for the research group. He was responsible for the building and commissioning of the Somerset nursery before being appointed plantation manager for north-west Tasmania in 1999.

[78] Fertigation is the technique of applying nutrients or fertiliser through an irrigation system. It is used in a potted nursery system where the potting medium is low in nutrients and specific nutrient regimes can be applied through the irrigation system at different times of the year and at different stages in the seedlings' development

[79] North Broken Hill Peko Limited changed its company name to North Limited in November 1994.

[80] Gunns Ltd (2011) Annual Report.