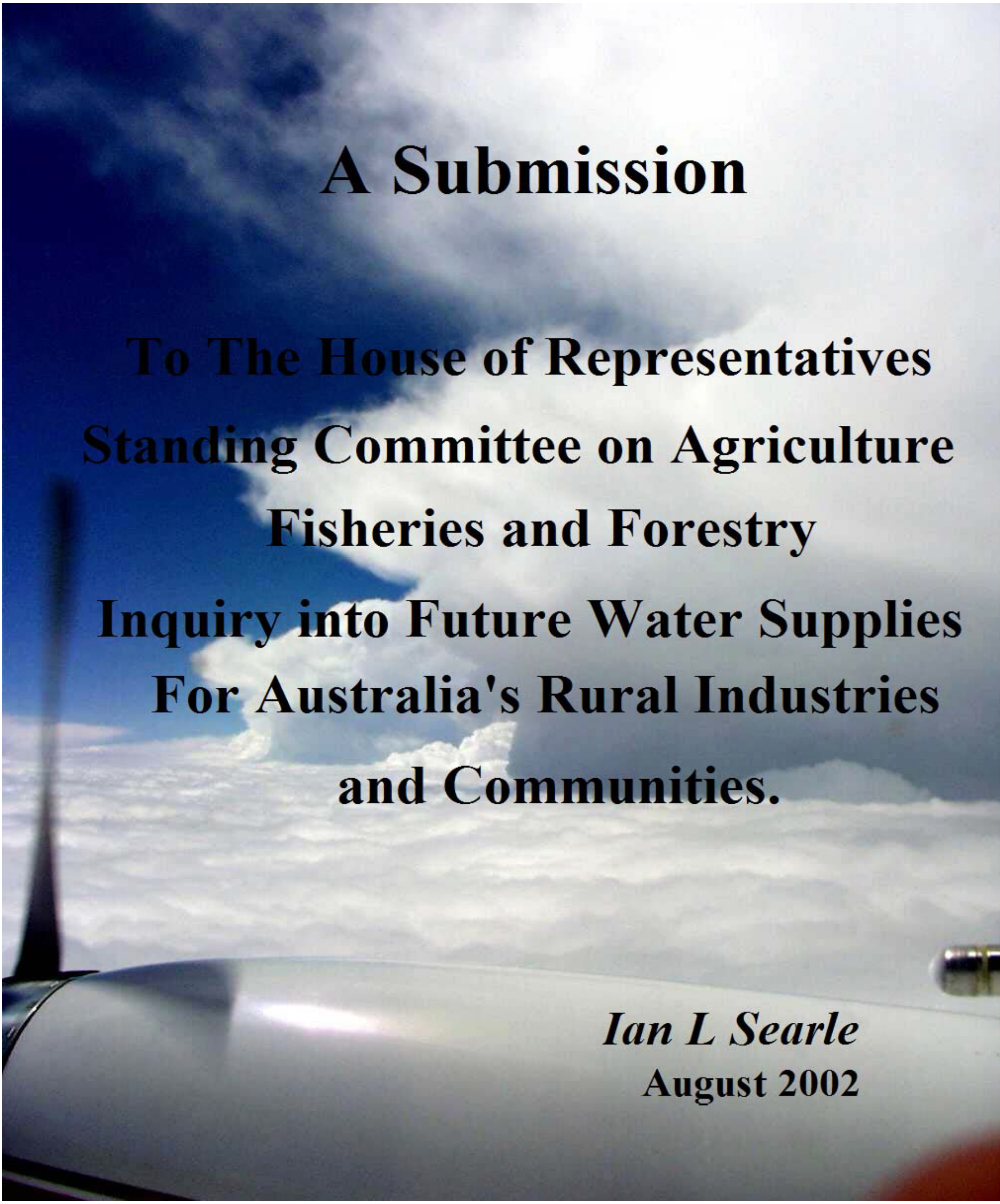

A Submission

To The House of Representatives Standing Committee on Agriculture Fisheries and Forestry Inquiry into Future Water Supplies For Australia's Rural Industries and Communities.

Ian L Searle

August 2002

A Submission to
The House of Representatives Standing Committee on Agriculture, Fisheries and Forestry Inquiry into Future Water Supplies for Australia's Rural Industries and Communities.

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Qualifications and Experience:

Longerenong Diploma of Agriculture (1964)
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27 years of actual cloud seeding experience (production operations, drought relief operations and controlled scientific experiments) in Victoria, Tasmania and New South Wales.
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Surveys of irrigation areas documenting water use and gauging pumping equipment on the Ouse, Shannon and Lake Rivers, for Hydro Tasmania

Main Issues Addressed in this Submission:

The Effect of Climate Change on Water Resources
Future Water Availability
Cloud Seeding – The Tasmanian Experience
Experience and Potential Outside Tasmania
Drought Relief Operations

A Proposal to:

- Enhance rainfall for dry-land agriculture,
- Conserve water in storages for irrigation and community water supply,
- Improve clean and green energy output for Hydro-Electric generators, and
- Increase environmental flows for degraded river systems,

Introduction

Water use in all Australian states is an ever-increasing problem. Most water managers will agree that we can no longer sustain our present rates of water use, nor can water supplies continue to be provided to users at give-away prices.

Increasing demand for fresh water coincides with degraded riverine environments and declining reserves brought about by an apparent change in climate, which has now been impacting on rainfall and streamflow for 27 years. Water use in the future is likely to be rationed and that which is made available will come at a much higher price than in previous times. Increasing amounts of the water once available for irrigation and hydro-electric power supply will be returned to natural water courses for environmental reasons.

We are not left helpless however, as with changes in management practices and the application of tried and proven technological solutions it should be possible to restore at least a significant proportion of that which has been lost. A prime example in Tasmania has been the application of cloud seeding over the last 38 years, as a water management tool to reduce hydrological risk in the operation of the hydro-electric power system. The water turbines driving the electric generators produce nearly all of Tasmania's electricity, and the system has been preserved to a large extent, free of failure to meet demand by enhancing inflows to storages by cloud seeding. Supplementary generation using expensive oil-fired steam turbines has been kept to a minimum and confined largely to the occasional drought years.

The Effect of Climate Change on Water Resources

The very obvious changes in climate in the most recent 27 years are impacting on water authorities across the country, some seriously, (50% reduction in inflows to Perth Water storages as in figure 1.) and others less so (Southern Midlands [Tas.] rainfall, figure 2.).

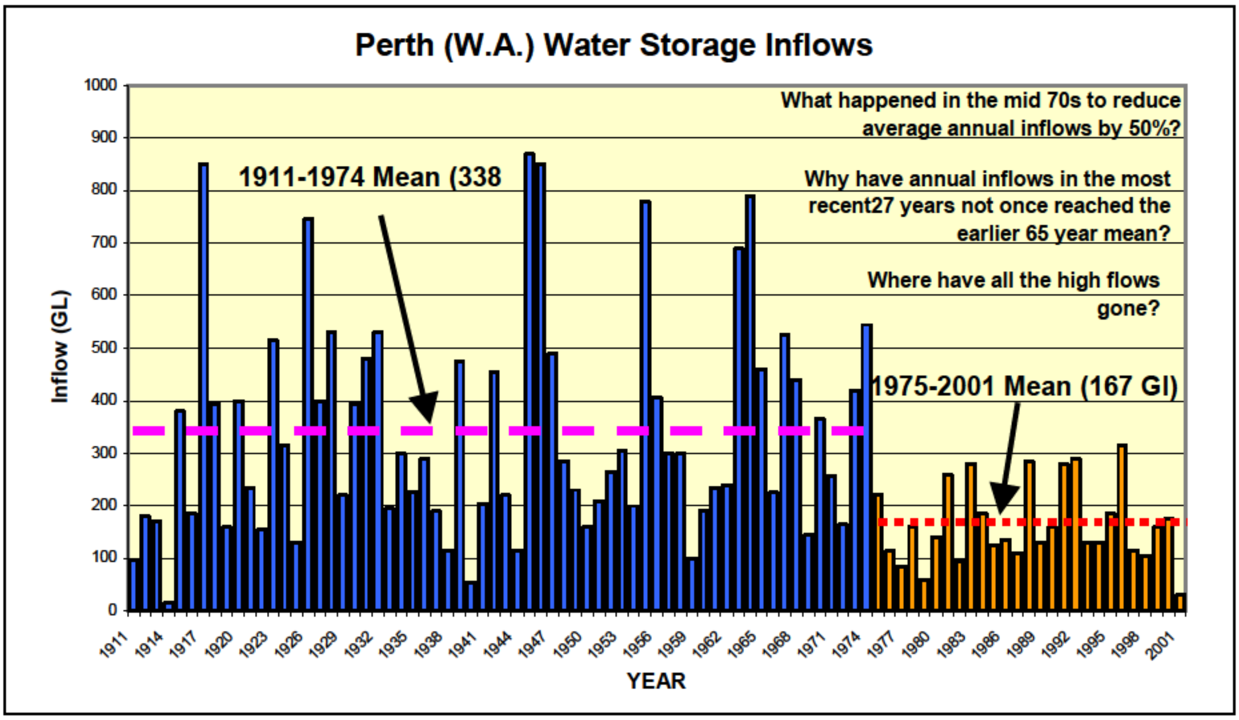


Figure 1. Annual Inflows to Storages - Perth Water Commission

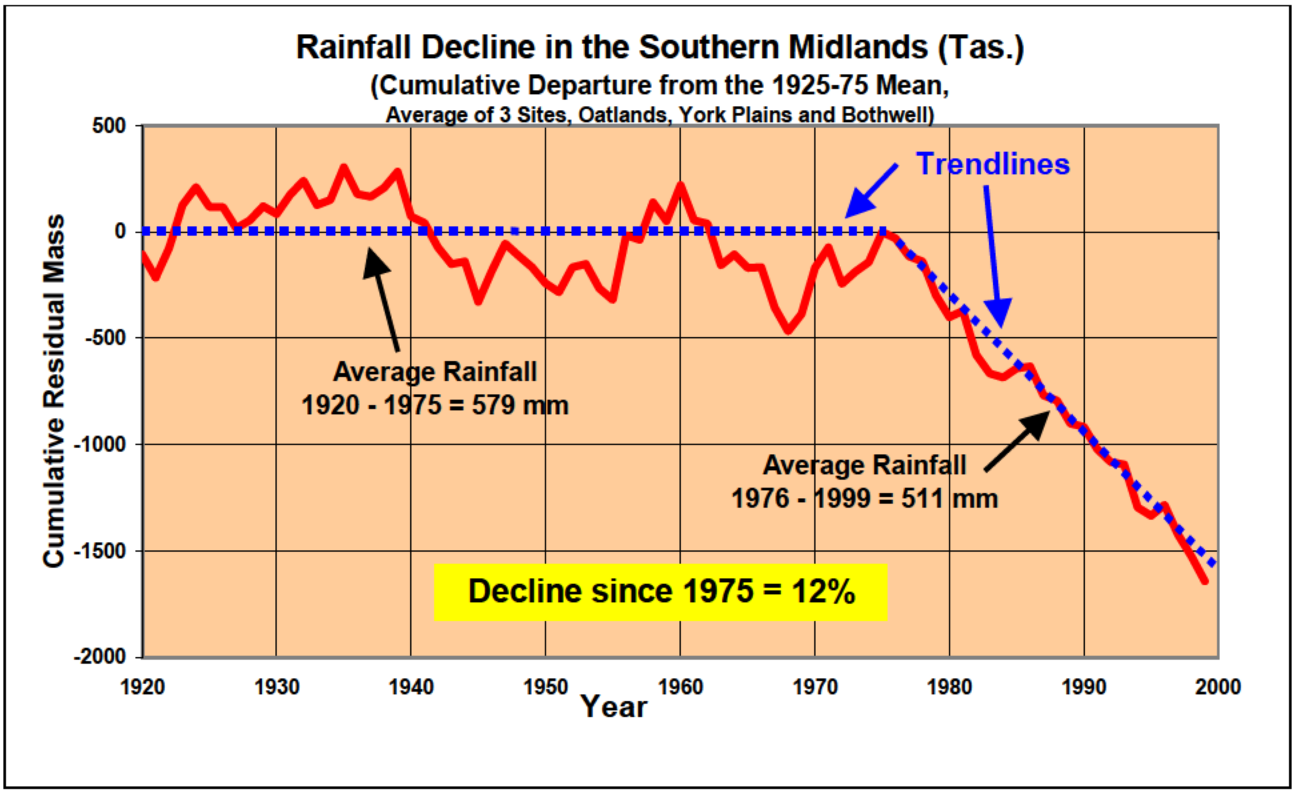


Figure 2. Rainfall Decline in Tasmania

In the opinion of this author, it is no longer tenable to argue that the widespread decline in rainfall, snowfall and streamflow is part of a normal cycle, since it has been going on too long with no sign of an upturn in 27 years. Furthermore, the downtrends coincide with changes in other global (or hemispherical) phenomena such as the Southern Oscillation Index (SOI, figure 3), global land and sea surface temperatures, (figure 4), and many others.

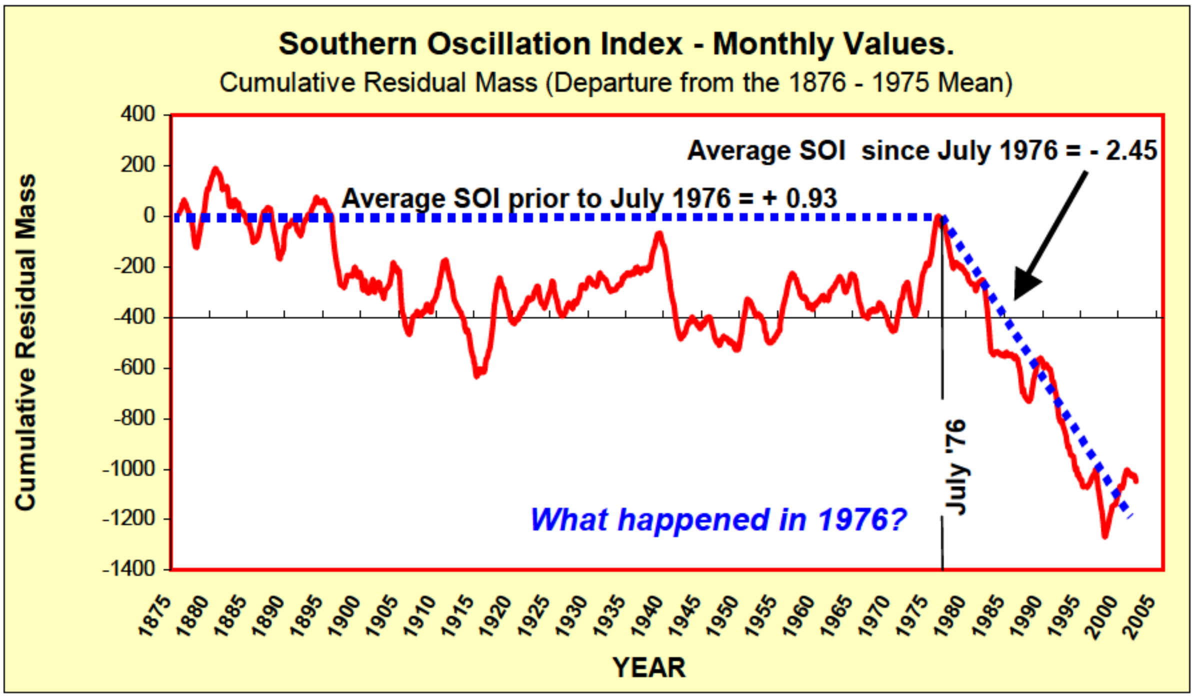


Figure 3. Trends in the Southern Oscillation Index

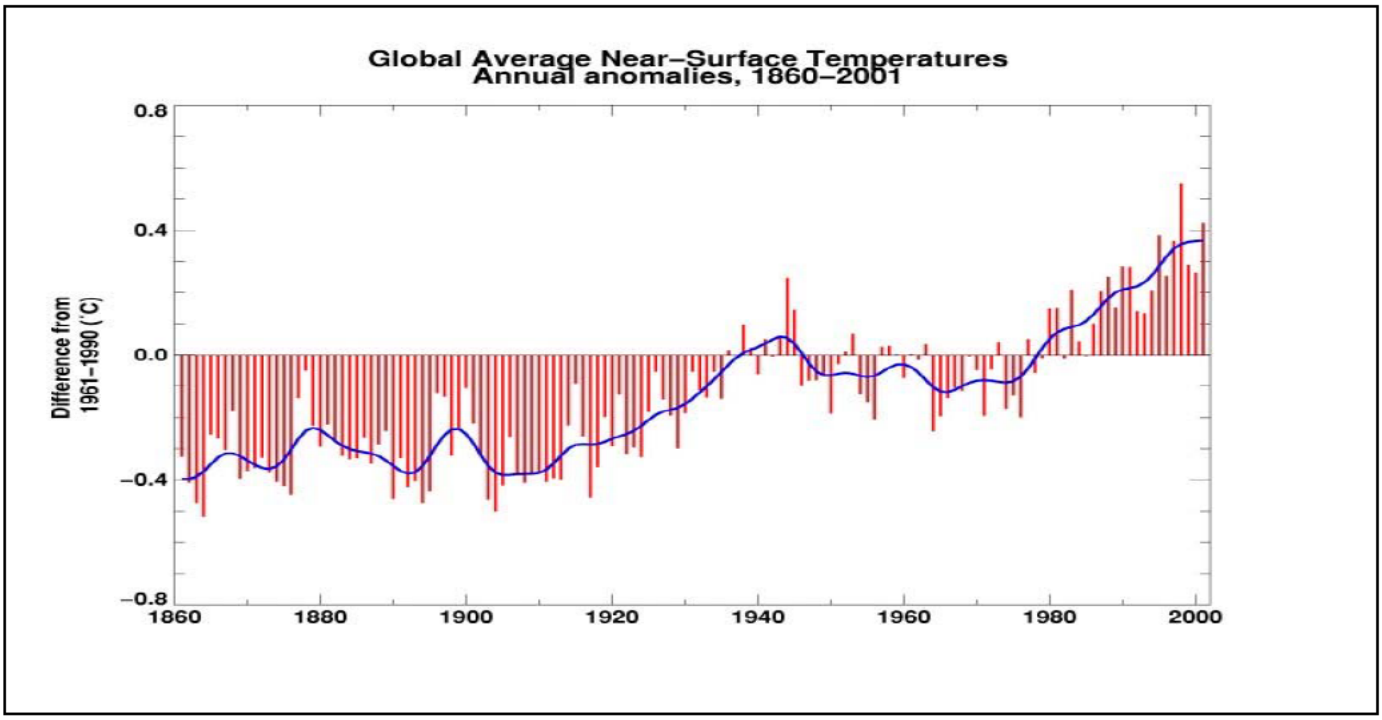


Figure 4. Change in Global Temperatures.

The changing climate in Tasmania is not a simple percentage reduction in rainfall throughout the year. The majority of the effect is in the summer and autumn months peaking in February and March, (figure 5.) where the rainfall loss is in the order of 20% of the 1924-1975 averages. This loss of inflows to hydro storages has a large impact on the storage and power station management strategies, as it extends the summer dry period when draw-down of the larger storages is required to maintain system security.

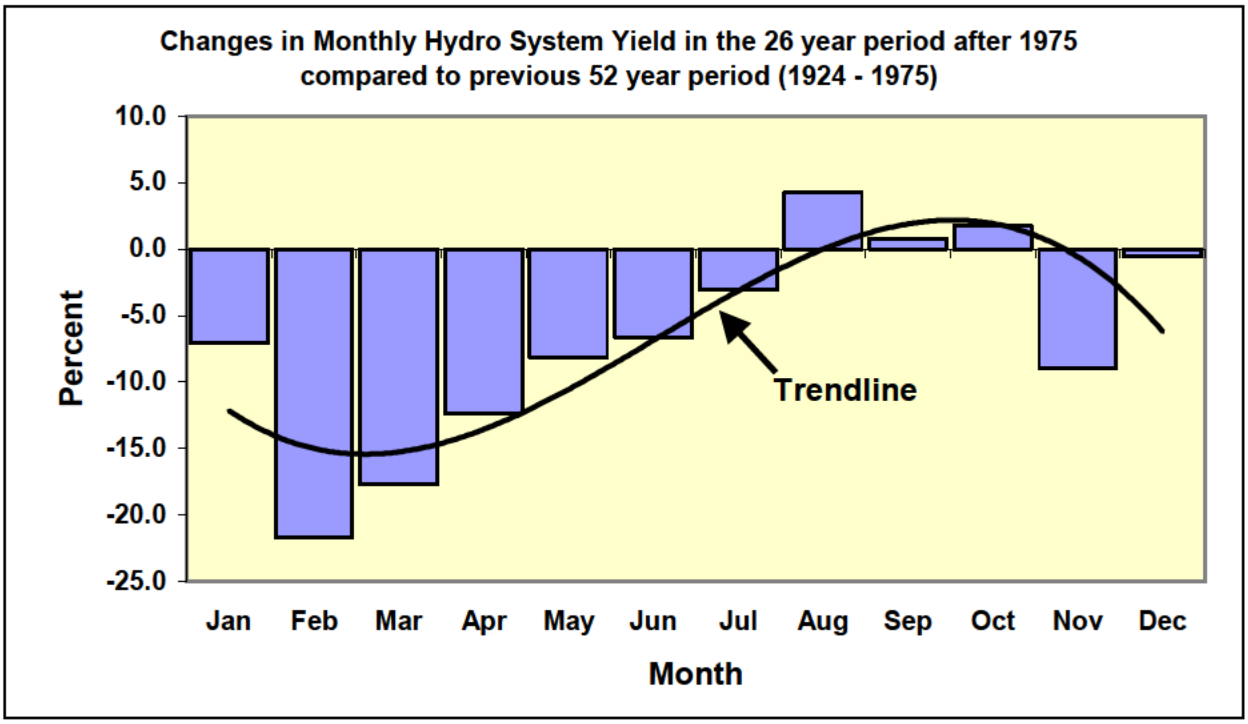


Figure 5. Changing Seasonality of Hydro Tasmania's System Yields.

The reduction of autumn rainfall is also having a serious effect in agricultural areas, particularly on levels of water in farm dams supplying livestock and on the amount of pasture growth before winter (Pook and Budd, 2002).

Future Water Availability

There are few remaining options left to water managers other than to better manage the present resources since most of Australia's river systems south of the tropics are already over-burdened by abstractions of fresh water and by pollution from wastewater and salt.

The last remaining frontier is the vast reserve of atmospheric water available in the clouds. Although a method of harvesting some of this water while it passes over the land was discovered in 1946, far too little effort has been applied in Australia to harvesting and conserving this water for present and future use. Some wonderful work on cloud seeding research was done by the CSIRO Divisions of Radio Physics and Cloud Physics between 1947 and 1970, until CSIRO handed responsibility for operational programs to the state governments.

What happened then was a rush of activity by Departments of Agriculture and Forestry in several states during the widespread drought of the mid sixties, which lapsed as soon as the drought was over. Once the cloud seeding projects were terminated however, it was then difficult to resume seeding operations when the next drought came along, because the specially modified aircraft, with their unique equipment and highly trained crews had been deployed elsewhere.

This haphazard approach to cloud seeding has been the greatest impediment to productive cloud seeding throughout Australia, except in Tasmania, where the Hydro-Electric Commission (now Hydro Tasmania), with an ongoing interest in water harvesting and economic power production, took a long-term view not constrained by political expediency. They were also far more interested in investing resources in an enterprise like cloud seeding, because they were also the primary recipients of the benefits. State departments on the other hand, had a two-fold problem. Funds had to be provided from the budget annually (in competition with numerous other worthy causes), and benefits would not accrue directly to the sponsor, but to the community as a whole, by way of increased productivity and prosperity. Unfortunately, state departments cannot sustain this level of altruism for long.

To make matters worse, the CSIRO Division of Cloud Physics was disbanded in 1983 under acrimonious circumstances, a decision which has proved to be one of the great disasters of Australian science. Had they continued with their research into cloud physics and cloud seeding, they probably would have solved the great mystery that surrounded the many cloud seeding experiments in mainland Australia over the preceding 30 years. The Acting Chief of the Division (Dr E. K. Bigg) had begun to take another look at the statistics and discovered that persistence effects had been occurring in all the experiments (Ecos 1985). He found almost identical effects in South African experiments where silver iodide had been used for many years. Bigg continued to work with Hydro Tasmania's cloud seeders in a private and voluntary capacity where the same effects were also occurring, but not to such a detrimental degree.

Cloud Seeding, The Tasmanian Experience

Hydro Tasmania has been involved with cloud seeding since 1964, when the first Tasmanian experiment began. This experiment was designed and conducted by CSIRO and jointly funded by the two parties. It ran for five years and was a great success, delivering rainfall increases of 23% over 3000 km^2 in the autumn and winter months. The chance of such a result occurring naturally was less than one in a thousand. A second confirmatory experiment was conducted in the years 1979 – 1983, using the same target area. Although there were differences in design, (mainly a reduction of the experimental unit from 2 weeks to one day) the results were similar to those of the first experiment. Rainfall on seeded days was increased by 36%. The chance of such a result occurring naturally was about 150:1

Figure 6 shows the effect of cloud seeding in Tasmania in all the years since cloud seeding began in 1964. The reference period of 30 unseeded years includes the years between projects, and the seeding effect is expressed as a percentage of the 30 year "normal".

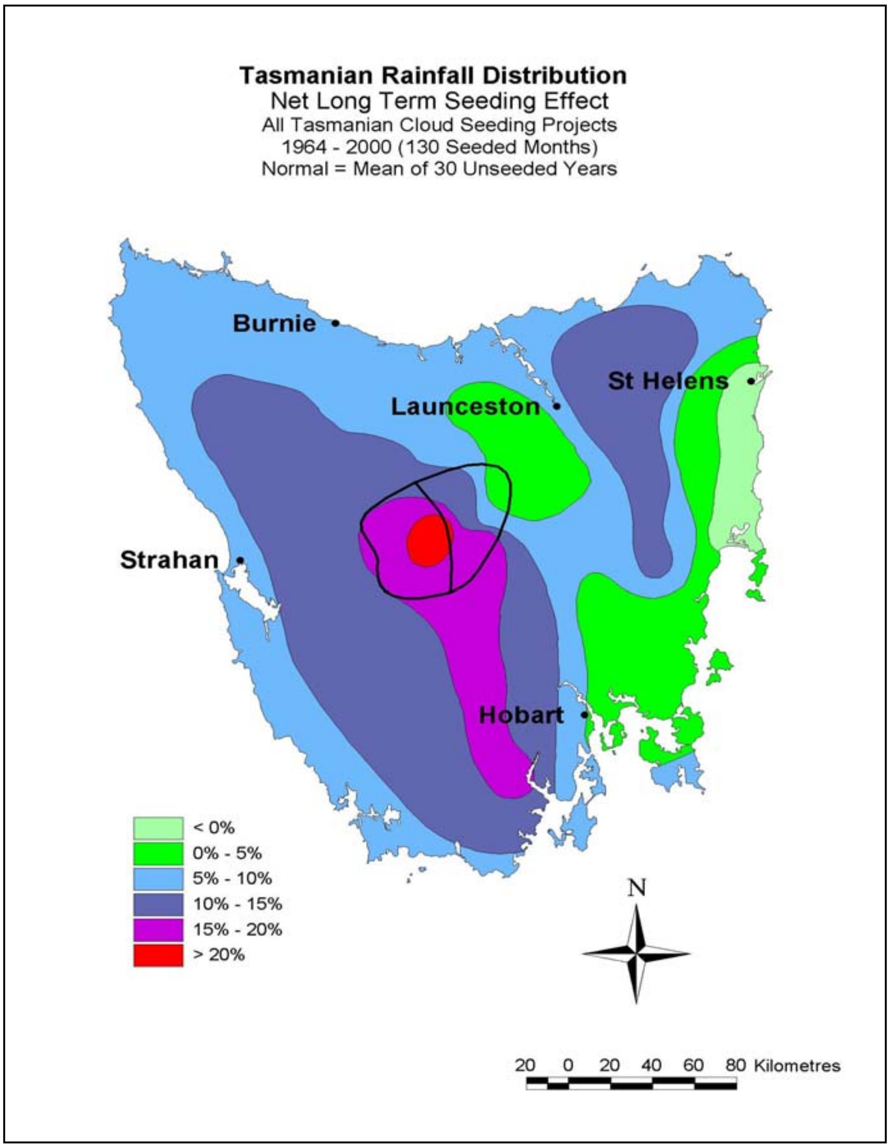


Figure 6. The long term average effect of cloud seeding on rainfall in Tasmania.

Examination of the statistics after 21 years of cloud seeding suggest that Hydro Tasmania has harvested between 75,000 and 750,000 Ml of extra rainwater by cloud seeding each year, (depending on the size of the area seeded and weather conditions each year). About 75% of the rain runs off the catchment into rivers and storages. If valued at $50/Ml, the annual return varies from $2.8 million to $28.0 million, vastly exceeding the cost of production.

Experiences and Potential Outside Tasmania

1. NSW generally

Essential reading relevant to NSW cloud seeding is a document prepared by the Regional Director of Agriculture (Orange) in April 1983. The report is entitled *"A Review of the Potential for Influencing Rainfall in New South Wales by Cloud seeding"* by D. J. McDonald, and is attached as Appendix A. The report is the most comprehensive and perceptive analysis of cloud seeding in NSW and the observations, conclusions and recommendations remain almost entirely valid today.

McDonald comments on a striking increase in rainfall in South Eastern Australia in the years 1946-1974 which coincided exactly with the time and area over which nearly all cloud seeding operations and experiments had been done. Some 6000 hours of actual seeding had taken place with the specific aim of increasing rainfall. Figure 7 shows the rainfall anomaly.

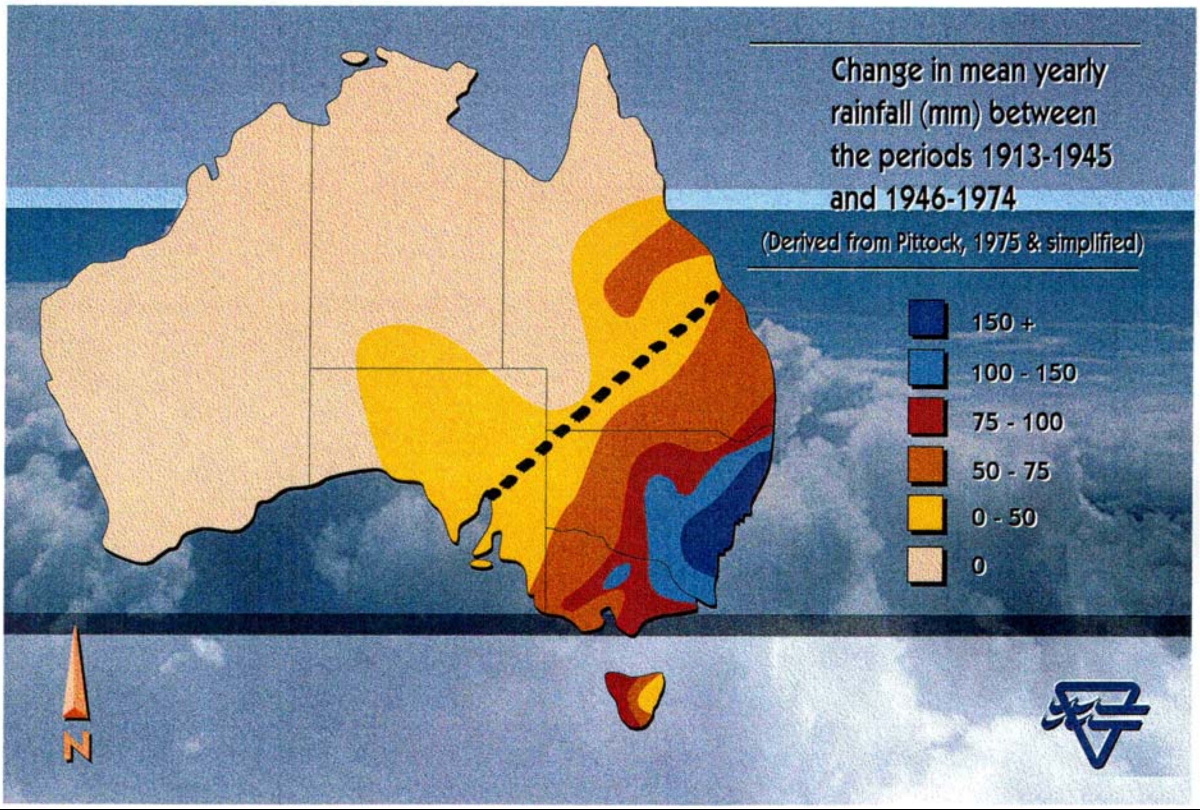


Figure 7. The rainfall anomaly over South Eastern Australia 1947 – 1974. A total of 6000 hours of cloud seeding was conducted east of the dashed line between 1947 & 1974.

The Australian government commissioned a report on the marked rainfall anomaly and this was conducted by the Australian Academy of Science in 1976. It was entitled *"Report of a Committee on Climate Change"* (ACS Report No 21 March 1976). There were 11 council members, 3 other staff, and 48 consultants. The report cites 78 references, lists 336 others but after all this, arrived at the conclusion that despite the evidence of elevated rainfalls in South east Australia, there was no evidence of major climatic change. It is astonishing, that the prolonged and at time intensive effort by cloud seeders in five states to enhance rainfall in South Eastern Australia over the 28 years in question, was dismissed by the committee as irrelevant. The significance of the remarkable coincidence escaped them, or perhaps they were unwilling to admit to the success of cloud seeding on such a scale.

The current generation of scientists have been just as slow to admit to climate change (this time in the negative direction). Only two years ago, this author's enquiries to the Bureau of Meteorology concerning the 25 year downward trend in the Southern Oscillation Index (figure 3.) and rainfalls various places, was met with obfuscation and buck-passing. The last in the buck-passing line suggested that it was a one-in-200-year event and part of the natural cycle.

2. Snowy Hydro

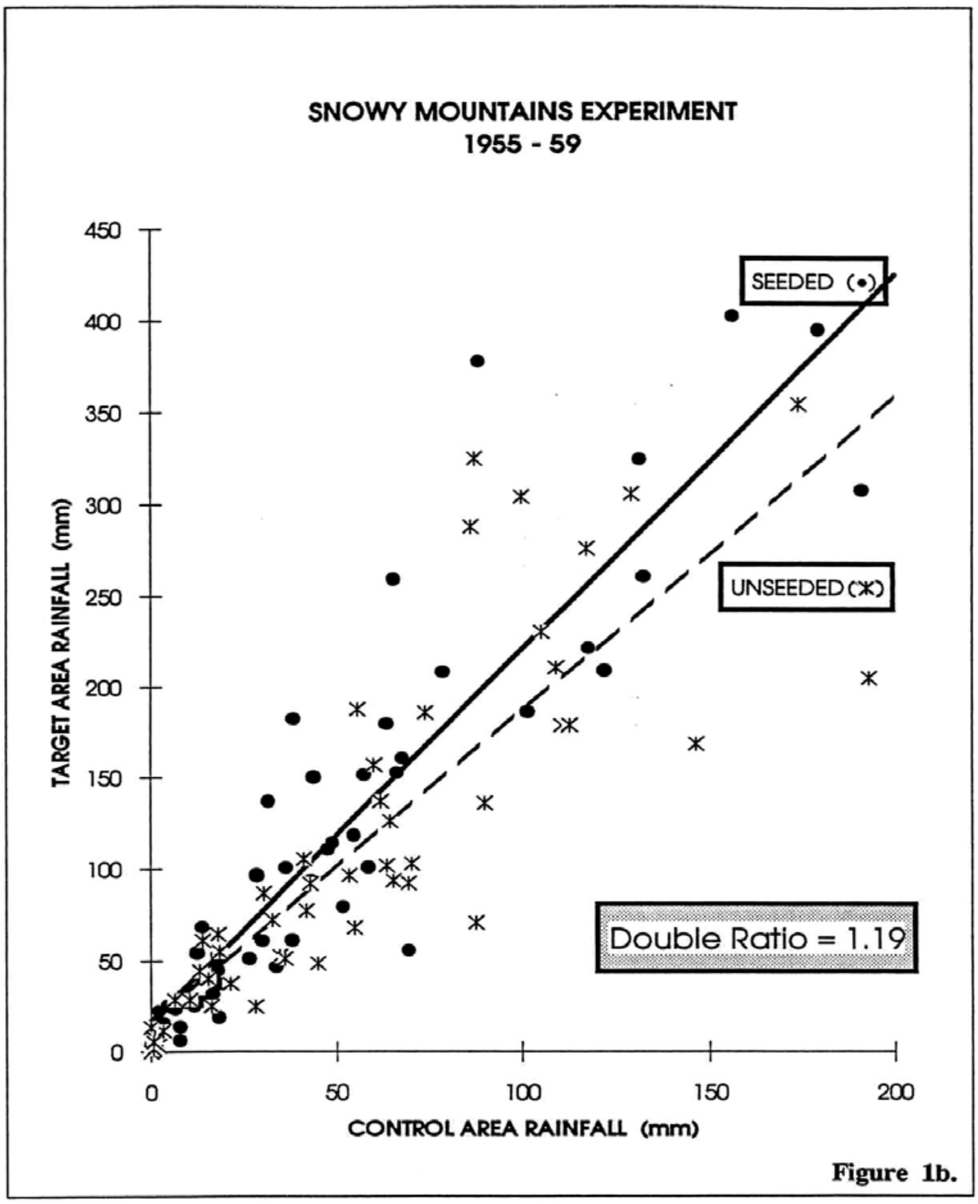
A five year experiment over the Snowy Mountains area of NSW in 1955 – 1960 produced a 17% increase in rainfall significant at the 3% level (Smith et al 1963). The project was evaluated in accordance with the statistical design as planned by CSIRO, but an unseemly squabble developed between CSIRO scientists and SMHEA engineers over an alternative analysis not canvassed prior to the experiment. Although the introduction of other methods of analysis after the event is not scientifically acceptable, it led to the results being officially declared inconclusive, although the statistics clearly indicated otherwise.

A proposal to re-run the experiment with improvements was never implemented. In the 40 years 1961-2000 following the experiment, no cloud seeding was done over Snowy hydro catchments. The loss of inflow based on the experimental statistics has amounted to about 144,000 Ml/yr, and the forfeiture of many millions of dollars worth of electricity annually.

This author has plotted the rainfall values for the 104 experimental units of the five year experiment and run a multiple regression analysis on the untransformed data. The plot together with the regression statistics is shown in figure 8.

It is interesting to note that the results from the Snowy experiment are much the same as the experimental results from Tasmania, and fit well with experience in other countries. The features common to both the Snowy Hydro and the Tasmanian experiments are;

- Rising terrain with elevation of target area greater than 1000 metres above the plains upwind
- Exposure to moist airstreams from the south-west, west and north west
- Frequent stratiform cloud systems in winter
- High levels of super-cooled liquid water in cloud (at –10°C level)
- Airborne seeding methodology (placing the right seeding material in the right place at the right time)
- Liquid fuelled silver iodide generators (the most efficient producers of ice nuclei).



REGRESSION ANALYSIS (104 events in 5 years)

T = 15.9 + (1.7134 C) + (0.3368 CS)
Where; T = Target Area rainfall (mm)
C = Control Area rainfall (mm)
S = Dummy variable, 1 = seeded, 0 = unseeded

Total seeding effect = 856 mm (Increase = 18%)
Confidence Limits, 90% = 283mm, 10% = 1428mm
$r^2 = 0.77$ Significance Level = 1.6%

Figure 8. Plot of Snowy Target and Control Area Rainfalls with Results of Statistical Analysis.

3. Warragamba Dam

The Warragamba Dam catchment has been the target of cloud seeding experiments on three separate occasions (1948 – 1952, 1956 – 1959 and 1960-1964). In each of these periods, rainfall over the catchment was significantly elevated above the historical median. The Warragamba Dam filled within the four-year cloud seeding experimental period even though Sydney Metropolitan Water Board engineers estimated that it would take a minimum of seven years, and a maximum of 21 years to fill.

4. New England Experiment

In the New England Tablelands, another 5 year area experiment was conducted using a crossover design (two discrete areas nominated either as target area or control area on a randomised basis). In the first year, a 30% increase in rainfall was recorded in the target area, but in subsequent years the increases became progressively smaller. This phenomenon of an apparent decline in yields from cloud seeding experiments, has now been explained by the effects of seeding persisting in time, and gravitating outside the target area. The net effect of persistence, is the contamination of control areas, and unseeded days behaving like seeded days. In the presence of persistence effects, the crossover design is the worst possible design to adopt, as both areas soon become equally affected by the seeding. The statistical method used to evaluate results becomes progressively unable to detect seeding effects in the target area, no matter how successful the seeding actually is.

5. Drought Relief Operations

Drought relief cloud seeding operations were conducted in NSW for 9 years between 1965 and 1974. These operations were never intended to be evaluated in the same way as randomised scientific experiments since the key requirement was maximum rainfall from every suitable cloud. Reports by cloud seeding officers of the NSW Department of Agriculture are consistent with experience elsewhere in describing observed effects of seeding (Mahon 1975).

The most recent drought relief cloud seeding operation was conducted in the summer of 1994/95 after substantial deliberations by NSW government ministers (Searle 1994). The aircraft and crew were based at Tamworth and operated over an area of 13,000 km^2 north of the city. The drought had left the landscape appearing like a desert, and it was not the most favourable time to display the worth of cloud seeding. Nevertheless, the Minister for Water Resources provided funds for just 12 weeks of cloud seeding. The project was conducted by Hydro Tasmania and managed by the author of this submission.

The target area included the catchments of Lake Keepit (Namoi River), Split Rock Dam (Manilla River), Copeton Dam (Gwydir River), and Pindari Dam (Severn River), a total area of over 13,000 km^2, about four times the size of the primary target area in Tasmania.

The operation was an outstanding success. Suitable clouds occurred every two or three days and heavy rainfalls followed seeding. Rainfall in the large target area for the 3 months ranged from 90% to 160% of normal (figure 9.).

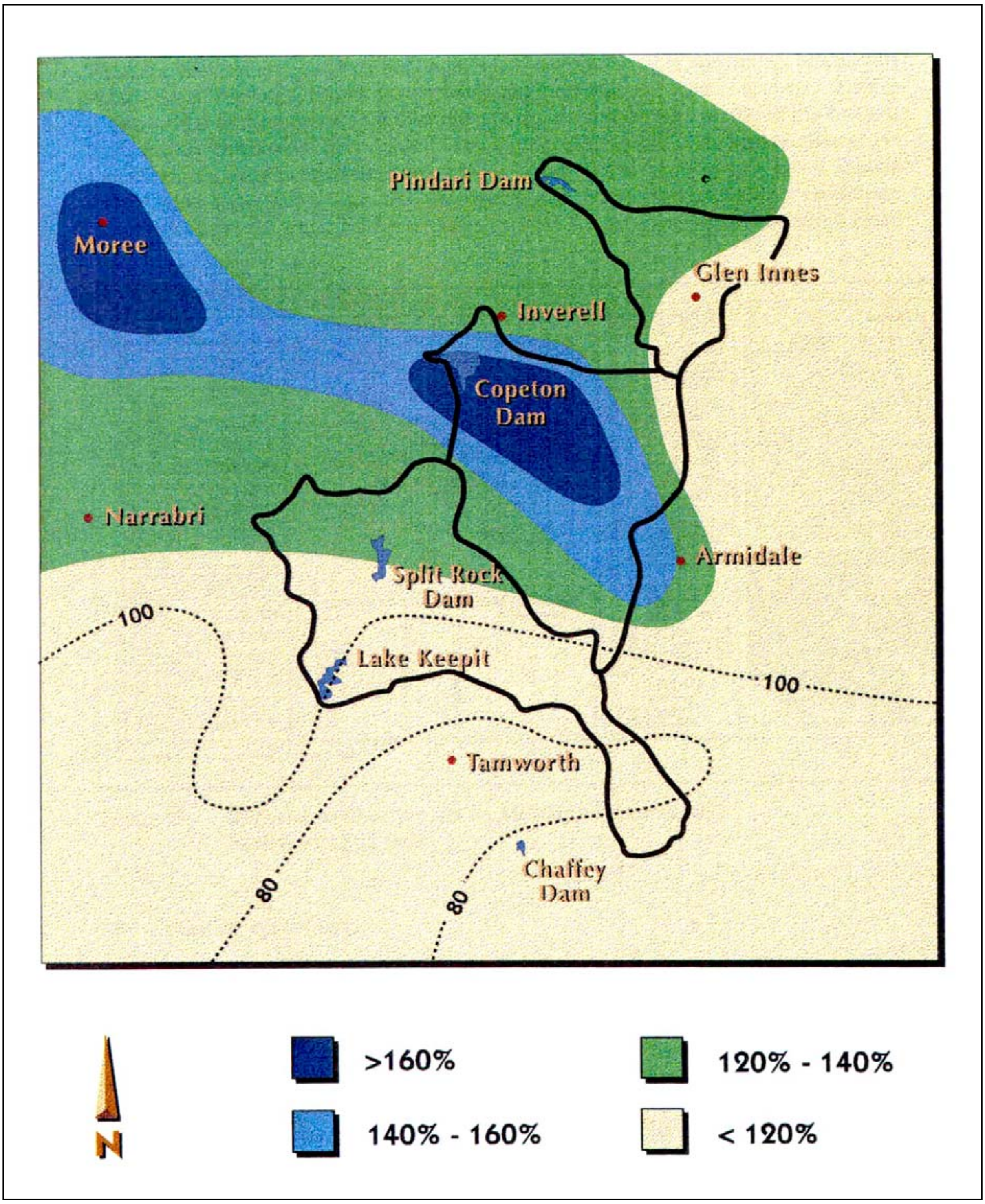


Figure 9. Rainfall Distribution 18 Nov 1994 – 12 Feb 1995 (Percent of Normal)

Cumulus cloud conditions (the dominant type during the summer months) were far larger and wetter than most seen in other regions where cloud seeding has been conducted (figure 10). A full report of the operation was written and widely distributed (Searle and Nebel 1995).

Unfortunately, a state election in NSW was held a few weeks after the conclusion of the trial, and the government changed hands. The proposed five year scientific experiment which was meant to follow the three-month trial never took place. Once again, science was gazumped by politics.

Figure 10. Large Cumulus clouds near Narrabri, November 1994

Long (1995) conducted a study into the economic benefits of the cloud seeding project operating over the North-West catchments and concluded that the benefit to cost ratio for runoff into storages alone was 9:1, but for rainfall on crops and pastures alone, the benefit to cost ratio rose to 33:1. He further stated that the benefit on the average seeded day, exceeded the cost of the whole three month program.

6. Victoria

Cloud seeding in Victoria began in 1966 with a drought relief operation based at Nhill. The base of operations was changed to Horsham in 1967 and continued there till 1971. The areas of operation during those years included the Wimmera-Mallee wheat country and the south western grazing country (each of about 25,000 km^2) in winter and spring, the Grampians water catchments, Gippsland agricultural areas, Melbourne Water catchments and the north eastern forests in summer and autumn.

None of these operations were intended to be controlled scientific experiments but drought relief operations only. Nevertheless, attempts were made to detect effects on rainfall after the event. The Department of Agriculture commissioned a biometrician to analyse rainfalls but the effort was doomed to failure, because there was no randomised treatment of clouds and no uncontaminated control areas against which to compare target area rainfalls.

A much better approach in such circumstances is to adopt the percent-normal method, as was done by McDonald in his report of 1983. In each of the five years 1966 – 1970, an area of increased rainfall appears, not in the target area itself but in the downwind direction. This phenomenon is best explained by the fact that the cloud seeders were not permitted to seed clouds upwind of the target area in South Australian airspace. All the cloud seeding operations were to be conducted east of the border between Victoria and South Australia.

Figure 11 shows a combined percent-normal plot for the seeded periods between 1966 and 1969 (prepared in 1970) for the whole of Victoria. The downwind effects of seeding on rainfall are quite obvious. Rainfall in the west near the South Australian border was about 75% - 85% of normal, while in the eastern part of the target area it rose to 100%, and further east again to over 115%, before falling away to about 90% in far eastern Victoria.

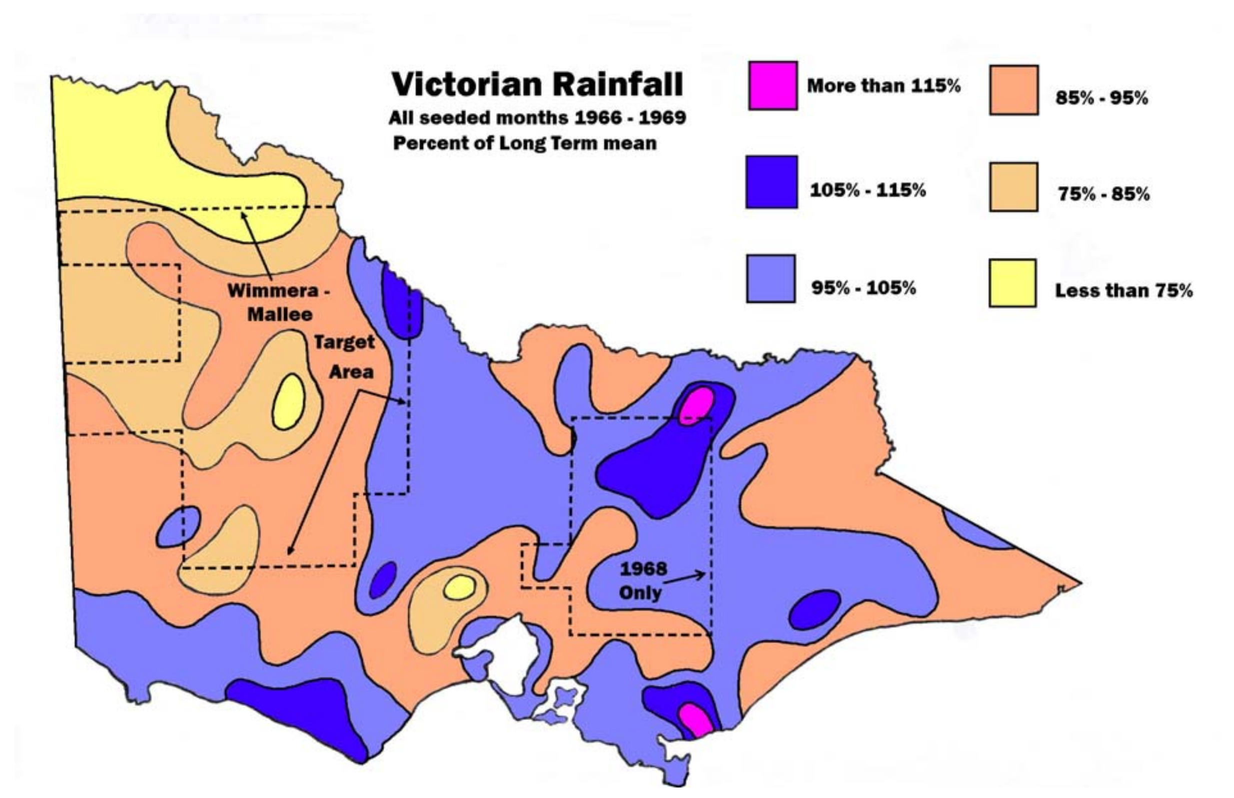


Figure 11. Combined Percent-Normal analysis of Victorian rainfall. All seeded months 1966 – 1969.

A controlled experiment was conducted in Victoria in the years 1987 – 1992 over the very small catchment of the Thomson dam (487 km^2). This author was involved in training cloud seeding officers for this experiment and in providing practical advice on experimental design and operation. In two respects only, my advice was ignored, these being to enlarge the target area, and to place automatic recording rain gauges downwind of the target area as well as in the target and control areas.

Melbourne Water have never released the data to Hydro Tasmania for analysis even after many specific requests. Reports that have been written suggest that a rainfall increase was measured in the buffer zone between the target and control area and in the downwind area, but not in the target area.

A Proposal

The proposal is to conduct cloud seeding operations in the area in which cloud seeding could be of most benefit, namely the Murray-darling Basin. However, the Murray-Darling basin is over a million square kilometres in area, and much of it is marginal agricultural land.

The Basin harbours a wide range of climatic types, and the environment varies from arid to rain forest and alpine. Rainfall and runoff vary greatly from west to east and figures 12 and 13 show both these features. Accordingly, agricultural enterprises vary from sparse grazing to intense cropping. Any cloud seeding effort needs to consider all these factors and concentrate the effort not only where clouds will most likely be suitable often enough to warrant such a program, but where the economic benefits will be greatest.

Option 1.

A first option is to duplicate the non-experimental rain making operations of the sixties in an attempt to also duplicate the rainfall anomaly of figure 7. Such a project has the benefit of treating the largest practical area, affecting agriculture and water supply for most if not all of the Murray-Darling Basin. This would require several cloud seeding aircraft based where they could cover the area east of the Darling River.

Option 2.

The western slopes of the Great Dividing Range contain nine large catchment areas feeding runoff into the rivers flowing westward from the ranges, all of which could be suitable targets for a cloud seeding operation. Table1 lists these catchments and the relevant statistics.

Table 1. Catchments of the Great Dividing Range

Catchment Name	River Name	Catchment Area km2	Dam Capacity (Gl)	Av. Annual Rainfall (mm)	Av. Annual Runoff (mm)
Hume / Dartmouth	Murray / Mitta Mitta	9350	6738	930	270
Snowy Mountains	Murray / M'bidgee / Snowy	5035	6792	2500	470
Burrinjuck	Murrumbidgee	12953	1026	640	116
Wyangela	Lachlan	8290	1220	750	87
Burrendong	Macquarie	13886	2046	700	42
Catlereigh / Upper Namoi	Castlereigh	15000	0	600	18
Keepit / Copeton	Gwydir/Namoi	12720	2184	715	73
Pindari	Macintyre/Dumaresq	2000	565	690	25
Upper Condamine	Condamine	20000	0	600	17
	TOTAL	**63606**	**4795**		

Four of these catchments (in the opinion of this author) are prime sites for cloud seeding experiments, because they each have large dams, which can store high value water.
These are;

- The Hume / Dartmouth catchments (feeding into the Murray River)
- The Snowy Mountains Hydro catchments (feeding into the Murray and Murrumbidgee Rivers, and possibly providing environmental flows into the Snowy River)
- Burrendong Dam catchment (feeding into the Darling via the Macquarie River)
- Keepit Dam / Copeton Dam catchments (feeding into the Darling via the Namoi and Gwydir Rivers). Chambers and Long (1992) reported on the feasibility of cloud seeding in this area.

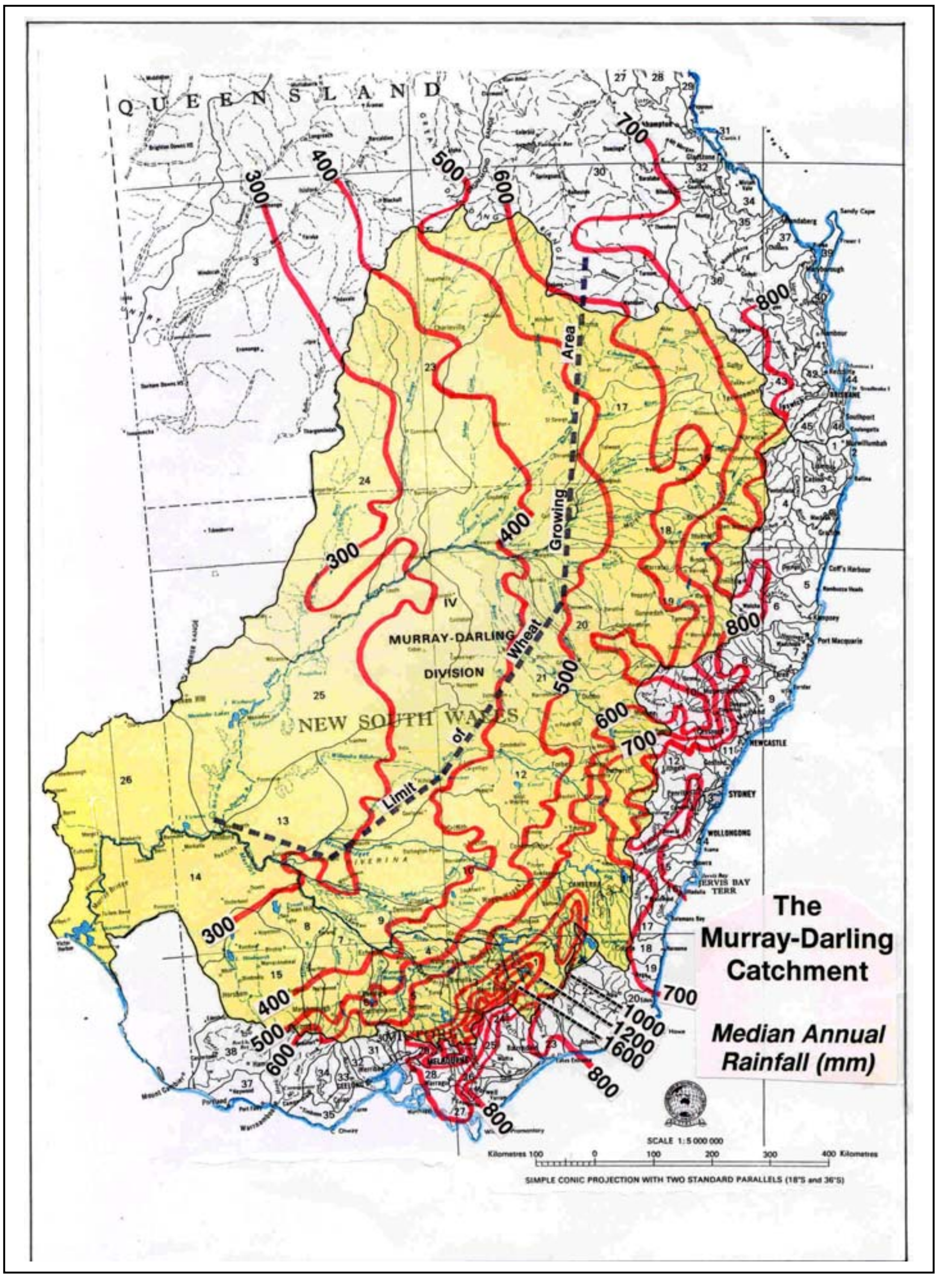


Figure 12. Rainfall Isohyets (mm)

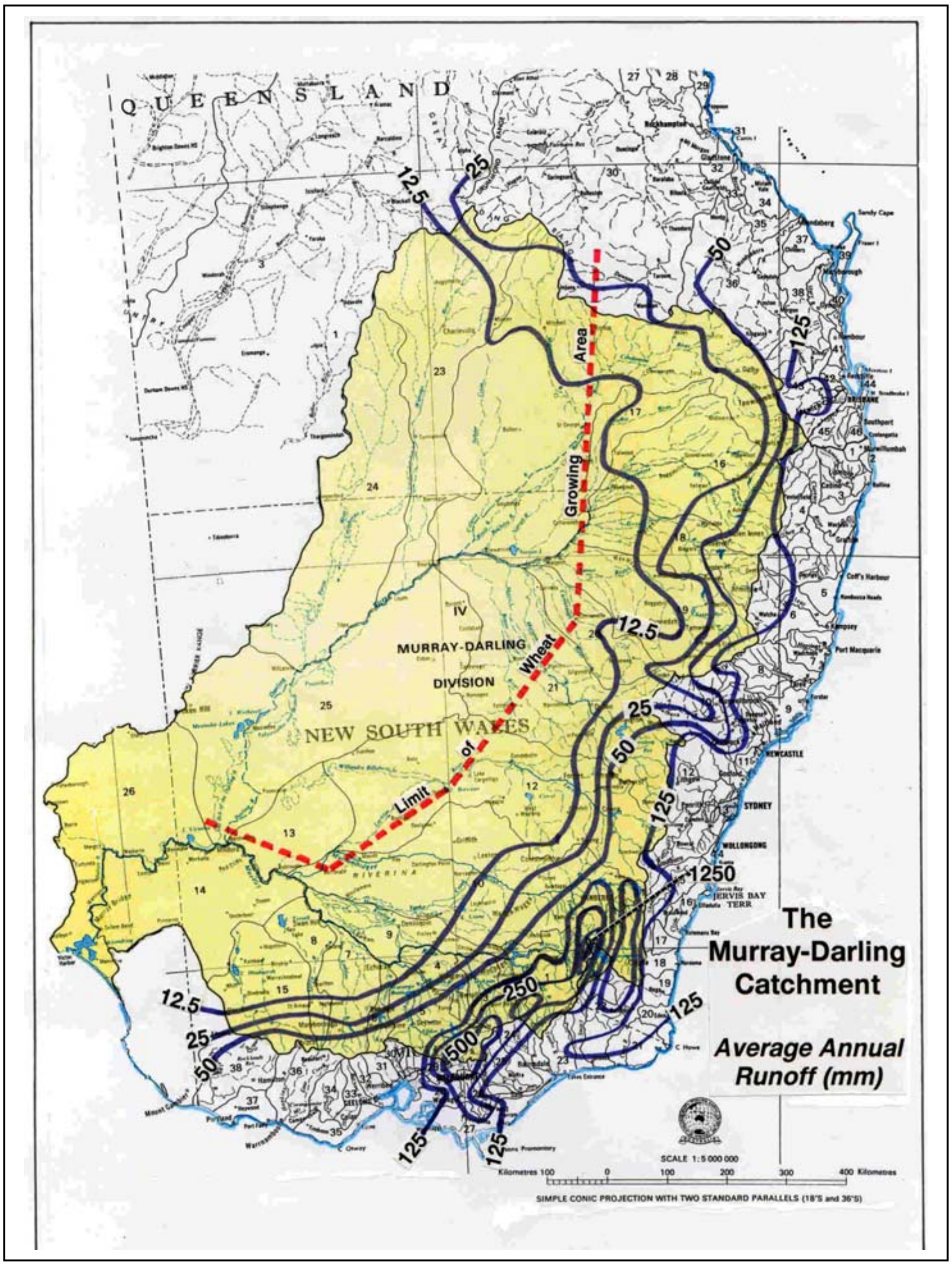


Figure 13. Isopleths of runoff (mm)

Cloud seeding operations would be based at airports with suitable facilities such as Albury, Dubbo and Tamworth. It would not be advisable to run experimental operations in adjacent catchments such as the Hume/Dartmouth catchment and the Snowy mountains catchments. Buffer zones between experimental target areas of considerable size are advisable, with well correlated control areas upwind (west) of each target area.

Costs

The cost of cloud seeding operations varies depending on design and area. As a guide, the Tasmanian cloud seeding operation (one turbine-engined aircraft, three full time staff, operating over 6000 km^2) costs a little over one million dollars a year. However, only part of the close network of automatic recording rain gauges that we use is paid for from the cloud seeding budget. Other users pay for the rest.

References

AAS 1976 Report of a Committee on Climatic Change. Report No 21, Australian Academy of Science, March 1976

Chambers, L.E., Long, A. B., 1992 Precipitation Enhancement Feasibility Study in Aid of Cotton Irrigation. CSIRO Div. Atmos. Research Report to DPIE Cotton Research and Development Corporation, Narrabri, NSW

Ecos No 45, Spring 1985 Cloud Seeding – Its Effects May Linger

Long, A. B., 1995 Economic Benefit:Cost Ratios and Environmental Impacts of Precipitation Augmentation by Cloud Seeding. Report to NSW Minister of Agriculture, 1995

Mahon, J. K. et al 1975(?) Final Report of a Cloud Seeding Research Project, Cobar Area 1965 - 69, 1969 – 1974. Department of Agriculture, NSW

McDonald, D. J., 1983 A Review of the Potential for Influencing Rainfall in New South Wales by Cloud Seeding. Department of Agriculture, Orange April 1983.

Pook, M. J. and Budd, W. F. 2002 An Evaluation of Cloud Seeding Operations carried Out in Tasmania by Hydro Tasmania. An Independent Report to Hydro Tasmania, Department of Primary Industries, Water and the Environment, and The Tasmanian Farmers and Graziers Association. CRC for Antarctica and the Southern Ocean, Hobart, June 2002.

Searle, I.. L., 1994 A Method of Increasing Rainfall and Runoff. Proceedings of the Forum on Cloud Seeding, Inverell, NSW, 10 Nov. 1994, NW Catchment Management Committee.

Searle, I. L., deHoog, M., Nebel, C. 1995 A Cloud Seeding Trial in North Western New South Wales. Report to NSW Department of Water Resources

Smith, E. J. et al 1963 A Cloud Seeding Experiment in the Snowy Mountains, Australia. J. Appl. Met. Vol 2.

Other Useful References Not Cited

Higgins, E. 1982 Rainmakers Hope for Fresh clouds on their Horizons. Special Science Report, Financial Review, 20 May 1982.

Searle, I. L., Nebel, C. 1998 Cloud Seeding, The Tasmanian Experience. General information publication, Hydro Tasmania, Hobart.

Searle, I. L. 1994. Cloud Seeding, A Method of Increasing Catchment Runoff. “The Fabric of Success”, The Seventh Australian Cotton Conference, Cotton Growers Research Association, Broadbeach, August 1994.

Ryan, B. F., King, W. D., 1997 A Critical Review of the Australian Experience in Cloud Seeding. Bulletin American Met. Soc. Vol 78. No. 2. Feb 1997