natural resources commission

PROGRESS REPORT ON THE SNOWY MOUNTAINS CLOUD SEEDING TRIAL

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Enquiries

Enquiries about this report should be directed to:

Tim Kirby

Phone (02) 8227 4300

E-mail tim.kirby@nrc.nsw.gov.au

Postal address GPO Box 4206, Sydney NSW 2001

List of acronyms

ANZECC	Australian and New Zealand Environment and Conservation Council
BACI	'before, after, control, impact'
CMA	Catchment Management Authority
DECC	Department of Environment and Climate Change
EMP	environmental management plan
GTV	guideline trigger value
NRC	Natural Resources Commission
NSW	New South Wales

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1 Introduction

The *Snowy Mountains Cloud Seeding Trial Act 2004*[1] (the Act) authorises Snowy Hydro to conduct a cloud seeding trial (the trial) in the Snowy Mountains, subject to certain conditions. Snowy Hydro has commenced the Snowy Precipitation Enhancement Research Project, and developed an environmental management plan (EMP) for the trial as requested by the Ministers for the Environment[2] and for Planning.[3] Under Section 8 of the Act the Natural Resources Commission (NRC) is charged with supervising the cloud seeding operations undertaken by Snowy Hydro and with reporting on the environmental impact of those operations.

In undertaking these roles, the NRC has prepared this progress report. It has visited cloud seeding sites in the Snowy Mountains, consulted with Snowy Hydro and a number of affected stakeholders, and evaluated Snowy Hydro's environmental reporting as contained within its 2005[4] and 2006[5] annual reports. The Minister for the Environment[6] specifically requested that the NRC review Snowy Hydro's 2005 Annual Report and Snowy Hydro's response to the NRC's review of the 2004 Annual Report.[7]

This report has been prepared for the Minister for Climate Change, Environment and Water and the Minister for Planning and presents and explains the NRC's findings and recommendations. There has been little change since we last reported on the trial. The NRC considers that Snowy Hydro is using the best available technology and procedures to undertake the trial and that the infrastructure impacts from cloud seeding equipment are being well managed. However, the monitoring program within the EMP remains inadequate, and there is no publicly available evidence to support Snowy Hydro's claim that cloud seeding increases snowfall. The NRC advises that the government should urgently direct Snowy Hydro to improve its EMP to require collection and frequent reporting on data that will address these issues.

1.1 How is the trial progressing?

Snowy Hydro is conducting the cloud seeding operations authorised by the Act, and is now midway through the six-year trial. Snowy Hydro's operations are currently being undertaken in compliance with the Act.

By the end of 2006, Snowy Hydro had completed 46 of the 110 experimental units planned to complete the trial. While the low snowfall experienced in 2006 meant that this is slightly less than expected at this stage, Snowy Hydro remain confident that the remaining 64 units can be completed within the 2007, 2008 and 2009 seeding seasons.

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1 *Snowy Mountains Cloud Seeding Trial Act 2004 No. 19* (New South Wales), at s. 4 (1)
2 Now the Minister for Climate Change, Environment and Water.
3 The EMP was developed through consultation between Snowy Hydro and the former Department of Environment and Conservation and approved by the relevant Ministers in 2004.
4 Snowy Hydro Limited (2006), Snowy Precipitation Enhancement Research Project – Annual Report 2005.
5 Snowy Hydro Limited (2007), Snowy Precipitation Enhancement Research Project – Annual Report 2006.
6 Now the Minister for Climate Change, Environment and Water.
7 Snowy Hydro Limited (2005), Snowy Precipitation Enhancement Research Project – Annual Report 2004.

Many of the recommendations made by the NRC in 2005 have not been acted on by Snowy Hydro, and continue to concern the NRC. This has meant that some opportunities to enhance the experimental design of the trial have been lost, and that the EMP remains inadequate.

Many of the issues that concern the community about cloud seeding, such as the effect on downwind rainfall, are not being addressed by Snowy Hydro through ongoing monitoring and public reports. This makes it difficult to understand and consider the appropriate trade-off between potentially beneficial and potentially adverse environmental impacts.

1.2 Is cloud seeding successfully increasing snowfall?

Snowy Hydro has publicly claimed that cloud seeding is successfully increasing snowfall but has not made available evidence to substantiate these claims. Snowy Hydro has been collecting data designed to enable evaluation of the trial and has analysed at least some of this data. Snowy Hydro has stated that it does not plan to report this data until the end of the trial in 2009. It is vital that any decision to continue or expand cloud seeding operations beyond the trial is informed by evidence about the effectiveness of cloud seeding in the Snowy Mountains. Hence the NRC recommends that the Ministers consider requiring Snowy Hydro to enhance the annual reporting requirements of the EMP to include data and information assessing the effectiveness of cloud seeding.

1.3 Is cloud seeding causing an environmental impact?

The information available from the trial is insufficient to determine if cloud seeding is causing an environmental impact. While Snowy Hydro has complied with most requirements of the trial's EMP, the NRC still considers that the environmental monitoring being undertaken is inadequate to allow a balanced assessment across a broad enough range of potential environmental impacts from cloud seeding.

Those potential impacts are considered in three broad categories:

- disturbance caused by the installation, maintenance and removal of cloud seeding equipment (the 'infrastructure impacts')
- effects caused by changes to precipitation (the 'precipitation impacts')
- ecotoxic effects caused by the chemicals used by the trial (the 'ecotoxicity impacts').

The NRC inspected cloud seeding equipment in the Snowy Mountains and considers that the impacts from the installation, maintenance and removal of this equipment are being well managed. Snowy Hydro could improve how this environmental management is reported to the Government and the community.

The NRC consulted with key stakeholders, including the Department of Environment and Climate Change (DECC[8]) and catchment management authorities, and found that they continue to be interested in the precipitation impacts of cloud seeding, such as increasing snowfall and river flows; producing rain instead of snow; affecting downwind rainfall; or affecting the length of the snow season.

8 Formerly the Department of Environment and Conservation.

The NRC found that the two annual reports recently issued by Snowy Hydro do not adequately address precipitation impacts that may be caused by the trial. While Snowy Hydro is collecting data on some matters related to precipitation, it is not progressively analysing these data, which would allow impacts to be monitored, reported and responded to where necessary.

The NRC analysed ecotoxicity data from the trial's 2005 and 2006 seasons and concludes that ecotoxicity monitoring undertaken by Snowy Hydro has not detected a potential ecotoxic impact at the small number of sites sampled. However, the NRC considers that the ecotoxicity monitoring is not thorough enough to extrapolate these findings over the full area of the Kosciuszko National Park or beyond.

The NRC considers that the EMP is inadequate and this report highlights continuing concerns regarding:

- the lack of analysis and reporting of data collected to assess the effectiveness of cloud seeding
- the unsuitably narrow focus (notwithstanding that it meets the requirements of the EMP) of the environmental monitoring
- the limited annual reporting of data, analysis and information concerning the environmental impacts of the trial.

As the trial has now reached its midpoint, the main deficiencies of the environmental monitoring can no longer be corrected using an environmental control area, as recommended by the NRC prior to the first experimental season commencing. The NRC now recommends that Snowy Hydro use other methods of monitoring to improve environmental assessment of the trial, which may include developing 'paired sites'[9] studies or, 'before-after'[10] studies. For both of these types of studies, Snowy Hydro could use snowfall and other environmental data already being routinely collected by themselves and other natural resource managers in the region. Snowy Hydro is currently considering the feasibility of undertaking these studies.

1.4 Summary of recommendations

The Ministers should consider requiring Snowy Hydro to provide some additional information immediately, to support current claims regarding the effectiveness of cloud seeding.

In addition, the Ministers should consider requiring Snowy Hydro to improve monitoring of the trial, to ensure better information is available for future evaluation of cloud seeding and assessment of environmental impacts. These improvements would enhance the monitoring and reporting requirements of the environmental management plan (EMP) in a number of areas, including:

- widening environmental monitoring
- strengthening current environmental monitoring
- enhancing annual reporting
- enhancing end-of-trial evaluation and reporting

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9 A 'paired catchment' or 'paired site' study compares environmental data between affected and unaffected sampling points. These studies are further discussed at Section 4.1.2 of this report.

10 A 'before –after' study compares environmental data collected before and after a potential impact.

A complete list of recommendations is contained in Attachment 1.

1.5 Structure of this report

The remainder of this report is divided into five chapters.

- Chapter 2 provides further background and examines the progress of the trial
- Chapter 3 assesses the environmental impacts arising from the installation, maintenance and removal of cloud seeding equipment
- Chapter 4 discusses the environmental impacts of causing changes to precipitation, including increasing snowfall, causing rain instead of snow, affecting downwind rainfall, and the impact on river flows, montane riverine and alpine ecosystems, and snow-dwelling fauna
- Chapter 5 assesses environmental impacts from the ecotoxicity of cloud seeding chemicals, including the impact of discharged silver and indium on potable water sources and soils
- Chapter 6 summarises how Snowy Hydro has responded to the NRC's 2005 recommendations regarding the trial.

2 Progress of the cloud seeding trial

Snowy Hydro is conducting the cloud seeding operations authorised by the *Snowy Mountains Cloud Seeding Trial Act 2004*, and is now midway through the six-year trial. By the end of 2006, Snowy Hydro had completed 46 of the 110 experimental units planned to complete the trial. While the low snowfall experienced in 2006 meant that this is slightly less than expected at this stage, Snowy Hydro remain confident that the remaining 64 units can be completed within the 2007, 2008 and 2009 seeding seasons.

The NRC believes the trial may not meet the expectations of the NSW Government and the community, as:

- the effectiveness of the trial is not being progressively demonstrated
- current monitoring is insufficient to scientifically prove that the trial is not causing any significant adverse environmental impacts.

Many of the recommendations made by the NRC in 2005 have not been adopted, and the NRC is also concerned that some opportunities to improve the trial have now been lost. The actions that should still be taken regarding the NRC 2005 recommendations are discussed in Chapter 6.

Recommendation 2.1
Snowy Hydro should provide data collected for the chemical marker study for the 2004, 2005 and 2006 seasons, and analysis of that data assessing the effectiveness of cloud seeding in the Snowy Mountains.

2.1 Purpose of the trial

In 2004 Snowy Hydro sought authorisation to conduct a trial of cloud seeding in the Snowy Mountains in response to a long-term downward trend in annual snowpack and a lengthy drought. Its aim for the trial is to determine whether it is feasible to use cloud seeding to increase the snowfall in this area. Snowy Hydro expects that the trial, if it does increase snowfall, will result in additional water for irrigators in the Murray system and improvements in the health of montane streams.

With the continuing drought, water storage in the Snowy Mountains Hydro-electric Scheme is at record low levels. While cloud seeding is unlikely to be of much assistance in drought years due to lack of suitable clouds to seed, cloud seeding may increase water capture in non-drought years and improve resilience of the Snowy Mountains Hydro-electric Scheme in future drought periods.

A panel of experts established by Snowy Hydro to advise it on the trial have also identified some potentially adverse impacts from cloud seeding.

2.2 Authorisation for cloud seeding operations

The NSW Parliament passed the *Snowy Mountains Cloud Seeding Trial Act 2004* (the Act). It permits Snowy Hydro to carry out authorised cloud seeding operations designed to increase precipitation within a designated target area by discharging a seeding agent into passing clouds[11] for a period of six years, unless terminated sooner.[12]

Cloud seeding operations may cause other environmental impacts through altering snowfall and rainfall patterns, the use of potentially toxic cloud seeding chemicals, or the installation and removal or infrastructure needed to undertake generation and monitoring. In addition, most cloud seeding operations take place on public land within the Kosciuszko National Park and may cause impacts within the park.

The Act provides that the relevant Ministers[13] may suspend or terminate the authorisation if:

- the cloud seeding operations are having or will have a significant adverse environmental impact
- Snowy Hydro has not complied with any requirements that have been imposed by the relevant Ministers to minimise environmental impact, such as a requirement to prepare or implement an environmental management plan
- Snowy Hydro has not provided the relevant Ministers with information relating to environmental impact that they have requested.[14]

2.3 Environmental management plan should be improved

As required by the Act, Snowy Hydro prepared an EMP in consultation with the former Department of Environment and Conservation (now part of DECC). The NRC considers that the EMP is not adequate. Many of the recommendations of this report could be implemented through improvements to the EMP.

The EMP has not been designed to facilitate ongoing monitoring and reporting of a broad range of environmental parameters. In the *Expert Panel Assessment of Snowy Precipitation Enhancement Trial*[15] (Expert Panel Report) Snowy Hydro's advisors recommended that monitoring of various parameters should be undertaken during the trial to determine the actual impact on the local environment, even though they concluded that it was not likely that cloud seeding operations would have a significant adverse environmental impact. The EMP does not address all of the environmental parameters identified within the Expert Panel Report.

Snowy Hydro has now produced three annual reports on implementation of the EMP. The NRC has reviewed these reports and found that they contain insufficient information to assess the effectiveness of the trial and the environmental impacts of cloud seeding operations. Some additional information, sought by NRC to supplement insufficient information contained in the annual reports, was withheld by Snowy Hydro.

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11 Section 4(1).

12 Section 5.

13 Section 3 of the Act defines the relevant Ministers as the Ministers administering the *Environmental Planning and Assessment Act 1979* and Part 4 of the *National Parks and Wildlife Act 1974*. The relevant Ministers are the Minister for Climate Change, Environment and Water (previously the Minister for the Environment) and the Minister for Planning.

14 Section 6(2)(a), (b) and (c).

15 Environ (2003) *Expert Panel Assessment of Snowy Precipitation Enhancement Trial*, Report for Snowy Hydro Limited, Cooma.

The NRC has found it difficult to assess the effectiveness of the trial due to these constraints. The NRC has met with Snowy Hydro on several occasions to discuss the NRC's concerns relating to the trial's environmental monitoring and the lack of data available to assess the environmental impact of the trial. Snowy Hydro has agreed to consider the NRC's recommendations for enhancing the environmental monitoring.

In addition, the annual reports do not contain information required by the EMP on two matters:

- Snowy Hydro has not reported on the video monitoring and verbal polling it is conducting to ensure precipitation is falling as snow and not rain (see Section 4.2).
- Snowy Hydro has not reported on the distinction between the effects of cloud seeding and natural variation as this directly relates to its end of trial reporting requirements.[16]

As the EMP requires reporting on both of these issues annually, the NRC considers that Snowy Hydro's reporting has not been undertaken strictly in compliance with the EMP.

Recommendation 2.2
Snowy Hydro should provide an improved EMP, which includes:

- ongoing monitoring of parameters including downwind precipitation, stream flow, subnivean space, end of season snowfall patterns, potable water sources after each seeding event and alpine ecosystem health (the NRC considers that paired site studies may be suitable for this purpose).
- annual reporting of data and analysis of all monitoring (including the chemical marker study, snow depth and density) and infrastructure impacts
- an approved plan for evaluation of the trial and reporting on the trial.

Recommendation 2.3
Snowy Hydro should provide a draft plan, for Ministerial approval, of how the outcomes of the trial will be evaluated and reported.

2.4 Community engagement

The NRC has consulted representatives of DECC and three catchment management authorities (CMAs). They have a strong interest in a successful trial outcome and also continue to express concerns about the environmental impact of the trial. The NRC considers that Snowy Hydro will need to improve how it communicates with the Snowy Mountains, and down-river, communities to gain their support for the outcomes of the trial.

DECC has close links with the local community through its Snowy Mountains Region Advisory Committee, and Snowy Hydro has an ongoing relationship with DECC, as both a regulator and 'landlord' of the area on which the Snowy Mountains Hydro-electric Scheme is situated. In addition, Snowy Hydro has worked closely with DECC when installing, maintaining and removing cloud seeding equipment within Kosciuszko National Park, and when conducting cloud seeding operations during the seeding season. These relationships should allow DECC to

16 These reporting requirements are contained in Section 10, Part 5 of Annexure B of the *Snowy Precipitation Enhancement Research Project Environmental Management Plan* (Snowy Hydro, March 2005).

share community concerns with Snowy Hydro, and allow Snowy Hydro to build community understanding of the trial, but the NRC does not consider that either has happened effectively.

CMAs represent regional communities and have responsibility for natural resource management, including achieving targets for water management. Cloud seeding may increase the volume of water that they manage for their constituents, but Snowy Hydro has not discussed the trial with the affected Murray, Murrumbidgee and Southern Rivers CMAs.

Snowy Hydro does notify a number of other interested government, commercial and community bodies when seeding events are occurring. The NRC will conduct wider consultation with the community (including stakeholders that Snowy Hydro specifically notifies during seeding) during the remainder of the trial to better understand how the community views the trial.

3 Infrastructure impacts

The NRC considers that the installation, maintenance and removal of cloud seeding infrastructure (including generating and monitoring equipment) is being well-managed.

Cloud seeding operations require generating equipment to be installed upwind of the target area, and monitoring equipment to be installed within the target area. During the three years of the trial to date DECC has expressed concern about impacts of the trial's infrastructure on the Kosciuszko National Park, particularly with respect to physical, aesthetic, wilderness and Aboriginal spiritual values. While the target area is within Kosciuszko National Park, Snowy Hydro has consulted with DECC about the location and installation of infrastructure. It has also taken care to use many sites that are already disturbed by existing infrastructure, either dams, pipelines, transmission cuttings or access roads. This has significantly reduced the visual impact of installed equipment and reduced disturbance caused by accessing sites.

During two site inspections in November 2006 and March 2007 (see Attachment 2 for a list of sites visited) the NRC observed that Snowy Hydro has developed new sites in undisturbed areas and installed new wind fences in a way that minimises impacts on the surrounding environment. The NRC found that there are some temporary environmental impacts within remote areas of Kosciuszko National Park due to installation of the trial's infrastructure, but that Snowy Hydro has adequately rehabilitated abandoned infrastructure sites.

The visual impacts of cloud seeding infrastructure have increased since the trial began. Some monitoring equipment was originally designed to be removed entirely during the summer months, and wind fences were not installed around the pluviometers.[17] These structures will now remain in situ all year round due to the installation of the wind fences, the high work load of installation and environmental disturbances that may occur during installation and removal. The area occupied by monitoring equipment has also been significantly increased with the addition of wind fences (double fences with 2m and 6m diameters) designed to reduce turbulence around the pluviometer and improve the validity of monitoring.

3.1 Generating equipment

Generators remain portable and are located on site only for the duration of the seeding season. They are mounted on trailers to allow easy installation and removal and are located at sites with existing access trails. All cloud seeding chemicals are contained within the trailers, which are appropriately secured and bunded. At some sites, towers lift the generators to the tree line and these towers remain in place year round.

Meteorological and snow chemistry data collected during the 2004 season were used by Snowy Hydro to improve calibration of the trial, and for advanced plume dispersion studies. The results of this analysis indicated that the seeding generators at the Tom Groggin and Quarry sites had lower targeting effectiveness and Snowy Hydro dismantled and relocated these generators to the north. The areas were rehabilitated prior to the commencement of the 2005 season. Three new generator sites were established at Clews Ridge (Scammels), Khancoban and Spring Creek.

17 Pluviometers are used to measure the quantity of precipitation.

Figure 1.1 Indi generator site, showing LPG tanks and trailer-based silver and indium generators (March 2007)

During the 2006 site visit, the NRC inspected the two old sites (Tom Groggin and Quarry) and two of the new generator sites (Khancoban and Spring Creek). The NRC found that Snowy Hydro has rehabilitated the abandoned sites appropriately and has taken care to minimise the impacts associated with removal of the equipment and restoration of the sites. At both the Tom Groggin and Quarry sites there was no sign of erosion or sedimentation, the previous location of the generators was no longer obvious and no rubbish was left at the sites. The two new generator sites inspected (Khancoban and Spring Flat) also appear to be constructed in an environmentally sensitive manner.

The NRC witnessed the test operation of two sets of generators during the 2007 site visit. Generators can be operated remotely or at the site and the main observed impact of operation is noise, however given the remote location of sites, this impact is considered to be negligible.

3.2 Monitoring equipment

Figure 1.2 Grey Hill site, showing a pedestal (foreground) and tripod (background) pluviometer with and without wind fences (March 2007)

At the commencement of the trial in 2004, pluviometers were erected as pedestal structures designed to be removed at the conclusion of the trial. Pedestal pluviometers have been installed within disturbed areas. During the trial it has become necessary to install pluviometers at some additional locations. Additional pedestal pluviometers were constructed prior to the 2005 and 2006 seeding seasons. Several pedestal pluviometers were also removed prior to the 2005 season.

Additional tripod pluviometers were installed in sensitive areas prior to the commencement of the 2005, 2006 and 2007 seasons. Tripod pluviometers were originally intended to be installed at the start of each season and removed at the end of each season to reduce visual impact. However, tripod pluviometers will now remain in place until the conclusion of the trial due to the installation of wind fences around pluviometers and to minimise disturbance of installation and removal.

It has become necessary for Snowy Hydro to install wind fences around some of the pluviometers to improve data collection, which has further increased the visual impact. The fences installed are half the size of standard wind fences and cause less visual impact than full

sized fences. The NRC visited the Guthega Pondage site during March 2007, which has been developed as a precipitation reference site. Three pluviometers are located at the site, one enclosed within a full sized wind fence, one within a half sized wind fence and one without a wind fence. Snowy Hydro has used this site to collect data on the effectiveness of the different sizes of wind fences. Snowy Hydro has found that the use of half sized wind fences significantly improves the effectiveness of data collection.

Snowy Hydro was in the process of installing new wind fences at some pluviometer sites during the NRC's site visit in 2007. Wind fences had been installed approximately one week prior to the site visit at two of the sites and two other sites were in the process of having wind fences installed. Very little evidence of disturbance was apparent at the sites where recent installation had been completed. In addition, installation work was progressing in an environmentally sensitive manner at the sites undergoing installation, for example:

- materials and personnel were transported to the sites via helicopter to minimise impacts of vehicles within Kosciuszko National Park
- materials were stockpiled in appropriate areas away from vegetation and sensitive areas
- disturbance to vegetation was minimised
- the physical impact of installation was minimised by using infrastructure designed to limit intrusive impacts, for example where possible duck bill footings have been used to eliminate the need for more permanent types of footings.

Snowy Hydro has consulted with DECC (National Parks and Wildlife Service) about minimising the impact of permanent infrastructure. Snowy Hydro has minimised the visual and other impacts of infrastructure by painting structures in unobtrusive colours, by siting infrastructure in suitable locations and by utilising infrastructure designed to be installed and removed with minimal intrusive impact. The NRC found that the installation of pluviometers in remote areas of Kosciuszko National Park is impacting on the aesthetic and wilderness values of these areas. However, these impacts are localised and temporary in nature, as the infrastructure is to be removed at the end of the trial.

Four original pluviometer sites were removed (Mt Anderson, Plains of Heaven, Etheridge, Cootapatamba) at the end of the 2005 season. The Mt Anderson, Etheridge and Cootapatamba sites have been adequately remediated following removal, as observed by the NRC during site inspections in 2006 and 2007. The NRC has not visited the Plains of Heaven site. The Mt Anderson pluviometer has now been relocated to a less obtrusive site at Mt Anderson. It is now located adjacent to an alpine peat bog that is currently undergoing remediation. The NRC observed installation of this pluviometer during March 2007 and is satisfied that adequate environmental management actions were implemented during installation.

3.3 Improving reporting of environmental performance

Snowy Hydro is installing and removing infrastructure in accordance with its EMP and is taking care to mitigate the impacts. Snowy Hydro operations including cloud seeding operations, are also subject to an ISO14001-certified environmental management system.

However, Snowy Hydro has not reported on its remediation activities within Kosciuszko National Park, monitoring of remediated areas, consultation with DECC (National Parks and Wildlife Service) about minimisation of visual and other impacts or installation of equipment such as wind fences. The NRC considers that future annual reports should contain information

about these aspects, as reporting on these issues would provide greater confidence in Snowy Hydro's environmental performance.

Recommendation 3.1
Snowy Hydro should report information annually regarding:

- techniques used to minimise the impacts of installing and removing equipment
- environmental management of operating and maintaining cloud seeding equipment
- progress with site rehabilitation.

4 Precipitation impacts

Cloud seeding operations have potential to:

- increase snowpack depth and density by increasing snowfall and altering snowflake size and shape
- reduce snowpack depth and density by producing rain instead of snow
- affect precipitation in areas down wind of the trial, either by increasing or decreasing it
- increase water supply for hydroelectricity generation, river flows and irrigation
- affect riverine ecosystems, by increasing run-off and stream flow
- affect snow dwelling fauna, by potentially altering winter habitats.

Some of these potential impacts may be seen as positive, while others are clearly negative impacts. These issues were highlighted in the initial Expert Panel Report and by various stakeholders during the NRC's review of the 2005 and 2006 seeding seasons.

The NRC is unable confirm whether any of these potential impacts are occurring due to the limited information collected and reported by Snowy Hydro. Each is considered in more detail below.

4.1 Increasing snowfall

Snowy Hydro is collecting chemical marker data designed to demonstrate whether cloud seeding is increasing snow fall and has analysed some of this data. However, Snowy Hydro has declined to make any analysed data available for review. This means that there is no information currently available to determine whether snowfall is increasing as a result of cloud seeding either during or between seasons.

Snowy Hydro does report on the changes to snowpack during each season, compared to the measurements taken since 1954. This reporting does not provide any evidence to support claims of increased snowfall caused by cloud seeding, or any statistical evidence that cloud seeding increased snowpack depth during either the 2005 or 2006 seasons.

4.1.1 Improvements to monitoring and reporting

Snowy Hydro has developed an experimental design that includes:

- a randomised cloud seeding technique
- a chemical marker study.

The randomised cloud seeding technique uses replication and randomisation in time as a substitute for conventional spatial replication and randomisation. Snowy Hydro is collecting precipitation data from the pluviometer and snow sampling sites for seeded and non-seeded storms, and plans to analyse and report on this information at the end of the trial.

The chemical marker study uses a chemical marker with the seeding agent to identify which snow has fallen in response to cloud seeding. Snowy Hydro is collecting data related to snow profiles for silver to indium ratio and snow density that can provide a measure of seeded precipitation. Snowy Hydro showed the NRC one graph of analysed chemical marker study data during the NRC's 2007 site visit. The analysis provided assurance that a chemical signature can be readily identified which may detect snow fallen in response to seeding operations. The NRC considers that Snowy Hydro should report this data and information on the progress of this study annually.

The NRC considers that to provide greater confidence in the experiment, it would be useful to back up any statistical analysis and modelled predictions with field measurements that demonstrate that any statistically significant increase has practical meaning. This could be done by comparing measurements of snow depth and snow density at snow courses taken before and after cloud seeding commenced and at 'paired sites' (see Section 4.1.2).

Recommendation 4.1
Snowy Hydro should report annually the data and ongoing analysis on the progress of the chemical marker study.

4.1.2 What is a paired catchment or paired sites study?

A paired sites study compares data for an environmental parameter at an un-impacted site with corresponding data at a matched impacted site. A paired sites study would be suitable for parameters such as snow depth and snow density, particularly where sufficient comparable pre-impact data were available to enable the matched sites to be correlated. Long term datasets are available for the snow courses routinely monitored by Snowy Hydro for operational purposes, which are independent of the trial.

Similarly, a paired catchments study compares data for an environmental parameter, such as stream flow, at a stream gauging station in an un-impacted catchment with corresponding data for a matched impacted catchment, desirably one with which it had been correlated. Such long term datasets are available for the gauging stations routinely monitored by Snowy Hydro for operational purposes.

Snowy Hydro is currently investigating if paired catchments or sites can be identified and could be used as part of an enhanced environmental monitoring program. Initially, this would include: spatial analysis to identify biophysically similar paired catchments or sites utilising data provided by DECC; and statistical analysis of available historical data to determine the inter-annual and spatial variability in snowpack between the three published snow courses. If suitable paired sites can be identified, and if the inter-annual and spatial variability enable

adequate correlation of 'before data,' then Snowy Hydro has agreed to undertake further investigation and analysis for a range of environmental parameters including snow depth and density, and stream flow. If it is found that these are impacted by seeding, then other terrestrial and aquatic ecosystem parameters may also be examined, such as impacts on snow dwelling fauna and macroinvertebrates.

Refer to recommendation 2.2
Snowy Hydro should provide an improved EMP, which includes:

- ongoing monitoring of parameters including downwind precipitation, stream flow, subnivean space, end of season snowfall patterns, potable water sources after each seeding event and alpine ecosystem health (the NRC considers that paired site studies may be suitable for this purpose).
- annual reporting of data and analysis of all monitoring (including the chemical marker study, snow depth and density) and infrastructure impacts
- an approved plan for evaluation of the trial and reporting on the trial.

4.2 Causing snow rather than rain

The available evidence suggests that precipitation during seeding events is falling as snow and not rain. The trial is required to produce precipitation as snow and not rain. This requirement is designed to ensure that the cloud seeding operations do not have an adverse impact on resort operators during the ski season. Snowy Hydro is undertaking monitoring, including video monitoring and verbal polling, to check that precipitation is falling as snow (and not rain) during seeding events.

The EMP requires Snowy Hydro to report on this monitoring within each annual report, but the 2005 and 2006 annual reports did not contain any information demonstrating that the required monitoring was undertaken or to confirm that precipitation is falling as snow and not rain.

4.2.1 Improvements to monitoring and reporting

Snowy Hydro demonstrated to the NRC in March 2007 that video monitoring and verbal polling is routinely undertaken using the methodology outlined in the EMP. Video monitoring is undertaken at Guthega Power Station and at the base of Thredbo and is remotely monitored from the trial's control centre in Cooma. The video images are recorded and retained. In addition, resort operators are contacted by telephone prior to the commencement of a seeding operation and are asked whether it is snowing or raining.

The trial weather monitoring infrastructure is used to provide information on surface and atmospheric weather conditions to identify conditions during which precipitation is likely to occur as snow. The primary way of measuring weather conditions is the upper air sounding taken from Khancoban. The EMP sets suspension criteria for insufficient likelihood of snow precipitation. This criterion is set to suspend cloud seeding if the 0^0 C level is above 1600 metre elevation, as determined by the Khancoban sounding.

The 2005 and 2006 annual reports show that Snowy Hydro is implementing the suspension criteria for insufficient likelihood of snow precipitation. During 2005, cloud seeding operations were suspended on three occasions during campaign three and 11 when the freezing levels rose above 1600 metre level; and during campaign eight when meteorological conditions became

unsuitable for seeding. During 2006, operations were suspended on two occasions during campaigns four and six when the freezing levels rose above 1600m level.

No complaints were reported in the 2005 or 2006 annual reports from the snowfield operators about rainfall during cloud seeding operations.

Recommendation 4.2
Snowy Hydro should report information annually regarding video monitoring and verbal polling, undertaken to ensure precipitation is falling as snow and not rain.

4.3 Affecting downwind precipitation

A significant community concern is the potential for changed rainfall patterns, particularly a reduction in downwind precipitation. The Expert Panel concluded that cloud seeding will not reduce downwind precipitation. In fact it suggests that it is likely to increase precipitation in downwind areas. This is because ice crystals formed by the seeding process last longer in the atmosphere and have a better chance of falling to the surface in the downwind areas than natural cloud droplets, which evaporate sooner and rarely grow big enough to precipitate.

As this is a sensitive issue, Snowy Hydro will need empirical evidence to verify its theoretical projections that cloud seeding will not reduce precipitation in downwind areas. No information is available yet to assess these impacts.

4.3.1 Improvements to monitoring and reporting

In accordance with the EMP, Snowy Hydro will prepare a report on the downwind effects of cloud seeding at the conclusion of the trial. The minimum requirements for reporting will include 'monitoring of precipitation downwind of the target area and evaluation for the randomised seeding events.'

Snowy Hydro has commenced development of a specific plan for analysis of downwind effects, to be included in the trial Evaluation Plan currently being developed to describe analysis that is required to be undertaken at the end of the trial. The assessment of downwind effects will include data collected from precipitation gauges installed specifically for the trial and long term historical data collected from Snowy Hydro and Bureau of Meteorology precipitation networks. In addition, the effects of natural inter-annual variability of the climate and the spatial and temporal variability of individual storms will be considered as part of the assessment.

The Evaluation Plan should be made publicly available and independently peer reviewed. Additionally, the NRC considers that data progressively collected as part of this study should be reported in future annual reports and not only at the conclusion of the trial. This would provide confidence to the community that appropriate data are being collected.

Refer to recommendation 2.3
Snowy Hydro should provide a draft plan, for Ministerial approval, of how the outcomes of the trial will be evaluated and reported.

Recommendation 4.3
Snowy Hydro should report annually the data and ongoing analysis of precipitation in downwind areas.

4.4 Increasing river flows

There should be increases in water flows in alpine and montane streams within and outside the target area if cloud seeding generates significant additional amounts of snow fall. The Expert Panel concluded that the cloud seeding trial would provide additional flows to the Murray and Snowy River catchments. However this is not being monitored by Snowy Hydro.

Snowy Hydro is currently developing a method for accounting for increased inflows resulting from cloud seeding, but this will not be applied until the completion of the trial.[18] The reliability of this modelling methodology should be assessed, the uncertainty associated with the method should be quantified and it should be independently peer reviewed. As any increased inflows to the Snowy Mountains Hydro-electric Scheme will eventually be released into the River Murray or the Snowy River, the NRC considers that Snowy Hydro should report any potential increases in river flows to catchment management authorities, water users and downstream communities.

4.4.1 Options for monitoring

Stream flow is being routinely measured by Snowy Hydro at many gauging stations both within and outside the target area and the impact of cloud seeding on stream flow could be monitored as part of the enhanced environmental monitoring program that Snowy Hydro is currently considering. As described in Section 4.1.2, a paired catchment study could be developed, combined with a comparison of before - after data, at individual gauging stations within and outside the target area. If the effect of cloud seeding in increasing stream flow cannot be detected at gauging stations it is unlikely to be of practical significance, regardless of modelling predictions.

Recommendation 4.4
Snowy Hydro should monitor impacts on stream flow.

Recommendation 4.5
Snowy Hydro should report annually the data and ongoing analysis stream flows.

Recommendation 4.6
Snowy Hydro should provide a draft methodology for Ministerial approval of how additional water generated by cloud seeding will be accounted for between the River Murray and the Snowy River.

4.5 Impact on montane riverine and alpine ecosystems

Snowy Hydro is not currently monitoring the impacts on montane riverine and alpine ecosystems as part of the trial. The Expert Panel Report concluded that there are likely to be long term beneficial impacts of snow enhancement on the alpine ecosystem. Snowy Hydro has an opportunity to monitor additional parameters to provide empirical evidence that cloud seeding is likely to benefit the alpine ecosystem.

The Expert Panel also stated that cloud seeding could impact on a range of environmental parameters without causing ecotoxicity. The trial presents an opportunity to establish empirically whether cloud seeding will improve the health of alpine and montane streams and

[18] Verbal advice from Snowy Hydro.

terrestrial alpine ecosystems, without causing adverse environmental impacts. The Expert Panel suggested that monitoring should be undertaken for various parameters, including: focal species monitoring; functional species monitoring for flora and fauna; and monitoring of levels of silver and indium in aquatic biota, and changes in these levels during and following the trial.

4.5.1 Options for monitoring

The structure of the macroinvertebrate and fish communities in montane streams could be assessed as part of a paired catchment study as described in Section 4.1.2. In addition, it would be beneficial for Snowy Hydro to develop and monitor indicators for alpine ecosystem health, in consultation with DECC.

Recommendation 4.7
Snowy Hydro should monitor impacts on macroinvertebrate and fish communities in alpine and montane streams, and changes in terrestrial alpine ecology.

4.6 Changing habitat for snow-dwelling fauna

A reduced subnivean[19] space and a combination of early snow melt and late season snow falls may constitute a threatening process for the mountain pygmy possum and other small snow-dwelling mammals. Snowy Hydro is not monitoring this potential environmental impact.

Subnivean space is created when snowpack is suspended above the ground within areas of low vegetation. These spaces can become a home and transport corridor for small mammals, such as the mountain pygmy possum and the broad-toothed rat. The snow cover provides insulation from temperature extremes and protection from predators such as foxes.

There is anecdotal evidence that seeded snow tends to be of smaller particle size and is denser than unseeded snow.[20] This may reduce subnivean space which may impact on the habitat of snow dwelling fauna.

In recent years the snowpack has tended to melt relatively early in the season only to be followed by one or more snow events late in the season. Cloud seeding could be beneficial if it delays early season snow melt. Alternatively, it could have a negative impact on the small mammals if it contributes to late season snow events following significant snow melt.

DECC ecologists consider that the combination of early snow melt and late snow events could constitute a threatening process for the mountain pygmy possum and other small mammals. Early snow melt results in the possum coming out of hibernation earlier, which does not coincide with the normal arrival time of the Bogong moth, a major food source for both the possum and the fox. As the possum has to search further for food with already depleted energy levels, it becomes an easy target for the fox. Late snowfall due to cloud seeding, following early snow melt, may compound this problem.

19 Subnivean space is the space between the ground and the underside of the snowpack.
20 Refer to Section 12.16.2 Effects of Seeding on Snow Density, of the Expert Panel Report.

4.6.1 Options for monitoring

Comparative measurements of subnivean spaces and re-analysis of snow course data may be necessary to study the impact of cloud seeding on snow-dwelling fauna. Snowy Hydro is not specifically collecting any data related to these issues as part of the trial.

The impact of seeded snow on subnivean space could be monitored by collecting and analysing data using a paired catchment study, as described in Section 4.1.2. Measurements for such a study should be taken at sites other than snow courses, as snow courses are mainly located within grassed areas, which have limited subnivean spaces.

Alternatively, Snowy Hydro could work with DECC to obtain information that would be useful to determine the impact of seeding on subnivean space. DECC is planning research to test the impact of snowfall patterns on fauna and monitoring will include snow melt, moth arrival dates, occurrence of late snow events, routine small mammal trapping and may include measurement of subnivean space.

In addition, it would be useful for Snowy Hydro to analyse the snow course data currently being collected to establish what effect, if any, cloud seeding has had on delaying the onset of snow melt and on inducing late season snow falls.

Recommendation 4.8
Snowy Hydro should monitor of impacts on snow dwelling fauna, including the effects of cloud seeding on habitat (subnivean space) and end of season snowfall patterns.

5 Ecotoxicity impacts

No significant ecotoxic impact has been detected by Snowy Hydro. However, the current monitoring program is not thorough enough to eliminate the potential for localised impacts within the large target area or the extended area potentially impacted by the seeded plume. Accordingly the NRC does not support claims that there is no significant environmental impact arising from the use of the seeder and tracer agents.

During the 13 cloud seeding campaigns of the 2005 season, 23.2kg silver iodide and 20.0kg indium trioxide were discharged to the atmosphere. During the 8 seeding campaigns of the 2006 season, 6.8kg silver iodide and 6.1kg indium trioxide were discharged to the atmosphere. The ecotoxic impact of these amounts would be negligible if they were distributed uniformly over the target area (an area of greater than 1000km^2). However, it is unlikely that distribution during operations would be uniform.

The release of silver iodide and indium trioxide as part of the cloud seeding trial may have an ecotoxic impact on alpine and montane terrestrial and riverine ecosystems. However the Expert Panel Report considered this risk to be low. Snowy Hydro undertook some monitoring during the 2005 and 2006 seeding seasons to examine the accumulation of silver iodide and indium trioxide in soils and potable water and hence the potential for ecotoxic and human health impacts, respectively. However monitoring of river ecosystems has not been undertaken to date.

The NRC considers that the monitoring approach should be further improved and that Snowy Hydro should report annually on monitoring results.

5.1 Silver and indium in potable water sources

There is potential for pollution of potable water sources due to the discharge of silver iodide and indium trioxide into the atmosphere. Snowy Hydro sampled potable water from eight sites at the end of the 2005 and 2006 seasons, and the maximum values recorded for silver and indium were well below the ANZECC Guideline Trigger Value (GTV) of 0.1 mg/L. [21]

Table 3.1 shows the comparison of metal concentration (maximum values recorded) at each site for the 2005 and 2006 sampling periods. The maximum concentration for silver was 9.5×10^{-7} mg/L and 1.2×10^{-7} mg/L for indium at the end of the 2006 season. As both these maximum values are well below the GTV of 0.1 mg/L, there is no evidence from these samples of potential human health effects from potable water sources.

The NRC considers that this monitoring, based on a single late-season grab sample at each monitoring site, would not necessarily detect pollution from cloud seeding operations, as both silver and indium settle out of the water column over time.

[21] ANZECC Drinking Water Quality Guideline value.

Table 5.1 Maximum value metal concentration in potable water sources in the target area

Site	Silver Maxima (x 10^{-7} mg/L)		Indium Maxima (x 10^{-7} mg/L)	
	2005	2006	2005	2006
Blue Cow	6.4	3.2	0.7	0.5
Charlotte Pass	4.1	2.9	0.6	0.2
Farm Creek	3.5	5.1	0.4	0.3
Perisher	4.0	2.9	0.5	0.3
Rainbow Lake	3.7	9.5	0.9	1.2
Smiggin Site 6	3.3	2.7	1.1	0.9
Merrits Creek	2.2	2.5	1.1	0.2
Thredbo River	4.7	5.2	0.9	0.2

5.1.1 Weakness of monitoring approach

The NRC believes that water samples taken at the end of each season, as opposed to samples taken shortly after a precipitation event, are likely to have lower metal concentrations due to silver and indium combining with organic matter over time and settling at the bottom of a water source. To determine the impact of silver and indium on potable water sources, water monitoring should be undertaken shortly after each precipitation event.

Recommendation 5.1
Snowy Hydro should extend current ecotoxicity monitoring to include sampling of potable water sources, recently after each cloud seeding event before silver and indium settle out of the water column.

5.2 Silver and indium in soils

Snowy Hydro investigated pre-trial levels of silver and indium in soil within four zones to ensure the guideline trigger values (GTVs) nominated in the EMP were appropriate. Further sampling was conducted at the end of the 2004, 2005 and 2006 seasons. Snowy Hydro provided the NRC with the data collected. The NRC compared trends of the means, standard deviations and maximum values in silver and indium concentrations in soil (including meadow soil). The analysis is presented in Tables 2.1 and 2.2 and Figures 2.1 and 2.2.

The NRC found that the concentrations of total[22] silver and indium at all sites monitored were below the relevant ANZECC Guideline Trigger Values (GTV) with the exception of five samples collected from one sample location during the 2006 sampling period. These samples showed concentrations of total indium higher than the GTV. These results triggered Snowy Hydro's protocol to further analyse these samples for the bioavailable levels of indium. This demonstrated that the bioavailable indium levels were all well below the GTV.

Table 5.2 Total silver concentration trends in soil within four surveyed zones

Site	Mean Ag (mg/kg)		Maximum Ag (mg/kg)	Mean and Maximum below GTV*?
	Pre-trial	Post 2006		
Generator sites	0.07	0.10	0.72 at end of 06	yes
Intermediate area	0.10	0.04	0.22 at end of 04	yes
Target area	0.05	0.07	0.15 at end of 06	yes
Downwind area	0.06	0.06	0.17 at end of 04	yes

* GTV = 1mg/kg

Table 5.3 Total indium concentration trends in soil within four surveyed zones

Site	Mean In (mg/kg)		Maximum In (mg/kg)	Mean and Maximum below GTV*?
	Pre-trial	Post 2006		
Generator sites	0.05	0.09 and 0.07#	2.18 at end of 06^	no~
Intermediate area	0.05	0.04	0.06 at end of 05	yes
Target area	0.04	0.05	0.08 at end of 06	yes
Downwind area	0.04	0.10	0.29 at end of 06	yes

* GTV = 1mg/kg
# 0.09mg/kg reflects the mean of results from the first round of sampling, including the results from Granite Knob which were above the GTV of 1mg/kg for total indium. 0.07mg/kg reflects the mean of results using second round sampling values from Granite Knob, which were below the GTV of 1mg/kg for total indium.
^ 2.18mg/kg was the maximum value recorded for total indium from the first round of sampling undertaken in 2006, which included values above the GTV of 1mg/kg at Granite Knob.
~ The maximum total indium level exceeded the GTV, however the bioavailable indium level was below the GTV.

5.2.1 Additional indium analysis

During the initial 2006 sampling period, five samples collected from the Granite Knob generator site were found to have total indium concentrations greater than the 1.0mg/kg GTV, with concentrations ranging from 1.23 mg/kg to 2.18 mg/kg. All five samples were taken from the same sample location, which is immediately north east of the indium generator. The sample location immediately north west of the indium generator also returned relatively high total

22 Total concentration is the analysed concentration of an element (in this case silver or indium) determined from a homogeneous sample, that is, the sample has not been separated into fine and coarse fractions prior to analysis.

indium concentrations for all five samples, with concentrations ranging from 0.42 mg/kg to 0.45 mg/kg.

As specified in the EMP, the five samples with concentrations above the GTV were analysed for bioavailable levels of indium. These results demonstrated that the bioavailable levels were well below the 1.0mg/kg GTV, ranging from 0.4×10^{-4}mg/kg to 0.9×10^{-4}mg/kg.

The EMP contains guidelines for collecting samples in the field which aim to provide a representative overview of contaminant levels within the area sampled. To achieve this, five soil samples should be collected from each sampling location—one sample from a mid point and four samples located around a circumference with a diameter of 7m through the mid point. Snowy Hydro advised that the sampling guidelines were not correctly followed for the entire soil sampling exercise at the end of the 2006 season and that five samples were effectively collected from the same point at each of the 104 sampling locations within the 13 generator sites.

While the sampling exercise was undertaken consistently across the entire sampling area, Snowy Hydro decided to resample the sample location with total indium concentrations above the GTV. This second round of sampling was undertaken approximately 2 months after the initial sampling period and re-sampling only occurred at one location at the Granite Knob generator site. The sampling was undertaken utilising the correct sampling protocol using a 7m diameter circle around the mid point. Snowy Hydro advised that this second round of sampling was undertaken to check if total indium concentrations remained high at this location. Results of the second round of sampling showed that total indium concentrations were below the GTV, ranging from 0.04 mg/kg to 0.07 mg/kg.

The high concentrations of total indium at the Granite Knob site could be attributed to several factors, including contamination of samples during sample collection or contamination during laboratory analysis. Alternatively, the high concentrations could have been present at the site at the time of sampling. Snowy Hydro requested the samples with high total concentrations be reanalysed for total indium and the results showed similar high concentrations to the initial analysis. This suggests that the high levels detected were not due to laboratory contamination. Snowy Hydro has commented that low precipitation rates during the 2006 season may have contributed to a build up of indium adjacent to the generator due to less dispersion of indium fall out. This theory is consistent with the very low total indium concentrations detected in second round samples, as there was significant precipitation at the site during the two months between sampling rounds. Snowy Hydro suggests that any indium located on the surface has been redistributed during heavy rainfall events.

The NRC is satisfied that Snowy Hydro's response of assessing the bioavailability of indium in samples with total concentrations above the GTV was appropriate and in accordance with the EMP and the ANZECC Guidelines. However the NRC believes that the manner in which the data were reported in the 2006 Annual Report is inappropriate. As all of the samples collected in 2006 followed the same sampling process, the high total concentrations should have been presented in the tables and graphs with the data for the other sites. The bioavailability data and total concentration from later sampling should have been reported separately.

5.2.2 Trend analysis

The NRC's analysis of data provided by Snowy Hydro shows that a maximum value total silver concentration of 0.72mg/kg was detected at the generator sites at the end of the 2006 season. The large standard deviation during 2006 for generator sites (see large standard deviation bars in Figure 2.1(a)) reflects the big differences in concentrations of silver across the various

generator sites. This is in contrast to the intermediate, target and downwind sites (see small standard deviation bars in Figure 2.1(b), (c) and (d)), where large differences between sites were not found. All of the mean and maximum values detected were well below the GTV value of 1mg/kg.

A maximum value total indium concentration of 2.18mg/kg was detected at the generator sites at the end of the 2006 season. This was above the GTV for total indium, but was below the GTV for bioavailable indium when analysed. The large standard deviation during 2006 for both generator and downwind sites (see large standard deviation bars in Figure 2.2(a) and (d)) reflects the variation in concentrations of indium detected across the various generator and downwind sites. This contrasts with the intermediate and target sites (see small standard deviation bars in Figure 2.2(b) and (c)), where the concentrations for indium were more consistent across the sites. Mean and maximum values detected were well below the GTV value of 1mg/kg, except for the maximum value for the generator sites, which significantly exceeded the GTV for total indium.

Figure 5.1 Trends in the mean concentration of silver in soil within each of the four zones surveyed over the survey periods to-date

(Error bars show standard error. '2004,' '2005'and '2006' indicate surveys conducted at the end of the 2004, 2005 and 2006 seeding seasons respectively. Guideline Trigger Values from the ANZECC and ARMCANZ (2000) guidelines are 1mg/kg.)

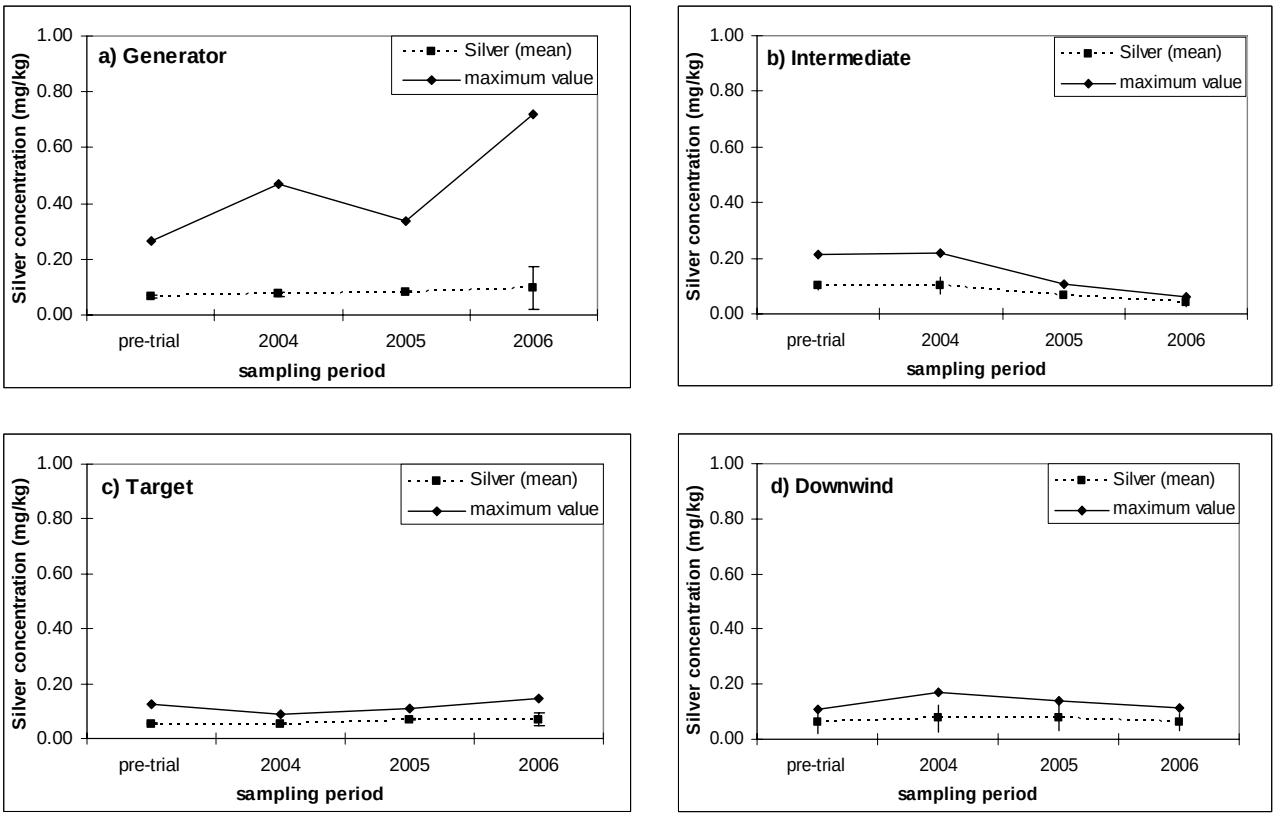
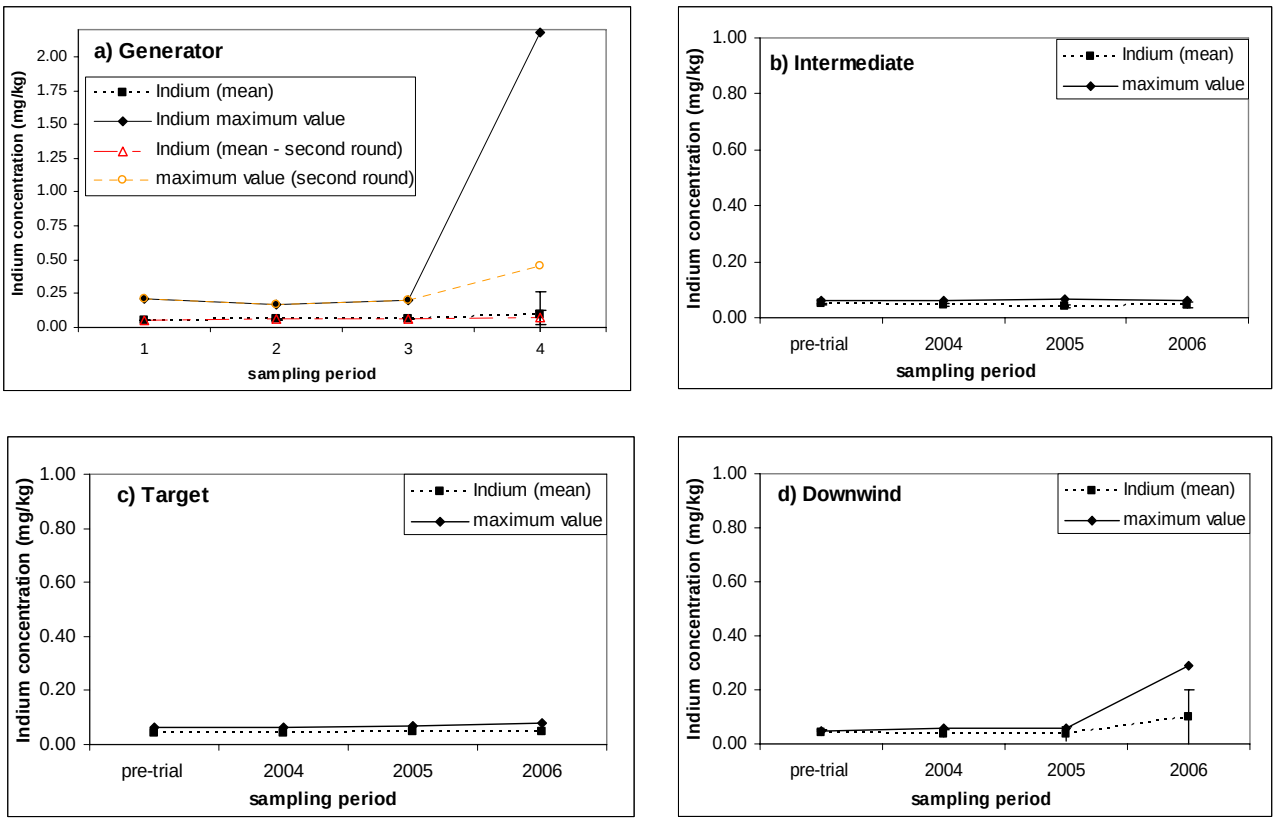


Figure 5.2 Trends in the mean concentration of indium in soil within each of the four zones surveyed over the survey periods to-date

(Error bars show standard error. '2004,' '2005'and '2006' indicate surveys conducted at the end of the 2004, 2005 and 2006 seeding seasons respectively. Guideline Trigger Values from the ANZECC and ARMCANZ (2000) guidelines are 1mg/kg.)



5.2.3 Weakness of monitoring approach

The density of sites sampled is still too low to categorically indicate that accumulation of silver or indium is not occurring at any location within Kosciuszko National Park.

The ecotoxicity survey design was amended prior to the commencement of the 2005 season based on the NRC's recommendation to:

- analyse all samples for total silver and indium concentrations (but not for bioavailable silver or indium unless GTV was exceeded)
- include additional locations in the sampling plan
- limit water monitoring to potable supplies only.

Subsequently, Snowy Hydro did not measure bioavailable silver and indium in the 2005 season, as all total silver and indium concentration values were below the relevant GTV. Snowy Hydro will continue to only analyse samples for bioavailable levels of silver and indium if the total concentration GTV is exceeded.

Snowy Hydro has also restricted water sampling to potable sources and has added additional potential terrestrial accumulation zones to the sampling plan for silver and indium. Sampling intensity in the target area was increased by monitoring 16 additional sites for metal concentrations in moss, peat and meadow soil. There were no changes in the monitoring

program in the generator, intermediate and downwind areas. Table 2.1 shows a comparison of monitoring undertaken at the sites.

The current survey is designed to detect whether silver or indium dispersed across a 1000km^2 area have accumulated at one of the sites being monitored, such that they might become toxic to plant or animal life at that site. Given the very small amounts of these chemicals used in the trial and the randomness of their distribution across the target area, the NRC considers that finding an accumulation at one of the very few sites is a very unlikely outcome.

The NRC considers that the results from sampling at so few sites are insufficient to assess whether cloud seeding is causing an ecotoxic impact over the entire target area. If Snowy Hydro wishes to rely on the ecotoxicity survey to provide credible support to claims about the absence of 'significant adverse environmental impacts' then the survey design would need to be amended to increase its statistical power and make it more representative of the intermediate, target and downwind areas.

Table 5.4 Comparison of monitoring sites

Location	Matrix	Number of sites		
		Pre-trial	2004 Season	2005 Season onwards
Generator	Soil	12	12	13
Intermediate Areas	Soil	3	3	3
Target Area	Sediment	2	2	2
	Potable water	8	8	8
	Alpine humus	16	16	16
	Moss/Peat	4	4	16
	Meadow soil	4	4	8
Downwind Areas	Soil	3	4	4

6 Response to previous NRC recommendations

During 2004, Snowy Hydro established and tested its cloud seeding equipment and developed protocols to monitor the effectiveness of its cloud seeding operations and their environmental impacts. The NRC recommended a number of improvements to the trial's experimental design and environmental monitoring based on a review of the trial's 2004 Annual Report.

Snowy Hydro has only adopted one of the five recommendations from that November 2005 report. This has meant that some opportunities to enhance the experimental design of the trial have been lost, and that environmental monitoring and reporting remains inadequate. The recommendations contained in this report address the NRC's concerns that are discussed below.

6.1 Should Snowy Hydro still take action on these matters?

The NRC is still concerned that the weaknesses in the environmental monitoring will mean that the trial cannot scientifically prove whether or not cloud seeding causes environmental impacts. Each of the recommendations is listed and discussed below.

NRC 2005 Recommendation 1
The experimental design of the trial should be amended to incorporate a conventional control area.

The NRC considers that it is now too late to act on this recommendation, and has recommended other options to improve the scientific credibility of the trial.

The lack of a conventional control remains a serious weakness in the trial's experimental design. While a conventional control is not essential to the assessment of the success of cloud seeding, it is important for the assessment of the range of impacts. To determine clear links between cause and effect in a large field experiment of this type, a 'Before - After - Control - Impact' type design should be used. Without a conventional control, this is not possible.

Snowy Hydro argues that there are no comparable areas that could be used as a conventional control. Topographical and management constraints for the trial have already led to a target area which is uncomfortably small for aiming the effects of cloud seeding. The proposed evaluation of the trial will include classical statistical analysis of the seeded versus non-seeded events, incorporating a variety of covariates, including precipitation measured in an upwind area unaffected by the seeding.

The NRC considers that the statistical analysis referred to by Snowy Hydro is relevant only to the assessment of the success of cloud seeding in increasing snowfall. It makes no contribution to the assessment of the trial's other impacts. The current experimental design will not establish links between cause and effect for these impacts. However, it is now too late to incorporate a conventional control area into the experimental design as the preliminary season and two of the five trial seasons have already been completed. The opportunity to introduce a conventional control for the environmental assessment passed when the first experimental year commenced.

An option to improve the scientific credibility of the environmental assessment would be to undertake paired catchment or site studies, as described in Section 4.1.2, for relevant environmental parameters. Alternatively some before-trial, during-trial and following-trial comparisons should be considered where available data enable this.

NRC 2005 Recommendation 2
Additional parameters should be monitored to enable a balanced assessment of the potential environmental impacts, including:
- *changes in snowpack density*
- *downwind precipitation*
- *changes in water yield and river flows*
- *changes in alpine and montane stream ecology.*

The NRC still considers that Snowy Hydro should undertake additional monitoring, and reporting, to provide additional lines of evidence to strengthen the scientific credibility of the outcomes of the trial.

The same concerns regarding the narrowness of current environmental monitoring, that were raised by the NRC in 2005, are also considered earlier in this report. There is still an opportunity to act on this recommendation and it should be taken.

NRC 2005 Recommendation 3
Any relocation of cloud seeding equipment should be avoided to minimise local impacts.

The NRC considers that Snowy Hydro has adopted this recommendation. The impacts of relocation of equipment by Snowy Hydro have been well managed, consistent with the requirements of the EMP.

The NRC noted that before the 2005 season, two generators were relocated further north and three new generator sites were established. The 2005 Annual Report does not provide any information on the condition of sites after rehabilitation. The NRC inspected the rehabilitated and new generator sites and considers that Snowy Hydro has acted in an environmentally responsible manner. Snowy Hydro should provide details within its annual reports on site rehabilitation and local environmental impacts of relocating any cloud seeding equipment. –

NRC 2005 Recommendation 4
The ecotoxicity survey design should be amended to increase its statistical power.

The NRC still considers that the design of the ecotoxicity survey should be improved.

Snowy Hydro agrees that the current survey design is extremely conservative. It argues that the Expert Panel concluded that the trial is a very low risk action. The trial operates at a large landscape scale and its chemical effects and trace additions can only be measured through highly sophisticated means of chemical analysis. The targeted risk-based approach to routine monitoring that is being deployed has the sensitivity to pick up early signs of impacts in the most likely zones of accumulation of silver and indium. Specific ecotoxicity studies will be undertaken if there is a clear pattern of accumulation above the GTVs.

The current survey is designed to detect whether silver or indium dispersed across a 1000km^2 area have accumulated at one of the sites being monitored, such that they might become toxic to plant or animal life at that site. Given the very small amounts of these chemicals used in the trial and the randomness of their distribution across the target area, the NRC considers that finding an accumulation at one of the very few sites is a very unlikely outcome.

The NRC considers that the results from sampling at so few sites are insufficient to assess whether cloud seeding is causing an ecotoxic impact over the entire target area. If Snowy Hydro wishes to rely on the ecotoxicity survey to provide credible support to claims about the absence

of 'significant adverse environmental impacts' then the survey design would need to be amended to increase its statistical power and make it more representative of the intermediate, target and downwind areas. If so, then additional baseline data should also be collected.

NRC 2005 Recommendation 5
The ecotoxicity protocols should be refined.

The NRC considers the monitoring for ecotoxity would also be assisted by analysing the ecotoxicity data for trends. The NRC has done that in Chapter 5 and considers that such analysis should be undertaken and reported by Snowy Hydro in future annual reports.

Attachment 1 Recommendations

Recommendations regarding evaluation of the trial

The Ministers should consider requiring Snowy Hydro to provide the following information. These will support current claims regarding the effectiveness of cloud seeding, and improve confidence that the evaluation of the trial will meet the needs of the Government.

- Snowy Hydro should provide data collected for the chemical marker study for the 2004, 2005 and 2006 seasons, and analysis of that data assessing the effectiveness of cloud seeding in the Snowy Mountains (**Recommendation 2.1**).
- Snowy Hydro should provide a draft plan, for Ministerial approval, of how the outcomes of the trial will be evaluated and reported (**Recommendation 2.3**).
- Snowy Hydro should provide a draft methodology for Ministerial approval of how additional water generated by cloud seeding will be accounted for between the River Murray and the Snowy River (**Recommendation 4.6**).

Recommendations regarding the Environmental Management Plan

The Ministers should consider requiring Snowy Hydro to review the trial's Environmental Management Plan (EMP), to allow improved assessment of a broad range of potential environmental impacts and improved understanding of the impacts of cloud seeding, by:

- Snowy Hydro should provide an improved EMP, which includes:
  - ongoing monitoring of parameters including downwind precipitation, stream flow, subnivean space, end of season snowfall patterns, potable water sources after each seeding event and alpine ecosystem health (the NRC considers that paired site studies may be suitable for this purpose).
  - annual reporting of data and analysis of all monitoring (including the chemical marker study, snow depth and density) and infrastructure impacts
  - an approved plan for evaluation of the trial and reporting on the trial (**Recommendation 2.2**).

Detailed recommendations regarding monitoring

Improved monitoring in the EMP would allow assessment of a broad range of potential environmental impacts caused by cloud seeding, by including the following.

- Snowy Hydro should monitor of impacts on snow dwelling fauna, including the effects of cloud seeding on habitat (subnivean space) and end of season snowfall patterns (**Recommendation 4.8**).
- Snowy Hydro should extend current ecotoxicity monitoring to include sampling of potable water sources, recently after each cloud seeding event before silver and indium settle out of the water column (**Recommendation 5.1**).

- Snowy Hydro should monitor impacts on macroinvertebrate and fish communities in alpine and montane streams, and changes in terrestrial alpine ecology (**Recommendation 4.7**).
- Snowy Hydro should monitor impacts on stream flow (**Recommendation 4.4**).

Detailed recommendations regarding reporting

Improved reporting on the EMP would allow improved understanding and oversight of the environmental impacts of cloud seeding, by including the following.

- Snowy Hydro should report annually the data and ongoing analysis on the progress of the chemical marker study (**Recommendation 4.1**).
- Snowy Hydro should report annually the data and ongoing analysis of precipitation in downwind areas (**Recommendation 4.3**).
- Snowy Hydro should report annually the data and ongoing analysis stream flows (**Recommendation 4.5**).
- Snowy Hydro should report information annually regarding video monitoring and verbal polling, undertaken to ensure precipitation is falling as snow and not rain (**Recommendation 4.2**).
- Snowy Hydro should report information annually regarding:
  - techniques used to minimise the impacts of installing and removing equipment
  - environmental management of operating and maintaining cloud seeding equipment
  - progress with site rehabilitation (**Recommendation 3.1**).

Attachment 2 Sites visited by the NRC during 2006 and 2007

Site	Site type	Infrastructure at time of site inspection
Blue Calf	Remote Sensing Facility	2D probe (ice crystal structure); anemometer; temperature, humidity monitoring; liquid water in clouds monitoring; video monitoring
Guthega Pondage	monitoring – pluviometer reference site	3 pedestal pluviometers (full, half and no DFIR*), 2 old tipping bucket pluviometers, anemometer, snow sampling board
Mt Anderson	monitoring	tripod pluviometer
Perisher Resort (Rock Creek)	monitoring	2 tripod pluviometers (with and without DFIR)
Rams Head	monitoring	tripod DFIR pluviometer, snow sampling board
Spencer's Picket	monitoring	pedestal DFIR* pluviometer
Threadbo	monitoring	tripod pluviometer
White's River	monitoring	pedestal DFIR pluviometer, snow sampling board, snow course
Grey Hill	generator and monitoring	silver generator, indium generator, pedestal DFIR pluviometer, pedestal pluviometer, snow sampling board
Grassy Flat	generator	silver tower generator, indium tower generator
Indi	generator	silver generator, indium generator
Murray 1	generator	silver generator, indium generator
The Quarry	abandoned generator	NA
Tom Groggin	abandoned generator	NA

* Double Fence Inter-comparison Reference type wind fence