NORTH AMERICAN WEATHER CONSULTANTS' POSITION STATEMENT

Issued January 2004 Regarding
The National Research Council's October 2003 Report
"Critical Issues in Weather Modification Research"

THE NRC REPORT

In October 2003, the National Research Council (NRC) released a report entitled *Critical Issues in Weather Modification Research*, which was prepared by their "Committee on the Status and Future Directions in U.S. Weather Modification Research and Operations." The NRC also produced a brief summary of the full report. That summary is entitled *Report In Brief - Critical Issues in Weather Modification Research*. The NRC committee's charge, as stated in the Executive Summary of the full report, was "to provide an updated assessment of the ability of current and proposed weather modification capabilities to provide beneficial impacts on water resource management and weather hazard mitigation." The full report and the *Report in Brief* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001 or via their web site at www.nap.edu/catalog/10829.html.

NAWC's SUMMARY RESPONSE

We at North American weather Consultants (NAWC) view the NRC report as simply a statement of opinion in favor of research, fundamentally a call for basic research into atmospheric processes, with potential eventual application to the field of weather modification. The report fails to provide an accurate, objective assessment of the current capabilities of the weather modification field, part of its stated basic charge. We reject the notion stated in the report that "the initiation of large-scale operational weather modification programs is premature." NAWC embraces a practical stance advocating continued application of weather modification at the current state of the art, in well designed and conducted projects. We have historically supported and continue to support focused research into weather modification issues, maintaining openness to operational and evaluation refinements once convinced that they have practical value. Our opinions regarding various statements in the report pertaining to weather modification issues are presented below.

1. Weather Modification Research

The NRC report does a rather thorough job of describing the various facets of weather modification which could benefit from further research capitalizing on enhanced research tools and methods. NAWC whole-heartedly supports the concept of continuing research into key facets of weather modification. This is healthy for any discipline. We are in agreement, in principle, with the committee in its call for research,

especially considering advancing observational, data analysis and atmospheric modeling capabilities in the community at large. However, we take exception to the approach and associated potential timeline the NRC authors have proposed. This point is further developed below in Differences in Perspective and Approach.

- The ability of nucleating agents such as silver iodide to produce microphysical changes in supercooled clouds has been unequivocally established. Operational application of cloud seeding is concerned largely with what could be referred to as the engineering aspects, e.g., opportunity recognition, seeding materials, seed rates, targeting and estimations of effectiveness. A fairly compelling body of evidence exists in support of that concept. Some experimental projects have shown positive effects with statistical significance. In addition, a significant number of other analyses, although lacking the statistical rigor and purity desired by some researchers, have rather consistently indicated positive effects of cloud seeding. A particularly rich source of references to a multitude of cloud seeding experiments and project evaluations can be found in Todd and Howell (1985). Thus, for most of those actively involved in the discipline, the basic questions do not include whether cloud seeding works, but, rather, how best to correctly apply the technology in each situation and how to assess the effects and results. This is where research can contribute, by addressing the "links in the chain" of the physical processes involved, to refine our understandings, our operational procedures and to develop and fine tune evaluation methods. Discussion can (and likely will) continue *ad infinitum* regarding the level of proof required to convince the various factions as to the effectiveness and utility of cloud seeding technology.

2. Weather Modification Capabilities

- The NRC report fails to provide an accurate, objective assessment of the current capabilities of the weather modification field, part of its stated basic charge. The committee refers to the scientific and operational communities' failure to "provide scientifically demonstrable success", a lack of "unequivocal scientific evidence," etc, but the authors fail to define the criteria by which they made their judgments. Reference is made to "strong suggestions of positive seeding effects in winter orographic glaciogenic systems", apparently indicating awareness of the rather large and, to some, rather compelling, body of positive evidence from decades of evaluations of some research projects and a multitude of operational seeding programs (as noted above). However, the committee does not specify what (if any) objective criteria may have been applied in assessing that large body of information. Thus, it is impossible to determine whether their findings are objective, biased, credible, or even correct. Due to the lack of specificity regarding the level of proof required for their statements and conclusions, **in our opinion, the report is seriously lacking as an assessment of current weather modification capabilities from either the operational or scientific perspectives**. By restating verbatim a 1964 NAS study conclusion regarding the

status of weather modification, the authors of the 2003 report are apparently of the opinion that nothing of consequence has occurred in the discipline to advance weather modification capabilities in nearly forty years.

- We take exception to the report's negative statements and inferences regarding the efficacy of weather modification operations. Those statements and inferences are based upon undefined criteria. **We reject the notion that "the initiation of large-scale operational weather modification programs is premature."** Due to the lack of evidence presented in the report, we consider that notion to be unfounded and illogical. In our opinion, the report paints an unrealistically negative picture of the overall discipline, evidenced by the rash of negative media coverage following its release, **the media consistently seizing on the message that cloud seeding "doesn't work."**

- Given reference in the report to a need to "demonstrate that the effects are entirely reproducible," we suspect that the "unequivocal scientific evidence" the authors of the report are alluding to includes a strong statistical evaluation component which may include a requirement of statistical significance at the .05 level or better. This means that there would only be a 5% or less probability that the indicated effects occurred by chance or, in other words, a 95% probability that there is a physical reason for the indicated effects. That level of significance has frequently been noted in the literature and at scientific meetings. We have two comments. First, requirement of the .05 level may well be inappropriate for experimentation in the atmosphere which, as we all know, exhibits great variability amongst a host of variables. It is more appropriate for true laboratory experimentation (e.g., clinical medicinal trials) where the experimental conditions can be tightly controlled. Second, the notion that "initiation of large-scale operational weather modification programs is premature" seems all the more illogical or inconsistent when viewed in the context of other decision making in applied meteorology. For example, weather forecasting in general is certainly not correct $\geq$95% of the time and entirely reproducible. Should the U.S. government and a host of private weather forecasting companies stop issuing weather forecasts because of a lack of this unrealistically high accuracy? The same can be said regarding issuance of severe weather warnings, for quantitative precipitation forecasting and for estimations of probable maximum precipitation used in dam design. Shall these facets of applied meteorology be halted because they don't currently satisfy those criteria? **The NRC report fails to provide even a brief summary of the number of research cloud seeding programs that have been conducted in the U.S. and a number of other countries.** Many of these programs were designed with the requirement that a 5% statistical significance level be achieved to be considered successful. Some of these programs even met this requirement, but they were not replicated and some "scientists" challenged the apparent positive results on other statistical grounds. Others, after the fact, stated that even with indicated statistically significant results, the results were still not conclusive since there was no

independent physical verification of the results. Many of these research programs indicated positive effects from cloud seeding, although some did not reach the level of statistical significance mandated in their program designs. Thus they were typically labeled as "inconclusive" or even (sadly) as "failures." The familiar conclusion reached, as often seems to be the case with research, was that the results are "encouraging" but more research is needed. **Table 1 provides a summary of the results of a number of randomized projects which report results significant at the .05 level or better. Table 2 shows a few additional landmark program evaluation results. The tables** contain citations regarding these programs. The two tables do not constitute an exhaustive collection of project references, but illustrate our point. Clearly, there is considerable evidence available that cloud seeding does work.

- Despite the difficulty in objectively quantifying the absolute values of seeding effects, we feel that the large body of positive indications reported by many, plus many analyses in the literature, constitute a collective positive signal/trend that is difficult to miss (see, for example, Todd and Howell, 1985). Objective consideration of the entire body of evidence, ranging from *a-posteriori* analyses in operational project reports to carefully designed and conducted research-oriented operations and analyses leads us to the conclusion that cloud seeding, when properly conducted, can, in some areas, have a positive effect on precipitation. Our position is supported by one of the observations of the NRC report noting an increase in operational cloud seeding programs in many parts of the world in recent years with a dramatic decrease in research funding for such programs. Are the numerous sponsors of these operational programs naive? We think not. Many clients are professional water managers (engineers, hydrologists, etc.) accustomed to making professional decisions based upon the available information. It is worth noting that the American Society of Civil Engineers (ASCE) has embraced cloud seeding for over four decades, even to the extent that ASCE has developed and published "Guidelines for Cloud Seeding to Augment Precipitation" ASCE Manual of Professional Practice No. 81 (first published in 1983, revised in 1995 and currently undergoing a third revision). Further, the ASCE is in the process of publishing standard practice documents regarding various applications of weather modification, such as hail suppression, precipitation enhancement and supercooled fog dispersal. The American Meteorological Society (AMS), the World Meteorological Organization (WMO) and the Weather Modification Association (WMA) have for decades maintained weather modification capability statements. The WMA statement is shown below.

- We note that those making a variety of important day to day decisions are doing so with less confidence than that required by the "scientific" community in evaluating cloud seeding programs (e.g., only a 5% possibility of making the wrong decision). **We submit that few of us in our daily lives have the luxury of making decisions that are 95% certain of being right.** Decisions regarding

sponsorship of operational cloud seeding programs can perhaps best be viewed as risk management assessment. What is the risk of making the wrong decision weighed against the potential benefit/cost ratio? Numerous studies have demonstrated that a 10-15% increase in precipitation can provide sizable benefits to a variety of beneficiaries (irrigated agriculture, hydroelectric power production, municipal water supplies, groundwater recharge) at very favorable benefit/cost ratios of 5-10/1 or higher. See, for example, Griffith and Solak (1999), Griffith and Solak (2002) and Henderson (2003). **A practical example:** If a potential sponsor of a cloud seeding program, following careful deliberation, decided that an 80% likelihood of obtaining a 10% increase in precipitation that would yield a benefit/cost ratio of 10/1 existed, what do you think the potential sponsor's decision would be?

3. Professional Responsibility

- All responsible individuals involved in weather modification recognize that continued research into critical facets of the discipline would be helpful and support the concept of **applied research** based on objective assessment of the status of weather modification and identification of the aspects of the field where such research would be most beneficial. We view the type of research advocated in the NRC report to initially be basic, not applied, research. Unfortunately, whether intended or not, the real-world effect of the report's release has been a blitz of media attention focused on **the media's consistent bottom line conclusion, that the NRC report states that cloud seeding doesn't work**. That interpretation is then used by the media to goad operators and researchers into responding, the perfect grist for the media's approach to "reporting" which seems to focus on controversy and sensationalism. So, the statements and inferences found in the NRC report have yielded much skepticism which, via the media, affects/becomes the public perception of the weather modification discipline overall. In the interest of building a convincing case for the utility of additional research, the NRC report has, in our opinion, overstated the degree of uncertainty associated with the effectiveness of weather modification.

- Like it or not, we cannot operate in a vacuum when generating reports and statements with potentially far-reaching consequences. In such circumstances, we all have a professional responsibility to define our assessment criteria, state the certainty or uncertainty associated with estimations of seeding effects and put our conclusions in the proper context. **Those outside the immediate ranks of this discipline (which includes most of the members of the committee that was formed to develop the NRC report)** are not necessarily attuned to the subtleties and fine distinctions regarding the level of proof appropriate to various situations, so the responsibility for providing objective information or opinions appropriate to the circumstances rests squarely on those individuals or groups issuing the statements. The level of proof issue is paramount. For <u>any</u>

statements to be considered credible and responsible, they must address the level of proof issue squarely and at the appropriate level, whether issued by the operational, regulatory, user or research communities - no exceptions. All parties have the professional responsibility to address the issues appropriately.

4. Differences in Perspective and Approach

It is clear that distinctly different perspectives exist regarding the current status of weather modification and the appropriate next steps in the discipline. The glass half empty versus half full analogy has some relevance here.

- On one hand, some "scientists"' (glass half empty) perspective seems to dwell on every conceivable aspect where understandings may fall short of being complete in every detail. Their response (approach) to the issues seems to be to stop conducting operations (e.g., the "premature" statement addressed earlier) for potentially decades (their estimate) and study all these conceivable aspects until they are understood in every detail and all the links and interrelationships in the chain of physical steps are fully explored. After perhaps a decade or more studying basic atmospheric processes (see pages 67-68 in the NRC report Conclusions and Recommendations), they would eventually turn to actual modification issues and, after perhaps another decade or so (our speculation), design meticulous exploratory, then confirmatory, experiments, seeking the prize of statistical significance and repeatability. However, in the process of conducting this further experimentation, someone undoubtedly would introduce a new observational tool or perhaps a new theory, or increase the gain on one or more of the observational systems, and a whole new round of questions would arise, potentially generating yet additional uncertainties and burning issues crying out for "understanding" before moving on to operational application. This potentially endless loop of investigation delaying action can be detrimental.

- On the other hand, the more operationally inclined (*vis a vis*, practical) members of the community, the glass half full folks, a) see the overall positive indications and trend in the full body of evidence, b) appreciate the potential great good that can result from application of cloud seeding technology, c) recognize (and apprise others of) the levels of uncertainty involved, d) weigh all the various factors, e) support and monitor the progress of <u>focused</u> research, implementing useful findings when appropriate and f) proceed. They do not see a need to stop operations while research proceeds. Their perspective and approach favor operations and research operating in parallel, with cooperation whenever and wherever practical. They are comfortable with proceeding, maintaining openness to operational and evaluation refinements once convinced that they have practical value.

5. NAWC's Perspective and Approach

NAWC embraces a practical stance and advocates continued application of weather modification at the current state of the art, in well designed and conducted projects.

- We advocate (and for decades have put into practice) as strong an evaluation component in each project as possible and practical.

- We are not suggesting, in principle, that healthy skepticism and questioning are not beneficial. To the contrary, NAWC has a history rich in participation and cooperation in research efforts in this field. We are strongly supportive of ongoing research efforts and look to the research community for findings that have practical value. We simply caution that, if not carefully managed and reported in the proper perspective, they can potentially cause undue delay and paralysis within the discipline.

Therefore, we restate our rejection of the notion stated in the NRC report that "the initiation of large-scale operational weather modification programs is premature." In our opinion, that statement paints an overly pessimistic view of the current status of the discipline and is out of touch with current understandings, given the large body of positive evidence that currently exists and considering the large number of operational cloud seeding programs currently being conducted in many parts of the world. We have previously supported and continue to favor the conduct of operational and applied research projects in parallel, with cooperation whenever and wherever practical and, perhaps most importantly, constructive communication among all involved.

Table 1 contains a list of randomized cloud seeding studies, published in refereed journals, that produced results with a P-value of 0.05 or better. Further additions to Table 1, plus the addition of a second Table for important studies not meeting these strict criteria, will be included at a later time.

TABLE 1
Some Results of Randomized Cloud Seeding Experiments with P Values of 0.05 or Better

Name	Location	Seeding Mode	Randomized?	Results*	References
Climax I & II	Colorado	AgI Ground	Randomized Crossover	+52% Snow, 0.03	Mielke (1981) JAM 20: 643-659
Tasmania	Australia	AgI Air	Randomized	+10-15% Snow, 0.01-0.04	Smith (1979) JAM 18: 804-815
Santa Barbara II, Phase I	Santa Barbara, California	AgI Ground	Randomized	+50-100% Convective Band Precip, <0.05 sig. at some stations	Elliott (1971) JAM 10: 785-795
Israel II	Israel	AgI Air	Randomized	+13-18%, 0.017-0.028	Gagin 1981 JAM 20: 1301-1311
Lake Almanor	Northeastern California	AgI Ground	Randomized	+35% Snow, 0.05	Mooney and Lunn (1968) JAM 8: 68-74

* P-values included in results column

References (Text and Table 1)

Elliott, R.D., P. St. Amand and J.R. Thompson, 1971: Santa Barbara Pyrotechnic Seeding Test Results 1967-70. J. Appl. Meteor., 10, 785-795.

Gagin, A and J. Neumann, 1981: The Second Israeli Randomized Seeding Experiment: Evaluation of the Results. J. Appl. Meteor., 20, 1301-1311.

Griffith, D.A. and M.E. Solak, 1999: A Cloud Seeding Program to Enhance Hydroelectric Power from the El Cajon Drainage, Honduras. Seventh WMO Conf. on Wea. Modif., Chiang Mai, Thailand, February 17-22, 1999.

Griffith, D.A. and M.E. Solak, 2002: Economic Feasibility Assessment of Winter Cloud Seding in the Boise River Drainage, Idaho. J. Wea. Modif, 34, 39-46.

Henderson, T.J., 2003: New Assessment of the Economic Impacts from Six Winter Snowpack Augmentation Projects. J. Wea. Modif., 35, 41-44.

Mielke, P.W., G.W. Brier, L.O. Grant, G.J. Mulvey and P.N. Rosenweig, 1981: A Statistical Reanalysis of the Replicated Climax I and II Wintertime Orograohic Cloud Seeding Experiments. J. Appl. Meteor., 20, 643-659.

Mooney, M.L. and G.W. Lunn, 1968: The Area of Maximum Effect Resulting from the Lake Almanor Randomized Cloud Seeding Experiment. J. Appl. Meteor., 8, 68-74.

Smith, E.J., L.G. Veitch, D.E. Shaw and A.J. Miller, 1979: A Cloud-Seeding Experiment in Tasmania. J. Appl. Meteor., 18, 804-815.

Todd, C.J. and W.E. Howell, 1985: World Atlas and Catalog of Reported Results of Precipitation Management by Cloud Seeding, August 1985, 67pp.

Weather Modification Capability Statements

The Weather Modification Association maintains a capability statement regarding cloud seeding. That statement is included below for ease of reference. The American Meteorological Society's weather modification capability statement can be found on their web site, www.ametsoc.org.

WEATHER MODIFICATION CAPABILITY STATEMENT
WEATHER MODIFICATION ASSOCIATION (1984)
(Undergoing review/update as of February, 2004)

INTRODUCTION

It has been established that weather can be modified by man under various circumstances. The problem is one of stating under what conditions predictable effects may be expected. The attainment of desirable weather modification effects depends upon several factors including: the prevailing weather regimes of a specific area, the design of a program to achieve a specific goal, the execution of the program, and the specification of a means of assessing the effects of the weather modification effort. Brief capability statements follow stating an assessment of the current state of weather modification technology for a variety of applications. A word of caution is necessary concerning these statements. This caution deals with the concept of transferability of results. Differences in cloud micro- physics, topography, seeding agent selection and dosage rates, and execution could alter these expectations.

Fog and Stratus Dispersal

The dispersal of shallow, cold (below freezing) fog or stratus cloud decks is an established operational technology: Dispensing ice phase seeding agents, such as dry ice or silver iodide, in these situations is effective in improving visibility. Clearings established in cloud decks embedded in strong wind fields fill in quickly unless seeding is done nearly continuously.

The dispersal of warm (above freezing) fog or stratus decks over areas as large as airport runways is feasible operationally through the provision of a significant heat source. The mixing of drier air by helicopter downwash can create localized clearings. Various hygroscopic substances have also been used to improve visibility in these situations primarily by the military:

Winter Precipitation Augmentation

Continental

Evaluations of both research and operational Winter orographic cloud seeding programs indicate that 5-20% seasonal increases in precipitation can be achieved. Detailed analysis of research programs demonstrate that both positive and negative effects of seeding can occur over short time intervals such

as individual storm events. Consequently, it is prudent to adopt seeding techniques and criteria, based upon meteorological conditions, designed to optimize the positive seeding effects during these shorter time intervals thereby maximizing the seasonal increases in precipitation.

Coastal

Evaluations of both research and operational wintertime programs conducted in more coastal environments with more limited topographic relief indicate the potential of 5 to as much as 30% increases in seasonal precipitation. Meteorological situations that appear to offer the most potential in these areas are convective in nature. It again appears prudent to adopt meteorologically-based seeding guidelines for real-time seeding decision-making in order to maximize the increases in seasonal precipitation.

Summer Precipitation Augmentation

The capability to augment summertime precipitation in an area-Wide fashion is promising. Assessments from some operational and some research programs are encouraging especially when a seeding mode is employed which allows selective seeding of individual clouds.

Evaluations of operationally conducted summer precipitation augmentation programs present a difficult problem due to their non-randomized nature and the normally high variability (temporal and spatial) present in summertime rainfall. Recognizing these evaluation limitations, the results of many of these evaluations have indicated a positive area-wide seeding effect in precipitation.

Results are mixed from research programs conducted on summertime cumulus clouds. Part of the resulting uncertainty is due to the variety of climatological and microphysical settings in which experimentation has been conducted. Another important factor is seeding mode, those projects that employed a broadcast mode of dispersal of a glaciogenic seeding material have generally indicated no effect or even decreases in rainfall. Projects which relied upon injection of glaciogenic seeding material directly into clouds that met certain seeding criteria (based essentially upon the stage of development of the cloud) generally indicate positive seeding effects on at least the seeded cloud's rainfall and oftentimes area-wide rainfall.

Hail Suppression

Most of what is currently known about the status of hail suppression, either success or failure, has been acquired through study of surface hail data in a project area during seeding periods. Little has yet been shown through careful study of the physical behavior of the interior of storms from the suppression efforts. Therefore, the scientific linkages establishing hail suppression are not well established, although the assessment of surface hail differences is generally suggestive of successful suppression in the realm of 20-50% reduction. Execution of the operations is important. Timing and correct placement of seeding material are especially critical to successful suppression.