ASCE STANDARD

ANSI/ASCE/EWRI

42-17

Standard Practice for the Design, Conduct, and Evaluation of Operational Precipitation Enhancement Projects

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AMERICAN SOCIETY OF CIVIL ENGINEERS

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PREFACE

Users of ASCE standards may need special knowledge or professional training and experience to apply a standard properly and safely. Those who use ASCE/EWRI Standard 42-17 shall accept full responsibility for its use. Standards shall not preclude professional judgment in situations where they are used.

This standard, ASCE/EWRI 42-17, is a combination of ASCE/EWRI 42-04, *Standard Practice Guideline for the Design and Operation of Precipitation Enhancement Projects,* and the material provided in this revision. ASCE/EWRI 42-17 has been prepared in accordance with the mandatory language for a standard and nonmandatory language in the Commentary portions per the ASCE Standards Writing Manual (http://www.asce.org/uploadedFiles/Technical_Areas/Codes_and_Standards/Content_Pieces/standards-writing-manual.pdf). This standard practice document was revised with recognized, industry best engineering and scientific principles. It shall not be used without the user's competent knowledge of the underlying principles for a given application.

The units used throughout this document are those recommended by the American Meteorological Society (AMS) and the Weather Modification Association (WMA) for their reports and journals. A conversion table (mandatory), as one of the appendixes, shall accommodate references to English common units or other units not necessarily standard to ASCE.

The American Society of Civil Engineers (ASCE) recognizes the work of the Atmospheric Water Management Standards Committee of the Environmental and Water Resources Institute (EWRI). Many individuals contributed materially to this document by their comments, review, illustrations, and photographs.

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CHAPTER 1
INTRODUCTION TO PRECIPITATION ENHANCEMENT PROJECTS

Traditionally, water resources development pertains to building dams and reservoirs, installing pipelines or using concrete to line ditches or canals, or in some way storing or distributing the available water. In many cases, however, there is only one means to increase water supplies, and that is to facilitate the conversion of atmospheric water vapor into precipitation. The latter is known as weather modification or cloud seeding. In many areas of the United States and the world, a need exists for new water supplies. In many of these areas, cloud seeding technology can be useful to augment the available water (Keyes et al. 2006).

Engineers and water planners must realize that both the direct and indirect effects of any contemplated cloud seeding project must be predicted, recognized, and evaluated throughout the entire project. The major parts of the planning and implementation of a cloud seeding project should include the following (Keyes et al. 2006):

- Origin and justification of the overall project.
- An interdisciplinary approach to decision making. Political and institutional aspects may be the most important.
- Feasibility studies that include a clear statement of the planned cloud seeding program. All weather modification plans should be evaluated by weather modification managers who are certified by the Weather Modification Association (WMA).
- Design, operational procedures, and evaluation of a cloud seeding program that should include long-range and short-range aspects in the interpretation of results and the practical significance of the overall findings.
- Project oversight that consists of technical advisory and citizen advisory groups that are involved in the evaluation and a rapid means of communication to avoid potentially hazardous conditions.
- Project management that incorporates a large amount of information dissemination, i.e., weekly and monthly updating of project progress and educational news releases to the public.

1.1 SCOPE OF STANDARD

This book, *Standard Practice for the Design, Conduct, and Evaluation of Operational Precipitation Enhancement Projects*, is intended to provide water resource managers and others with the standard approach for designing, operating, and evaluating precipitation enhancement projects. They typically need to make a decision on the use of cloud seeding to augment available water supplies. ASCE Manual of Practice 81 (Keyes et al. 2006, 2016) contains the information and, in some respects, insights gathered during the course of many design and operational trials of the standard practice for designing, conducting, and evaluating operational precipitation enhancement projects. Mandatory definitions used in this standard appear in Appendix B. Note that Appendix B may also include other definitions that might not be mandatory.

1.2 HISTORICAL PERSPECTIVE

Precipitation enhancement projects have been conducted primarily in regions where *orographic* clouds (those developed by the lifting of moist air as it flows over elevated topography) are common in the cold season, or where warm-season *cumuliform* clouds are generated by vigorous convection, since the mid-1940s (e.g., Schaefer 1946) based on the scientific principles of the precipitation process (e.g., Bergeron 1935; Findeisen 1938). The underlying concept is to treat those storms or portions of storms that are naturally inefficient to make them more efficient through cloud seeding. The first tests of both dry ice and silver iodide (AgI) as cloud seeding materials were carried out during 1946 and 1947 by a General Electric Laboratory group (Schaefer 1946; Vonnegut 1947). As word of the successful 1946 and 1947 first tests spread, it was not long before operational weather modification projects were conducted (e.g., Dennis 1980; Marwitz 1986; Keyes et al. 2016).

1.2.1 Orographic Clouds. Cloud seeding for enhancing winter snowpack in western mountainous areas is considered highly successful since the mid-1980s (e.g., Elliott 1986). The physical understanding and documentation of the chain of events in both natural and artificially stimulated precipitation processes was emphasized through the Sierra Cooperative Pilot Project (SCPP), which used a revolutionary approach to cloud seeding experiments and physical studies (Marwitz 1986). It found that shallow widespread winter orographic cloud systems provided the best potential for precipitation augmentation through cloud seeding operations because their supercooled liquid water is long lasting and distributed over a large area. This provided the rationale to apply cloud seeding technology to the upper elevations of the American River Basin with the aim of producing additional snowfall for spring runoff (Reynolds and Dennis 1986).

Commentary: Other projects or programs have been designed for research and development of precipitation enhancement technology and evaluation techniques (e.g., Kraus and Squires 1947; Battan and Kassander 1960; Simpson et al. 1965; Bowen 1966; Simpson et al. 1967; Smith et al. 1971; Gagin and Neuman 1974, 1981; Smith 1974; Dennis et al. 1975; Braham 1979, 1986; Dennis 1980; Elliott 1986; Mielke et al. 1970, 1971; Cooper and Saunders 1980; Cooper and Marwitz 1980; Gagin et al. 1986; Ben-Zvi and Fanar 1996, 1997; Super and Heimbach 1988; Super et al. 1989; Boe et al. 1992; Long and Huggins 1992;

Sassen and Zhao 1993; Rosenfeld and Woodley 1993; Boe 1994; Bruintjes et al. 1994; Mather et al. 1997; Silverman et al. 1999; Super 1999; Woodley et al. 1999; Breed et al. 2014).

1.2.2 Convective Clouds. The results of convective cloud seeding have been mixed and often inconclusive since the discovery of the effects of dry ice on supercooled stratiform cloud precipitation process efficiency. Kraus and Squires (1947) dropped 136 kg of powdered dry ice into a cumulus cloud, one of many in a sky filled with such clouds. The seeded cloud proceeded to develop into a large cumulonimbus cloud, producing more than 12 mm of rain over a 130-km^2 area. The seeding of isolated individual clouds has led to definite, mostly positive changes in precipitation amounts (Dennis 1980; Silverman et al. 1999; Woodley et al. 1999; Woodley and Rosenfeld 2004). Woodley and Rosenfeld (2004) developed and tested a computerized method for the objective evaluation of short-term, nonrandomized operational convective cloud seeding projects on a floating-target-area basis. This was done in the context of the operational cloud seeding projects of Texas, using WSR-88D mosaic radar data to define fields of circular (25-km radius) floating-target analysis units with lifetimes from the first echo to the disappearance of all echoes and then superimposing the track and seeding actions of the project seeder aircraft onto the unit fields to define seeded (S) and nonseeded (NS) analysis units. As with the Florida Area Cumulus Experiment (FACE) randomized seeding, their results indicated that rainfall was increased downwind of the seeding activity, primarily as the seeded clouds moved out of the target and into downwind areas. Downwind, or extra-area effects are further discussed by DeFelice et al. (2014).

Commentary: Randomized hygroscopic seeding experiments in South Africa (Mather et al. 1997) and in Thailand (Silverman et al. 1999) have reached statistical significance and show substantial increases in radar-estimated rainfall (ranging from 30% to 60%) from the seeded clouds. Numerical calculations of the growth of the salt particles to precipitation-sized hydrometeors support the field results (Cooper et al. 1997).

1.3 STATUS OF PRECIPITATION ENHANCEMENT TECHNOLOGY

After considerable research in the United States from 1950 to 1996, research efforts have now diminished dramatically, although operational cloud seeding in the United States and elsewhere is quite active.

Cloud seeding technology has developed over the past 60 years as a means for augmenting precipitation in regions where additional precipitation is viewed as an economic asset. Augmentation is normally successful in the range of 5% to 20% (see Appendix C). This additional precipitation over agricultural areas would benefit crops; over mountainous terrain, it would benefit the hydroelectric power industry, municipal water interests, and irrigation interests. A perceived wider interaction of this augmentation with the environment and with society in general has brought peripheral issues into focus. Because the smallest possible scale of treatment covers several hundred hectares, it has been necessary to develop public consensus within an intended target area. In a farm area that has mixed crops, many farmers might benefit from enhanced precipitation while others might not. In a mountainous region where hydroelectric power generation would be greatly benefited, traffic over mountain passes might be impaired, while ski resorts might be aided (Keyes et al. 2006).

Additional information about the status of precipitation enhancement technology is provided in Section 2.2.

Commentary: The renewed interest in hygroscopic seeding using flares may provide impetus for more research and development of the field. The current status of precipitation enhancement technology has been addressed by four of the major organizations that have dealt with weather modification during the past 60 years: American Meteorological Society (AMS), American Society of Civil Engineers (ASCE), WMA, and World Meteorological Organization (WMO). The position statements of these organizations on weather modification are summarized in Appendix C.

1.4 APPROPRIATE ASCE/EWRI STANDARDS

The ASCE/EWRI standards published on atmospheric water management include the following:

ANSI/ASCE/EWRI. (2015). "Guidelines for operational hail suppression programs." ANSI/ASCE/EWRI 39, ASCE, Reston, VA.

ASCE/EWRI. (2004). "Standard practice for the design and operation of precipitation enhancement projects." ASCE/EWRI 42, ASCE, Reston, VA.

ANSI/ASCE/EWRI. (2013). "Standard practice for the design and operation of supercooled fog dispersal projects." ANSI/ASCE/EWRI 44, ASCE, Reston, VA.

Mandatory definitions used in this standard appear in Appendix B. Note that Appendix B may also include other definitions that might not be mandatory.

1.5 APPROPRIATE ASCE/EWRI MANUALS OF PROFESSIONAL PRACTICE

Other appropriate ASCE Manuals of Professional Practice and/or portions thereof to be used extensively in this standard are the following:

Bomar, G. (2016). "Legal aspects of weather modification operations." *Guidelines for cloud seeding to augment precipitation*, 2nd Ed., ASCE, Reston, VA, 53–73.

Czys, R. R., DeFelice, T. P., and Griffith, D. A. (2006). "The scientific basis." *Guidelines for cloud seeding to augment precipitation*, 2nd Ed., ASCE, Reston, VA, 61–80.

DeFelice, T. P., and Czys, R. (2016). "The scientific basis." *Guidelines for cloud seeding to augment precipitation*, 3rd Ed., ASCE, Reston VA, 75–96.

Keyes, C. G., Jr., Boe, B. A., Bomar, G. W., Czys, R. R., DeFelice, T. P., and Griffith, D. A. (2006). *Guidelines for cloud seeding to augment precipitation*, 2nd Ed., ASCE, Reston, VA.

Keyes, C. G., Jr., Bomar, G. W., DeFelice, T. P., Griffith, D. A., and Langerud, D. (2016). *Guidelines for cloud seeding to augment precipitation*, 3rd Ed., ASCE, Reston, VA.

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