SUBMIT OPTION SUBMITTAL FORM BY:
1. EMAIL TO: COLORADORIVERBASINSTUDY@USBR.GOV
2. U.S. MAIL TO: BUREAU OF RECLAMATION, ATTENTION MS. PAM ADAMS, LC-2721, P.O. BOX 61470, BOULDER CITY, NV 89006-1470
3. FACSIMILE TO: 702-293-8418

Option Submittal Form

Contact Information (optional): ☐ **Keep my contact information private.**

Contact Name: Title:
Affiliation:
Address:
Telephone: E-mail Address:

Date Option Submitted: February 1, 2012

Option Name:

Weather Modification Program (i.e. Cloud Seeding) to Augment the Flow of the Colorado River

Description of Option:

Congress recognized the severity of dwindling water supplies several years ago when it charged the Secretary of the Interior ("Secretary") in the Colorado River Basin Act of 1968 ("CRBA"), 43 U.S.C. § 1501(a) (1984), with augmenting Colorado River water supplies. The CRBA directed the Secretary to prepare a plan to augment current river basin supplies "to meet the future water needs of the Western United States." *Id.* at § 1511. It further declared that the first obligation of any water augmentation project would be satisfaction of the requirements of the Mexican Water Treaty. *Id.* at § 1511. Thereafter, Congress directed the Secretary to prepare a plan to improve the quality of Colorado River water. 43 U.S.C. § 1571(a) (1974).

In 1981, the House Subcommittee on Water and Power held a hearing to assess the Secretary's progress. Division of Atmospheric Resources Research, Bureau of Reclamation, U.S. Dep't of the Interior ("DOI"), CREST Program Plan (April 15, 1983) [hereinafter "CREST"]. The Subcommittee concluded that the greatest potential for augmenting the flow of the Colorado River was to perform a technique known as "weather modification" (i.e. "cloud seeding") to increase precipitation in the Colorado River's drainage basin. CREST, *Id.* at 10.

On May 2, 2005, the DOI issued a letter outlining the Secretary's intent to develop Lower Basin shortage guidelines and to explore management options of Lakes Mead and Powell. In response, Reclamation published a June 15, 2005 Federal Register notice to solicit comments on the Secretary's request. A meeting of the seven Basin States resulted in a letter to the Secretary that addressed three major topics to accommodate the Secretary's concerns, one of which included augmentation of supply. The states concluded that "[a] weather modification project should be pursued as a means of augmenting Colorado River System water supplies."
See Seven Basin States' Preliminary Proposal, p.11 (2006), *available at* http://www.usbr.gov /lc/region/programs/strategies/consultation/Feb06SevenBasinStatesPreliminaryProposal.pdf.

Accordingly, a weather modification program (hereinafter "cloud seeding" or "weather modification") should be considered as an option to balance the supply and demand imbalances projected to occur in the Basin over the next 50 years. Not only is this a preferred option, but it mandated under our treaty with Mexico, which requires the United States to have sufficient water supplies for delivery thereto.

The concept of cloud seeding is simple. Several studies have suggested that there is a cold "temperature window" of opportunity for cloud seeding. Water droplets located in clouds can remain unfrozen at temperatures well below freezing. These droplets are called "supercooled". These water droplets must come in contact with a foreign particle ("seed") to cause them to freeze. Once a supercooled water droplet is frozen, its turns into an ice crystal, and eventually grows into a snowflake large enough to fall from the cloud and reach the ground. *See* The Potential Use of Winter Cloud Seeding Programs to Augment the Flow of the Colorado River, Report Prepared for Upper Colorado River Commission, pp. 8-9 (2006), *available at* http://www.nawcinc.com/Colorado%20River%20Seeding.pdf (hereinafter "Report").

Studies have shown that the ideal location for cloud seeding to occur is in the mountainous western states where orographic clouds are often associated with passing winter storms. Located within these orographic clouds are an abundance of supercooled water droplets that can remain suspended unless introduced to a foreign particle. Thus, the goal is to design a winter orographic cloud seeding project that will tap this reservoir of water droplets and convert them into snowflakes that otherwise would be lost through evaporation over the downwind side of a mountain barrier. Report, pp. 8-9.

In order to achieve this goal, a seeding agent must be introduced into the clouds. There are generally three main seeding agents: (1) silver iodide; (2) dry ice; and (3) liquid propane. Silver Iodide remains the preferred seeding agent due to its favorable results. Seeding must be released into the atmoshphere by some means. The most common release methods, depending on the altitude of the release location, occur via aircraft or a cannon-like module located on the ground. Report, pp. 10-13.

Location: Describe location(s) where option could be implemented and other areas that the option would affect, if applicable. Attach a map, if applicable.

As is previously noted, cloud seeding is most appropriate in the mountainous western states during the winter months. Ideally, this would occur near mountains in Arizona, Colorado, Utah and Wyoming that allow for the accumulation of snowpack. The resulting water supplies, however, would benefit all of the Basin states.

Quantity and Timing: Roughly quantify the range of the potential amount of water that the option could provide over the next 50 years and in what timeframe that amount could be available. If option could be implemented in phases, include quantity estimates associated with each phase. If known, specify any important seasonal (e.g., more water could be available in winter) and/or frequency (e.g., more water could likely be available during above-average hydrologic years) considerations. If known, describe any key assumptions made in order to quantify the potential amount.

Cloud seeding would likely occur annually, during the winter months. However, because seeding may be implemented and, if needed, terminated rather quickly, intermediate seeding could occur outside of the winter months if weather conditions are ideal.

Additional Information

Technical Feasibility: Describe the maturity and feasibility of the concept/technology being proposed, and what research and/or technological development might first be needed.

The potential for use of cloud seeding dates back to some early discoveries and experiments, first conducted in the laboratory and then in the atmosphere, in the late 1940's. Early positive results led to operational programs being conducted in the 1950's. Additional research was conducted during the 1960's until the present. While some skepticism remains regarding the effectiveness of cloud seeding, several scientific groups now believe that winter time precipitation in mountains can be increased approximately 5% to 15%. Report, p. 39.

Like any concept/technology, cloud seeding techniques can always be refined to produce more efficient and productive results. These tests, however, have been limited due to Governmental resistance and their reliance on the private sector to develop cloud seeding programs.

Costs: Provide cost and funding information, if available, including capital, operations, maintenance, repair, replacement, and any other costs and sources of funds (e.g., public, private, or both public and private). Identify what is and is not included in the provided cost numbers and provide references used for cost justification. Methodologies for calculating unit costs (e.g., $/acre-foot or $/million gallons) vary widely; therefore, do not provide unit costs without also providing the assumed capital and annual costs for the option, and the methodology used to calculate unit costs.

It should be noted from the outset that relying on private entities is not a feasible solution, as entrepreneurs have no incentive (neither the legal authority) to seed over public lands and lands owned by others, as it is nearly impossible for that person to capture all or some of the water that is produced.

The cost of administering a program is relatively inexpensive in comparison to other proposals. A 1996 study estimated that the annual cost of developing new cloud seeding programs, in addition to augmenting existing programs in four states (AZ, UT, WY and CO), would cost approximately $6,965,000 to produce a total of 1,381,004 acre feet ($5.04/acre foot). Report, p. 39.

Permitting: List the permits and/or approvals required and status of any permits and/or approvals received.

The National Oceanic and Atmospheric Administration requires that all cloud seeding operations be reported prior to being conducted, so that the Agency can anticipate man-made weather changes that couldn't be forecast otherwise.

In addition, installation of ground-based equipment on Federal lands would likely require issuance of special permits and possibly preparation of an Environmental Assessment and/or an Environmental Impact Statement.

Legal / Public Policy Considerations: Describe legal/public policy considerations associated with the option. Describe any agreements necessary for implementation and any potential water rights issues, if known.

Conducting cloud seeding operations over state lines has the potential to create ownership disputes, especially as it relates to interstate waters.

Implementation Risk / Uncertainty: Describe any aspects of the option that involves risk or uncertainty related to implementing the option.

As with any other experiment, there is always an inherent risk and level of uncertainty involved. High winds could cause the seed to travel further down-wind than anticipated, therefore increasing rain chances in an unanticipated location. Also, there is the risk that seeding clouds in one location could reduce the moisture in the atmosphere as that air mass moves into another location.

The risks and uncertainties can only be analyzed and mitigated if the Government implements a cloud seeding program. Until then, one may only hypothesize as to the unknown adverse risks.

Reliability: Describe the anticipated reliability of the option and any known risks to supply or demand, such as: drought risk, water contamination risk, risk of infrastructure failure, etc.

An attractive aspect of cloud seeding programs is that they can be implemented and, if needed, terminated comparatively quickly, since they generally do not involve the development of large permanent infrastructure. Further, operations can readily be suspended during very wet periods and restarted when appropriate.

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Water Quality: Identify key water quality implications (salinity and other constituents) associated with the option in all of the locations the option may affect.

The most common seeding agent used in winter cloud seeding programs is silver iodide. The long-term use of silver iodine, coupled with its positive weather modification delivery results, makes it highly unlikely that other agents, with the exception of dry ice, will be used on a large scale. Silver iodide's environmental impacts have been studied extensively and the result appears to represent negligible hazards. Studies of ingestion of large silver doses have revealed no physiological concerns. Another study found no significant environmental effects have been noted around operational projects, many had operated for 30 to 40 years. The same study found that the concentration of silver in rain water or snow from a seeded cloud is approximately 1000 times less than the Environmental Protection Agency's standard. Report, p. 38.

Energy Needs: Describe, and quantify if known, the energy needs associated with the option. Include any energy required to obtain, treat, and deliver the water to the defined location at the defined quality.

Energy Required	Source(s) of Energy
Natural Energy/Gravity	The snowpack is similar to that of natural snow; both will begin melting in the spring and, by virtue of gravity, will slowly trickle down into the various springs and tributaries that lead into water bodies like the Colorado River. The water is then delivered downstream and into various canals (like the Central Arizona Project) in the same manner as naturally occurring water. In fact, it is likely that the additional power created by the high flows will exceed the power necessary for delivery of the water.

Hydroelectric Energy Generation: Describe, and quantify if known, any anticipated increases or decreases in hydroelectric energy generation as a result of the option.

Location of Generation	Impact to Generation
The Upper and Lower Basin States	Dams and Small-Head Hydropower facilities throughout the upper and lower basin states will likely see increases in capacity, and therefore, hydroelectric energy generation as a result of the increased water supplies.

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Recreation: Describe any anticipated positive or negative effects on recreation.

Location(s)	Anticipate Benefits or Impacts
Colorado River and its Tributaries	Increased rapids and water flow for recreational rafting, fishing and related activities.
" "	If there is an increased supply of water, the need to reduce demand is alleviated. Therefore, imposing water restrictions in the future may not be necessary. Several recreational activities will benefit: golf, pools, lakes, skiing, etc…

Environment: Describe any anticipated positive or negative effects on ecosystems within or outside of the Colorado River Basin.

Location(s)	Anticipated Benefits or Impacts
The Upper and Lower Basin States	No significant negative environmental impacts are anticipated from conducting cloud seeding programs, based upon the finding from a number of large scale office and field environmental programs funded by the Bureau of Reclamation.
Arizona	There is the possibility that the floods associated with fires experienced this past summer in northeastern Arizona could be avoided. First, increased precipitation could alleviate drought concerns. Second, water runoff could be avoided by increased vegetation resulting from precipitation.
Arizona	Increased snow in and around ski resorts will likely have a corollary effect on the use of reclaimed water to create snow for skiing. In Flagstaff Arizona, the Hopi Indians have opposed decisions to use reclaimed water to make snow at the Arizona Snowbowl. The Hopi's claim it disrespects their cultural and ancestral values to used reclaimed water on these sacred sites.

Socioeconomics: Describe anticipated positive or negative socioeconomic (social and economic factors) effects.

Arizona and other states rely on water for much of their way of life. Decreasing or rationing water supplies would greatly deter not only everyday life, but could have lasting impacts on tourism, travel, agriculture and industry. The positive effects of cloud seeding, coupled with other measures, would likely alleviate these adverse affects.

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Other Information: Provide other information as appropriate, including potential secondary benefits or considerations. Attach supporting documentation or references, if applicable.

Not Available