COUNTY OF SANTA BARBARA

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Santa Barbara County and Twitchell Reservoir Cloud Seeding Program

CEQA Final Mitigated Negative Declaration

13NGD-00000-00011

October 15, 2013

Picture Below: Twitchell Reservoir July 2011

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1.0 REQUEST/PROJECT DESCRIPTION

Santa Barbara County Water Agency (SBCWA) proposes to continue the cloud seeding program currently being implemented. This program has been ongoing since 1981 and serves to augment natural rainfall to increase available water supplies by inducing larger amounts of inflow into surface reservoirs. The cloud seeding program targets two geographical areas: the Santa Ynez River watershed above Lake Cachuma in Santa Barbara County and the Alamo and Huasna tributaries of the Twitchell Reservoir watershed within Santa Barbara and San Luis Obispo Counties.

Principles of Cloud Seeding in Santa Barbara County

Most winter storms that arrive in the area are abundant in moisture but limited in "freezing nuclei". Freezing or ice nuclei are required for cloud droplets that are colder than freezing to freeze. These frozen droplets turn into tiny ice crystals. Some ice nuclei can also act as condensation nuclei (ones that water vapor can condense on), but at temperatures below approximately -5C such droplets freeze nearly spontaneously since the same nuclei also act to freeze the droplets as soon as they form (the condensation-freezing nucleation process). Natural ice forming nuclei in the environment are typically microscopic particles of dust, debris or bacteria. One method of cloud seeding is accomplished by injecting Silver Iodide (AgI) complexes into certain types of storm clouds as artificial ice nuclei to facilitate the formation of ice crystals from supercooled water droplets. Supercooled water droplets are those that exist at temperatures below freezing. These droplets do not freeze due to their purity. Natural ice nuclei present in the atmosphere will cause these droplets to freeze on contact but the concentration of naturally occurring ice nuclei that are active in temperature ranges of approximately -5 to -15C are low. Silver Iodide complexes are much more active in these temperature ranges and therefore offer a window of opportunity to freeze more of these supercooled cloud droplets thereby increasing the efficiency of precipitation production from certain types of clouds. Once ice crystals are formed in clouds they may quickly grow into snowflakes through vapor deposition, aggregation and riming processes. These snowflakes then fall toward earth due to their enhanced vertical velocities (a function of increased mass) often melting and changing into rain drops if they fall through the freezing level. Effective cloud seeding programs specifically target areas or "cells" within clouds that contain significant amounts of supercooled liquid water. Silver Iodide complexes may be effective for up to one to two hours after being released.

Program Description

The proposed program is operated by a qualified weather modification consultant working in coordination with SBCWA and the Santa Barbara County Flood Control District. The proposed program may utilize land-based seeding sites alone, aerial seeding operations alone, or both in combination. The mode of seeding utilized is decided based on funding and operational factors. Candidate storms are identified as they approach the target area using weather observation data and forecasting methods. The State of California supports weather modification programs (**Appendix A**, 2009 California Water Plan Precipitation Enhancement Section) and all requirements of the State are adhered to including reporting and notice of intent publication every five years. Adjacent Counties (San Luis Obispo, Kern and Ventura) are notified of the program on a year by year basis.

Land Based Seeding Sites

SBCWA currently leases six ground sites for land based seeding along the Coastal Mountains of Santa Barbara County (Figure 1). The ground sites are maintained in a state of readiness and activated as appropriate based on weather conditions and storm seedability. During any specific storm event, all or none of the land-based sites may be utilized and for different durations and time periods. These sites are all remote controlled units using a supervisory control and data acquisition system (SCADA). The Water Agency may install additional sites in the future as part of this program. The placement of seeders at new sites would involve the following factors:

- Coverage: The site would be located to maximize coverage of the target watershed.
- Accessibility: Road access is required for occasional servicing of equipment. (Existing roads would be utilized.)
- Altitude: Placement at higher altitudes (above 2000 feet) allows for dispersion of AgI compounds into clouds at optimal meteorological conditions.
- Site Constraints: Sites are selected to minimize grading and vegetation disturbance.
- Biological Survey: A biological survey would be conducted to confirm the absence of endangered species.

Land based seeding locations may be adjusted over time to reflect changes in flood prevention requirements (see Flood Prevention and Suspension Criteria, page 9). All ground sites are cleared of vegetation in a 30’ radius from the seeder. Spark Arresters have been placed on all flare racks to ensure that no spark leaves the site, only the AgI complex.

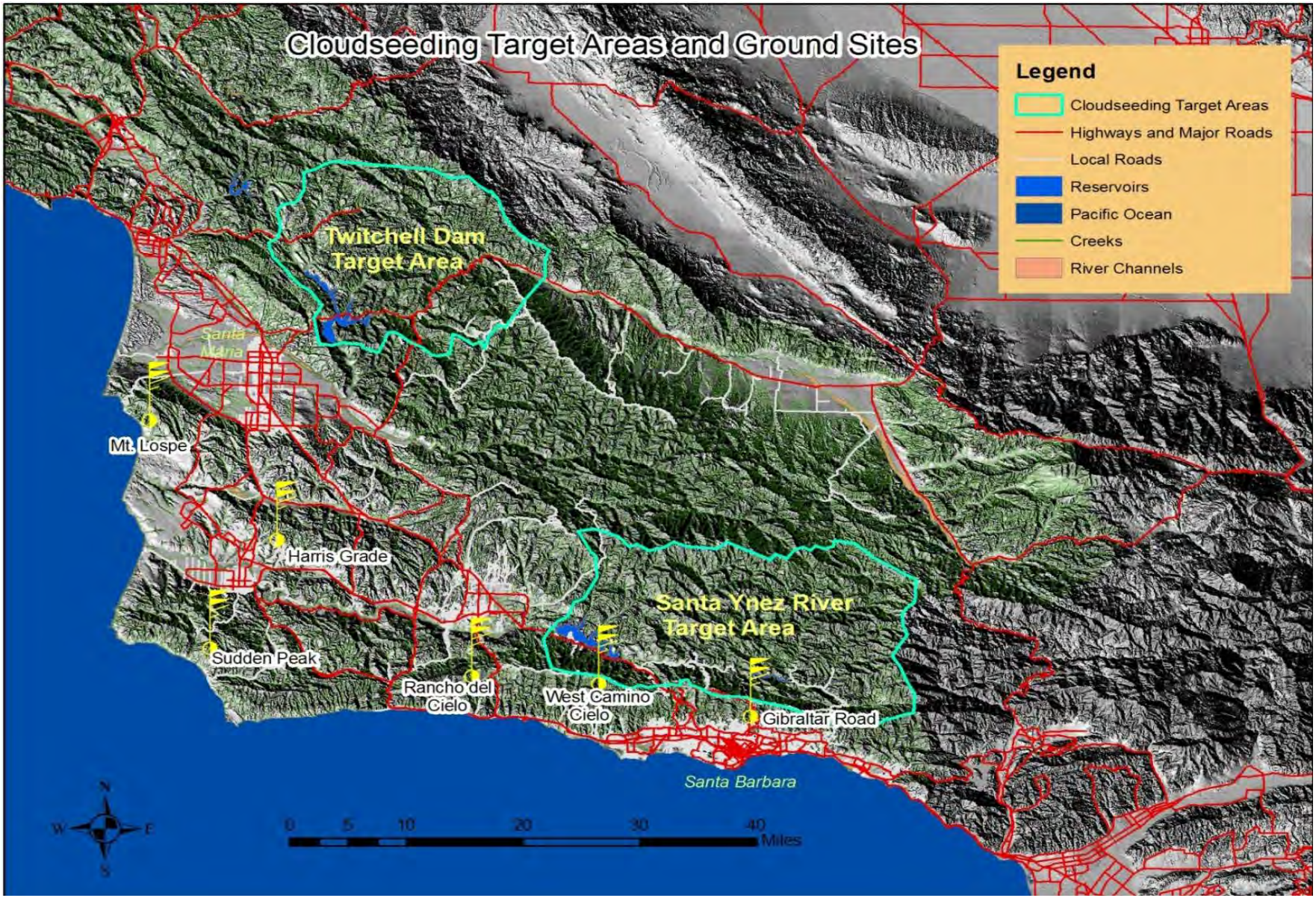

Figure 1: Cloud Seeding Target Area and Ground Seeding Site Locations

Figure 2: Harris Grade Ground Site

Figure 3: Flare Burn with Spark Arrestor

A typical land-based seeding site would consist of the following:

- Two flare masts which hold a total of thirty-two 150 gram flares
- Spark arrestors that enclose each flare
- An environmentally sealed control box containing a cellular phone communications system, digital firing sequence relays/controller, data logger and system battery
- A solar panel and charge regulator to maintain site power
- A cellular phone antenna
- Lightning protection

Aerial Seeding

Aircraft may be based at various airports in the Santa Barbara and San Luis Obispo county areas with all flights coordinated with the FAA and Vandenberg AFB. Historically, the cloud seeding program utilized a twin-engine, all-weather aircraft equipped with two silver iodide-acetone wing-tip generators. More recently, a Cessna 340A has been used equipped with two wing mounted 38 position AgI complex flare racks. These flares are “burn in place” flares and are not ejected from the aircraft. The type and make of aircraft may be altered in future programs based on availability and technology but will continue to meet all FAA and regulatory requirements.

Figure 4: Cessna 340 Aircraft


Figure 5: Flare Rack Mounted to Cessna 340 Aircraft

Seeding Materials

The flare used is similar to roadside flares in appearance and performance. It consists of 150 grams of glaciogenic pyrotechnic composition glued into a phenolic paper tube with an igniter held into the end and sealed with a plastic cap. The electronic igniter is activated using the voltage supplied from the aircraft power system or from the SCADA control system at ground sites to the firing box. When activated, the flare burns in place for between 3.5 and 4 minutes. The flare contains Ammonium Perchlorate, Zinc Powder, Aluminum Powder, Silver Iodide, Copper Iodide and Ammonium Iodide. None of these chemicals are listed as hazardous materials by the U.S. Environmental Protection Agency (USEPA). Burning a 150 gram seeding flare releases approximately 15 grams of microscopic silver-copper iodide particles. The seeding flare MSDS sheet is attached as **Appendix E**.

Three ingredients are listed on the HSIS (Hazardous Substances Information System): Ammonium Perchlorate, Zinc Powder and Aluminum Powder. None of these chemicals have any listed health effects. All three have physiochemical effects only.

The Ammonium Perchlorate is used as an oxidizer in the flares as well as solid rocket boosters in the military industry. This allows the Aluminum and Zinc, which are reactive metals, to burn within the solid propellant without any additional oxygen needed for combustion from the atmosphere. The Ammonium Perchlorate does not survive the combustion process. The Zinc and Aluminum Powders are used as propellants.

The three other chemicals: Silver Iodide, Copper Iodide and Ammonium Iodide are not listed on the HSIS. These three chemicals have listed irritant health effects according to their manufacturers MSDS but are used in the flare below the listed levels for irritant hazard category. Upon combustion, a Silver Iodide complex is produced which serves as the seeding agent.

The resulting products of combustion, in addition to the Silver Iodide Complexes include: Aluminum Oxide, Aluminum Chloride, Zinc Oxide, Zinc Chloride, Nitrogen, and water. All chemicals produced from the combustion process are “inert”, that is they do not readily react with plants or animals.

All chemicals used in the process would be stored and transported according to applicable laws and regulations.

The program has released an average of approximately 1,500 grams (approximately 3.3 pounds) of Silver Iodide Complexes per season based on the 2002-2003 through 2012-2013 rainy seasons. There was no seeding during the 2007-2008 Season after the “Zaca Fire”.

No known substantial AgI accumulations have formed at the existing sites in the 33 year history of the program. Recent studies such as the Cardno Entrix Geochemistry and Impacts of Silver Iodide use in Cloud seeding (**Appendix B**) and Walker River Basin Cloud Seeding Project Environmental Assessment indicates no harmful effects to either plant or animal life.

Flood Prevention and Suspension Criteria

The proposed program would be constantly monitored to predict flood hazards. Weather forecast and evaluation would be conducted by a private consultant prior to and during all seeding operations. Each year, SBCWA would develop operational rules ("Suspension Criteria") that would define when and where seeding operations must cease to avoid seeding during potential flood producing situations. The Santa Barbara County Flood Control District would approve these operational rules and retains final authority to suspend seeding at any time as determined by the Flood Control Engineer or Hydrologist. If a substantial hazard of flooding existed within all or part of the seeding area, seeding operations would be immediately suspended in that part.

Suspension Criteria would be developed prior to the initiation of each season's cloud seeding program. These criteria would account for the loss of vegetative cover in burn (wildfire) areas, changes in permissible flow due to river vegetation, and available reservoir capacity. Each of these factors affects the potential for flooding. Before and during operations, National Weather Service advisories and predictions of flood conditions would be monitored. Suspension Criteria are developed at the onset of each season program as watershed changes such as fires can occur through the fall. As an example the 2012-2013 Winter Season Suspension Criteria are listed on the following pages:

2012-2013 CLOUD SEEDING PROGRAM SUSPENSION CRITERIA

A. General Criteria for the Entire Project Area in both Santa Barbara and San Luis Obispo Counties

Criteria in this category apply to the entire project area including all of Santa Barbara County and the Twitchell Reservoir Drainage of Southern San Luis Obispo County.

1. Whenever the National Weather Service (NWS) issues a severe storm, precipitation, or flood warning that affects any part of the project area, the project meteorologist shall suspend operations which may affect that part. Operations will be suspended at least for the period that the warning is in effect.

2. The Project Meteorologist or District/Agency personnel shall retain independent authority to suspend cloud seeding operations for any part, or all of the project area in the event that unforeseen conditions develop during storm events which in their best judgment have the potential to cause flooding or other adverse conditions anywhere within the project area.

B. Specific Criteria for Individual Areas/Watersheds

South Coastal Areas:

1. No targeting of or seeding operations which affect the South Coast of Santa Barbara County south of the Santa Ynez Mountains Ridgeline will be conducted.

Santa Ynez River Watershed including the Zaca Fire Area:

1. Due to the ongoing recovery of the Zaca Fire area, high intensity storms will not be seeded that would impact recovering areas since high intensity events may cause accelerated sediment flux. If the NWS predicts 0.8" per hour or greater rainfall intensity, seeding will not be conducted in project areas where such intensities are predicted. If 0.8" per hour intensities are observed anywhere in the Santa Ynez River Watershed, seeding activities shall be immediately suspended for the remainder of that storm event.

2. Prior to and during each storm event the District will make stream flow runoff forecasts for the Santa Ynez River using a hydrologic computer model, Alert telemetered rainfall data, radar, and quantitative precipitation forecasts. If, prior to any storm event the model indicates that the storm has the potential to generate a 15,000 cubic feet per second (cfs) or greater flow in the Santa Ynez River near Lompoc, the storm may be seeded *only* if; (1) both the District/Agency and Project meteorologist concur, and (2) measures are taken to continuously monitor the storm event. If stream flow runoff forecasts predict flows of over 15,000 cfs in the Santa Ynez River near Lompoc based on **observed** rainfall data, seeding operations which may impact the Santa Ynez River flow below Bradbury Dam shall be immediately suspended.

3. Should it be predicted that Lake Cachuma entirely fill and/or spill based on the Flood Control's Santa Ynez River computer flow model, seeding operations to target the Santa Ynez Watershed will be suspended for the remainder of the season.

The La Brea Fire Area:

1. The La Brea Fire Area is not a targeted area of the cloud seeding program. However, due to ongoing recovery and the fact that this area is *adjacent* to the Twitchell Reservoir target, if the NWS predicts 0.8" per hour or greater rainfall intensity for the La Brea Fire Area, seeding would not be conducted in

the adjacent project area (Huasna and Alamo drainages). If 0.8" per hour intensities are observed in the Twitchell target area, seeding activities shall be immediately suspended for the remainder of that storm event.

Twitchell Reservoir and the Cuyama River Watershed:

1. Cloud seeding operations shall be suspended in the Twitchell Watershed when District/Agency project that the conservation pool of Twitchell Reservoir will fill. The conservation pool is full at elevation 622.30' (108,758 acre-feet of storage). This leaves 89,000 AF of Flood Control capacity.

2. Seeding operations shall be suspended if the current or projected flow on the Cuyama River is 15,000 cfs or greater, as determined by the District/Agency.

3. Seeding operations shall be suspended if the NWS or NOAA predicts a storm of 6" or greater over any 24-hour period to occur in any location within the Sisquoc Watershed. The Sisquoc River has no control facilities on it and significant flows emanating from it can affect the Santa Maria River levee.

Note: All suspension criteria are subject to revision should hydrologic conditions warrant it. All revisions must be documented in writing and be approved by District/Agency representatives with notification provided to the project meteorologist.

2.0 PROJECT LOCATION

The cloud seeding program targets two geographical areas: the Santa Ynez River watershed above Lake Cachuma in Santa Barbara County and the Alamo and Huasna tributaries of the Twitchell Reservoir watershed within Santa Barbara and San Luis Obispo Counties. Land-based AgI seeding sites are located on ridges or peaks in remote areas away from residential land uses. The project is conducted in all Supervisorial Districts.

2.1 Site Information	
Comprehensive Plan Designation	Rural, inland
Zoning District, Ordinance	All
Site Size	NA
Present Use & Development	NA
Surrounding Uses/Zoning	North: All South: All East: All West: All
Access	Public Airspace and Private Property
Public Services	Water Supply: NA Sewage: NA Fire: NA Other: NA

3.0 ENVIRONMENTAL SETTING

3.1 PHYSICAL SETTING

The project is regional in scope and would affect various types of vegetation, landforms and biological habitat. The primary and most observable effect of the increases in rainfall resulting from the cloud seeding activities would be an occasional increase in stream and river flow. This would lead to greater average annual inflow to surface reservoirs (Gibraltar Dam, Lake Cachuma, Twitchell Reservoir) and a corresponding increase in recharge to groundwater basins. Cloud seeding water is never wasted to the Ocean. If it is predicted that Lake Cachuma or Twitchell Reservoir will fill or spill cloud seeding operations are immediately ceased.

4.0 POTENTIALLY SIGNIFICANT EFFECTS CHECKLIST

The following checklist indicates the potential level of impact and is defined as follows:

Potentially Significant Impact: A fair argument can be made, based on the substantial evidence in the file, that an effect may be significant.

Less Than Significant Impact with Mitigation: Incorporation of mitigation measures has reduced an effect from a Potentially Significant Impact to a Less Than Significant Impact.

Less Than Significant Impact: An impact is considered adverse but does not trigger a significance threshold.

No Impact: There is adequate support that the referenced information sources show that the impact simply does not apply to the subject project.

Reviewed Under Previous Document: The analysis contained in a previously adopted/certified environmental document addresses this issue adequately for use in the current case and is summarized in the discussion below. The discussion should include reference to the previous documents, a citation of the page(s) where the information is found, and identification of mitigation measures incorporated from the previous documents.

4.1 AESTHETICS/VISUAL RESOURCES

Will the proposal result in:	Poten. Signif.	Less than Signif. with Mitigation	Less Than Signif.	No Impact	Reviewed Under Previous Document
a. The obstruction of any scenic vista or view open to the public or the creation of an aesthetically offensive site open to public view?				X	
b. Change to the visual character of an area?				X	
c. Glare or night lighting which may affect adjoining areas?				X	
d. Visually incompatible structures?				X	

The cloud seeding program involves remotely-sited land-based AgI seeding sites and aircraft. Thus, no change in the visual character of the project area would occur with implementation of the program.

Mitigation and Residual Impact:

No impacts are identified. No mitigations are necessary.

4.2 AGRICULTURAL RESOURCES

Will the proposal result in:	Poten. Signif.	Less than Signif. with Mitigation	Less Than Signif.	No Impact	Reviewed Under Previous Document
a. Convert prime agricultural land to non-agricultural use, impair agricultural land productivity (whether prime or non-prime) or conflict with agricultural preserve programs?				X	
b. An effect upon any unique or other farmland of State or Local Importance?				X	

The project would not involve the conversion of prime agricultural land to another use. Although an increase in rainfall could affect farming operations, the occasional and incremental increase in rainfall from individual storms during a winter season would not be anticipated to have a substantial effect on existing farming operations. In very wet winters where disruption of farming operations can occur, cloud seeding operations are not conducted due to potential flood hazards. In terms of water supply, the cloud seeding program would benefit agricultural land uses through the incremental increase in recharge of the groundwater basins relied upon to irrigate crops.

The project site does not contain a combination of acreage and/or soils which render the site an important agricultural resource.

Mitigation and Residual Impact:

No impacts are identified. No mitigations are necessary.

4.3 AIR QUALITY

Will the proposal result in:	**Poten. Signif.**	**Less than Signif. with Mitigation**	**Less Than Signif.**	**No Impact**	**Reviewed Under Previous Document**
a. The violation of any ambient air quality standard, a substantial contribution to an existing or projected air quality violation, or exposure of sensitive receptors to substantial pollutant concentrations (emissions from direct, indirect, mobile and stationary sources)?				X	
b. The creation of objectionable smoke, ash or odors?			X		
c. Extensive dust generation?				X	
Greenhouse Gas Emissions	**Poten. Signif.**	**Less than Signif. with Mitigation**	**Less Than Signif.**	**No Impact**	**Reviewed Under Previous Document**
d. Emissions equivalent to or greater than 10,000 metric tons (MT) of CO_2 per year from **stationar**y **sources** during long-term operations?				X	
e. Emissions equivalent to or greater than 1,100 MT of CO_2e (carbon dioxide equivalent) per year or 4.6 MT CO_2e/Service Population (residents + employees) per year from **other than stationary sources** during long-term operations?				X	
f. Emissions equivalent to or greater than 6.6 MT CO_2e/Service Population (residents + employees) per year for **plans** (General Plan Elements, Community Plans, etc.)?				X	

Impact Discussion:

The cloud seeding activities would not generate emissions that would violate any existing air quality standard or result in the creation of excessive dust. Furthermore, the proposed activities would occur only occasionally during certain storm events. Air pollution concerns are at a minimum during winter storms and smoke and odors created would be remote to areas of human contact. Thus, impacts would be less than significant. The project would not result in significant new vehicle emissions (i.e., new vehicular trips to or from the site would be fewer than 100). It would not involve new stationary sources (i.e., equipment, machinery, hazardous materials storage, industrial or chemical processing, etc.) that would increase the amount of pollutants released into the atmosphere. The project's contribution to global warming from the generation

of greenhouse gases would be negligible. If additional ground sites were developed there would not be any significant increase in vehicle emissions.

Mitigation and Residual Impact:

No mitigation required. Residual impacts would be less than significant. Potential new ground seeding sites would not result in new significant emissions.

4.4 BIOLOGICAL RESOURCES

Will the proposal result in:	Poten. Signif.	Less than Signif. with Mitigation	Less Than Signif.	No Impact	Reviewed Under Previous Document
Flora					
a. A loss or disturbance to a unique, rare or threatened plant community?				X	
b. A reduction in the numbers or restriction in the range of any unique, rare or threatened species of plants?				X	
c. A reduction in the extent, diversity, or quality of native vegetation (including brush removal for fire prevention and flood control improvements)?				X	
d. An impact on non-native vegetation whether naturalized or horticultural if of habitat value?				X	
e. The loss of healthy native specimen trees?				X	
f. Introduction of herbicides, pesticides, animal life, human habitation, non-native plants or other factors that would change or hamper the existing habitat?				X	
Fauna					
g. A reduction in the numbers, a restriction in the range, or an impact to the critical habitat of any unique, rare, threatened or endangered species of animals?				X	
h. A reduction in the diversity or numbers of animals onsite (including mammals, birds, reptiles, amphibians, fish or invertebrates)?				X	
i. A deterioration of existing fish or wildlife habitat (for foraging, breeding, roosting, nesting, etc.)?				X	
j. Introduction of barriers to movement of any resident or migratory fish or wildlife species?				X	
k. Introduction of any factors (light, fencing, noise, human presence and/or domestic animals) which could hinder the normal activities of wildlife?				X	

Existing Plant and Animal Communities/Conditions:

The project area involves large sections of Santa Barbara and San Luis Obispo counties. All types of plant and animal communities native to this area would be occasionally affected by the incremental increase in rainfall resulting from successful cloud seeding efforts.

Impact Discussion:

An observable effect of cloud seeding activities would be an occasional increase in stream and river flow over natural conditions within the project area. These increases in flow would occur in different areas at different times with each seeded storm event, and result in an overall increase in long-term average annual flow of area streams and rivers. Although some increase in sedimentation would be expected with the cloud seeding-induced higher stream flow, these effects on habitat are not anticipated to be substantial. This conclusion is based on the intermittent nature of cloud seeding efforts (not all storms are seeded), the fact that cloud seeding efforts over the long-term only incrementally increase rainfall on the order of 10-15 percent, and the fact that most erosion and sediment flux in rivers occurs during major flood events when cloud seeding operations would be suspended.

The increase in rainfall would have a beneficial effect on biological resources. Increased rainfall and stream flow would promote additional vegetative growth and cause seasonal wetlands to be more extensive and to last further into the summer months and drought periods than would otherwise occur.

Mitigation and Residual Impact:

No impacts are identified. No mitigations are necessary.

4.5 CULTURAL RESOURCES

Will the proposal result in:	Poten. Signif.	Less than Signif. with Mitigation	Less Than Signif.	No Impact	Reviewed Under Previous Document
Archaeological Resources					
a. Disruption, alteration, destruction, or adverse effect on a recorded prehistoric or historic archaeological site (note site number below)?				X	
b. Disruption or removal of human remains?				X	
c. Increased potential for trespassing, vandalizing, or sabotaging archaeological resources?				X	
d. Ground disturbances in an area with potential cultural resource sensitivity based on the location of known historic or prehistoric sites?		X			
Ethnic Resources					
e. Disruption of or adverse effects upon a prehistoric or historic archaeological site or property of historic or cultural significance to a community or ethnic group?				X	
f. Increased potential for trespassing, vandalizing, or sabotaging ethnic, sacred, or ceremonial places?				X	
g. The potential to conflict with or restrict existing religious, sacred, or educational use of the area?				X	

Impact Discussion:

The proposed project, if utilizing existing land-based facilities, would not have any foreseeable effect on cultural resources. Installation of new land-based AgI seeding sites, however, could potentially impact cultural resources as they are placed on remote hilltop locations where cultural resources could potentially be present. Although the site preparation is minimal for an AgI seeding

site and does not require even a foundation as portable equipment is available, some potential remains for the disturbance of cultural remains. There are no plans for development of new land-based AgI seeding sites at this time.

Mitigation and Residual Impact:

1. In the event archaeological remains are encountered during installation of a silver iodide seeding site, work shall be stopped immediately or redirected until a P&D qualified archaeologist and Native American representative are retained by SBCWA or authorized representative to evaluate the significance of the find pursuant to Phase 2 investigations of the County Archaeological Guidelines. If remains are found to be significant, they shall be subject to a Phase 3 mitigation program consistent with County Archaeological Guidelines and funded by the County Water Agency.

Plan Requirements/Timing: SBCWA shall inform in writing all contractors retained to install an AgI seeding site of this condition.

Monitoring: SBCWA personnel shall meet with contractors prior to station installation and shall inspect the site during construction to assure compliance with this condition.

With this mitigation measure, residual impacts on cultural resources would be less than significant (Class II).

4.6 ENERGY

Will the proposal result in:	Poten. Signif.	Less than Signif. with Mitigation	Less Than Signif.	No Impact	Reviewed Under Previous Document
a. Substantial increase in demand, especially during peak periods, upon existing sources of energy?				X	
b. Requirement for the development or extension of new sources of energy?				X	

Impact Discussion:

The proposed project would not involve any effect on energy supplies or the demand for energy.

Mitigation and Residual Impact:

No impacts are identified. No mitigations are necessary.

4.7 FIRE PROTECTION

Will the proposal result in:	Poten. Signif.	Less than Signif. with Mitigation	Less Than Signif.	No Impact	Reviewed Under Previous Document
a. Introduction of development into an existing high fire hazard area?			X		
b. Project-caused high fire hazard?				X	
c. Introduction of development into an area without adequate water pressure, fire hydrants or adequate access for firefighting?				X	
d. Introduction of development that will hamper fire prevention techniques such as controlled burns or backfiring in high fire hazard areas?				X	

Will the proposal result in:	Poten. Signif.	Less than Signif. with Mitigation	Less Than Signif.	No Impact	Reviewed Under Previous Document
e. Development of structures beyond safe Fire Dept. response time?				X	

Impact Discussion:

Although the land-based seeding sites utilize flame to burn the silver iodide complexes, they do not pose a substantial fire risk. This is because they would only be operated during wet weather conditions in the winter season. In addition, the ground sites are periodically cleared of all vegetation in a 30' radius around all sites and spark arrestors cover the seeding flares.

Mitigation and Residual Impact:

No mitigation is required. Residual impacts are less than significant.

4.8 GEOLOGIC PROCESSES

Will the proposal result in:	Poten. Signif.	Less than Signif. with Mitigation	Less Than Signif.	No Impact	Reviewed Under Previous Document
a. Exposure to or production of unstable earth conditions such as landslides, earthquakes, liquefaction, soil creep, mudslides, ground failure (including expansive, compressible, collapsible soils), or similar hazards?				X	
b. Disruption, displacement, compaction or overcovering of the soil by cuts, fills or extensive grading?				X	
c. Exposure to or production of permanent changes in topography, such as bluff retreat or sea level rise?				X	
d. The destruction, covering or modification of any unique geologic, paleontologic or physical features?				X	
e. Any increase in wind or water erosion of soils, either on or off the site?				X	
f. Changes in deposition or erosion of beach sands or dunes, or changes in siltation, deposition or erosion which may modify the channel of a river, or stream, or the bed of the ocean, or any bay, inlet or lake?				X	
g. The placement of septic disposal systems in impermeable soils with severe constraints to disposal of liquid effluent?				X	
h. Extraction of mineral or ore?				X	
i. Excessive grading on slopes of over 20%?				X	
j. Sand or gravel removal or loss of topsoil?				X	
k. Vibrations, from short-term construction or long-term operation, which may affect adjoining areas?				X	
l. Excessive spoils, tailings or over-burden?				X	

Impact Discussion:

In general, incremental increases in the intensity of rainfall events and annual precipitation due to cloud seeding activities have the potential to trigger landslides and increased erosion and

sedimentation. This potential is limited, however, and not considered substantial due to the operational constraints on the cloud seeding program, the incremental nature of the potential increase in long-term precipitation (on the order of 10-15 percent) and the low likelihood that people or manmade structures would be affected given the low level of development in the targeted watershed areas.

Most landslide failures of area hillsides are triggered or are accelerated during very wet winter seasons or storms characterized by flooding along streams and rivers. During these events, however, cloud seeding is suspended due to flood hazard concerns. Unstable slopes that are prone to landslide failure would likely fail during major rainfall events or heavy rainfall seasons unaffected by cloud seeding activities. Furthermore, the Suspension Criteria adopted for any particular year would preclude cloud seeding activities that could affect burn areas susceptible to erosion. In addition, increased vegetative growth due to increased rainfall would at least partially offset the erosive potential of increased rainfall. There is no substantial evidence that cloud seeding activities conducted by Santa Barbara County over the past 33 years have caused a major slope failure.

As discussed in the Biological Resources section above, an observable effect of cloud seeding activities would be an occasional increase in stream and river flow over natural conditions within the project area. These increases in flow would occur in different areas at different times with each seeded storm event, and result in an overall increase in long-term average annual flow of area streams and rivers. Although some increase in erosion and sedimentation would be expected with the cloud seeding-induced higher stream flow, these effects are not anticipated to be substantial. This conclusion is based on the intermittent nature of cloud seeding efforts (not all storms are seeded), the fact that cloud seeding efforts over the long-term only incrementally increase rainfall on the order of 10-15 percent, and the fact that most erosion in rivers occurs during flood events when cloud seeding operations would be suspended.

Installation of new land-based seeding sites is not anticipated to cause or be subject to severe geologic hazards. Such stations are not occupied structures which present a public health and safety concern involving geologic hazards that could “impact” site inhabitants. Given their small size and the criteria for placement included in the project description, the construction of these facilities are also not anticipated to involve the creation of new geologic hazards such as severe erosion and slope failure.

Mitigation and Residual Impact:

No impacts are identified. No mitigations are necessary.

4.9 HAZARDOUS MATERIALS/RISK OF UPSET

Will the proposal result in:	Poten. Signif.	Less than Signif. with Mitigation	Less Than Signif.	No Impact	Reviewed Under Previous Document
a. In the known history of this property, have there been any past uses, storage or discharge of hazardous materials (e.g., fuel or oil stored in underground tanks, pesticides, solvents or other chemicals)?				X	
b. The use, storage or distribution of hazardous or toxic materials?				X	
c. A risk of an explosion or the release of hazardous substances (e.g., oil, gas, biocides, bacteria, pesticides, chemicals or radiation) in the event of an accident or upset conditions?				X	
d. Possible interference with an emergency response plan or an emergency evacuation plan?				X	
e. The creation of a potential public health hazard?				X	
f. Public safety hazards (e.g., due to development near chemical or industrial activity, producing oil wells, toxic disposal sites, etc.)?		X			
g. Exposure to hazards from oil or gas pipelines or oil well facilities?				X	
h. The contamination of a public water supply?				X	

Impact Discussion:

The operation of land-based AgI seeding sites involves the handling and storage of silver iodide complex flares. Potential hazards associated with these project components are addressed by standard hazardous material and Uniform Fire Code regulations enforced by the fire departments having jurisdiction in the project area. Among these regulations is the requirement that brush be cleared in the immediate area around the generator unit prior to the initiation of each season of generator operation. Of the materials used, only silver iodide complexes used at land-based generator sites have the potential to accumulate in a localized area. The potential for substantial accumulation of this substance around generator sites is minimized by placement of the seeding sites in areas of greatest updraft and atmospheric dispersion. No known substantial AgI accumulations have formed at the existing sites in the 33 year history of the program. Based on a history of problem-free operation and the regulation of the use and storage of the chemicals, no substantial contamination or fire hazards are anticipated with the operation of the seeding facilities. Finally, any new seeding sites could present public safety hazards were they not fenced.

With the mitigation measure provided below, impacts would be considered potentially significant but subject to effective mitigation (Class II).

Mitigation and Residual Impact:

1. All new land-based AgI seeding sites that are accessible by the public shall be fenced. **Plan Requirements and Timing:** Prior to the use of a new AgI seeding site, a chain-link fence shall be erected to completely enclose the facility to prevent unauthorized access.

Monitoring: SBCWA shall include fencing requirements in construction plans and shall conduct site inspections to assure compliance with this condition.

With incorporation of this mitigation measure, residual impacts would be less than significant.

4.10 HISTORIC RESOURCES

Will the proposal result in:	Poten. Signif.	Less than Signif. with Mitigation	Less Than Signif.	No Impact	Reviewed Under Previous Document
a. Adverse physical or aesthetic impacts on a structure or property at least 50 years old and/or of historic or cultural significance to the community, state or nation?				X	
b. Beneficial impacts to an historic resource by providing rehabilitation, protection in a conservation/open easement, etc.?				X	

Impact Discussion:

No historic structures would be affected by the proposed cloud seeding activities. Therefore, no impacts to historic resources would result.

Mitigation and Residual Impact:

No impacts are identified. No mitigations are necessary

4.11 LAND USE

Will the proposal result in:	Poten. Signif.	Less than Signif. with Mitigation	Less Than Signif.	No Impact	Reviewed Under Previous Document
a. Structures and/or land use incompatible with existing land use?				X	
b. Conflict with any applicable land use plan, policy, or regulation of an agency with jurisdiction over the project (including, but not limited to the general plan, specific plan, local coastal program, or zoning ordinance) adopted for the purpose of avoiding or mitigating an environmental effect?				X	
c. The induction of substantial growth or concentration of population?				X	
d. The extension of sewer trunk lines or access roads with capacity to serve new development beyond this proposed project?				X	
e. Loss of existing affordable dwellings through demolition, conversion or removal?				X	
f. Displacement of substantial numbers of existing housing, necessitating the construction of replacement housing elsewhere?				X	

Will the proposal result in:	Poten. Signif.	Less than Signif. with Mitigation	Less Than Signif.	No Impact	Reviewed Under Previous Document
g. Displacement of substantial numbers of people, necessitating the construction of replacement housing elsewhere?				X	
h. The loss of a substantial amount of open space?				X	
i. An economic or social effect that would result in a physical change? (i.e. Closure of a freeway ramp results in isolation of an area, businesses located in the vicinity close, neighborhood degenerates, and buildings deteriorate. Or, if construction of new freeway divides an existing community, the construction would be the physical change, but the economic/social effect on the community would be the basis for determining that the physical change would be significant.)				X	
j. Conflicts with adopted airport safety zones?				X	

Impact Discussion:

The proposed cloud seeding program would have no effect on land use within the project area.

Mitigation and Residual Impact:

No impacts are identified. No mitigations are necessary

4.12 NOISE

Will the proposal result in:	Poten. Signif.	Less than Signif. with Mitigation	Less Than Signif.	No Impact	Reviewed Under Previous Document
a. Long-term exposure of people to noise levels exceeding County thresholds (e.g. locating noise sensitive uses next to an airport)?				X	
b. Short-term exposure of people to noise levels exceeding County thresholds?				X	
c. Project-generated substantial increase in the ambient noise levels for adjoining areas (either day or night)?				X	

Impact Discussion:

Existing land-based AgI seeding sites and potential future land-based seeding sites would be, located in remote areas away from residential uses or other sensitive receptors.

Mitigation and Residual Impact:

No impacts are identified. No mitigations are necessary

4.13 PUBLIC FACILITIES

Will the proposal result in:	Poten. Signif.	Less than Signif. with Mitigation	Less Than Signif.	No Impact	Reviewed Under Previous Document
a. A need for new or altered police protection and/or health care services?				X	
b. Student generation exceeding school capacity?				X	
c. Significant amounts of solid waste or breach any national, state, or local standards or thresholds relating to solid waste disposal and generation (including recycling facilities and existing landfill capacity)?				X	
d. A need for new or altered sewer system facilities (sewer lines, lift-stations, etc.)?				X	
e. The construction of new storm water drainage or water quality control facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?				X	

Impact Discussion: No new public facilities would be required to serve the proposed project.

Mitigation and Residual Impact:

No impacts are identified. No mitigations are necessary.

4.14 RECREATION

Will the proposal result in:	Poten. Signif.	Less than Signif. with Mitigation	Less Than Signif.	No Impact	Reviewed Under Previous Document
a. Conflict with established recreational uses of the area?				X	
b. Conflict with biking, equestrian and hiking trails?				X	
c. Substantial impact on the quality or quantity of existing recreational opportunities (e.g., overuse of an area with constraints on numbers of people, vehicles, animals, etc. which might safely use the area)?				X	

Impact Discussion: The cloud seeding activities would have no foreseeable effect on recreation in the project area.

Mitigation and Residual Impact:

No impacts are identified. No mitigations are necessary.

4.15 TRANSPORTATION/CIRCULATION

Will the proposal result in:	Poten. Signif.	Less than Signif. with Mitigation	Less Than Signif.	No Impact	Reviewed Under Previous Document
a. Generation of substantial additional vehicular movement (daily, peak-hour, etc.) in relation to existing traffic load and capacity of the street system?				X	
b. A need for private or public road maintenance, or need for new road(s)?				X	
c. Effects on existing parking facilities, or demand for new parking?				X	
d. Substantial impact upon existing transit systems (e.g. bus service) or alteration of present patterns of circulation or movement of people and/or goods?				X	
e. Alteration to waterborne, rail or air traffic?				X	
f. Increase in traffic hazards to motor vehicles, bicyclists or pedestrians (including short-term construction and long-term operational)?				X	
g. Inadequate sight distance?				X	
ingress/egress?				X	
general road capacity?				X	
emergency access?				X	
h. Impacts to Congestion Management Plan system?				X	

Impact Discussion:

The cloud seeding activities would have no foreseeable effect on traffic in the project area. Staff access ground seeding sites only periodically thus there is no significant traffic generation.

Mitigation and Residual Impact:

No impacts are identified. No mitigations are necessary

4.16 WATER RESOURCES/FLOODING

Will the proposal result in:	Poten. Signif.	Less than Signif. with Mitigation	Less Than Signif.	No Impact	Reviewed Under Previous Document
a. Changes in currents, or the course or direction of water movements, in either marine or fresh waters?				X	
b. Changes in percolation rates, drainage patterns or the rate and amount of surface water runoff?				X	
c. Change in the amount of surface water in any water body?			X		
d. Discharge, directly or through a storm drain system, into surface waters (including but not limited to wetlands, riparian areas, ponds, springs, creeks, streams, rivers, lakes, estuaries, tidal areas, bays, ocean, etc.) or alteration of surface water quality, including but not limited to temperature, dissolved oxygen, turbidity, or thermal water pollution?				X	

Will the proposal result in:	Poten. Signif.	Less than Signif. with Mitigation	Less Than Signif.	No Impact	Reviewed Under Previous Document
e. Alterations to the course or flow of flood water or need for private or public flood control projects?				X	
f. Exposure of people or property to water related hazards such as flooding (placement of project in 100 year flood plain), accelerated runoff or tsunamis, sea level rise, or seawater intrusion?				X	
g. Alteration of the direction or rate of flow of groundwater?				X	
h. Change in the quantity of groundwater, either through direct additions or withdrawals, or through interception of an aquifer by cuts or excavations or recharge interference?				X	
i. Overdraft or over-commitment of any groundwater basin? Or, a significant increase in the existing overdraft or over-commitment of any groundwater basin?				X	
j. The substantial degradation of groundwater quality including saltwater intrusion?				X	
k. Substantial reduction in the amount of water otherwise available for public water supplies?				X	
l. Introduction of storm water pollutants (e.g., oil, grease, pesticides, nutrients, sediments, pathogens, etc.) into groundwater or surface water?				X	

Impact Discussion:

The proposed project is anticipated to result in an increase in annual rainfall in target areas of about 10-15 percent. An increase in surface water runoff and associated recharge to groundwater basins is the project objective and constitutes a beneficial impact on water resources as it would increase available water supplies. The cloud seeding activities would not involve a change in the direction of surface water or groundwater flow, or result in degradation of groundwater quality. The project would not contribute to flood hazards based upon the operational limits imposed by the Suspension Criteria. Impacts on water resources are considered less than significant.

Mitigation and Residual Impact:

No mitigation required. Residual impacts are less than significant.

5.0 INFORMATION SOURCES

5.1 County Departments Consulted

Police, Fire, Public Works, Flood Control, Parks, Environmental Health, Special Districts, Regional Programs, Other: _____

5.2 Comprehensive Plan

X Seismic Safety/Safety Element
Open Space Element
X Conservation Element
Noise Element

	Coastal Plan and Maps		Circulation Element
	ERME		

5.3 Other Sources

	Field work		Ag Preserve maps
	Calculations		Flood Control maps
X	Project plans	X	Other technical references (reports, survey, etc.)
	Traffic studies		
X	Records	X	Planning files, maps, reports
	Grading plans		Zoning maps
	Elevation, architectural renderings		Soils maps/reports
X	Published geological map/reports		Plant maps
X	Topographical maps	X	Archaeological maps and reports
			Other

6.0 PROJECT SPECIFIC *(short- and long-term)* AND CUMULATIVE IMPACT SUMMARY

Project Specific Impacts:

Class I Impacts: None

Class II Impacts: Cultural Resources, Risk of Upset (public safety).

Cumulative Impacts:

Evaluation of cumulative impacts not required.

7.0 MANDATORY FINDINGS OF SIGNIFICANCE

Will the proposal result in:	Poten. Signif.	Less than Signif. with Mitigation	Less Than Signif.	No Impact	Reviewed Under Previous Document
1. Does the project have the potential to substantially degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, substantially reduce the number or restrict the range of a rare or endangered plant or animal, contribute significantly to greenhouse gas emissions or significantly increase energy consumption, or eliminate important examples of the major periods of California history or prehistory?			X		
2. Does the project have the potential to achieve short-term to the disadvantage of long-term environmental goals?				X	
3. Does the project have impacts that are individually limited, but cumulatively considerable? ("Cumulatively considerable" means that the incremental effects of a project are considerable when viewed in connection with the effects of past projects, the effects of other current projects and the effects of probable future projects.)				X	
4. Does the project have environmental effects which will cause substantial adverse effects on human beings, either directly or indirectly?				X	
5. Is there disagreement supported by facts, reasonable assumptions predicated upon facts and/or expert opinion supported by facts over the significance of an effect which would warrant investigation in an EIR?				X	

Impact Discussion:

The proposed project does not the potential to substantially degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, substantially reduce the number or restrict the range of a rare or endangered plant or animal, contribute significantly to greenhouse gas emissions or significantly increase energy consumption, or eliminate important examples of the major periods of California history or prehistory. It does not have the potential to achieve short-term to the disadvantage of long-term environmental goals. It does not have impacts that are individually limited, but cumulatively considerable. It does not create environmental effects which will cause substantial adverse effects on human beings, either directly or indirectly. There is no disagreement supported by facts, reasonable assumptions predicated upon facts and/or expert opinion supported by facts over the significance of an effect which would warrant investigation in an EIR.

8.0 PROJECT ALTERNATIVES

As no potentially significant, adverse un-mitigitable impacts would result, project alternatives are not required to be evaluated.

9.0 INITIAL REVIEW OF PROJECT CONSISTENCY WITH APPLICABLE SUBDIVISION, ZONING AND COMPREHENSIVE PLAN REQUIREMENTS

The proposed project is not subject to Santa Barbara County Land Use and Development Code requirements as it is a project undertaken by an agency governed by the Board of Supervisors. The project would be consistent with the Groundwater Resources Element of the Conservation Element of the County Comprehensive Plan.

10.0 RECOMMENDATION BY P&D STAFF

On the basis of the Initial Study, the staff of Planning and Development:

____ Finds that the proposed project WILL NOT have a significant effect on the environment and, therefore, recommends that a Negative Declaration (ND) be prepared.

__X__ Finds that although the proposed project could have a significant effect on the environment, there will not be a significant effect in this case because the mitigation measures incorporated into the REVISED PROJECT DESCRIPTION would successfully mitigate the potentially significant impacts. Staff recommends the preparation of an ND. The ND finding is based on the assumption that mitigation measures will be acceptable to the applicant; if not acceptable a revised Initial Study finding for the preparation of an EIR may result.

____ Finds that the proposed project MAY have a significant effect on the environment, and recommends that an EIR be prepared.

____ Finds that from existing documents (previous EIRs, etc.) that a subsequent document (containing updated and site-specific information, etc.) pursuant to CEQA Sections 15162/15163/15164 should be prepared.

Potentially significant unavoidable adverse impact areas:

__X__ With Public Hearing _____ Without Public Hearing

PREVIOUS DOCUMENT: 00-ND-29, 92-ND-41, 81-ND-87

PROJECT EVALUATOR: DGabby **DATE:** 10/16/13

11.0 DETERMINATION BY ENVIRONMENTAL HEARING OFFICER

__✓__ I agree with staff conclusions. Preparation of the appropriate document may proceed.
____ I DO NOT agree with staff conclusions. The following actions will be taken:
____ I require consultation and further information prior to making my determination.

SIGNATURE: _____ **INITIAL STUDY DATE:** _____

SIGNATURE: _____ **NEGATIVE DECLARATION DATE:** _____

SIGNATURE: _____ **REVISION DATE:** _____

SIGNATURE: _____ **FINAL NEGATIVE DECLARATION DATE:** 10/16/13

Appendix A

2009 DWR Water Plan Precipitation Enhancement Section

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Precipitation Enhancement

Photo caption. Clouds over green foothills.

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Chapter 10. Precipitation Enhancement

Precipitation enhancement, commonly called "cloud seeding," artificially stimulates clouds to produce more rainfall or snowfall than they would naturally. Cloud seeding injects special substances into the clouds that enable snowflakes and raindrops to form more easily. Precipitation enhancement is the one form of weather modification done in California. Hail suppression (reducing the formation of large, damaging hailstones) and fog dispersal (when fog is below freezing temperature) projects are conducted in other states.

Winter orographic cloud seeding has been practiced in California since the early 1950s. Most of the projects are along the central and southern Sierra Nevada with some in the Coast Range. The projects generally use silver iodide as the active seeding agent, supplemented by dry ice if aerial seeding is done. Silver iodide can be applied from ground generators or from airplanes. Occasionally, other agents, such as liquid propane, are used. In recent years, some projects have been trying hygroscopic materials (substances that take up water from the air) as supplemental seeding agents. Figure 10-1 shows rain and snow enhancement programs which had operated at some time during the 2005-2007 seasons. (Most are long-term projects and were operated in all of the three years. A few, such as Monterey County, only ran in one or two seasons.) Historically, the number of operating projects has increased during droughts—up to 20 in 1991—but have leveled off at about a dozen in the more normal years. Most of the projects suspend operations during the very wet years once enough snow has accumulated to meet their water needs.

State requirements for sponsors of weather modification projects consist of filing a Notice of Intention (NOI) initially and every five years for continuing projects, some record keeping by operators and annual or biennial reports to the California Department of Water Resources. The items to include in the NOI can be obtained from DWR. In addition, sponsors need to comply with the California Environmental Quality Act (CEQA). Annual letter notices should also be sent to the board of supervisors of affected counties and to DWR. Activity reports are sent to the National Oceanic and Atmospheric Administration (NOAA) giving the number of days and hours of operation and the amount of seeding material applied.

Policy statements by both the American Meteorological Society and the World Meteorological Organization support the effectiveness of winter orographic cloud seeding projects. The American Society of Civil Engineers (ASCE) has also shown interest with its Policy Statement No. 275 on Atmospheric Water Management in 2003 and a report (ASCE/EWRI 42-04) "Standard Practice for the Design and Operation of Precipitation Enhancement Projects" in 2004. This standards document was followed by a second edition of ASCE Manual No. 81, "Guidelines for Cloud Seeding to Augment Precipitation," published in 2006.

Figure 10-1 **Rain and snow enhancement programs, 2005 through 2007 seasons**

	PROJECT	SPONSOR
1.	Lake Almanor	Pacific Gas & Electric Company
2.	Tahoe-Truckee	Desert Research Institute
3.	Upper American River	Sacramento Municipal Utility District
4.	Upper Mokelumne River	Pacific Gas & Electric Company
5.	Carson and Walker Rivers	Desert Research Institute
6.	Tuolumne River	Turlock and Modesto Irrigation Districts
7.	San Joaquin River	Southern California Edison Company
8.	Eastern Sierra	City of Los Angeles
9.	Kings River	Kings River Conservation District
10.	Kaweah River	Kaweah Delta Water Conservation District
11.	Kern River	North Kern Water Storage District
12.	Santa Barbara County	Santa Barbara County
13.	Monterey County	Monterey County
14.	North Fork Stanislaus River	Northern California Power Agency

For years weather modification supporters have faced a perceived negative bias in the scientific community. In June 2008, the international journal *Nature* advocated a renewed push for scientific research into weather modification activities. The editorial in a widely respected scientific journal may mark a turn in opinion. Massive weather modification efforts in China for the Olympics also lent support to the efficacy of the practice.

Cloud seeding has advantages over many other strategies for providing water. A project can be developed and implemented relatively quickly without multiyear lead times. In the snow zone, it can offset some of the loss in snowpack expected from global warming. This may be of benefit to mountain meadows and could delay the start of the fire season in the forest. As one of the resource strategies in California Water Plan Update 2005, precipitation enhancement can be considered as part of integrated regional water management in some regions in developing water management portfolios. Seeding opportunities tend to be greater in Northern California than in the south because of more frequent storms and cooler temperatures.

Since Update 2005, there have been several developments in weather modification. First, a new long-term project has been added on the North Fork of the Stanislaus River sponsored by the Northern California Power Authority. Its primary purpose is production of more hydroelectric power.

Pacific Gas and Electric Company (PG&E) is planning a new project on the Pit and McCloud rivers in Northern California at the headwaters of Shasta Lake. Since seeding opportunities tend to be greater as one moves north into colder winter weather and more frequent storms, this will likely be a fairly productive program. The plan is to increase precipitation recharge of the large volcanic aquifers that feed the Pit and McCloud Rivers year round and thereby increase hydroelectric power production. An added benefit would be water supply in the upper Sacramento River system at Shasta Reservoir. Projected yields, according to PG&E, could average 250,000 acre-feet (AF) per year, or about a 9 percent increase in runoff. The company plans to start seeding operations in the 2010-2011 water year. Once the aquifer is built up, the project is expected to produce 330 gigawatt hours (GWh) per year of additional hydroelectric energy.

The third area is the Colorado River Basin where a lengthy drought has caused the seven states through which it and its headwaters flow to look at all potential options. The best hope of augmenting Colorado River water supply is wintertime cloud seeding in the headwater states of Colorado, Utah, and Wyoming. Many seeding programs are in place. However, the basin states have agreed to work together in a program for implementing new programs and to designate new areas for seeding and possibly longer seasons of operation for existing projects. Fifteen projects are operating in the upper Colorado River region; there may be a potential for up to 15 more in the basin, including four in Arizona. A 2006 study by North American Weather Consultants estimated the combined potential yield of the new programs could average 800,000 AF per year. This is based on a 10 percent increase in precipitation. Additional amounts could be obtained by augmenting the existing programs. As a starter, the Lower Basin states added about $400,000 in the three years from 2006 through 2008 for Upper Basin cloud seeding efforts to enhance and extend the operating season.

On a discouraging note, Nevada's budget shortfalls in summer 2009 have greatly reduced the scope of the Desert Research Institute weather modification activities in California. Support has found to continue the Tahoe-Truckee project, but cloud seeding

in the Carson-Walker project has been discontinued, except possibly on a few ground seeding sites in the Walker River Basin.

Much more research in weather modification is desirable. The equipment required to conduct research is unaffordable for independent project sponsors, although much can be gained from piggybacking research onto existing programs. To this end, legislation was introduced in the 110th Congress by Senator Kay Hutchison of Texas and Congressman Mark Udall of Colorado for weather modification research and to increase the effectiveness of existing programs through applied research.

In California, proposals have been made to the California Energy Commission's Public Interest Energy Research (PIER) program for additional research into cloud seeding to evaluate the effectiveness of existing programs in the state and optimize their effectiveness. This approach would survey the latest scientific advances in cloud physics, remote sensing, atmospheric science, and seeding technologies; evaluate strategies; and recommend the best course of action to maximize the contribution of operational cloud seeding programs for the state's water and energy supplies. Research could also be conducted on the potential effect of global warming and atmospheric pollution on seeding practices and capabilities. DWR recommends that PIER include and fund research on cloud seeding in their activities.

The State of Wyoming has undertaken a major weather modification research program, which is entering its 5th year (2009-2010). The objective is to evaluate, with help from scientists at the National Center for Atmospheric Research, the potential for increased snowpack in the Sierra Madre and Medicine Bow Mountains with a randomized experimental design. Some storms will be seeded and some will be left unseeded with extensive measurements of moisture tracking in the air and results on the ground. Another three years will be needed after the current one to gain the 120 to 150 cases needed to detect with confidence a 10 percent increase in snowpack due to seeding. A full operational program might yield 250,000 AFY on average.

Benefits from Current and Potential Precipitation Enhancement

In California, all precipitation enhancement projects are intended to increase water supply or hydroelectric power. The amount of water produced is difficult to determine, but estimates range from a 2 to 15 percent increase in annual precipitation or runoff. A National Research Council (NRC) 2003 report on weather modification suggested that there is considerable evidence that winter orographic weather modification does work, possibly up to a 10 percent increase. A detailed study by the Utah Department of Natural Resources in 2005 showed an average increase in April 1 snowpack water content ranging from 2 to 18 percent from a group of projects that had been operating from 2 (High Uintas) to 27 (Central/Southern Utah) years. The overall estimated annual runoff increase for the state was about 230,000 AF, or 7 percent for the study

Box 10-1 Acronyms and Abbreviations

AF	acre-feet
ASCE	American Society of Civil Engineers
CEQA	California Environmental Quality Act
DWR	California Department of Water Resources
GWh	gigawatt hours
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intention
NRC	National Research Council
PG&E	Pacific Gas and Electric
PIER	Public Interest Energy Research
S.	US Senate bill
TAF	thousand acre-feet
USBR	US Bureau of Reclamation

area. Actual increases in annual runoff are probably less in California than in Utah. A conservative estimate made for Water Plan Update 2005 by DWR staff is that the combined California precipitation enhancement projects generate 300 to 400 thousand AF annually, which would be an average of about a 4 percent increase in runoff. Nearly half of the projects are conducted by utilities, so there is also a substantial incremental benefit to hydroelectric power generation.

Although the planned Pit River project occupies one of the most favorable areas for cloud seeding, another 200 to 300 thousand AF per year may yet be available. Many of the best prospects are in other parts of the Sacramento River Basin, in watersheds that are not now seeded. The Lahontan region is already well covered by cloud seeding projects, except for the Susan River. With the exception of the upper Trinity River watershed, and perhaps the Russian River, there is little new potential in the North Coast region because not much extra rainfall could be captured due to limited storage capacity. There is, however, potential to increase water production by more effective seeding operations in existing projects.

Precipitation enhancement should not be viewed as a remedy for drought. Cloud seeding opportunities are generally fewer in dry years. It works better in combination with surface or groundwater storage to increase average supplies. In the very wet years, when sponsors already have enough water, cloud seeding operations are usually suspended.

Potential Costs

Costs for cloud seeding are generally less than $20 per AF per year. State law says that water gained from cloud seeding is treated the same as natural supply in regard to water rights. It is estimated that about $3 million to $4 million is spent now on

yearly operations. Achieving an additional 200 to 300 TAF of potential new supply (beyond the planned Pit-McCloud project) could require an initial investment of around $7 million for planning, reports, and initial equipment, plus around $4 million in annual operating costs. Over the next 25 years, that would total $107 million, an average of nearly $20 per AF.

Major Issues for Precipitation Enhancement

Reliable Data

No complete and rigorous comprehensive study has been made of all California precipitation enhancement projects. Part of the reason is the difficulty in locating unaffected control basins. Some studies of individual projects have been made in the past on certain projects, such as the Kings River, that have shown increases in water.

Operational Precision

It is difficult to accurately target the location and time of cloud seeding. There is an incomplete understanding of the effectiveness of current targeting practices. Chemical tracer experiments have provided support for some targeting practices. New atmospheric measuring tools (currently being employed by the NOAA hydrometeorological test bed experiments) can be used in studies of new seeding agents, transport, and diffusion to improve operational precision.

Concern over Potential Impacts

Questions about potential unintended impacts from precipitation enhancement have been raised and addressed over the years. Common concerns relate to downwind effects (enhancing precipitation in one area at the expense of those downwind), long-term toxic effects of silver, and added snow removal costs in mountain counties. The US Bureau of Reclamation (USBR) did extensive studies on these issues. The finding is reported in its Project Skywater programmatic environmental statement in 1977 and its Sierra Cooperative Pilot Project environmental impact statement in 1981. The available

Photo Image of ground-based seeder. Image courtesy of Pacific Gas and Electric Company

evidence does not show that seeding clouds with silver iodide causes a decrease in downwind precipitation; in fact, at times some of the increase of the target area may extend up to 100 miles downwind.

The potential for eventual toxic effects of silver has not been shown to be a problem. Silver and silver compounds have a rather low order of toxicity. According to USBR, the small amounts used in cloud seeding do not compare to industry emissions of 100 times as much into the atmosphere in many parts of the country or individual exposure from tooth fillings. Watershed concentrations would be extremely low because only small amounts of seeding agent are used. Accumulations in the soil, vegetation, and surface runoff have not been large enough to measure above natural background. A 2004 study done for Snowy Hydro Limited in Australia has confirmed the earlier findings cited above. Some recent silver accumulation testing by PG&E on the Mokelumne River and Lake Almanor watersheds was reported at the 2007 annual meeting of the Weather Modification Association. Both watersheds have been seeded for more than 50 years. Sampling at Upper Blue Lake and Salt Springs Reservoir showed very low to nondetectable concentrations in water and sediment. Similar results were found at Lake Almanor in testing water, sediment, and fish samples during the 2000 to 2003 period. Amounts were far below any toxic levels, and there was little to suggest bioaccumulation. Therefore, continued operations should not result in any significant chronic effect on sensitive aquatic organisms.

In regard to snow removal, little direct relationship to increased costs was found for small incremental changes in storm size because the amount of equipment and manpower to maintain the roadway is essentially unchanged. That is, the effort is practically the same to clear a road of 5.5 inches as it is to clear 5 inches.

All operating projects have suspension criteria designed to stop cloud seeding any time there is a flood threat. Moreover, the types of storms that produce large floods are naturally quite efficient in processing moisture into rain anyway. In such conditions, seeding is unlikely to make a difference.

Funding

Little federal research funding for weather modification has been available in the past 15 years. USBR had some funding in 2002 and 2003 in the Weather Damage Mitigation program. Desert Research Institute of Nevada did obtain a grant of $318,000 from this source early in 2003 to evaluate its seeding in the eastern Sierra.

As noted earlier, bills were introduced in the 110th Congress which would re-establish federal support for more weather modification research, some of which would provide research support on existing operating projects. The legislation was supported by the Western States Water Council, the seven Colorado River Basin states, the Colorado River Board of California, DWR and others. The bill was reintroduced in 2009 as S. 601 in the 111th Congress and was remolded into the Weather Mitigation Research and Development Act which would establish a Weather Mitigation Research Office within

the National Science Foundation with a budget of $ 25 million a year. Prospects of passage do not appear bright.

Inadvertent Weather Modification

There is evidence that human activities such as biomass burning, transportation, and agricultural and industrial activities modify local and sometimes regional weather. The effect of aerosols on clouds and precipitation is complex. Recent studies by Ramanathan and Rosenfeld suggest suppressed precipitation formation in affected clouds due to pollution and dust. Some aerosols can enhance precipitation and some, especially the very fine aerosols in diesel smoke, can reduce precipitation. Much more research is needed to evaluate the air pollution effects on precipitation processes and the amount of impact as well as possible effects on cloud seeding programs. It is possible that some of the California cloud seeding projects have offset a potential loss in precipitation from air pollution, which may have obscured a more positive signal from the weather modification projects. Research work in Israel has demonstrated such effects.

Recommendations to Increase Precipitation Enhancement

1. The State should support the continuation of current projects as well as the development of new projects and help seek research funds for both old and new projects. Operational funding support for new projects may be available in the integrated regional water management program.

2. DWR should collect base data and project-sponsor evaluations of existing California and other western states' precipitation enhancement projects, independently analyze them, and perform research on the effectiveness of this technology to supplement water supplies while minimizing negative impacts. Specifically, DWR staff should monitor progress and research results of the Wyoming Weather Modification Pilot Program, a major research program which is costing Wyoming about $1 million dollars a year.

3. DWR should support efforts to investigate the potential to augment Colorado River supply by cloud seeding, in cooperation with the Colorado River Board, the other Colorado River Basin states, USBR, and Metropolitan Water District of Southern California.

4. DWR should support research on cloud physics and cloud modeling being done by NOAA labs and academic institutions. With improvement, these models may become tools to further verify and test the effectiveness of cloud seeding activities.

5. The State should support research on potential new seeding agents, particularly ones that work at higher temperatures. Global warming may limit the effectiveness

of silver iodide, the most commonly used agent, which requires cloud temperatures well below freezing, around -5º C, to be effective.

6. DWR should support efforts by California weather modification project sponsors, such as that proposed in 2002-03 by Santa Barbara County Water Agency, to obtain federal and State research funds for local research experiments built upon their operating cloud seeding projects. In this regard, DWR recommends that the California Energy Commission PIER program includes research studies on weather modification.

References

American Society of Civil Engineers, Environmental and Water Resources Institute. 2004. Standard practice for the design and operation of precipitation enhancement projects. Reston (VA): American Society of Civil Engineers. 63 p. ASCE/EWRI 42-04.

American Society of Civil Engineers. 2006. Guidelines for cloud seeding to augment precipitation. 2nd ed. Reston (VA): American Society of Civil Engineers. 200 p. ASCE Manual No. 81.

American Society of Civil Engineers. 2009. Atmospheric water resources management. ASCE Policy Statement 275. First Approved in 1980. Reston (VA): American Society of Civil Engineers. Available at: http://www.asce.org/pressroom/news/policy_details.cfm?hdlid=149

Department of Environment and Conservation. 2007. Final draft report. Workshop on Cloud Seeding; 2007 Jan 31; Sydney (NSW) Australia. Sydney (NSW) Australia: NSW Department of Environment and Conservation and Sydney Catchment Authority. 5 p. Available at: http://www.bom.gov.au/bmrc/basic/events/cloud seeding/NSW_DEC_SCA_cloud seeding_report31Jan2007.pdf

Givati, A; Rosenfeld, D. 2004. Quantifying precipitation suppression due to air pollution. Journal of Applied Meteorology. 43(7):1038–1056.

Griffith, D; Solak, M. 2006. The potential use of winter cloud seeding programs to augment the flow of the Colorado river. Proposed for the Upper Colorado River Commission. Sandy (UT): North American Weather Consultants. 49 p.

Harris, ER. 1981. Sierra Cooperative Pilot Project: environmental assessment and finding of no significant impact. Denver (CO): Office of Atmospheric Resources Research. 196 p. Available at: http://www.usbr.gov/library/

Hunter, SA. 2007. Optimizing cloud seeding for water and energy in California. Prepared for the California Energy Commission PIER Program. Denver (CO): US Bureau of Reclamation. 38 p.

Marler, B; White, C; McCarthy, E; Stone, R. 2007. Cloud seeding impacts? Water, sediment and tissue studies. Powerpoint Presentation. Annual meeting of the Weather Modification Association; 2007 Apr 18-19; San Francisco (CA). Fresno (CA): Weather Modification Association. 23 slides. Available at: http://www.weathermodification.org/meeting_presentations_2007.htm

National Research Council. 2003. Critical issues in weather modification research. Washington (DC): The National Academies Press. 88 p.

Nature. 2008. Change in the weather. Editorial. Nature. 453(Jun 19):957-958. Available at: doi:10.1038/453957b

North American Interstate Weather Modification Council. 2004. North American Interstate Weather Modification Council response to "Critical Issues in Weather Modification Research," a report by the National Research Council. **[Internet].** [cited: 2009 Nov]. 2 p. Available at: http://www.naiwmc.org/4dcgi/GetContentPDF/PB-862/NRCresp.pdf

Ramanathan, V; Crutzen, P, J; Kiehl, J, T; Rosenfeld, D. 2001. Aerosols, climate, and the hydrologic cycle. Science 7. 294(5549):2119-2124. Available at: doi: 10.1126/science.1064034

Ramanathan, V; Ramana, M V. 2003. Atmospheric brown clouds, long range transport and climate impacts. EM. (Dec):28-33. Available at: http://cas.ucsd.edu/research/researchunit.cfm

Ryan, T. 2005. Weather modification for precipitation augmentation and its potential usefulness to the Colorado river basin states. Los Angeles (CA): Metropolitan Water District of Southern California. 34 p. Available at: http://cwcb.state.co.us/NR/rdonlyres/EEC21797-FAB1-46EF-BC82-BF7A1E2170A9/0/WxModBasinStates1.pdf

Southwest Hydrology. 2007. Cloud seeding. Mar/Apr. Tucson (AZ): Sustainability of semi-Arid Hydrology and Riparian Areas. 6(2):44 p. Available at: http://www.swhydro.arizona.edu/archive/V6_N2/

United Nations Environmental Program, Center for Clouds, Chemistry and Climate (C^4). 2002. The Asian brown cloud: climate and other environmental impacts. Nairobi: UNEP. Available at: http://www.rrcap.unep.org/abc/impactstudy/

US Bureau of Reclamation. 1975-1987. Project Skywater publications. Denver (CO): US Bureau of Reclamation. Available at: http://www.usbr.gov/library/

Utah Division of Water Resources. 2005. Utah cloud seeding program, increased runoff/cost analysis. Salt Lake City (UT): Utah Division of Water Resources. 15 p.

Weather Modification Association. 2004. Response to "Critical issues in weather modification research," report of a review panel. Journal of Weather Modification. 36:53-82.

Weather Modification Association. 2009. Weather Modification Association (WMA) position statement on the environmental impact of using silver iodide as a cloud seeding agent. **[Internet].** Fresno (CA): Weather Modification Association. [cited: 2009 Nov]. 5 p. Available at: http://www.weathermodification.org/statements.htm

Williams, BD; Denholm, JA. 2009. An assessment of the environmental toxicity of silver iodide - with reference to a cloud seeding trial in the snowy mountains of Australia. Journal of Weather Modification. 41:75-96.

Legal

[CEQA]. California Environmental Quality Act. Public Resources Code, section 21000 et seq. (1970).

[S. 601]. federal Weather Mitigation Research and Development Policy Authorization Act of 2009. 111th Congress. (2009).

Web sites

American Meteorological Society. **[Internet].** 2009. [cited: 2009 Nov]. Available at: http://www.ametsoc.org/

Desert Research Institute. **[Internet].** 2009. Reno (NV): [cited: 2009 Nov]. Available at: http://www.dri.edu/

National Oceanic and Atmospheric Administration. **[Internet].** 2009. [cited: 2009 Nov]. Available at: http://www.noaa.gov/

World Meteorological Organization. **[Internet].** 2009. [cited: 2009 Nov]. Available at: http://www.wmo.int

Appendix B

Geochemistry and Impacts of AgI Use in Cloud Seeding

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Cardno

ENTRIX

Shaping the Future

Geochemistry and Impacts

of Silver Iodide Use in Cloud Seeding

May 2011

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1 Introduction

Silver iodide and the closely-related silver chloroiodide ($AgI_{0.8}Cl_{0.2}$) is one of the most common nucleating materials used in cloud seeding, including projects in the Sierra Nevada range in California. The crystalline structure of silver iodide closely resembles that of ice, and as such it makes a very effective surrogate for ice as nucleating agents in the cloud. The first layer of water molecules to be laid down on a silver iodide particle substrate fits very closely, so the surface energy in the interface is small (Dennis, 1980).

Another reason that silver iodide is so commonly used for cloud seeding is that it is practically insoluble in water. That is, it stays in the solid form rather than dissolving in water. This characteristic is essential to the success of cloud seeding, because if the nucleating agent were to dissolve in water it would no longer be useful as a nucleation site for precipitation. In addition, by remaining in a solid form, the introduced silver iodide does not become biologically available in the environment, and as such does not have an adverse effect to human health and the environment.

Several multiyear studies have been conducted on cloud seeding, including the geochemistry and toxicity of silver iodide, as follows:

- Project Skywater (Howell, 1977), a program of research of weather modification by cloud seeding sponsored by the US Bureau of Reclamation.
- Critical Issues in Weather Modification Research (NAS, 2003), a study by the Academy to evaluate the effectiveness of current cloud seeding efforts.
- California Energy Commission Public Interest Energy Research Program (Hunter, 2007), presents the results of evaluating the state of the art in cloud seeding, and directions for further research.
- Mokelumne Lake and Sediment Study (Stone, 2006), a comprehensive monitoring effort using high-precision analytical techniques to evaluate the effects of cloud seeding using silver iodide on surface waters and sediments.

These studies are unanimous in their conclusion that silver iodide used in cloud seeding is practically insoluble, does not tend to dissociate to its component ions of silver and iodine, and is not bioavailable in the aquatic environment but instead remains in soils and sediments. These studies are the basis for the Department of Water Resources recommending weather modification by cloud seeding in its 2009 California Water Plan Update (DWR, 2009). This section summarizes the information available in the literature on this topic, including toxicity of elemental silver in the environment.

2 Properties of Silver Iodide

This section discusses the most important properties of silver iodide, including:

- Silver speciation, or the different elemental and molecular forms of silver in the environment;
- Silver iodide solubility, or its ability to dissolve in water;

- Silver iodide dissociation, or its ability to break down into its component elements silver and iodine;
- Silver iodide adsorptivity, or its ability to bind to soil and other particles.

2.1 Silver Speciation

Silver is relatively rare in the earth's crust, with an abundance of approximately 0.07 mg/kg. It is found in igneous rocks at concentrations ranging from 0.07 to 0.1 mg/kg (Eisler, 1996). It is concentrated in ore-forming processes, most commonly hydrothermal systems surrounding cooling plutons (subsurface magma bodies), and it is these deposits that are mined for human use. Silver can be found in its elemental state, and as silver sulfide, silver arsenide, silver chloride, silver nitrate, and silver iodide. Each of these is known as a silver species, and the different forms of silver found in the environment are known as silver speciation.

Elemental silver can be found in oxidation states of Ag^{0}, Ag^{+1}, Ag^{+2}, and Ag^{+3}, but only the Ag^{0} state (solid silver) and the Ag^{+1} state (free silver ion in water) occur in ambient environmental conditions. In water, silver can exist as simply free silver ion, or in various degrees of association with negative ions such as sulfate, bicarbonate, nitrate, iodide, and chloride. The properties of each silver species are very different. The free silver ion in water (Ag^{+}) is fungicidal, algicidal, and bactericidal at concentrations ranging from 10 – 1,000 µg/L. Ionic silver has also been used in medical applications for sterilizing potable water. In contrast, silver iodide, silver sulfide, and silver chloride are practically insoluble. Ratte (1999) has shown that insoluble or complexed silver (that is, not the free silver ion) are virtually non-toxic to terrestrial and aquatic vertebrates. For example, silver thiosulfate was found to be 15,000 times and silver chloride 11,000 times less toxic than the highly soluble silver nitrate (Ratte, 1999). Particulate silver chloride is described by Bury et al. (1999) and Rodgers et al. (1997) as virtually non-toxic.

In addition to forming different silver species which reduce silver's toxicity, the free silver ion (Ag^{+}) bonds, or forms complexes with, organic matter in water. Therefore, the toxicity of free silver ion can also be reduced by bonding with these particulates.

Most studies of silver in the environment have measured total silver, not the concentrations of the individual silver species. Since the free silver ion is the toxic form of silver, these studies overestimate the actual toxicity of the measured silver concentration. It is important to note that in discussions of toxicity, concentrations of silver iodide are compared to standards for elemental silver. This comparison is not meant to imply that elemental silver and silver iodide are equivalent, because they are not. Rather, the comparison is made to demonstrate that, **even if** one were to make the assumption that all silver iodide dissociates to silver and iodine (which in fact it does not), the concentrations of silver affected by cloud seeding are **still** less than any human health, aquatic life, or terrestrial life standards.

2.2 Solubility of Silver Iodide

Solubility is the measure of a compound's ability to dissolve in water. Solubility is measured by the solubility product, or K_{sp}. The reaction is expressed as:

$$Ag^{+} \text{ (liquid)} + I^{-} \text{ (liquid)} \rightarrow AgI \text{ (solid)}.$$

The solubility product for this reaction is K_{sp} value = 8.5×10^{-17}, which indicates that the reaction goes strongly to the solid form, AgI. The maximum concentration of free silver ion in contact with solid silver iodide at 25 ° C (standard conditions) is 9.84×10^{-7} g/L, or 9.84×10^{-4} mg/L (parts per million), or 0.984 µg/L (parts per billion) (Stone, 2006). This value of 0.984 µg/L, the maximum concentration of free silver ion that can be found in water that comes in contact with silver iodide particles from cloud seeding, is less than any toxicity standards or guidelines for silver, as described below in Section 3. Furthermore, any water that comes in contact with silver iodide particles will be greatly diluted by water or snow that did not come in contact with the particles. Accordingly the maximum amount of free silver ion that can be derived from contact with silver iodide particles in the natural environment is far less than this maximum possible value derived from the solubility.

2.3 Dissociation of Silver Iodide

Dissociation of a compound is a breaking down into its component parts. For silver iodide, dissociation produces silver (Ag^{+}) and iodine (I^{-}) ions in water. These ions will tend to bond and form the silver iodide solid, as described above in the discussion of solubility.

The solubility production of AgI, $K_{sp}=8.3 \times 10^{-17}$, is directly proportional to the dissociation constant, K_D. In a mixture of pure water and silver iodide solid, only a small amount of the silver iodide will dissociate and dissolve, producing a maximum possible concentration of 0.984 µg/L (see solubility discussion above). Table 1 lists the solubility for some common silver salts, including silver iodide (from Stone, 2006).

Table 1 Solubility of Selected Silver Salts

Silver Salts	Solubility, in g/100 ml	
	Cold water	Hot water
Silver nitrate AgNO3	122	952
Silver chloride AgCl	0.000089	0.0021
Silver iodide AgI	Insoluble	Insoluble
Silver sulfide Ag2S	Insoluble	Insoluble

Source: Stone, 2006

In a system with other ions that also bond to silver, such as sulfide ion, chloride ion, or dissolved organic carbon, dissociation of silver iodide can lead to new compounds, such as silver sulfide or silver chloride, forming in addition to silver iodide. The sulfide, chloride, and iodide in the system will preferentially form complexes with silver before silver ion (Ag^{+}) can remain stable.

Therefore, dissociation of silver iodide and other silver species in water will lead to a new equilibrium distribution of silver species. However, these species tend to be insoluble so that very little free silver ion remains available. In fact, only a high proportion of the very soluble (and dissociative) silver nitrate will produce appreciable amounts of the toxic free silver ion (Table 1).

2.4 Adsorptivity of Silver Iodide

Silver has been shown to strongly adsorb onto particulate matter in water. Some silver complexes and silver ions are readily adsorbed to particulate matter to the extent that only some 25 percent of total silver is estimated to be dissolved as either ion colloid or complexes (Wen et al., 1997, Stone, 2006). Silver also adsorbs to manganese dioxide, ferric compounds, and clay minerals (Stone, 2006).

Therefore, almost all of the silver iodide that is introduced by cloud seeding will remain in the solid form. First, silver iodide has a very low solubility and does not readily dissociate, so most of the silver introduced as silver iodide will stay as a solid silver iodide. The small amounts of free silver ion that may be produced, though less than any health or ecological standards, will in part adsorb to other solids. The solid silver iodide primarily remains as a solid, and resides in soil and sediments.

3 Measurements of Silver Iodide in the Environment

The Concise International Chemical Assessment Document 44 (CICAD 44) (WHO, 2002), has presented data from ultra-trace sampling and analysis techniques. For pristine, unpolluted areas such as rivers, lakes and estuaries, levels of < 0.01 µg/L were found, while for urban and industrialized areas the levels were typically 0.01-0.1 µg/L. Stone (2006) also uses these techniques, and notes the importance of sample contamination by dirty hands. CICAD 44 notes that, because ultra-clean metal sampling did not begin until the late 1980's, silver analyses reported for environmental studies and toxicity research prior to that period should be treated with caution. In the following, the data is presented as reported in the literature, but the improvement in sampling and analytical methods that has occurred since the 1990's has led to a better understanding of the occurrence of silver and silver species at the very low concentrations typical of environmental conditions outside silver mining districts, areas for the manufacture of photographic materials, and other areas of unusual concentration of silver.

Figure 1, taken from the comprehensive study of the effects of cloud seeding by silver iodide sponsored by the US Bureau of Reclamation (Howell, 1977), illustrates the various compartments in the environment where silver species can be found, and their approximate concentrations. The diagram also illustrates the exchange between compartments. The following discussion of the figure is taken from Howell (1977).

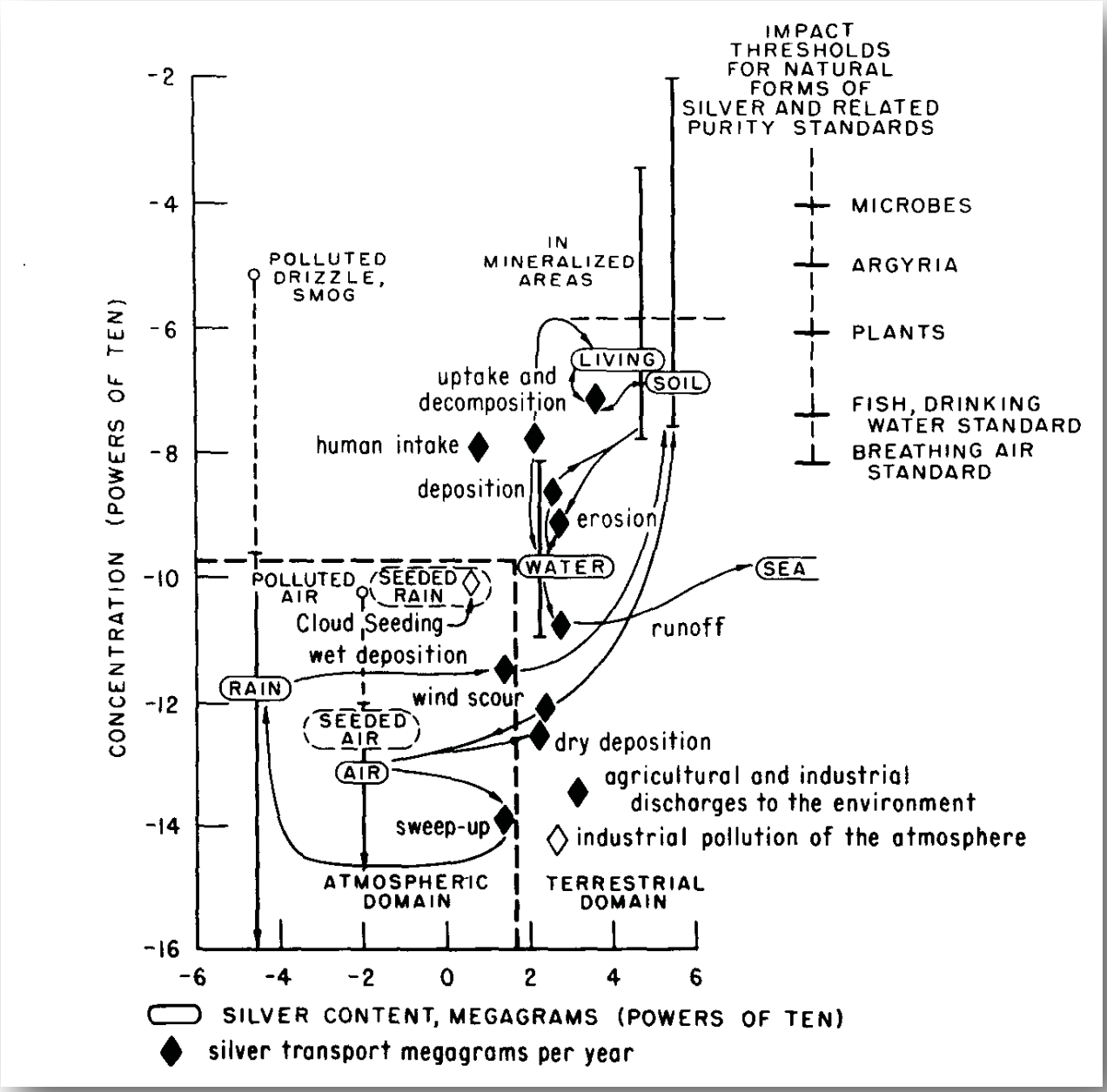

Figure 1 Generalized Approximate Content and Concentration of Silver in Environmental Compartments from the Contiguous United States, Pathways of Exchange between Compartments, and Impact Threshold Concentrations

The soil compartment (including also mud and vegetable litter), calculated for the top 20 cm compromising the root zone, contains by far the largest quantity of silver, at concentrations that may become quite high in areas subject to silver mining. Living matter of all sorts from microbes and fungi to animals (Shown as "Living" in Figure 1), which has on the average a slight tendency to concentrate silver from the soil, contains the next largest quantity. The exchange between living matter and soil through uptake and decomposition (designated by the diamonds

related to the bottom scale) dominates all other exchanges by at least an order of magnitude. The rates of exchanges are slow enough so that contents of these two compartments must change only slowly.

The silver concentration and content in lakes and rivers (shown in Figure 1 as "Water") are determined mainly by depositional and erosional exchanges with the soil and by runoff to the sea. Whereas, uptake and decomposition exchanges with plants play a lesser role. In the aquatic compartment, annual transports are of the same order of magnitude as contents. Most transport is thought to be waterborne sediment.

The atmospheric domain receives silver in the form of windblown dust, some of which is swept up by particles of precipitation (the label "Rain" includes snow) and is carried with it to the ground, to lakes, or to the sea. The silver content of the atmospheric compartment at any moment is small in comparison with the annual transport through it. Silver transports associated with cloud seeding and with pollution are shown in Figure 1 by open diamonds. Atmospheric pollution causes local temporary changes within the atmosphere compartment that are large in comparison with natural amounts. Industrial atmospheric emissions are variously estimated at 135 to >360 Mg (150-400 tons) per year (Carson and Smith, 1975; USEPA, 1973), at concentrations ranging from $\sim 10^{-10}$ in city air to extreme of 6×10^{-6} measured in the smog water within the downwind plume from a copper smelter (J. Fletcher, 1976, personal communication to Howell in Howell, 1977). The other main source of silver pollution affecting soil and surface waters is fertilizer, either Florida phosphates or processed sewage sludge (Carson and Smith, 1975).

Cloud seeding, if it became widespread, would result in local, temporary concentrations in precipitation of the same order of magnitude as the natural concentration in surface waters. However, the rates of exchange would remain more than an order of magnitude smaller that the principal exchanges affecting the aquatic compartment. The rates of exchange would also be many orders of magnitude smaller than those affecting plants and soil, even in localized areas of precipitation management, using silver iodide as the cloud-seeding agent. This is the case even assuming that all the silver dispersed in the course of a century accumulated in the top 2 cm of soil, would not cause the silver concentration there to exceed the normal background. Silver from seed rain follows a pathway essentially identical to those from natural rain, and the effect of it on the silver transport by wet deposition (an increase of <20%) is too small to be illustrated conveniently in Figure 1.

3.1 Background Concentrations of Silver

As reported in Eisler's study of silver in the environment (1996), the maximum concentrations of total silver recorded in various locations include the following: 36.5 $\mu g/m^3$ in air near a smelter in Idaho; 2.0 $\mu g/m^3$ in atmospheric dust; 0.1 µg/L in oil well brines; 6.0 µg/L in groundwater near a hazardous waste site; 8.9 µg/L in seawater from Galveston Bay, Texas; 260 µg/L in the Genesee River, New York—the recipient of photoprocessing wastes; 300 µg/L in steam wells; 300 ng/L in treated photoprocessing wastewaters; 31 mg/kg in some Idaho soils; 43 mg/L in water from certain hot springs; 50 mg/kg in granite; as much as 100 mg/kg in crude oils; 150 mg/kg in some Genesee River sediments; and 27,000 mg/kg in some solid wastes from photoprocessing effluents. Eisler (1996) emphasizes that only a small portion of the total silver

in each of these compartments is biologically available. For example, typical publicly owned treatment works receiving photoprocessing effluents show silver removal efficiencies greater than 90%; the mean concentration of free silver ion present in the effluents from these plants ranged from 0.001 to 0.07 µg/L (Lytle, 1987; Bober et al., 1992).

Therefore, the concentration of silver in the environment is variable depending on the location, geology, and past use history. The remainder of this section focuses on the western United States, and in areas outside of significant mining or photographic equipment manufacture.

Several projects and monitoring efforts document the background of silver in reservoirs, steams, and alpine lake settings. The concentration of silver in snow in the Sierra Nevada has been well documented over the past fifty years by a number of investigations for example, Warburton et al. (1994) and Stone (2006) as well as many other studies by Stone that are not referenced in his 2006 paper. Silver concentrations have remained essentially constant over the time span covered by these studies.

Table 2 provides a listing of the mean background silver concentration measured in several programs from other Sierra Nevada locations and seasons beginning in 1966. Assuming normal distribution, the average background concentration of silver can be stated as [Ag] =1.88 x 10^{-3} µg/L ($\sigma \pm 1.11 \times 10^{-3}$ µg/L). The highest mean concentration of silver was found to be <5.4 x 10^{-3} µg/L in the Tahoe Basin, Sierra Nevada; and the lowest concentration was found to be <1 x 10^{-3} µg/Lin the Ruby Mountains of Eastern Nevada (Stone, 2006).

Table 2 Natural Silver Background in Snow in the Western U.S.

Location	Period	Number of Samples	Mean [Ag] (x 10^{-3} µg/L)	Analytical Technique
Tahoe Basin, Sierra Nevada	1966-1969	169	<3.9	Ion Exchange – NAA
Tahoe Basin, Sierra Nevada	1970-1971	18	<4.7	Ion Exchange – NAA
Tahoe Basin, Sierra Nevada	1971-1972	26	<5.4	Ion Exchange – GFAAS
Tahoe Basin, Sierra Nevada	1972-1973	12	<4.5	Ion Exchange – GFAAS
Tahoe Basin, Sierra Nevada	1973-1974	9	<3.8	Ion Exchange –GFAAS
Tahoe Basin, Sierra Nevada	1973-1974	24	<3.0	Ion Exchange –GFAAS
Walker River Watershed, Sierra Nevada	1976-1977	24	3.0	GFAAS
Mokelumne Watershed, Sierra Nevada	1976-1979	18	1.6	GFAAS
Tahoe Basin, Sierra Nevada	1978-1979	10	1.7	GFAAS
Central Sierra Nevada	1983	847	<1.5	GFAAS
Ruby Mountains, Eastern Nevada	1983, 1996	20	<1.0	GFAAS
Lake Almanor Watershed, Northern Sierra Nevada	1983-1989	200	<2.0	GFAAS
Tushar Mountains, Southern Utah	1982-1984	35	2.0	GFAAS
Upper San Joaquin, Southern Sierra Nevada	1994	30	<1.9	GFAAS, ICPMS
Payette Basin, Idaho	1996	74	<1.3	GFAAS
Payette Basin, Idaho	2004	15	1.17	HR-ICPMS

Source: Stone, 2006

Notes: NAA is neutron activation analysis; GFAAS is graphite furnace atomic adsorbtion spectroscopy; ICPMS is inductively coupled plasma mass spectrometry; HR is high resolution

3.2 Concentrations of Silver Found in Precipitation

Silver concentration in precipitation from unseeded storms have been measured from 0.0 to 0.02×10^{-3} µg/L, while concentrations in precipitation from seeded storms range from .01 to 0.3 µg/L (Eisler, 1996). In some studies of the effectiveness of cloud seeding, an increase in the silver content of precipitation was used to indicate that the method was successful. Although generally a reasonable assumption, the National Academy of Science's review of weather modification (NAS, 2003) notes that these efforts lacked statistical rigor. For the purposes of this report, however, these values provide an indication of the increased silver concentration in rainfall that can result from the use of silver iodide as a nucleating agent.

3.3 Concentration of Silver Found in Lakes and Streams

Silver in lakes and streams reflects the average concentration of silver in all storms in the contributing watershed, both seeded storms and unseeded storms. In addition to this dilution effect, the concentrations in lakes and streams are further reduced by adsorption on vegetation and sediments. For these reasons, the concentrations of silver in surface waters decrease with distance from the source (Cooper and Jolly, 1970).

As noted in the discussion of background silver concentration, the geology and past use history can have an overriding effect on the abundance of silver. For example, a value of 4.5 µg/L total silver is reported from an alpine lake in the Buckeye Mountains near Leadville, Colorado (Freeman, 1979). Although the area had been subject to cloud seeding in the 10 years prior to the study, the location is in a silver mining district, and Freeman (1979) documents that the lake is substantially supported by groundwater inflow. This result is reported in compilations by the USEPA (1980), the US Public Health Service (1990), and Eisler (1996) as representative of the maximum silver concentration that is known to occur in seeded areas. However, Freeman (1979) does not attribute the value to past cloud seeding. In fact, it is thought that the concentration represents a high background concentration caused by the silver mineralization of the surrounding rocks.

PG&E has conducted cloud seeding operations targeting the Mokelumne watershed under various permits from the United States Forest Service since 1953. Two studies were conducted at Lower Blue Lake and the Salt Spring Reservoir to assure that water samples from target watershed continue to remain well below the "no effect" threshold (Stone, 2006). The 2006 Mokelumne study used an HR-ICP-MS. The addition of high resolution mass spectrometry to the inductively coupled plasma reduces interference in the silver range and in most cases provides detection limits in the parts-per-trillion (ppt) to parts-per-quadrillion (ppq) range. As such, the results are discussed here as they represent the highest resolution analytical results currently available.

Lower Blue Lake is a watershed upwind from the cloud seeding area. Since it is upwind from the target area, detectable silver was found in only one sample. The average silver concentration is 0.00004 µg/L. The Salt Spring Reservoir provides an ideal location for measuring any elevated metals concentrations of silver above natural background levels in water or sediment samples. This is because a majority of runoff from the target area flows past this location. Results from Salt Spring Reservoir demonstrate that silver was detectable in four of the five samples. The

average silver concentration observed at Salt Springs Reservoir was <0.0005 µg/L. Overall, both measurements lie well within the natural background concentration.

A recent study (Williams and Denholm, 2009) concerned with a winter cloud seeding program in Australia confirmed these findings. Williams and Denholm (2009) agree that the bioavailability of silver is unlikely to change from the current background levels. Furthermore, extensive investigations undertaken prior to the commencement of the project confirmed background levels of silver and the presence of many ameliorating factors know to limit toxicity of the silver ion.

3.4 Concentrations of Silver Found in Soil

As noted in the section on background concentrations of silver (Section 3.1), the area geology and past use history governs the soil concentration. Howell (1977) notes that, even with prolonged seeding, the soil levels still remain at background levels. This occurs despite the fact that almost all of the applied silver iodide will reside in the soil or sediment of the area. However, the amounts added by cloud seeding are negligible compared to the amount of solid in the upper 20 cm of the soil horizon.

Tsiouris et al. (2002) investigated the soil silver content of an agricultural area subjected to cloud seeding with silver iodide. The research analyzed 2,500 soil samples using a spectrophotometric method capable of detecting Ag in parts per billion. This study reflected low total amount of AgI used in cloud seeding in two regions (469 kg in Hemathia-Pella and 361 kg in Serres, Greece). The average silver concentration in 1,438 soil samples from Hemathia-Pella and 1,063 samples from Serres were 44.5 µg/L and 37.2 µg/L, respectively. These averages were found to be within the range of those in control areas and comparable to those reported in the literature for unaffected soils (Table 3).

Table 3 Silver Concentration (**Mg**/G Dry Weight) Reported from Various Soils, Sediments and Areas

Location	Mean [Ag] (g Ag/g dry weight x 10- 6)
Uncontaminated soils, Wales	0.01 – 1
Surface mineral soils, United States	0.7
Organic soils, United States	2 – 5
Earth's Crust	0.07
Typical Soils	0.1-1
Restronguent Estuary U.K	7*.
Acushnet Estuary, New Bedford Hr	40*
Sorfjord, Norway	190*
Thermaikos, Greece	2.36*
Eleusina, Greece	3.32*
Elizabeth and Nansemond rivers, Virginia	0.0-0.8*
Axios River, Greece	0.1-0.5

Source: Tsouris et al. 2002
* samples originate from sediments

The Mokelumne Lake and Sediment study found the average silver concentration of the dissolved sediment samples collected from Lower Blue Lake and Salt Springs Reservoir range between 0.35 µg/L to 1.07 µg/L respectively. These values are thought to be at background levels (Stone, 2006).

4 Silver Iodide and Silver Toxicity Guidelines

There are several water quality objectives for silver that reflect protection of human health and the environment. There are also several proposed standards that have not been adopted and do not have associated regulatory requirements. These are summarized in Appendix A, and a materials safety data sheet (MSDS) for silver iodide is provided in Appendix B.

The compilation of standards is taken from Eisler (1996), of the USFWS. In presenting the compilation, Eisler notes that most measurements of silver in natural waters prior to the use of clean techniques are considered inaccurate. He also notes that most of proposed standards are formulated as total recoverable silver per liter, but total silver measurements do not provide an accurate assessment of the potential hazard because silver ion (Ag^{+}) is the most toxic of the many silver species. In fact, EPA is considering moving to measurements of acid-soluble silver rather than total recoverable silver, to reflect that the silver ion is the potentially toxic form. Eisler notes that silver and its compounds do not pose serious health concerns to humans, but that lower concentrations may affect freshwater and marine organisms. The drinking water standard for silver is 100 µg/L.

The remainder of this section discusses these standards and objectives. Much of the work summarized in this section is taken from the US National Biological Service Report Silver Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review (Eisler, 1996), supplemented by other references.

4.1 Impacts of Silver to Human Health

Much of our knowledge of the effects of silver iodide on the human body is derived from experience in the 1930s when doctors prescribed a nasal spray with 1 to 4 percent silver iodide. While there is no evidence that occasional use of this medication had adverse effects, prolonged use resulted in an ashen pigmentation of the skin known as argyria; no other adverse effects were noted (Vonnegut and Standler, 1972). Humans are also routinely exposed to silver from dental fillings and silverware. California and the United States regulate silver in surface water through the Federal Water Pollution Control Act (Clean Water Act), and in the California Code of Regulations. The silver criteria contain values to protect human health from ingestion of contaminated aquatic organisms and maximum acceptable concentrations to protect organisms that live in freshwater and salt water from toxic effects. The human health component of the silver criteria was drawn directly from the drinking water MCL. California and the United States have established a drinking water standard (maximum contaminant level, or MCL) of 100 µg/L for dissolved silver in drinking water. As summarized in the Compilation of Water Quality Goals (RWQCB-CV 2003), the USEPA Integrated Risk Information System (IRIS) reference dose as a drinking water level is set at 35 µg/L. However, RWQCB-CV (2003) recommends that

California-derived limits are preferred within California government. As such, the MCL of 100 µg/L is preferred for regulatory purposes in California.

4.2 Impacts of Acute Silver to Aquatic Species

The EPA has set a guideline of 4.1 µg/L in fresh water with a hardness of 120 mg/L as the acute toxic limit. In solution, high levels of ionic silver are toxic to aquatic plants and animals. Water concentration of 1.2-4.1 µg/L can have adverse effects to representative species of aquatic life, including representative species of insects, daphnids, amphipods, trout, flounders, sticklebacks, guppies, and dace (Eisler, 1996). Adverse effects occur on development of trout at concentration as low as 1.7 µg/L (Eisler, 1996). Freshwater fish and amphibians appear to be the most sensitive vertebrates to dissolved silver. Sensitive aquatic plants accumulated silver from water containing as little as 2 µg/L, and grew poorly at 3.3- 8.2 µg/L (Eisler, 1996).

4.3 Impacts of Silver to Algae.

At higher concentrations of 2-7 µg/L for 3 to 4 weeks, silver inputs caused disappearance of *Anacystis marina*, a mat-forming blue-green alga; increased dominance by *Skeletonema costatum*, a chain-forming centric diatom; and increased silver concentrations in various species of phytoplankton to 8.6-43.7 Ag µg/g DW (Eisler, 1996). Silver Iodide can retard the growth of algae, fungi, bacteria, and fish in fresh water (Cooper and Jolly, 1970).

4.4 Impacts of Silver to Terrestrial Animals.

No data were found on effects of silver on avian life. AgI may be deposited on forages in the seeded target area and enter the food chain of livestock. Only one article was found in the literature that related AgI toxicity in livestock. Younger and Crookshank (1978) documents the effects of silver iodide on sheep. They state that, "AgI complexes used in weather modification operations are not likely to induce overtly toxic effects on livestock. Silver may be absorbed from the gastrointestinal tract during continuous exposure to AgI, and this fact may be a function of time and dose".

4.5 Impacts of Silver to Terrestrial Plants.

According to Cooper and Jolly (1970), silver levels that may damage plants are many times higher than would occur in precipitation from seeded storms. Further, reports that sprays containing 9,800 µg /L kill corn (*Zea mays*), and sprays containing 100,000-1,000,000 µg /L kill young tomato (*Lycopersicon esculentum*) and bean (*Phaseolus* spp.) plants. Hirsch et al. (1993) planted seeds of corn, lettuce (*Lactuca sativa*), oat (*Avena sativa*), turnip (*Brassica rapa*), soybean (*Glycine max*), spinach (*Spinacia oleracea*), and Chinese cabbage (*Brassica* spp.) in soils amended with silver sulfide and sewage sludge to contain 10, 50, or 100 mg Ag/kg (dry weight) soil. All plants germinated and most grew normally at the highest soil concentration of silver tested, but growth of Chinese cabbage and lettuce was adversely affected at 10 mg Ag/kg DW soil and higher (Eisler, 1996). Silver concentrations in edible portions from all plants at all

soil levels of silver tested, except lettuce, were less than 80 µg/kg. Lettuce grown in soil containing 100 mg Ag/kg had about 1.2 mg Ag/kg DW (Hirsch et al. 1993).

5 Summary of Findings

The geochemistry of silver in the environment generally restricts silver iodide to a solid form. In fact, this property is important for the success of its use for cloud seeding, since dissolution of the nuclei would fail to provide nucleation sites for precipitation. Based on the solubility of silver iodide, the maximum possible concentration in contact with water would be 0.984 µg/L. This value would be much reduced by dilution with snowmelt or rainwater not in direct contact with silver iodide nucleating agents. Once on the ground, the silver in solution then readily forms complexes with sediments and inorganic materials, as well as forming complexes with other negative ions. Therefore, the maximum concentration of the free silver ion, the only silver species shown to be toxic to some biota in the environment, would be far less than 0.9 µg/L.

The human health-based drinking water standard is based on concerns related to change in skin pigment, and the safe level is set at 100 µg/L. Other standards for ecosystem protection are all greater than 1.4 µg/L. Based on the Mokelumne case study and the concurring opinion of Williams and Denholm (2009), the values stated in aquatic water samples do not pose adverse ecotoxicological impacts to human health or the environment. Comprehensive studies and data reviews of the environmental affect of the use of silver iodide for cloud seeding all concur that there is no evidence for adverse effects to human health or the environment from the use of silver iodide for cloud seeding.

6 References

Bober, T.W., Dagon, T.J., and Fowler, H.E. 1992. *Handbook of industrial waste treatment*. Treatment of photographic processing wastes 1: 173-227. New York, NY: Marcel Dekker.

Bury, N.R., McGeer, J.C., Wood, C.M. 1999. Effect of Altering Freshwater Chemistry on Physiological Responses of Rainbow Trout to Silver Exposure. *Environmental Toxicology and Chemistry* 18: 49-55.

Department of Water Resources (DWR). 2009. California Water Plan Update. Vol. 2: Resource Management Strategies. Website (http://www.waterplan.water.ca.gov/docs/cwpu2009/0310final/v2-cover_lowres_opt.pdf) accessed on September 20, 2010.

Carson, B.L., Smith, I.C. 1975. *Silver: An Appraisal of Environmental Exposure*. Research Triangle Park, North Carolina: National Institute of Environmental Health Science.

Cooper, Charles F., Jolly, William C. 1970. Ecological Effects of Silver Iodide and Other Weather Modification Agents: A Review. *Water Resources Research* 6:88-98.

Dennis, Arnett S. 1980.*Weather Modification by Cloud Seeding*: 1-132. New York, NY: Academic Press.

Eisler, Ronald. 1996. Silver Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. Patuxent Wildlife Research Center. U.S. National Biological Service. *Biological Report; Contaminant Hazards Report* 32.

Freeman, R.A. 1979. *Aquatic Toxicology*. Ecological Kinetics of Silver in an Alpine Lake Ecosystem, 342-358. Philadelphia, PA: American Society for Testing and Materials.

Hirsch, M., Ritter, M., Roser, K., Garrisi, P., Forsythe, S. 1993. The Effects of Silver on Plants growth in Sludge Amended Soils. *Proceeding of the First International Conference on Transport, Fate, and Effects of Silver in the Environment*: 69-73.

Howell, Wallace. 1977. Environmental Impacts of Precipitation management: results from Project Skywater. *Bureau of Reclamation: Division of Atmospheric Water Resources*: 488-501.

Hunter, Steven M. 2007. Optimizing Cloud Seeding for water and Energy in California: PIER Final Project Report. *California Research Commission, Public Interest Energy Research Program*: 1-34.

Lytle, P.E. 1987. Fate and Speciation of Silver in Publicly Owned Treatment Works. *Environmental Toxicology*. 3: 21-30.

National Academy of Sciences (NAS). 2003. Committee on the Status of and Future Directions in U.S. Weather Modification Research and Operations. *Critical Issues in Weather Modification Research*. Washington D.C: The National Academic Press.

Ratte, H.T. 1999. Bioaccumulation and toxicity of silver compounds: a review. *Environmental Toxicology and Chemistry* 18:89-108.

Regional Water Quality Control Board-Central Valley Region (RWQCB-CV). 2003. A Compilation of Water Quality Goals. California Environmental Protection Agency.

Rodgers, J.H., Deaver, E., Rodgers, P.L. 1997. Comparative Aqueous Toxicity of Silver Compounds: Laboratory Studies with Freshwater Species. *Bulletin of Environmental Contamination and Toxicology* 58: 851-858.

Stone, Richard H. 2006. Mokelumne Watershed Lake and Sediment Study. Final Report to the Pacific Gas and Electric Company, Technical and Ecological Services, San Ramon, CA.

Tsiouris, S.E., Aravanopoulous, F.A., Papadoyannis, I.N., Sofonious, M.K., Polyzopoulos, N., Christodoulou. M., Samanidou, V.F., Zachariadis, G.A., Constantinidou. H.A.I. 2002. Soil Silver Content of Agricultural Areas Subjected to Cloud Seeding with Silver Iodide. *Fresenius Environmental Bulletin* 11: 697-702.

U.S. Environmental Protection Agency (USEPA). 1973. National Emissions Inventory of Sources and Emissions of Silver. Washington DC: Office of Air and Water Programs.

U.S. Environmental Protection Agency (USEPA). 1980. *Ambient Water Quality Criteria for Silver*. Washington DC: Office of Water.

U.S. Public Health Service (USPHS). 1990. Toxicological Profile for Silver. *Agency for Toxic Substances and Disease Registry TP-90-24I.*

Vonnegut, B., Standler, R.B. 1972. Estimated Possible Effects of AgI Cloud Seeding on Human Health. *Journal of Applied Meteorology* 11: 1388-1391.

Warburton, J.A, Young, L.G and Stone, R.H. 1994. Assessment of Seeding Effects in Snowpack Augmentation Programs: Ice Nucleation and Scavenging of Seeding Aerosols. *Journal of Applied Meteorology* 34:121-130.

Wen, L-S., Santschi, P.H., Gill, G.A., Paternostro, C.L., Lehman, R.D. 1997. Colloidal and Particulate Silver in River and Estuarine Waters of Texas. *Environmental Science and Technology* 31:723-731.

Williams, B.D., Denholm, J.A. 2009. As Assessment of the Environmental Toxicity of Silver Iodide- With Reference to a Cloud Seeding trial in the Snowy Mountains of Australia. *WMA Journal of Weather Modification* 41: 75-96.

World Health Organization (WHO). 2002. Silver and Silver Compounds: Environmental Aspects Concise International Chemical Assessment Document 44. Website (http://www.inchem.org/documents/cicads/cicads/cicad44.htm) accessed September 26, 2010.

Younger, R.L., Crookshank, H.R. 1978. Chronic Exposure of Sheep to Silver Iodide. *Water, Air, Soil Pollution* 9: 281-28.

Appendix A

Proposed Standards (not regulatory requirements)

There are several proposed standards that have not been adopted and do not have associated regulatory requirements.

The compilation of standards included below is taken from Eisler (1996), of the USFWS. In presenting the compilation, Eisler notes that most measurements of silver in natural waters prior to the use of clean techniques are considered inaccurate. He also notes that most of proposed standards are formulated as total recoverable silver per liter, but total silver measurements do not provide an accurate assessment of the potential hazard because silver ion (Ag^{+}) is the most toxic of the many silver species. In fact, the US Environmental Protection Agency is considering moving to measurements of acid-soluble silver rather than total recoverable silver, to reflect that the silver ion is the potentially toxic form. Eisler notes that silver and its compounds do not pose serious health concerns to humans, but that lower concentrations may affect freshwater and marine organisms.

Resource, crtterlon, and other variables	Effective sllv•r concentration
Agricultural crops	
Sois	<100 mg total silver/kg dry weight soil for most species; <10 mg/kg for sensitive species
Fruhwater aquatic life protection	
Acute exposure	
Total recoverable siver	<L32Jlg/L
Acid-soluble silver'>	4-<fay average shall not exceed 0.12 Jlg/L more than once every three years; 1-h average not to exceed 0.92 Jlg/L more than once every 3 years
Acute exposure	
Total recoverable sllver, in - should not exceed e<•-721"{hardnessD-6. at any time.	
Examples follow	
50 mg CaCO:YL	<1.2 l'g/L
tOO mg CaCO:YL	<4.1 l'9lL
200 mg CaCO:YL	<13.0 Jlg/L
Chronic exposure	<0.12-<0.13 l'g total recoverable silver/l
Tossue residues	
Adverse effects on growth of the Asiatic clam, *Corbicula ffuminea*	>1.65 mg total siver/kg soft tissues, fresh weight basis
Marine life protection	
Acute exposure	
Total recoverable siver	<2.3 11g/L at any t me
Acid-soluble silver'>	4-<fay average concentration not to exceed 0.92 11g/L more than once every 3 years on average and the 1-h concentration not to exceed 7.2 11g/L more than once every 3 years
Tissue residues	
Marine clams, soft parts	
Normal	<1 mg total silver/kg dry weight
Stressful or fatal	>100 mg total silver/kg dry weight
Human health	
Air, United States	
CUrrent level of exposure-natiQnw;de	100 l'9 total silver daily per person
Short-tenn exposure limit (15 min;up to 4 times daily with 60-min intervals at <0.01 mg Agfm3 air)	<0.03 mg total silvertm3
Threshold limit value (8 h daily, 5 days weekly)	
Aerosol *silver* compounds	<0.01 mg total silver/m3
Metallic sver dust	<0.1 mg total silverfm3
Diet, United States	
Current level of exposure	35 to 40 "g daily per person
Drinking water	
United States	
Long-term exposure (>10 days)	<50 "g total silver/L
Proposed long-term exposure	<90 !'g/L total siver
Short-term exposure (1-10 days)	<1,142 llg total silver/L
California	<10jlg/L
Germany	<100 "giL
Space vehicles	
Former Soviet Union	Max. 200 "g total s lver/L
United State$	100 to Max. 200 11g total siver/L
Switzertand	<200 "g total silver/l
Gro< nd water	<50 l19 total silver/L

Sowte: SibEr Hazil'ds to Fish, UUildlife, and Inuerb!baWs: A Syroptic RE.\liew (Eilse1900)

Appendix B

MSDS of Silver Iodide and Silver

Material Safety Data Sheet
Silver Iodide MSDS

Available online at: http://www.espimetals.com

Section 1: Chemical Product and Company Identification

Product Name: Silver iodide

CAS#: 7783-96-2

Chemical Formula: AgI

Section 2: Composition and Information on Ingredients

Composition:

Name CAS # % by Weight

Silver iodide 7783-96-2 100

Toxicological Data on Ingredients: Silver iodide: ORAL (LD50): Acute: 2820 mg/kg [Rat].

Section 3: Hazards Identification

Potential Acute Health Effects: Hazardous in case of skin contact (irritant), of eye contact (irritant), of ingestion, of inhalation. Potential

Chronic Health Effects: CARCINOGENIC

EFFECTS: Not available. MUTAGENIC

EFFECTS: Not available. TERATOGENIC

EFFECTS: Not available. DEVELOPMENTAL

TOXICITY: Not available.

Repeated or prolonged exposure is not known to aggravate medical condition.

Section 4: First Aid Measures

Eye Contact: Check for and remove any contact lenses. Do not use an eye ointment. Seek medical attention.

Skin Contact:

Dispersion Properties: Not available.

Solubility: Insoluble in cold water, hot water.

After contact with skin, wash immediately with plenty of water. Gently and thoroughly wash the contaminated skin with running water and non-abrasive soap. Be particularly careful to clean folds, crevices, creases and groin. Cover the irritated skin with an emollient. If irritation persists, seek medical attention.

Serious Skin Contact:

Wash with a disinfectant soap and cover the contaminated skin with an anti-bacterial cream. Seek medical attention.

Inhalation: Allow the victim to rest in a well ventilated area. Seek immediate medical attention.

Serious Inhalation: Not available.

Ingestion:

Do not induce vomiting. Loosen tight clothing such as a collar, tie, belt or waistband. If the victim is not breathing, perform mouth-to-mouth resuscitation. Seek immediate medical attention.

Serious Ingestion: Not available.

Section 5: Fire and Explosion Data

Flammability of the Product: Non-flammable.

Auto-Ignition Temperature: Not applicable.

Flash Points: Not applicable.

Flammable Limits: Not applicable.

Products of Combustion: Not available.

Fire Hazards in Presence of Various Substances: Not applicable.

Explosion Hazards in Presence of Various Substances:

Risks of explosion of the product in presence of mechanical impact: Not available.

Risks of explosion of the product in presence of static discharge: Not available.

Fire Fighting Media and Instructions: Not applicable.

Special Remarks on Fire Hazards: Not available.

Special Remarks on Explosion Hazards: Not available.

Section 6: Accidental Release Measures

Small Spill:

Use appropriate tools to put the spilled solid in a convenient waste disposal container. Finish cleaning by spreading water on the contaminated surface and dispose of according to local and regional authority requirements.

Large Spill:

Use a shovel to put the material into a convenient waste disposal container. Finish cleaning by spreading water on the contaminated surface and allow to evacuate through the sanitary system. Be careful that the product is not present at a concentration level above TLV. Check TLV on the MSDS and with local authorities.

Section 7: Handling and Storage

Precautions:

Do not ingest. Do not breathe dust. Wear suitable protective clothing In case of insufficient ventilation, wear suitable respiratory equipment If ingested, seek medical advice immediately and show the container or the label. Avoid contact with skin and eyes

Storage:

No specific storage is required. Use shelves or cabinets sturdy enough to bear the weight of the chemicals. Be sure that it is not necessary to strain to reach materials, and that shelves are not overloaded.

Section 8: Exposure Controls/Personal Protection

Engineering Controls:

Use process enclosures, local exhaust ventilation, or other engineering controls to keep airborne levels below recommended exposure limits. If user operations generate dust, fume or mist, use ventilation to keep exposure to airborne contaminants below the exposure limit.

Personal Protection:

Splash goggles. Lab coat. Dust respirator. Be sure to use an approved/certified respirator or equivalent. Gloves.

Personal Protection in Case of a Large Spill:

Splash goggles. Full suit. Dust respirator. Boots. Gloves. A self contained breathing apparatus should be used to avoid inhalation of the product. Suggested protective clothing might not be sufficient; consult a specialist BEFORE handling this product.

Exposure Limits:

TWA: 0.01 (mg/m3) from ACGIH

Consult local authorities for acceptable exposure limits.

Section 9: Physical and Chemical Properties

Physical state and appearance: Solid.

Odor: Not available.

Taste: Not available.

Molecular Weight: 234.79 g/mole

Color: Not available.

pH (1% soln/water): Not applicable.

Boiling Point: 1506°C (2742.8°F)

Melting Point: 552°C (1025.6°F)

Critical Temperature: Not available.

Specific Gravity: 5.675 (Water = 1)

Vapor Pressure: Not applicable.

Vapor Density: Not available.

Volatility: Not available.

Odor Threshold: Not available.

Water/Oil Dist. Coeff: Not available.

Ionicity (in Water): Not available.

Section 10: Stability and Reactivity Data

Stability: The product is stable.

Instability Temperature: Not available.

Conditions of Instability: Not available.

Incompatibility with various substances: Not available.

Corrosivity: Non-corrosive in presence of glass.

Special Remarks on Reactivity: Not available.

Special Remarks on Corrosivity: Not available.

Polymerization: No.

Section 11: Toxicological Information

Routes of Entry: Eye contact. Inhalation. Ingestion.

Toxicity to Animals: Acute oral toxicity (LD50): 2820 mg/kg [Rat].

Chronic Effects on Humans: Not available.

Other Toxic Effects on Humans: Hazardous in case of skin contact (irritant), of ingestion, of inhalation.

Special Remarks on Toxicity to Animals: Not available.

Special Remarks on Chronic Effects on Humans: Not available.

Special Remarks on other Toxic Effects on Humans: Not available.

Section 12: Ecological Information

Ecotoxicity: Not available.

BOD5 and COD: Not available.

Products of Biodegradation:

Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.

Toxicity of the Products of Biodegradation: The products of degradation are more toxic.

Special Remarks on the Products of Biodegradation: Not available.

Section 13: Disposal Considerations

Waste Disposal:

Section 14: Transport Information

DOT Classification: Not a DOT controlled material (United States).

Identification: Not applicable.

Special Provisions for Transport: Not applicable.

Section 15: Other Regulatory Information

Federal and State Regulations:

Pennsylvania RTK: Silver iodide

Massachusetts RTK: Silver iodide

TSCA 8(b) inventory: Silver iodide

CERCLA: Hazardous substances.: Silver iodide

Other Regulations: Not available..

Other Classifications:

WHMIS (Canada): Not controlled under WHMIS (Canada).

DSCL (EEC): R36/38- Irritating to eyes and skin.

HMIS (U.S.A.):

Health Hazard: 2

Fire Hazard: 0

Reactivity: 0

Personal Protection: E

National Fire Protection Association (U.S.A.):

Health: 2

Flammability: 0

Reactivity: 0

Specific hazard:

Protective Equipment:

Gloves.

Lab coat.

Dust respirator. Be sure to use an approved/certified respirator or equivalent.

Splash goggles.

Section 16: Other Information

References: Not available.

Other Special Considerations: Not available.

Material Safety Data Sheet
Silver MSDS

Available online at: http://www.espimetals.com

Section 1: Chemical Product and Company Identification

Product Name: Silver

Catalog Codes: SLS4222, SLS2005, SLS3427, SLS1210,

SLS2632, SLS4054, SLS1837

CAS#: 7440-22-4

RTECS: VW3500000

TSCA: TSCA 8(b) inventory: Silver

CI#: Not applicable.

Synonym:

Chemical Formula: Ag

Contact Information:

Sciencelab.com, Inc.

14025 Smith Rd.

Houston, Texas 77396

US Sales: 1-800-901-7247

International Sales: 1-281-441-4400

Order Online: ScienceLab.com

CHEMTREC (24HR Emergency Telephone), call:

1-800-424-9300

International CHEMTREC, call: 1-703-527-3887

For non-emergency assistance, call: 1-281-441-4400

Section 2: Composition and Information on Ingredients

Composition:

Name CAS # % by Weight

Silver 7440-22-4 100

Toxicological Data on Ingredients: Silver: ORAL (LD50): Acute: 100 mg/kg [Mouse].

Section 3: Hazards Identification

Potential Acute Health Effects:

Very hazardous in case of eye contact (irritant), of ingestion, of inhalation. Severe over-exposure can result in death.

Inflammation of the eye is characterized by redness, watering, and itching.

Potential Chronic Health Effects:

CARCINOGENIC EFFECTS: Not available. MUTAGENIC EFFECTS: Not available. TERATOGENIC EFFECTS: Not available. DEVELOPMENTAL TOXICITY: Not available. Repeated exposure to an highly toxic material may produce general deterioration of health by an accumulation in one or many human organs.

Section 4: First Aid Measures

Eye Contact: Check for and remove any contact lenses. Do not use an eye ointment. Seek medical attention.

Skin Contact: No known effect on skin contact, rinse with water for a few minutes.

Serious Skin Contact: Not available.

Inhalation: Allow the victim to rest in a well ventilated area. Seek immediate medical attention.

Serious Inhalation:

Evacuate the victim to a safe area as soon as possible. Loosen tight clothing such as a collar, tie, belt or waistband. If breathing is difficult, administer oxygen. If the victim is not breathing, perform mouth-to-mouth resuscitation. Seek medical attention.

Ingestion:

Do not induce vomiting. Examine the lips and mouth to ascertain whether the tissues are damaged, a possible indication that the toxic material was ingested; the absence of such signs, however, is not conclusive. Loosen tight clothing such as a collar, tie, belt or waistband. If the victim is not breathing, perform mouth-to-mouth resuscitation. Seek immediate medical attention.

Serious Ingestion: Not available.

Section 5: Fire and Explosion Data

Flammability of the Product: May be combustible at high temperature.

Auto-Ignition Temperature: Not available.

Flash Points: Not available.

Flammable Limits: Not available.

Products of Combustion: Some metallic oxides.

Fire Hazards in Presence of Various Substances: Not available.

Explosion Hazards in Presence of Various Substances:

Risks of explosion of the product in presence of mechanical impact: Not available. Risks of explosion of the product in presence of static discharge: Not available.

Fire Fighting Media and Instructions:

SMALL FIRE: Use DRY chemical powder. LARGE FIRE: Use water spray, fog or foam. Do not use water jet.

Special Remarks on Fire Hazards: Not available.

Special Remarks on Explosion Hazards: Not available.

Section 6: Accidental Release Measures

Small Spill:

Use appropriate tools to put the spilled solid in a convenient waste disposal container.

Large Spill:

Use a shovel to put the material into a convenient waste disposal container. Be careful that the product is not present at a concentration level above TLV. Check TLV on the MSDS and with local authorities.

Section 7: Handling and Storage

Precautions:

Keep locked up Keep away from heat. Keep away from sources of ignition. Empty containers pose a fire risk, evaporate the residue under a fume hood. Ground all equipment containing material. Do not ingest. Do not breathe dust. Avoid contact with eyes In case of insufficient ventilation, wear suitable respiratory equipment If ingested, seek medical advice immediately and show the container or the label.

Storage:

Keep container dry. Keep in a cool place. Ground all equipment containing material. Keep container tightly closed. Keep in a cool, well-ventilated place. Highly toxic or infectious materials should be stored in a separate locked safety storage cabinet or room.

Section 8: Exposure Controls/Personal Protection

Engineering Controls:

Use process enclosures, local exhaust ventilation, or other engineering controls to keep airborne levels below recommended exposure limits. If user operations generate dust, fume or mist, use ventilation to keep exposure to airborne contaminants below the exposure limit.

Personal Protection: Splash goggles. Lab coat.

Personal Protection in Case of a Large Spill:

Splash goggles. Full suit. Boots. Gloves. Suggested protective clothing might not be sufficient; consult a specialist BEFORE handling this product.

Exposure Limits:

TWA: 0.01 (mg/m3) from OSHA (PEL) TWA: 0.01 (mg/m3) from OSHA NIOSH Australia: TWA: 0.1 (mg/m3)Consult local authorities for acceptable exposure limits.

Section 9: Physical and Chemical Properties

Physical state and appearance: Solid. (Solid metallic powder. Metal solid.)

Odor: Not available.

Taste: Not available.

Molecular Weight: 107.87 g/mole

Color: Not available.

pH (1% soln/water): Not applicable.

Boiling Point: 2212°C (4013.6°F)

Melting Point: 961°C (1761.8°F)

Critical Temperature: Not available.

Specific Gravity: 10.4 (Water = 1)

Vapor Pressure: Not applicable.

Vapor Density: Not available.

Volatility: Not available.

Odor Threshold: Not available.

Water/Oil Dist. Coeff.: Not available.

Ionicity (in Water): Not available.

Dispersion Properties: Is not dispersed in cold water, hot water.

Solubility: Insoluble in cold water, hot water.

Section 10: Stability and Reactivity Data

Stability: The product is stable.

Instability Temperature: Not available.

Conditions of Instability: Not available.

Incompatibility with various substances: Not available.

Corrosivity: Non-corrosive in presence of glass.

Special Remarks on Reactivity: Not available.

Special Remarks on Corrosivity: Not available.

Polymerization: No.

Section 11: Toxicological Information

Routes of Entry: Absorbed through skin. Eye contact. Inhalation. Ingestion.

Toxicity to Animals: Acute oral toxicity (LD50): 100 mg/kg [Mouse].

Chronic Effects on Humans: Not available.

Other Toxic Effects on Humans: Very hazardous in case of ingestion, of inhalation.

Special Remarks on Toxicity to Animals: Not available.

Special Remarks on Chronic Effects on Humans: Not available.

Special Remarks on other Toxic Effects on Humans: Not available.

Section 12: Ecological Information

Ecotoxicity: Not available.

BOD5 and COD: Not available.

Products of Biodegradation:

Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.

Toxicity of the Products of Biodegradation: The products of degradation are as toxic as the original product.

Special Remarks on the Products of Biodegradation: Not available.

Section 13: Disposal Considerations

Waste Disposal:

Section 14: Transport Information

DOT Classification:

Identification:

Special Provisions for Transport: Not available.

Section 15: Other Regulatory Information

Federal and State Regulations:

Rhode Island RTK hazardous substances: Silver Pennsylvania RTK: Silver Minnesota: Silver Massachusetts RTK: Silver New Jersey: Silver TSCA 8(b) inventory: Silver TSCA 8(a) PAIR: Silver TSCA 8(d) H and S data reporting: Silver SARA 313 toxic chemical notification and release reporting: Silver: 1% CERCLA: Hazardous substances.: Silver: 1000 lbs. (453.6 kg)

Other Regulations:

OSHA: Hazardous by definition of Hazard Communication Standard (29 CFR 1910.1200). EINECS: This product is on the European Inventory of Existing Commercial Chemical Substances.

Other Classifications:

WHMIS (Canada):

CLASS D-1B: Material causing immediate and serious toxic effects (TOXIC). CLASS D-2B: Material causing other toxic effects

(TOXIC).

DSCL (EEC): R41- Risk of serious damage to eyes.

HMIS (U.S.A.):

Health Hazard: 2

Fire Hazard: 1

Reactivity: 0

Personal Protection: j

National Fire Protection Association (U.S.A.):

Health: 2

Flammability: 1

Reactivity: 0

Specific hazard:

Protective Equipment:

Not applicable. Lab coat. Wear appropriate respirator when ventilation is inadequate. Splash goggles.

Section 16: Other Information

References: Not available.

Other Special Considerations: Not available. Created: 10/10/2005 08:26 PM

Last Updated: 11/06/2008 12:00 PM

The above information is believed to be correct, but does not purport to be all inclusive and shall be used only as a guide. ESPI shall not be held liable for any damage resulting from handling or from contact with the above product.

Appendix C

Weather Modification Association Statement on AgI Toxicity

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WEATHER MODIFICATION ASSOCIATION (WMA) POSITION STATEMENT ON THE ENVIRONMENTAL IMPACT OF USING SILVER IODIDE AS A CLOUD SEEDING AGENT
JULY 2009

The Weather Modification Association (WMA) is occasionally asked to comment on questions regarding the environmental effects of silver iodide aerosols used in cloud seeding, which include silver iodide aerosol complexes such as silver iodide-silver chloride. Silver iodide is the primary component of silver iodide-based ice-nucleating complexes used in cloud seeding, and all these complexes will be referred to as silver iodide (**AgI**) in this statement. The published scientific literature clearly shows ***no environmentally harmful effects*** arising from cloud seeding with silver iodide aerosols have been observed; nor would they be expected to occur. Based on this work, the WMA finds that silver iodide is environmentally safe as it is currently being dispensed during cloud seeding programs.

Background

Silver and chemical compounds containing silver are used by various industries and small portions of this silver are emitted into the environment as a process waste product. Industrial sources were much larger in the past than they are today; notable sources include silver emissions from the photographic and electrochemical plating industries, urban refuse, sewage treatment plants, specialty metal alloy production and electrical components. In 1978 an estimated 2,740 metric tons (metric ton = 1,000 kg) of silver were released into the US environment. This led the US Health Services and EPA to conduct studies regarding the potential for environmental and human health hazards related to silver. These agencies and other state agencies applied the Clean Water Act of 1977 and 1987 to establish regulations on this type of pollution. Standards were established for industry and laboratory disposal practices of drain water into sewer systems, safe silver limits in the public water supply, and thresholds of adverse effects of silver on the biosphere. In 1978 cloud seeding activities were the source of about three metric tons of silver (as silver iodide) released into the environment, or about 0.1 per cent of the total (Eisler 1996). About the same amount of silver iodide is being used annually for cloud seeding activities in the U.S. and Canada today. Cloud seeding activities release silver iodide to the atmosphere over specific areas of the western states of the U.S., Canada and some other areas around the globe to augment rainfall, augment snowfall or reduce hail damage. Environmental impact studies related to silver iodide usage in cloud seeding were conducted starting in the 1960s and continue to be conducted today; all findings to date indicate no adverse environmental and human health impacts (ASCE 2004, 2006; WMA 2005; WMO 2007).

How much silver is released into the environment by cloud seeding?

Silver iodide is usually sold by commercial chemical company distributors in granular or powder form. It is used in combination with various other chemicals, most often salts, and has been used for half a century as a glaciogenic agent (microscopic sized particles, referred to as ice nuclei, ice forming nuclei, or occasionally freezing nuclei, that spawn ice crystal formation). Silver Iodide is considered water insoluble (solubility constant at 10^{-9} g[of Ag] g^{-1} [of solvent-water]; see units note), which means that if one gram of the chemical is added to one gram of water, roughly one billionth of that gram of silver iodide would dissolve in to the water; the remainder will stay in the water undissolved. This property allows the silver iodide particles to maintain their structure prior to contact with supercooled (colder than freezing) cloud droplets. Silver iodide, as used in cloud seeding, is either dissolved in a flammable solution or combined

with other flammable solids to produce seeding flares or other devices, which are burned to release submicron-sized, virtually invisible, silver iodide aerosol complexes into the atmosphere. These complexes are plentiful in number and increase the probability of ice crystals forming when they reach cloud environments at temperatures near or colder than the AgI ice nucleation (or crystallization) temperature threshold (about -5°C). This is significantly warmer than the threshold of most naturally occurring ice-forming nuclei, which commonly have thresholds near - 15°C and colder.

Only small quantities of seeding material are released from individual cloud seeding generators typically in the range of 5-25 grams of silver iodide per hour from ground generators and up to a few kilograms per hour from aircraft depending on the size of the target area. Moreover, this is being done only during certain periods and locations of precipitation-producing weather systems. The reason that such small quantities can be used is that AgI dispensing systems generally produce up to 10^{15} (see power of 10's note) ice forming nuclei per gram of AgI expended (e.g., ASCE 2004, 2006). This means small amounts of AgI seeding material can produce tremendous numbers of ice crystal seeds that can create ice crystals, which can grow into snowflakes. The insolubility of AgI is a crucial factor for such small particles that allows them to maintain their identity (structure) intact and not condense water (and thus lose their structure) inside a cloud droplet. Without this property there would be no cloud seeding effect.

As a metric of cloud seeding chemicals, silver concentrations have been measured in the snowpack of several cloud seeding target areas in the western U. S. The average concentrations throughout the snowpack have generally ranged from 4-20 x 10^{-12} g[of Ag] g^{-1}[of solvent-water], rarely exceeding 100.0 x 10^{-12} g g^{-1} (Warburton *et al.* 1995a,b, 1996; McGurty 1999). Since seeding clouds could lead to rain (if snowflakes melt during their fall to earth) measurements of seeding chemical concentrations in the rainwater have also been done and found to be in similarly low concentrations (e.g., Sanchez *et al.* 1999).

Why is there concern about using silver iodide in cloud seeding?

It is well established that silver in some forms can be toxic to lower organisms without being toxic to higher animals (Kotrba 1968). Numerous controlled laboratory studies have shown that silver, silver nitrate and even silver iodide when added to laboratory aquariums, even at trace levels, can be toxic to some fish and other aquatic life when exposed over long time periods; the toxicity is related to specific compounds, concentrations and other factors such as water hardness, etc (e.g., Davies & Goettl 1978). However, these laboratory conditions bear little resemblance to outdoor freshwater bodies where the mobility of any of these silver compounds is essentially zero and these compounds are rapidly converted to less toxic compounds by the presence of other chemicals found in nature. Hence, they are not freely bio-available to the environment. Laboratory results derived from biological studies cannot be taken to imply any meaningful information about silver iodide used in cloud seeding because its insoluble nature makes it nearly impossible to dissociate sufficiently or rapidly enough to ever achieve toxic levels. Meaningful evaluation must include the specifics of the chemical form of silver (i.e., ionic silver, silver nitrate, silver iodide), the quantities involved, and the chemical, even physical, nature of the environment. Hence, care must be taken when comparing the potential impact of silver iodide on the environment as used in cloud seeding programs with the impact of silver or soluble silver in laboratory settings, which are not representative of the natural environment where cloud seeding is conducted.

Basis for asserting that cloud seeding using silver iodide has negligible environmental impact.

The potential environmental impacts of cloud seeding programs using silver iodide have been studied since the 1960s. These studies have all concluded that ice-nucleating agents,

specifically silver iodide as used in cloud seeding, represent a negligible environmental hazard, (i.e., findings of no significant effects on plants and animals), (e.g., Cooper & Jolly 1970; Howell 1977; Klein 1978; Dennis 1980; Harris 1981; Todd & Howell 1985; Berg 1988; Reinking *et al.* 1995; Eliopoulos & Mourelatos 1998; Ouzounidou & Constantinidou 1999; Di Toro *et al*. 2001; Bianchini *et al*. 2002; Tsiouris *et al.* 2002a; Tsiouris *et al.* 2002b; Christodoulou *et al.* 2004; Edwards *et al.* 2005; Keyes *et al.* 2006; Williams & Denholm 2009).

The U.S. Public Health Service established a concentration limit of 50 micrograms of silver per liter of water in public water supply to protect human health (e.g., Erdreich *et al.* 1985). The concentrations of silver potentially introduced by modern cloud seeding efforts are significantly less than this level. The literature embodies tens of thousands of samples collected from cloud seeding program areas over a thirty-year period showing the average concentration of silver in rainwater, snow and surface water samples is typically less than 0.01 micrograms per liter. More importantly, these measurements represent the total amount of silver contained in any given sample and are not specific to the form of silver present in a sample. Nevertheless, these measurements show that silver is virtually undetectable in any form in the vast majority of the tens of thousands of samples collected from these areas.

More than 100 Sierra Nevada lakes and rivers have been studied since the 1980's (e.g., Stone 1986); no detectable silver above the natural background was found in seeded target area water bodies, precipitation and lake sediment samples, nor any evidence of silver accumulation after more than fifty years of continuous seeding operations (Stone 1995; Stone 2006). Many of these alpine lakes have virtually no buffering capacity, making them extremely susceptible to the effects of acidification and sensitive to changes in trace metal chemistry. Therefore studies were conducted as part of environmental monitoring efforts to determine if cloud seeding was impacting these lakes. No evidence was found that silver from seeding operations was detectable above the background level. There was also no evidence of an impact on lake water chemistry, which is consistent with the insoluble nature and long times required to mobilize any silver iodide released over these watersheds. Comparisons of silver with other naturally occurring trace metals measured in lake and sediment samples collected from the Mokelumne watershed in the Sierra Nevada indicate that the silver was of natural origin (Stone 2006). Similarly, Sanchez *et al.* (1999) analyzed the chemistry of water bodies and rainwater from samples collected during a summer cloud seeding program in Spain, and determined the silver input from cloud seeding to be indistinguishable from natural inputs. Greek scientists studying the effects on soils, plants and their physiology, atmospheric precipitation, plankton, animals and man, as well as the impact of irrigation and organic matter to AgI leaching from the Greek cloud seeding activities found similar results following the analyses of 2500 soil samples (e.g., Tsiouris *et al.* 2002a; Tsiouris *et al.* 2002b).

Summary

The published scientific literature clearly shows ***no environmentally harmful effects*** arising from cloud seeding with silver iodide aerosols have been observed, nor would be expected to occur. Based on this work, the WMA finds that silver iodide is environmentally safe as it is currently being used in the conduct of cloud seeding programs.

Bibliography

ASCE (2004). "*Standard Practice for the Design and Operation of Precipitation Enhancement Projects*". ASCE(American Society Civil Engineers) /EWRI Standard 42-04, Reston, VA.

ASCE (2006). "*Guidelines for Cloud seeding to Augment Precipitation*". 2nd Edition. American Society Civil Engineers(ASCE)/EWRI, Reston, VA.

Berg, N.H. (1988). A Twelve-Year study of environmental aspects of weather modification in the Central Sierra Nevada and Carson Range. *The Sierra Ecology Project,* Unpublished report on file at Pacific SW Res. Station, Forest Service USDA, Albany CA.

Bianchini, A., M. Grosell, S.M. Gregory, C.M. Wood (2002). Acute silver toxicity in aquatic animals is a function of sodium uptake rate, *Env. Sci. & Techn.*, **36**, 1763-1766.

Christodoulou, M., S. Tsiouris, I. Papadoyannis, F. Aravanopoulos, I. Vlemmas, D. Mourelatos, S. Mourelatos, H.-L. Constantinidou (2004). Determination and impact of silver iodide on terrestrial and aquatic ecosystems of areas where cloud seeding has been applied. *Proceedings of the 7th Panhellenic (International) Conference of Meteorology, Climatology and Atmospheric Physics,* Volume A, 195-203.

Cooper, C.F., W.C. Jolly (1970). Ecological Effects of Silver Iodide and other Weather Modification Agents: A review. *Water Resources Research,* **6**, AGU, 88-98.

Davies, P.H., J.P. Goettl, Jr. (1978). Evaluation of the potential impacts of silver and/or silver iodide on rainbow trout in laboratory and high mountain lake environments. In: Environmental impacts of artificial ice nucleating agents. Klein, D.A. (Ed.). Dowden, Hutchinson and Ross Inc., Stroudsburg, PA.

Davies, P.H., J.P. Goettl, Jr., J.R. Winley (1978). Toxicity of silver to rainbow trout (Salmo gairdneri). Water Res., **12**, 113-117.

Dennis, A. S. (1980). "*Weather Modification by Cloud seeding*". International Geophysics Series, **24,** Academic Press, New York, NY, 21-22.

Di Toro, D.M., H.E. Allen, H.L. Bergman, J.S. Meyer, P.R. Paquin, R.C. Santore (2001). Biotic Ligand Model of the acute toxicity of metals. 1. Technical basis. *Environmental Toxicology and Chemistry*, **20**, 2383-2396.

Edwards, R., A. Huggins, J. McConnell (2005). "*Trace Chemistry Evaluation of the Idaho Power Company Operational Cloud seeding Program 2003 to 2005*". DRI Publication #41223.

Eisler, R. (1996). Silver Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review, *Contaminant Hazard Reviews*, **32,** Patuxent Wildlife Research Center, U.S. National Biological Service, Laurel, MD.

Eliopoulos P., D. Mourelatos (1998). Lack of genetoxicity of Silver Iodide in the SCE Assay in vitro, in vivo, and in the Ames/Microsome Test. *Terratogenesis, Carcinogenesis and Mutagenesis,* **18**, 303-308.

Erdreich, L., R. Bruins, J. Withey (1985). Drinking Water Criteria Document for Silver (Final Draft). U.S. EPA, Washington, D.C., EPA/600/X-85/040 (NTIS PB86118288).

Harris, E. (1981). "*Environmental Assessment and Finding of No Significant Impact*". Sierra Cooperative Pilot Project, Bureau of Reclamation, Denver, Co.

Howell, W. E. (1977). Environmental impacts of precipitation management: Results and inferences from Project Skywater. Bull. Amer. Meteor. Soc., **58**, 488-501.

Keyes, et al. (2006). "*Guidelines for Cloud seeding to Augment Precipitation"*. 2nd Edition. American Society Civil Engineers, Reston, VA.

Kotrba, G. (1968). "*The Encyclopedia of the Chemical Elements*", Hampel, C. A., Editor, Reinhold Book Corporation, New York, Amsterdam, and London.

Klein, D.A. (1978). "*Environmental Impacts of Artificial Ice Nucleating Agents*" Colorado State University, Dowden, Hutchinson & Ross, Inc. Library of Congress Catalog Card Number, 78-7985.
McGurty, B. M. (1999). Turning silver into gold: Measuring the benefits of cloud seeding. *HydroReview*, **18**, 2-6. Ouzounidou G., H.-I.A. Constantinidou (1999). Changes in growth and physiology of tobacco and cotton under Ag exposure and recovery. Are they of direct or indirect nature? *Arch. Environ. Contam. Toxicol.,* **37**, 480-487.
Reinking, R.F., N.H. Berg, B.C. Farhar, O.H. Foehner (1995). "*Economic, Environ-mental, and Societal Aspects of Precipitation Enhancement by Cloud seeding,*" Manual 81, Guidelines for Cloud seeding to Augment Precipitation, ASCE, Reston, VA, 9-47.
Sánchez, J. L., J. Dessens, J.L. Marcos, J.T. Fernández (1999). Comparison of rain-water silver concentrations from seeded and non-seeded days in Leon (Spain). *J. Weather Mod.*, **31**, 87-90.
Stone, R.H. (1986). "*Sierra Lakes Chemistry Study*." Final Report to Southern California Edison Co., Contract No. C2755903.
Stone, R.H., K. Smith-Miller, P. Neeley (1995). Mokelumne Watershed Lake Water and Sediment Silver Survey. Final Report to the Pacific Gas and Electric Company, Technical and Ecological Services, San Ramon, Ca.
Stone, R.H. (2006). "*2006 Mokelumne Watershed Lake Water and Sediment Survey*." Final Report to the Pacific Gas and Electric Company, Technical and Ecological Services, San Ramon, Ca.
Todd, C.J., W.E. Howell (1985). "*Weather Modification*". In Handbook of Applied Meteorology, David D. Houghton, Editor, John Wiley and Sons, Chapter 38, 1065-1139.
Tsiouris E.S., A.F. Aravanopoulos, N.L. Papadoyiannis, K.M. Sofoniou, N. Polyzopoulos, M.M. Christodoulou, F.V. Samanidou, A.G. Zachariadis, H.-I.A. Constantinidou (2002α). Soil Silver Content of Agricultural Areas Subjected to Cloud seeding with Silver Iodide. *Fresenius Environmental Bulletin,* **11**, 697-702.
Tsiouris E.S., A.F. Aravanopoulos, N.L. Papadoyiannis, K.M. Sofoniou, F.V. Samanidou, A.G. Zachariadis, H.-I.A. Constantinidou (2002b). Soil Silver Mobility in Areas Subjected to Cloud seeding with AgI. *Fresenius Environmental Bulletin,* **12**, 1059-1063.
Warburton, J.A., L.G. Young, R.H. Stone (1995a). Assessment of seeding effects in snowpack augmentation programs: Ice nucleation and scavenging of seeding aerosols. *J. Appl. Meteor.*, **34**, 121-130.
Warburton, J.A., R.H. Stone, B.L. Marler (1995b). How the transport and dispersion of AgI aerosols may affect detectability of seeding effects by statistical methods. *J. Appl. Meteor.*, **34**, 1929-1941.
Warburton, J.A., S.K. Chai, R.H. Stone, L.G. Young (1996). The assessment of snowpack enhancement by silver iodide cloud-seeding using the physics and chemistry of the snowfall. *J. Weather Mod.*, **28**, 19-28.
Weather Modification Association (2005). "*Weather Modification Association Capability Statement.*" WMA; www.weathermodification.org/capabilities.htm.
Williams, B.D., J.A. Denholm (2009). Assessment of the Environmental Toxicity of Silver Iodide-With Reference to a Cloud seeding Trial in the Snowy Mountains of Australia. . *J. Weather Mod.*, 41, 75-96.
World Health Organization (2002). "*Concise International Chemical Document 44 (CICAD44): Silver and silver compounds: Envionmental Aspects.*" WHO; www.inchem.org/documents/ cicads/cicads/cicad44.htm
World Meteorological Organization (2007). "*WMO Statement on Weather Modification.*" WMO; www.wmo.int/pages/prog/arep/wmp/documents/WM_statement_guidelines_approved.pdf.

NOTES:

Following are intended to help non-technically trained readers understand information provided above.

Power of 10's note: Very large and very small numbers are often expressed in scientific or powers of 10 notation. The 10^{15} stated in the WMA statement means that 1 is 10 multiplied by 10, 15 times and it equals 1,000,000,000,000,000. When 10 is raised to a negative power it means 1 divided by 10 the power number of times; for example, 1×10^{-1} equals 0.1.

Units note: g g^{-1} as used here means grams of chemical divided by grams of water in the sample, so that 1×10^{-12} g g^{-1} means 0.000000000001 grams of silver per 1.0 grams of water.

Appendix D

ASCE Policy Statement on Weather Modification

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Atmospheric Water Resources Management
ASCE Policy Statement 275

Approved by the Energy, Environment and Water Policy Committee on February 12, 2009
Approved by the Policy Review Committee on March 6, 2009
Adopted by the Board of Direction on April 23, 2009

Policy

The American Society of Civil Engineers (ASCE) supports and encourages the protection and prudent development of atmospheric water (also known as "weather modification" or "cloud seeding") for beneficial uses. Sustained support for atmospheric water data collection, research and operational programs, and the careful evaluations of such efforts including the assessment of extra-area and long-term environmental effects, is essential for prudent development. ASCE recommends that the results and findings of all atmospheric water-management programs and projects be freely disseminated to the professional community, appropriate water managers and to the public.

Issue

Atmospheric water management capabilities are still developing and represent an evolving technology. Longer-term commitments to atmospheric water resource management research and operational programs are necessary to realize the full potential of this technology.

Rationale

Water resources worldwide are being stressed by the increasing demands placed upon it by competing demands generated by population growth and environmental concerns. As a result, nations have become more sensitive to year-to-year variations in natural precipitation. The careful and well-designed management of atmospheric water offers the potential to significantly augment naturally-occurring water resources, while minimizing capital expenditures or construction of new facilities. New tools, such as radar and satellite tracking capabilities and other imaging devices, atmospheric tracer techniques and advanced numerical cloud modeling offer means through which many critical questions might now be answered. Continued development of atmospheric water-management technology is essential. ASCE has developed materials providing guidance in the use of atmospheric water-management technology with weather modification organizations for dissemination to local communities and governments as well as state, regional and international interest.

ASCE Policy Statement 275
First Approved in 1980

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Appendix E

ICE Silver Iodide Complex Seeding Flare MSDS Sheet

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Ice Crystal Engineering, LLC
5074 165th Ave SE
Kindred, ND 58051 USA

Phone: 701 428 9882
www.iceflares.com

Material Safety Data Sheet

1. PRODUCT IDENTIFICATION/COMPANY DETAILS

PRODUCT NAME: ICE Glaciogenic Burn In Place Flare
PRODUCT TYPE: Pyrotechnic Device
USE: Weather modification, aircraft mounted.
SYNONYMS: ICE Glacio
ICE EB
MANUFACTURER: ICE Crystal Engineering (LLC)
FACTORY ADDRESS: 5074 165th Ave SE, Kindred, ND 58051 USA
POSTAL ADDRESS: As Above
TELEPHONE: +1 701 428 9882
FACSIMILE: +1 701 428 9884
EMERGENCY CONTACT TELEPHONE NUMBER: +1 703 527 3887 (Code ICEC)

2. HAZARDS IDENTIFICATION

The flare contains three ingredients (Ammonium Perchlorate, Zinc Powder, and Aluminum Powder) which are listed on the internet database Hazardous Substances Information System (HSIS). None of these chemicals have any listed health effects. All three have physiochemical effects only.
The flare also contains two other chemicals, Copper Iodide and Ammonium Iodide which whilst not listed on the HSIS have potential irritant health effects according to their manufacturers MSDS. However, these chemicals exist in the mixture below the cut-off levels for the irritant hazard category, as specified in the Approved Criteria for Classifying Hazardous Substances [NOHSC: 10008(2004)], 3rd Edition, October 2004.
Overall, when classified in accordance with the Approved Criteria for Classifying Hazardous Substances [NOHSC: 10008(2004)], 3rd Edition, October 2004, the mixture of the flare ingredients is not considered as hazardous.
The flare is designed for use only by specially trained personnel when mounted on an appropriately modified aircraft.

DANGEROUS GOODS
The product is classified as Dangerous Goods, 1.4S, in accordance with the Australian Code for the Transport of Explosives by Road and Rail, 2nd ed., March 2000.
CLASS: 1.4S **U.N. NO:** 0432
SUBSIDIARY RISK: Nil
Risk Phrases
The following risk phrases relate to the finished product when stored, transported, and handled appropriately.
R10 Flammable.
R36/37 Irritating to eyes and respiratory system
The following risk phrases relate to the mixture contained within the flare and are applicable only if the casing is breached.
R9 Explosive when mixed with combustible material.
R10 Flammable.
R15 Contact with water liberates extremely flammable gases.
R36/37/38 Irritating to eyes, respiratory system and skin
R44 Risk of explosion if heated under confinement.
Safety Phrases
The following safety phrases relate to the finished product when stored, transported, and handled appropriately.
S1/2 Keep locked up and out of the reach of children.
S16 Keep away from ignition sources – No smoking.
S35 This material and its container must be disposed of in a safe way.
S41 In case of fire do not breathe fumes.
The following safety phrases relate to the mixture contained within the flare and are applicable only if the casing is breached.
S1/2 Keep locked up and out of the reach of children.
7/8 Keep container tightly closed and dry
S22 Do not breathe dust.
S24 Avoid contact with skin.
S27 Take off immediately all contaminated clothing.
S36/37 Wear suitable protective gloves/clothing.
S43 In case of fire use water.

3. COMPOSITION / INFORMATION ON INGREDIENTS

The pyrotechnic composition consists of (~70%) Ammonium Perchlorate, Zinc powder (non pyrophoric), Aluminum powder (non pyrophoric), and an organic binder. The remainder (~30%) consists of Silver Iodide, Copper Iodide, and Ammonium Iodide.

4. FIRST AID MEASURES

In the unlikely event of receiving burns from this device, seek medical attention immediately.
Exposure to the smoke may cause irritation to the eyes. Move the patient to fresh air.
Symptoms that may arise if the product is mishandled are:
Ingestion: *Symptoms.* Discomfort
Give plenty of water to drink but only if conscious. Do not induce vomiting. Seek medical attention at once.

Eye Contact: *Symptoms.* Irritation
Immediately flush the eyes with copious quantities of water. Eyelids to be held open. If irritation persists seek medical advice.
Skin Contact: *Symptoms.* Irritation
Wash the exposed area with copious amounts of soap and water. Remove contaminated clothing and wash before reuse. If irritation occurs seek medical advice
Inhalation: *Symptoms.* Throat irritation, shortness of breath

Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. If irritation persists, seek medical assistance.

5. FIRE FIGHTING MEASURES

In the case of fire, isolate the immediate area and deny entry.
In the event of a fire or intense heat that reaches the storage/cargo area, the pyrotechnic articles are likely to ignite. They will burn, spreading burning particles over a limited area. A mass explosion is not expected. Smoke and potentially irritating gases will be produced in a fire.
Fire can be fought with water spray if necessary, although disposal and clean up will be simplified if material is allowed to burn. If flares are exposed to heat and flames, flood with water, or direct water spray on outside of container to cool it down. Continue spray until well after fire is out. Self contained breathing apparatus (SCBA) and structural firefighter's protective clothing will provide some limited protection.
Vehicle fire (other than cargo area): Flood with water. Tire fires may start again. Unhook and separate vehicle from trailer (if applicable and possible). Remove vehicles that are not involved in fire from fire area if you can do so without risk. If cargo area is exposed to heat and flames, direct water spray on outside of container to cool it down.
Cargo Fire: Do not move cargo or vehicle if cargo has been exposed to heat. Withdraw from area if and when fire reaches cargo and let fire burn if situation allows. If fire must be fought, flood with water spray. Use firefighting team to prevent spread of fire to adjacent structures and materials.
For additional information, call the shippers emergency telephone number at +1 703 527 3887 (Code ICEC)

6. ACCIDENTAL RELEASE MEASURES

Remove all ignition sources.
If the pyrotechnic articles are spilled as the result of an accident but do not ignite, they can safely be picked up and repackaged. The area should be kept clear of unnecessary people while this is being done. There shall be no flares, smoking and/or tools capable of producing sparks or flames in the vicinity of the spilled material. Cautiously pick up the spilled devices, place them in cardboard cartons and dispose in accordance with local regulations. The site should be cleaned up with water.

7. HANDLING AND STORAGE

The composition is an explosive (Class 1) and hence should be handled and stored in accordance with the Explosives Regulations of the relevant Competent Authority.
Store in manufacturer's approved packaging in a dry area away from sources of heat and direct sunlight. The shelf life of this product is indefinite if stored properly.

8. EXPOSURE CONTROLS AND PERSONNEL PROTECTION

No chemical composition is released or exposed during normal handling, storage and transportation.

9. PHYSICAL AND CHEMICAL PROPERTIES

The flare consists of 150 grams of glaciogenic pyrotechnic composition glued into a phenolic paper tube with the igniter held into the end and sealed with a plastic cap. The electronic igniter is fired using the voltage supplied from the aircraft to the firing box. When activated the flare burns for between 3.5 and 4 minutes. The temperature of ignition is in excess of 260º Celsius.

10. STABILITY AND REACTIVITY

Stability
This device is stable under normal conditions.
Solubility
The device is sealed from water ingress.
Reactivity
Not applicable.

Chemical Incompatibilities
None known.

11. TOXICOLOGICAL INFORMATION

No adverse health effects are expected if the product is handled according to this MSDS. If mishandling occurs, consult first aid measures above.
The most likely route of exposure would be by inhalation of the gases following combustion. It is recommended that any effects from inhalation of the gases should be treated as outlined in Section 4: First Aid Measures.

12. ECOTOXICITY INFORMATION

Spillage of the composition or deposition of the reaction products in the soil or aquatic environment may represent a short term hazard.
If contamination of the waterways occurred this would be expected to be of a fairly low level. In the event of spillage of the flares, they should be cleaned up in accordance with Section 6 Accidental Release Measures.

13. DISPOSAL CONSIDERATIONS

Damaged or inappropriately stored flares should be destroyed under controlled conditions in accordance with local regulations.

14. TRANSPORT INFORMATION

CLASS: 1.4S **U.N. NO:** 0432
Proper Shipping Name: Articles, pyrotechnic
Gross Weight: 270 grams **NEQ:** 150 grams
Packaging instruction 135 for Inner and Outer Packaging (Australian Code for the transport of Explosives by Road and Rail, 2nd ed, March 2000, Appendix A4).

Appendix F

Walker River Basin Finding of No Significant Impact

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U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Mid-Pacific Region
Lahontan Basin Area Office, Carson City, Nevada

Finding of No Significant Impact
Walker River Basin Cloud Seeding Project

FONSI NO: LO-10-05

Jane Schmidt — 12/27/2010
Recommended by: Jane Schmidt, Natural Resource Specialist — Date

Carol A. Grenier — 12/28/2010
Concurred by: Carol Grenier, Desert Terminal Lakes Program Program Manager — Date

Kenneth S Parr — 01/05/11
Approved by: Kenneth Parr, Area Manager — Date

INTRODUCTION

In accordance with the National Environmental Policy Act (NEPA) of 1969, as amended, the Lahontan Basin Area Office of the United States Bureau of Reclamation (Reclamation) has prepared an *Environmental Assessment for the Walker River Basin Cloud Seeding Project* (EA) dated December 2010, which is hereby incorporated by reference. The EA describes the environmental effects of Reclamation's action to provide federal funding to the Desert Research Institute (DRI) for ground-based and airborne cloud seeding that is intended to enhance precipitation, primarily in the form of snowfall, in a portion of the Walker River Basin in California and Nevada. The benefit of the seeding operations would be evaluated using a hydrologic model developed specifically by DRI for predicting stream flow for the Walker River.

BACKGROUND

Under the Proposed Action in the EA, Reclamation proposes to provide $1,358,000 in funding to DRI to conduct the Walker River Basin Cloud Seeding Project over a period of five years. The grant funding would allow DRI to extend their cloud seeding program which has been used in the upper Walker River Basin from 1992-2009, with minor changes. The Walker River Basin is located in eastern California in Mono County and in western Nevada in Lyon, Mineral, Douglas and Churchill Counties. Airborne cloud seeding is also proposed to be conducted over Tuolomne County, California which is expected to result in additional snowfall within the Walker River Basin.

Reclamation would provide the funding to DRI from Desert Terminal Lakes legislation related to the Walker River Basin. The public laws related to the proposed Cloud Seeding project include PL 107-171 (Farm and Rural Security Investment Act enacted in 2002) Section 2507 which provided $200 million to Reclamation to provide water to at-risk natural desert terminal lakes; PL 108-7 (Omnibus Appropriations Bill enacted in 2003) Section 207 clarified that the money provided in PL 107-171 could only be used for Pyramid, Summit, and Walker Lakes in Nevada; PL 110-246 (Food, Conservation, and Energy Act of 2008) amended PL 107-171 to provide an additional $175 million to benefit at-risk natural desert terminal lakes; and, PL111-85 (Energy and Water Development Appropriations Act of 2010) amended previous Desert Terminal Lakes legislation including adding that permitted uses of funding is for efforts consistent with researching, supporting, and conserving fish, wildlife, plant, and habitat resources in the Walker River Basin.

The cloud seeding project is expected to provide water to Walker Lake by providing some additional water for all decreed rights that are supplied by the Walker River which would include augmenting decreed rights acquired or leased by the National Fish and Wildlife Foundation (NFWF) for intended transfer to Walker Lake (the benefits to the lake would occur during years after the acquired

water right transfers are approved and implemented). NFWF is authorized in legislation to make acquisitions from willing sellers that NFWF determines are the most beneficial to environmental restoration in the Walker River Basin. The cloud seeding project is also expected to augment flows to Walker Lake during potential high run-off events during the non-irrigation winter months when Walker Lake typically receives the bulk of its inflows.

During each winter season of the project, DRI would install and operate five ground-based seeding generators in the Walker River Basin and implement airborne seeding. Based on prior research results DRI would evaluate the benefits of the seeding operations based on a modeling system developed specifically for predicting stream flow for the Walker River.

SUMMARY OF EFFECTS

In support of the environmental assessment, a review of research on the effects of cloud seeding was conducted to evaluate issues concerning the potential toxicity of silver iodide used for cloud seeding material; the estimated increases in precipitation expected from cloud seeding; safety precautions; predicted precipitation enhancement areas; and downwind effects of cloud seeding. The Proposed Action includes a research component, where DRI would collect and model data to assess the change in stream flow in the Walker River. DRI's modeling efforts through this proposed project could contribute new knowledge and information to the existing research on cloud seeding.

Key findings and conclusions from the review of cloud seeding research on these topics include:

The contribution of silver iodide (AgI) to the environment from cloud seeding is negligible (i.e., in quantities too small to be measured) compared to background levels and are well below threshold limits for human safety, aquatic organisms, and water quality standards.

An estimated 5% to 15% increase in annual precipitation in the Walker River Basin could result from the cloud seeding project. This range of potential increase is smaller than the annual range of variability in precipitation expected under natural conditions.

DRI utilizes safety guidelines, also known as "suspension criteria," to stop cloud seeding when there are concerns about predicted flood conditions in or around the project area, avalanche danger, warm winter storm predictions, high winds, adverse wind direction, excessive water content in the snowpack, and major winter holiday periods due to traffic concerns and potential effects on roadways.

Studies indicated there is a high degree of confidence in the accuracy of predicting the precipitation enhancement area, where snow is expected to fall following cloud seeding activities.

Based on the most recent literature, the assumption is that there would be no measurable change to background precipitation downwind of the target area. Any changes to downwind precipitation are expected to be within the annual range of variability of precipitation.

Vegetative Communities. There would be no effect on vegetation from the ground-based cloud seeding generator sites, as no new construction would occur and access is provided by existing roads. Enhanced precipitation from cloud seeding is expected to be within the existing range of variability for seasonal precipitation and therefore no discernable effect on upland vegetation is expected. While cloud seeding could add an estimated 5% to 15% in precipitation, it is unknown how much water would reach the Walker River or Walker Lake. Cloud seeding could augment water used for agricultural vegetation, but is not expected to have a measurable effect on riparian vegetation or noxious weeds along the Walker River, or on vegetative communities around Walker Lake. Therefore, there are no significant impacts on vegetative communities from the proposed project.

Water Resources. Soil moisture and surface runoff in the precipitation enhancement area may increase but it is unlikely the project would result in major inflows to Walker Lake that would significantly reduce the rate of decline in lake level. Increased precipitation held in the snowpack could result in increased agricultural diversions from the Walker River. Water rights acquired or leased by NFWF could be augmented by the increased precipitation and would be transferred to Walker Lake during any years that they are transferred. Enhanced precipitation from cloud seeding could have a slight improvement in water quality but these effects are not expected to be measureable. The project is not expected to have a discernable effect on stream erosion and sediment transport. Cloud seeding material (AgI) has been studied for many years and has been found to be present in well below background levels of naturally occurring silver in the environment, is in an insoluable form that is not toxic to the environment, and does not bio-accumulate. DRI mixes chemicals off-site and provides secondary containment in the event of a spill. Therefore, there are no significant impacts on water resources from the proposed project.

Fish and Threatened Fish Species. A variety of native and introduced fish species occupy the aquatic habitat in the Walker River Basin. Special-status fish species within the project area include Lahontan cutthroat trout *(Oncorhynchus clarki)* listed as a threatened species under the Endangered Species Act (ESA). It is unlikely the project would result in significantly increased flows in the Walker River that would show a discernable positive effect on fish habitat or populations. The same situation applies to increased inflows to Walker Lake, where water

quality could be positively affected, but likely not to a level that could be measured or have a discernable positive effect on fish habitat or populations. Any increased precipitation that is held in the snowpack and is subject to diversion during the irrigation season may not benefit fisheries in a measurable or significant way. The ground based generator sites are located on mountain tops or ridges, removed from watercourses. Studies indicate that cloud seeding material (AgI) occurs in an insoluble form that is not toxic to the environment, does not bio-accumulate, and does not contribute to accumulation of silver in the environment. Therefore, there are no significant impacts on fish and threatened fish species from the proposed project.

Wildlife and Endangered, Threatened, Candidate Wildlife Species. A large number of wildlife species occupy the varied habitat encompassed by the Walker River Basin. Special-status species include Sierra Nevada bighorn sheep, (*Ovis Canadensis)*, endangered; Greater sage-grouse, (*Centrocercus urophasianus)*, Bi-state Distinct Population Segment DPS, Candidate; Yosemite toad, (*Bufo canorus)*, Candidate; Mountain yellow-legged frog (Sierra Nevada DPS), (*Rana muscosa)*, Candidate. Pygmy rabbit (*Brachylagus idahoensis*), which had been under status review for listing under the ESA, the northern sagebrush lizard listed by the Bureau of Land Management (BLM) as a sensitive species, bald eagles and golden eagles, and migratory birds are also of concern.

Terrestrial wildlife and the plants that constitute their habitat are adapted to annual changes in precipitation that are expected to occur from the cloud seeding project. Additional precipitation generated from cloud seeding is expected to remain within the annual range of variability associated with natural precipitation. Excessive amounts of precipitation from cloud seeding activity would not occur because project suspension criteria would be in place, so the project would not contribute to severe weather events that could adversely affect wildlife species. Additional precipitation from cloud seeding could provide increased moisture for both native plants and irrigated agriculture that would be beneficial for these different types of wildlife habitat.

Studies indicate that cloud seeding material (AgI) occurs in an insoluble form that is not toxic to the environment, does not bio-accumulate, and does not contribute to accumulation of silver in the environment.

Ground-based cloud seeding generator sites could have potential negative effects on greater sage-grouse depending on proximity to occupied habitat. The primary concerns are habitat for avian predators, disturbance from winter cloud seeding noise, and disturbance from vehicle traffic for site support. Mitigation measures include removing the equipment during non-use, lowering the antenna if equipment removal is not feasible, and minimizing site support traffic. The BLM will evaluate existing and proposed ground cloud seeding sites for possible effects to pygmy rabbit and northern sagebrush lizard and determine if any additional protection measures should be incorporated in their land use permit to DRI.

Therefore, there are no significant impacts on wildlife and endangered, threatened, candidate wildlife species resulting from the proposed project.

Pursuant to Section 7 of the Endangered Species Act of 1973, Reclamation completed a Biological Assessment to analyze the effects of the proposed action on species listed by the U.S. Fish and Wildlife Service (FWS) as threatened, endangered or candidate species and concluded the proposed project would have "no effect" on these species.

Land Uses and Socio-Economics. The primary target area for enhanced precipitation is the upper Walker River Basin in Lyon and Mineral Counties, Nevada, and in Mono County, California. The Proposed Action is not expected to affect the local economies and socioeconomics of the area. Cloud seeding has been conducted in the area in the past with no apparent effects to these resources. The proposed ground based cloud seeding generator site east of Conway Summit is expected to have no physical effect on communications equipment located at the site because it would always be downwind of existing tower structures during seeding operations. Therefore, there are no significant impacts on land uses and socio-economics from the proposed project.

Air Quality, Climate Change and Greenhouse Gases. The emissions from cloud seeding operations would be minimal relative to background levels from traffic on nearby roads and highways, commercial and military aircraft flying over the project area, and propane used by businesses and residences in and near the project area.

The estimated increase in annual precipitation resulting from the cloud seeding project is smaller than the annual range of variability in natural precipitation, therefore there would be no significant impacts on climate change resulting from implementation of the Proposed Action. Therefore, there are no significant impacts on air quality, climate change and greenhouse gases.

Cultural Resources. Section 106 of the National Historic Preservation Act requires Federal agencies to consider the effects of an action or activity on historic properties which include archaeological sites, built environment, and sites of religious and cultural significance eligible for inclusion on the National Register of Historic Places. Reclamation archaeologists have determined the proposed action to fund the Walker River Basin Cloud Seeding Project has no potential to affect cultural resources.

Indian Trust Assets. The project is a continuation of many years of similar cloud seeding activities in the Walker River Basin and adjacent areas in Nevada and California. The primary cloud seeding material (AgI) has been studied for many years and has been found to be present in well below background levels of naturally occurring silver in the environment, is in an insoluble form that is not toxic to the environment, and does not bio-accumulate. Increases in precipitation are expected to have minor beneficial effects to a variety of trust assets including:

native plants, instream flows, fisheries, wildlife habitat, and associated hunting and fishing. Suspension criteria would be in place if meteorological conditions indicated a risk of unacceptably severe weather. Therefore, there are no significant impacts on Indian trust assets from the proposed project.

Environmental Justice. The Proposed Action's impacts on increased precipitation and stream flow would be within the range of annual variability and unlikely to be discernable from background conditions. There would be no expected downwind reduction in precipitation from the cloud seeding project. There would be no adverse human health or environmental effects to minority or low-income populations as a result of the proposed project. Therefore, there are no significant impacts on environmental justice from the proposed project.

Cumulative Effects. The contribution of the enhanced precipitation from the cloud seeding project would be minor compared to the contribution of other programs and projects. The effects of the Proposed Action are individually and cumulatively limited in scope, scale and duration. The effect of cloud seeding on increased precipitation and stream flow would be within the range of annual variability and would not contribute to a significant cumulative impact in combination with other past, present, and reasonably foreseeable projects.

FINDINGS

Based on the analysis of the environmental impacts as described in the EA for the Walker River Basin Cloud Seeding Project, Reclamation has determined that the proposed federal action will not significantly affect the quality of the human environment, thus an environmental impact statement is not required. This Finding of No Significant Impact (FONSI) is supported by the *Environmental Assessment for the Walker River Basin Cloud Seeding Project.*

DECISION

It is Reclamation's decision to provide funding from Desert Terminal Lakes legislation in the amount of $1,358,000 to the Desert Research Institute to conduct ground based and airborne cloud seeding in the Walker River Basin for a period of 5 years. The cloud seeding project is intended to enhance precipitation in the western portion of the Walker River Basin and ultimately benefit flows to Walker Lake. As part of the Walker River Basin Cloud Seeding Project, DRI will evaluate project effectiveness using a unique hydrologic model to provide an objective assessment of project benefits to stream flow in the Walker River.

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COUNTY OF SANTA BARBARA
PUBLIC WORKS DEPARTMENT
NORTH COUNTY OFFICE
620 West Foster Road
Santa Maria, California 93455
805\739-8750 FAX 805\739-8753

SCOTT MCGOLPIN

Director

Memorandum

To: Cloud Seeding CEQA compliance file, 2013 Mitigated Negative Declaration (MND) 13NGD-00000-00011
From: Dennis Gibbs, Senior Hydrologist

Date: September 17, 2013

RE: **Summary of Comments Received at the August 20, 2013 Environmental Hearing for the Santa Barbara County and Twitchell Reservoir Cloud Seeding Program**

An environmental hearing for the Santa Barbara County and Twitchell Reservoir Cloud Seeding Program was conducted on August 20, 2013 at Santa Barbara County Planning Commission Room to allow members of the public to make comments on the Draft Mitigated Negative Declaration (MND) that was prepared and circulated for public comment on August 1, 2013.

Three members of the public attended the hearing and one provided comment. The following is a summary of comment received.

Commenter: Stanley Boydston

Mr. Boydston spoke of an assumed cloud seeding or spraying program that is being conducted over the Santa Ynez Mountains three times a week during benign weather days and handed out a flyer as well as provided a video that appears to show contrails from jet airplanes at high altitude. While he acknowledged that the Santa Barbara County Water Agency Cloud Seeding Program may not be responsible for these "contrails" he added that the mixture of the two issues, cloud seeding on rainy or inclement weather days and the airplane contrails on benign weather days, can have hazardous effects on the atmosphere, like mixing bleach with ammonia. He stated that a credible group from the company Novim and UCSB physics professors are studying the issue.

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-----Original Message-----
From: Stanley Boydston [mailto:stanley159@cox.net]
Sent: Thursday, August 22, 2013 12:07 PM
To: Gibbs, Dennis
Subject: cloudseeding

Dennis,

Can you please provide a list of the local papers where the notice of the Planning Commission's CEQ meeting was sent and which one's it appeared in. I saw no notice of it in, "The Independant," for the weekend (aug 2-4) you referred to as having placed notice.

Best,
Stanley Boydston

-----Original Message-----
From: Gibbs, Dennis
Sent: Tuesday, August 27, 2013 8:48 AM
To: 'Stanley Boydston'
Cc: Fayram, Tom; Naftaly, Matt; Crease, Fray
Subject: RE: cloudseeding

Hi Stanley,

It was published in the SLO Tribune, Santa Maria Times, Ventura Star and Bakersfield Californian on 7/31/2013 and 8/16/2013 in the legal ads sections.

Let me know if you have any other questions -

Dennis

On Aug 27, 2013, at 9:36 AM, Gibbs, Dennis wrote:

Stanley, I forgot to mention the Santa Barbara News Press! Regards,
Dennis

From: Stanley Boydston [mailto:stanley159@cox.net]
Sent: Friday, August 30, 2013 6:11 PM
To: Gibbs, Dennis
Subject: Re: cloudseeding

Hi Dennis,

Thank you for the info. Were you and Mr. Fayran at the CEQA hearing meeting in Santa Barbara on the 20th?

I was the only speaker, delivered a video and a paper prepared in the name of "Artists For Sunlight." Is your dept. interested in addressing the concern that was raised? If so, would your dept. like to meet and discuss the matter?

Best,
Stanley Boydston

On Sep 3, 2013, at 9:14 AM, Naftaly, Matt wrote:

Hi Stanley,

Dennis forwarded to me your request to meet regarding your comments from the hearing. We will update the Mitigated Negative Declaration to address the concerns that you presented. We don't feel it necessary to meet regarding these issues at this time.

Thank you for your input to this process.

Matt Naftaly, P.H.
Water Agency Manager
Santa Barbara County Water Agency
(805) 568-3542

From: Stanley Boydston [mailto:stanley159@cox.net]
Sent: Tuesday, September 10, 2013 10:48 AM
To: Naftaly, Matt
Subject: Re: cloudseeding

Mike,

What is the SB County water department's position on the comparison and conclusion made in the evidence that I submitted in regard to the SB County water board's 2013 MND of the CEQA?

Again, taking into account the credibility held by the Novim, UCSB physics professors that placed this photo on their, ",Climate Engineering," document,...

Why would a group that could literally right the handbook for climatologists and hydrologists on, ,"climate engineering," publish any other photo than the one they put out(pictured on the bottom of the sheet given to you),?,

...and that is identical to what I and others have been seeing above Gibraltor reservoir for at least a year now.

Please explain the SB County water depts.' reasoning on the evidence presented in order to know whether or not it would be appropriate to go to the city council and continue this discussion or something your dept. might see as a reason to drop it.

Whether your city dept., sees it is true or not –

...you can see online a group of local professors (Novim), that could be experts in court on the topic of climate engineering and they have put forth this document

http://novim.org/projects/climate-engineering

and it is identical to the video we filmed this june, and that photograph is found on Novim's website under the heading that reads, "Climate Engineering."

That is a big cause for concern in my view!

Does the county SB County water dept. share this concern or not and how is it being addressed in conversation anywhere?

http://novim.org/projects/climate-engineering

Your help in this matter is greatly appreciated!

Best,

Stanley.

From: Naftaly, Matt
Sent: Tuesday, September 10, 2013 4:45 PM
To: 'Stanley Boydston'
Cc: Fayram, Tom; Gibbs, Dennis; Almy, Anne
Subject: RE: cloudseeding

Stanley,

We have reviewed the information, website, and video footage that you have submitted. We believe that the Mitigated Negative Declaration (MND) and CEQA process will adequately consider the concerns that you have raised. In addition, all comments received during the public review process will be attached to the MND that will be provided to the decision making body for its consideration.

Thank you again for your comments and input to this process.

Matt Naftaly, P.H.
Water Agency Manager
Santa Barbara County Water Agency
(805) 568-3542

From: Stanley Boydston [mailto:stanley159@cox.net]
Sent: Wednesday, September 11, 2013 12:03 PM
To: Naftaly, Matt
Subject: Re: cloudseeding

Matt,
I'd like to note a correction on the last email: " Whether your city dept., sees it is true or not –."

Should read, "whether or not your county dept. sees it as true or not–."

I would like thank your dept. for its attention, however, I would also like to note a reluctance on the SB county water depts.' lack of conversation with the public regarding your formal position on evidence presented.
This ideally should be a sharing of concerns and conversation before it deadlines. There was no one at the CEQA meeting that introduced themselves from the water dept.. The goal here on our end is safety of the citizens and with that in mind, I suggest a deeper input on this matter,from your dept., other than just putting your views to the CEQA board; without meeting and conversing on it with concerned citizens.

Best,

Stanley