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The New Levelogger Gold represents the next generation of Solinst Levelogger®. Vastly improved over previous versions, the Levelogger Gold is completely designed, developed and manufactured in-house, in the tradition of all Solinst high quality products. Offering higher resolution and high accuracy of 0.05% for a much reduced price, the Levelogger Gold has improved transducer, temperature, and clock accuracies. Altitude, water density, temperature and barometric compensations also add to the major jump in accuracy.

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- Higher accuracy, improved temperature compensation, altitude adjustment and more
- Backward compatible
“Seeding is believing” was heard at a recent cloud seeding conference, and the practitioners of cloud seeding are indeed an enthusiastic bunch. Although many uncertainties in understanding the process and results of cloud seeding remain, the potential for achieving additional precipitation for relatively low investment is great enough to foster several large projects in the Southwest. Is this “weather modification” a solution to our long-term water supply concerns? Cloud seeding might augment the water supply somewhat in some areas, but don’t scrap the desalination and conservation programs just yet.

Plans for the Aug. 29-Sept. 1 joint Southwest Hydrology/Arizona Hydrological Society symposium, “Sustainable Water, Unlimited Growth, Quality of Life: Can We Have It All?” are well underway. We have many distinguished speakers confirmed and ready to discuss hard questions about water supplies, policy, and technology. Concurrent technical sessions will feature a diversity of relevant topics. In addition, optional workshops and field trips are available to help you make the most of your trip to Tucson. Many sponsors and exhibitors have already made generous contributions, but there’s still space for more! Registration will open in late April, but you can reserve your room now at the beautiful Westin La Paloma Resort and Spa for $109 (single/double), or $83 for government employees. Visit www.watersymposium.org for all the details.

As always, we are grateful to our contributors and sponsors for providing the means to produce this publication.

Betsy Woodhouse, Publisher

A water cloud spills eastward and evaporates beyond the crest of the Sierra Nevada toward Reno, Nevada, after having deposited some of its water in the form of snow on the ridge. Cloud seeding can accelerate the conversion of cloud water to precipitation and enhance the snowpack. Photo by D. Rosenfeld during the SUPRECIP field campaign, March 2, 2005.
Cloud Seeding

As western water managers look for ways to diversify their water portfolios, they’re increasingly looking up to the clouds, wondering if they can squeeze any additional water from them. Is cloud seeding a viable new source of water for the West? Perhaps. Under certain conditions, microscopic-sized materials injected into clouds can cause more precipitation to occur than would have fallen naturally. But many questions remain regarding the details of the process, the success of programs, and the impacts of air pollution. Such questions have held up federal funding of research programs, but some local groups are proceeding on their own.

Basic Cloud Seeding Concepts
William R. Cotton
This primer describes precipitation processes and the types of seeding appropriate for particular seasons, weather, and orographic conditions.

Cloud Seeding in the Upper Colorado Basin: Management Perspective
Don A. Ostler
Colorado River managers, faced with recent sustained droughts and potential shortages, are increasingly considering winter cloud seeding as a technique to supplement water resources.

Cloud Seeding in the Upper Colorado Basin: Technical Feasibility
Don A. Griffith and Mark E. Solak
The results of a 2006 study on the potential impact, costs, and benefits of cloud seeding for enhancing streamflow in the Colorado may surprise you.

The Double-Sided Sensitivity of Clouds to Air Pollution and Intentional Seeding
Daniel Rosenfeld and William L. Woodley
Aerosols from smoke and urban air pollution can actually suppress raindrop formation, particularly from orographic clouds. Could cloud seeding offset this effect?

Weather Modification and the Law
George W. Bonnar
The “sparse and contradictory” history of case law on weather modification has been hampered by inadequate understanding of the formation of precipitation. What licensing and permitting procedures are currently in place?

Testing the Effects of Cloud Seeding in Wyoming
Bruce Boe and Barry Lawrence
A five-year cloud seeding pilot project underway in Wyoming is unique in that it gained full funding from the legislature, will be independently evaluated by NCAR, and involved local, state, federal, and tribal interests from the start.

Seeding Is Not Just Believing: More Science Is Needed
Roelof Bruintjes
Human activities can affect the weather, and seeding will cause changes to a cloud. However, in many cases we are still unable to translate these induced changes into verifiable changes in rainfall, hail fall, and snowfall on the ground, or to employ methods that produce scientifically credible, repeatable changes in precipitation.

Will Congress Act to Support Weather Modification?
Tom DeFelice
A National Weather Modification Program that would administer resources for all R&D efforts for optimizing cloud seeding technologies has been proposed to Congress.

ASCE’s Standard Practice Provides Procedures Overview
Betsy Woodhouse
For an overview of how cloud seeding works from both the scientific and practical perspectives, turn to ASCE’s Standard Practice.
Turn to Hach Environmental to get the total solution for water level monitoring.

Nobody ever claimed measuring water level is a walk in the park. So Hach Environmental offers a complete line of OTT water level monitoring instruments to meet a full range of needs. Our autonomous bubbler and shaft encoder, as well as our radar level and pressure sensors are easy to install, easy to maintain and provide accurate results in unpredictable conditions. Plus, we’re backing you with the superior service and support of Hach Environmental. To learn more about how we can help make your job easier, call your local sales representative or toll-free at 1-800-949-3766 ext. 1 today.
NDMA – a Primer

Andrew Masters – Maxxam Analytics Inc.

N-nitrosodimethylamine (NDMA) was first identified in drinking water as a contaminant in the late 1990s. Because it is a potential human carcinogen, numerous subsequent studies have examined its occurrence, sources, and toxicity.

NDMA is an N-nitroso organic compound. It is a volatile yellow liquid that is water soluble, relatively polar, of low molecular weight (74.08 grams per mol), reactive, and with a low partition coefficient. These characteristics make NDMA easily transportable by water and very persistent, and also difficult to differentiate from many other contaminants in laboratory analyses.

**Industrial and Natural Sources**

Currently there are no commercial uses of NDMA in the United States or Canada, but it was used in the past as a fire retardant, in chemical production, for copolymer softening, and in lubricants. Many industrial processes have been identified as sources of NDMA, particularly its use in 1,1-dimethylhydrazine, a liquid rocket fuel used from the 1950s to 1976, including in NASA’s Apollo missions. Although NDMA is no longer deliberately manufactured in North America, it is unintentionally formed during the manufacture of many commercial products and can be found in tobacco, processed food, cosmetics, and detergents, as well as in discharges from industries involved in rubber production, leather tanning, pesticide manufacture, food processing, dye manufacturing, and by foundries.

Identified biological, chemical, and photochemical processes that result in NDMA formation include the reaction of naturally occurring precursors (typically secondary amines) and nitrosylating agents such as nitrite. NDMA can also form from reaction of dimethylamine with oxides of nitrogen in the air or be produced by soil bacteria, which can generate NDMA from precursor compounds such as nitrate, nitrite, and many amines.

Disinfection of drinking water and wastewater with chlorine/chloramines also has been found to generate NDMA as a byproduct. Water from advanced treatment plants for indirect potable re-use can contain levels of NDMA in excess of typical action limits, a discovery that has led to serious concerns over the practice.

**In the Environment**

NDMA is found at nanograms per liter (ng/l) concentrations in the environment throughout North America due to the prevalent use of chlorination as a disinfectant and because of the many industrial activities that are potential sources of NDMA. It frequently is found in groundwater surrounding industrial sites and where rocket launching or engine testing has occurred. Many secondary wastewater effluents contain levels of NDMA greater than 100 ng/l, and even advanced wastewater treatment plants have produced effluent with NDMA levels of 80 ng/l. In California, NDMA has been measured in water wells from Los Angeles, Sacramento, and Orange County at levels above the California action limits.

Toxicology studies have shown that NDMA causes carcinomas and tumors of the esophagus, nose, and liver in rodents. The U.S. EPA has listed NDMA as a probable human carcinogen, and it is on California’s Safe Drinking Water and Toxic Enforcement Act list of chemicals known to cause cancer or birth defects or other reproductive harm. Chronic exposure is linked to liver disease.

**Regulatory Status**

The absence of federal standards for NDMA has prompted many jurisdictions to set their own action limits. The province of Ontario, Canada, set an interim maximum acceptable concentration of 9 ng/L for drinking water. California’s Department of Health Services set its notification limit (formally an action limit) at 10 ng/L, and has prepared draft groundwater recharge reuse requirements for the compound. The Arizona Department of Environmental Quality now includes NDMA on the monitoring list for National Pollutant Discharge Elimination System permits.

**Remediation Approaches**

The physical and chemical properties of NDMA limit treatment options. Air stripping, biodegradation, and carbon adsorption are not generally effective. Treatment options involving UV irradiation with or without oxidation do work, and are more cost-effective than other conventional treatment options. More effective approaches focus on removing NDMA precursors or avoiding conditions that promote NDMA formation in the first place.

Contact Andrew Masters at Andrew.masters@maxxamanalytics.com.
No single screen type is appropriate for all wells. Roscoe Moss Company is the only manufacturer in the world producing shutter screen, continuous slot screen, bridge slot screen, and slotted pipe. This ensures that Roscoe Moss Company’s customers receive unbiased technical assistance directed toward solving their specific problems.
LA Restores Lower Owens Flow

Ninety-three years after Owens River water was diverted to the burgeoning city of Los Angeles by the behemoth-like Los Angeles Department of Water and Power (LADWP), city leaders restored streamflow in a 62-mile stretch of the river in December. Under the cooperative effort, called the Lower Owens River Project, flow is released from the aqueduct intake into its former channel, along which it flows to the delta of Owens Lake just south of Lone Pine. The discharge rate will be gradually ramped up to the full flow of 40 cubic feet per second by mid-summer. A pumping station just north of Owens Lake will be used to return a portion of the water to the Los Angeles Aqueduct or to the Owens Lake dust control project. The project will consume about 9,000 acre-feet of water per year, which Los Angeles will offset through conservation measures and additional water purchases.

According to the Christian Science Monitor, many consider the restoration effort one of the most ambitious ever attempted in the country. The project developed out of a 1970 court case, eventually followed by a 1997 promise by LADWP to restore flow by 2003. Further delays and fines ensued, but water was finally released into the river “nearly two months ahead of schedule,” according to an LADWP press release.


Californians Approve Water Protection Measures

In November, Californians approved Proposition 84, the Clean Water and Coastal Protection Bond Act of 2006. It enables the sale of $5.4 billion in bonds to provide water-related activities and services in the state, including integrated water management and water quality protection ($1.3 billion), river, lake, and stream protection ($928 million), flood control ($800 million), climate change reduction and sustainable communities ($580 million), protection of beaches, bays, and coasts ($540 million), parks and educational facilities ($500 million), conservation ($450 million), and water planning and design ($65 million).

Proposition 1E also passed, authorizing $4.1 billion in bonds to repair aging levees in the Central Valley and Sacramento-San Joaquin River Delta.


Riverside, CA Wins EPA Pretreatment Award

Last fall, the U.S. EPA presented the city of Riverside, California with a first-place...
award for its wastewater pretreatment and pollution prevention achievements.

“The city of Riverside has an outstanding pretreatment program coupled with strong pollution prevention elements that focus on pollutants that either impact or could have an effect on the Santa Ana River and its watershed,” said Alexis Strauss, director of EPA’s Water Division for the Pacific Southwest Region.

Generally, publicly owned treatment works (POTWs) are designed to treat domestic sewage, but they also receive some industrial wastewater. EPA’s General Pretreatment Regulations established the responsibilities of federal, state, and local government, industry, and the public to implement pretreatment standards to control pollutants from industrial usage that may pass through or interfere with POTW processes or contaminate sewage sludge. The pretreatment awards recognize municipalities that successfully navigate the complex regulatory program and go beyond EPA’s basic requirements to demonstrate innovation in implementing the program.

Riverside’s water treatment services include primary, secondary, and tertiary treatment of about 30 million gallons of wastewater per day. In addition, the city’s Industrial Waste Inspection program oversees enforcement of all regulations pertaining to the quality of industrial, commercial, and industrial wastewater discharged into public sewer lines for reclamation at the City’s Water Quality Control Plant, and implementation of the industrial pretreatment program.

Visit epa.gov/region9/water/pretreatment/.

Yosemite Projects Halted Over River Concerns

Environmental interests declared victory in November as a federal judge blocked $60 million worth of construction projects at Yosemite National Park until better protection for the Merced River is in place. U.S. District Judge Anthony W. Ishii rejected the National Park Service’s (NPS) latest version of the Merced River protection plan, a document that has been more than 15 years in development, according to Friends of Yosemite Valley (FOYV), on the grounds that it did not specify limits to the number of people allowed in sensitive areas of the river.

In 2000, FOYV and another citizens’ organization, Mariposans for the Environment and Responsible Government, filed a lawsuit against NPS to stop all construction projects that would affect the river environment until a valid river protection plan is in place. Two years ago, the 9th Circuit Court of Appeals ordered NPS to prepare a “new or revised” plan for the Merced.

In his ruling, Ishii said that the plaintiffs demonstrated that “restoration” activities identified by NPS were in fact anchoring other projects that could affect the visiting capacity of the river corridor, and that “NPS is ‘simply incorrect’ in believing that they have filled the requirements for proper environmental analysis,” according to an FOYV news release.


Trinity River Improvements Slated for Texas

Last fall, Texas Gov. Rick Perry announced a major environmental initiative on the Trinity River to improve its ecosystem and water quality. More than $500,000 in state seed money and in-kind contributions is being made available to the Trinity River Basin Environmental Restoration Project.

The state funds will be used for storm water control, irrigation programs, and education. These bonds plus additional state and private dollars could leverage as much as $30 million in the next several years to develop a comprehensive water flow model with the Army Corps of Engineers, improve water quality, enhance wildlife habitat, and expand ecotourism opportunities in the Trinity River Basin. Funds also will be used to leverage federal dollars for grants for the rural areas of the basin.

Texas A&M University’s Texas Water Resources Institute will lead and coordinate urban activities with regard to the project. The university’s Institute for Renewable Natural Resources will manage rural efforts working closely with the Trinity Basin Conservation Foundation, a group of local landowners, conservationists, and parks and wildlife advocates.

The Trinity River has a long history of water quality problems, dating back to the early 1900s when it was known as the “River of Death.” This trend was reversed in the early 1920s with the development of sewer systems and wastewater treatment in Dallas and Fort Worth. Over the past several decades, water quality has improved and the river’s fisheries are returning to a much healthier state.

The Trinity River Basin is the only basin in the country that connects two major metropolitan areas, Dallas-Fort Worth and Houston. The river is in close proximity to 8.9 million residents and provides water to 40 percent of the state’s population.

Visit twri.tamu.edu and irnr.tamu.edu.

Platte River Agreement Finalized

With Secretary of the Interior Dirk Kempthorne’s signature following those of the governors of Colorado, Nebraska, and Wyoming, the Platte River Recovery Program Implementation Cooperative Agreement was set in motion in December. The program pools resources and expertise throughout the basin to protect and restore habitat for threatened and endangered species while ensuring current uses of water can continue. Without the agreement, Endangered
Species Act consultation requirements would have to be addressed separately for each of the hundreds of federal and private water projects in the basin.

The federal government will provide half the funding; the remainder will be contributed by the three states through nonfederal funds, water, and lands. The estimated total value of these cash and cash-equivalent contributions over the first 13 years of the program is about $317 million. A governance committee, comprised of representatives from the three states, water users, environmental groups, and federal agencies, will act as the implementation team.

Visit www.usbr.gov.

AZ Superfund Site Delisted

EPA removed the 19th Avenue Landfill Site in Phoenix from the National Priorities List of Superfund hazardous waste sites last fall after 23 years on the list, having determined that no further cleanup activities are necessary to protect human health and the environment.

Located by the Salt River, the site is a closed landfill owned by the city of Phoenix. The landfill opened in 1946 to accept municipal wastes, as well as hazardous and industrial wastes that may have included pesticides, solvents, and medical wastes. Phoenix operated the landfill from 1964 until 1979, when the Arizona Department of Health closed it after several floods in the late 1970s intermittently covered the landfill with water, with some even washing refuse from it.

Cleanup actions included building levees along the banks of the Salt River for flood protection; widening the river to withstand a 100-year flood event; placing a soil cap and vegetative/erosion layer on the landfill to prevent rainwater seepage; building landfill gas collection and treatment systems; monitoring landfill gas, ambient air, and groundwater; and developing a contingency plan to address potential groundwater impacts. According to the Arizona Republic, Phoenix spent $22.5 million on these activities.

Phoenix will continue to monitor and maintain the site and conduct routine operations. The Arizona Department of Environmental Quality will continue to oversee activities at the site and conduct a formal review every five years to ensure the effectiveness of the cleanup.

Visit www.epa.gov/superfund/.

AZ Water Protection Grants Awarded

The Arizona Water Protection Fund, established within the Arizona Department of Water Resources in 1994, announced the distribution of $2.5 million in grants.

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Assessing Ground Water Movement and Contaminant Migration Through Aquitards

From Investigative Techniques to Hydrogeologic Characterization

Aquitards (low-hydraulic conductivity hydrogeologic units) are critically important to groundwater and contaminant movement. Characterizing aquitards for environmental and water resource projects is important for protecting deep aquifers and understanding potential contaminant pathways for previously impacted aquifers. Both unconsolidated and bedrock aquitards share inherent low hydraulic conductivities, but approaches and field methods for characterizing each type can be completely different. Appropriate characterization requires site-specific understanding about the aquitard’s origin, unit distribution, heterogeneity, fracturing, and the effects of secondary weathering or tectonics.

Learn Up-To-Date Methods for Investigating & Characterizing Aquitards

- Improve your characterization of ground water movement & contaminant migration through aquitards by gaining a better understanding of aquitard hydraulics, vertical seepage, confining conditions and more
- Discover the importance of differentiating a sequence of low hydraulic conductivity units
- Discover new techniques and field instrumentation for monitoring aquitards
- Compare water sampling and slug test procedures in low hydraulic conductivity units
- Identify and characterize fractures from an angle boring using continuous rotasonic sampling
- Explore new approaches for ground water and solute transport modeling in aquitards
- Gain better understanding about petroleum contamination in weathering zones within fine-grained sediments
- Understand the potential for pathogenic virus contamination in deep aquifers thought to be protected by overlying aquitards

Register at: www.midwestgeo.com
to 10 recipients for fiscal year 2007. The grants will fund reclamation projects including stream restoration, erosion reduction and control, removal of tamarisk trees, and enhancement of riparian areas. Individual grants ranged from $603,000 to Yuma Crossing Natural Heritage Area for the South Channel restoration project, to $24,000 to the Pima Association of Governments for Cienega Creek studies.

Visit www.awpf.state.az.us.

**EPA Clarifies Pesticides Rule**

Last fall, the Environmental Protection Agency issued a final rule clarifying two circumstances under which a National Pollutant Discharge Elimination System permit is not required to apply pesticides to waters of the United States. They are: 1) the application of pesticides directly to water in order to control pests; and 2) the application of pesticides to control pests that are present over or near water, where a portion of the pesticides will unavoidably be deposited to the water in order to target the pests.

“This clean water rule strengthens and streamlines efforts of public health officials and communities to control pests and invasive species while maintaining important environmental safeguards,” said EPA Assistant Administrator for Water Benjamin H. Grumbles. According to the *Sacramento Bee*, farmers and those trying to prevent the spread of West Nile virus praised the decision, which has been the subject of conflicting court decisions for several years, while environmentalists warned that this interpretation of the Clean Water Act by EPA was “unlawful,” suggesting future challenges to the decision could arise.

The rule is available at cfpub.epa.gov/npdes/home.cfm?program_id=41#water_transfer. Also see www.sacbee.com.

**USDA, EPA Sign Water Quality Credit Trading Agreement**

In October, the USDA Natural Resources and Environment Under Secretary Mark Rey and Benjamin Grumbles, assistant administrator of EPA’s Office of Water, signed an agreement to establish and promote water quality credit trading markets through cooperative conservation.

Water quality credit trading uses a market-based approach that offers incentives to farmers and ranchers who implement conservation practices that improve water quality. While reducing pollution, they can earn credits that can be traded with industrial or municipal facilities that are required by the Clean Water Act and other laws to reduce the amount of pollution in wastewater.

Allowing the market to determine the price per credit by using the principle of supply and demand offers incentives that generate interest among more participants, expanding conservation practices to more acres of agricultural lands. Private-sector water quality markets complement existing federally supported conservation efforts by creating additional revenue streams for water quality improvement.

Visit www.nrcs.usda.gov/about/strategicplan/ and www.epa.gov/waterqualitytrading/.

**EPA Issues Groundwater Rule**

EPA promulgated the final Ground Water Rule in October to reduce the risk of exposure to fecal contamination that may be present in public water systems that use groundwater. The rule applies to systems that use groundwater and to those that mix surface water and groundwater, if the groundwater is added directly to the distribution system and provided to consumers without treatment equivalent to surface water treatment.

The rule adopts a risk-targeting approach that relies on four major components:

- for systems that do not already treat drinking water to reliably remove 99.99 percent of viruses, source-water monitoring requirements are triggered when a positive sample is identified during Total Coliform Rule monitoring. Optional assessment monitoring targeted at high-risk systems may also be required by individual states;
- implementation of corrective actions by groundwater systems with a significant deficiency or evidence of source water fecal contamination; and
- compliance monitoring for systems that are sufficiently treating drinking water to ensure effective removal of pathogens.

The compliance date for triggered and compliance monitoring is Dec. 1, 2009.

Visit www.epa.gov/safewater/disinfection/gwr/.
New Publications from WEF

The Sacramento-based Water Education Foundation (WEF) published several new materials last year. The 28-page Layperson’s Guide to Nevada Water provides an overview of the history of water development and use in the state. It includes sections on Nevada’s water rights laws, the history of the Truckee and Carson rivers, water supplies for the Las Vegas area, groundwater, water quality, environmental issues, and today’s water supply challenges. The book was funded by the U.S. Bureau of Reclamation and costs $7.

Proceedings of the 2005 Colorado River Symposium, “Sharing the Risks: Shortage, Surplus, and Beyond,” are now available. The invitation-only meeting assembled top policymakers in the Colorado River Basin to discuss past and present drought and hydrologic conditions, shortage sharing, water rights and international border issues, agricultural-to-urban water use transitions, and the impacts of climate change. The 160-page book costs $50.

Finally, WEF produced a new map of the Sacramento-San Joaquin Delta that focuses on delta sustainability. The map’s text, photos, and graphics explain issues related to subsidence, levees and flooding, and salt water intrusion. Funded by the California Bay-Delta Authority, the 24- by 36-inch map costs $10.

Groups Request Pristine Waters Designation in New Mexico

A coalition of conservation and wildlife groups has asked the State of New Mexico to protect some of its cleanest waters that flow from roadless national forests. Last fall, Forest Guardians, New Mexico Wildlife Federation, New Mexico Wilderness Alliance, and the Sierra Club jointly filed a formal petition with the New Mexico Water Quality Control Commission to name the waters inside the Inventoried Roadless Areas on the Santa Fe National Forests north of the cities of Pecos and Las Vegas as Outstanding National Resource Waters (ONRWs).

According to Forest Guardians, this Clean Water Act designation would permanently protect the critical source of drinking water for the city of Las Vegas, New Mexico, provide a measure of protection for the forests in which these waters are found, and protect healthy landscapes for future generations of humans and wildlife. Among the streams nominated for protection are the Pecos and Gallinas rivers and numerous tributaries, which provide abundant habitat for fish and wildlife and a variety of recreational opportunities. In total, the nomination calls for the protection of more than 100 miles of waterway.

The petition is part of an innovative strategy that responds to the Bush administration’s repeal of the Roadless Area Conservation Rule of 2001. Although a California judge ruled last fall that Bush’s replacement policy for managing roadless areas violates the National Environmental Policy Act, the Bush administration has made it clear that it does not intend to reinstate the Roadless Area Conservation Rule. This leaves 1.6 million acres in New Mexico unprotected from logging, mining, oil and gas development, and other such activities.

Rather than wait for this legal situation to be worked out in the courts, the coalition is pursuing an alternative. By asking the state to designate waters inside Inventoried Roadless Areas as ONRWs, the coalition says it hopes to protect both the roadless forests threatened by Bush’s policy and keep the waters these forests naturally provide forever clean.

Designation as an ONRW would not limit existing uses, but merely ensure the water quality is not polluted beyond its current condition. The nominated waterways meet the criteria for ONRW designation because of their exceptional recreational and ecological values. Such broad water protections are not unprecedented; Montana and Wyoming have named all surface waters in national parks, national wilderness and primitive areas as ONRWs.

The nomination is available at www.fguardians.org/support_docs/petition-nominate-onrw_pecos_10-25-06.pdf.

Irrigation Association Recognizes San Antonio System

The San Antonio Water System (SAWS), which implemented a comprehensive year-round water conservation program, received the 2006 Irrigation Association National Water and Energy Conservation Award. After experiencing a severe drought in 2001, SAWS spent four years working with the irrigation industry and others with an interest in water usage to develop a comprehensive ordinance that would conserve water without disproportionately impacting irrigation businesses and other water users.

Passed in 2005, the ordinance requires rain sensors for irrigation systems, encourages irrigation audits, and rewards efficient landscape and irrigation designs. In addition, SAWS’ Seasonal Irrigation Program provides customers easy access to evapotranspiration data to help them make informed decisions about when and how much to irrigate. The ordinance and SAWS efforts are credited with saving 1.3 billion gallons of water per year.


WEF Holds Big Bash, Adopts Climate Change Resolution

WEFTEC.06, the Water Environment Federation’s 79th annual technical exhibition and conference, hosted some 17,000 attendees and a record 965 companies in Dallas last October, the largest annual water quality exhibition in the world. In addition to an expansive exhibit area, the meeting offered 95 technical sessions, 25 workshops, 8 facility tours, and several special...
events. Sessions on compounds of emerging concern and a new Water Environment Research Foundation biosolids report drew particular interest.

During the meeting, WEF announced the adoption of a new climate change resolution by its board of trustees. The resolution recognizes climate change and its impacts on the planet’s natural hydrologic cycle, and commits WEF to working with its members, member associations, and others to help reduce the impacts of climate change and better prepare the water quality community for its effects. It also urges WEF members and local agencies to become leaders in their own communities by taking steps to reduce greenhouse gas emissions from treatment facilities and related operations, and by educating the public. The announcement of the resolution followed a keynote address by James Hansen, a leading U.S. expert on climate change and global warming and the director of NASA’s Goddard Institute for Space Studies.

Preparations are well underway for WEFTEC.07, to be held Oct. 13-17, 2007 in San Diego. If you’re into water quality, put it on your calendar now.


NGWA Recognizes Leaders at Groundwater Expo

The National Ground Water Association’s 2006 Ground Water Expo was held in early December in Las Vegas. A record-setting 6,600 people attended the event, including 315 exhibitors. A number of awards were presented, including several to individuals from the Southwest.

Robert E. Mace of the Texas Water Development Board in Austin received the Technology Award, recognizing his role in pioneering the use of groundwater modeling to inform policy makers and citizens about the state of groundwater in Texas. Through his direction, computer models have been developed for aquifers covering 73 percent of Texas and encompassing 95 percent of groundwater produced in the state.

Bill C. Stoner of Corsicana, Texas, received the Ross L. Oliver Award for outstanding contributions to the groundwater industry. Stoner is president of Stoner Drilling Inc. and has been a director of the Texas Ground Water Association for 28 years.

Thomas C. Winter of the U.S. Geological Survey in Denver received a Life Member Award for his special service in furtherance of the groundwater industry. He was cited for his innovative research on the hydrology of lakes and wetlands that has fundamentally altered the way in which the national and international scientific communities view these aquatic systems.

Cloud seeding is increasingly being used for both water supply enhancement and weather damage reduction. In the West, cloud seeding is performed with the goal of increasing the overall precipitation into a watershed. Elsewhere, particularly the High Plains of the United States and Canada, it is used for hail suppression to reduce damage to crops and urban areas.

Compelling evidence suggests that seeding supercooled orographic clouds, those formed by air lifting over mountains, can increase precipitation on the ground and cause significant increases in the snowpack. Although the amounts of precipitation increase are under debate, a 10 percent increase is conservatively estimated.

In the Colorado River Basin, we focus on glaciogenic seeding (using ice-forming materials) of winter orographic clouds because the strongest scientific evidence that seeding can increase precipitation comes from this method. In addition, western reservoirs are replenished primarily from snowmelt, derived largely from snowfall from winter orographic clouds, when conditions minimize losses to evaporation. In contrast, rainfall from summer convective clouds contributes much less to reservoirs, as it is largely absorbed locally by vegetation and lost via evaporation and evapotranspiration.

### About Orographic Clouds

The figure at far right illustrates the formation of an orographic cloud as air is forced to lift in order to pass over mountains. Updraft velocities, which can be several meters per second, depend upon the speed and direction of the wind and the height of the barrier. Orographic clouds may be quite transitory, although with steady winds, they can last for hours. Precipitation can form in the time it takes the air parcel to move from the upwind lateral boundary to the downwind boundary, typically around 20 minutes. Because stable, wintertime orographic clouds have low liquid water content, usually less than 0.5 grams per kilogram, precipitation production requires efficient conversion of cloud droplets to precipitation.

The goal of seeding these clouds is to reduce the timescale of precipitation formation so that precipitation is optimized on the upwind side of the mountain crest. Orographic clouds offer several advantages over cumulus clouds for seeding: they are persistent and produce precipitation even in the absence of large-scale meteorological disturbances, and much of the precipitation is spatially confined to high mountainous regions, simplifying set-up of ground-based seeding and observational networks.

### How Precipitation Forms

Warm cloud precipitation processes (above 0°C) involve larger-sized droplets settling through the cloud relative to smaller ones and colliding and coalescing to form still larger droplets. Precipitation growth proceeds very rapidly once droplets exceed 40 microns in diameter. The efficiency of the process depends on the time available for precipitation formation, the liquid water content of the cloud, and the concentration of cloud droplets that form.

Cloud droplets form on hygroscopic (salt and salt-like, including ammonium sulfate) particles in the atmosphere called cloud condensation nuclei (CCN). CCN concentrations are generally less than 100 per cubic centimeter over oceans, and range from a few hundred to 1,000 per cubic centimeter over remote land areas, up to several thousand per cubic centimeter in areas affected by human activities. Clouds with low CCN concentrations and high liquid water contents are most efficient at producing warm rain by collision and coalescence.

Ice phase precipitation processes (when most or all of the cloud is below 0°C) include vapor deposition growth of ice crystals, ice particles collecting cloud droplets (riming), and collision and coalescence of ice crystals (aggregation). Because the saturation vapor pressure...
over ice is less than that over water, ice crystals that form on ice nuclei (IN) in a water-saturated cloud of droplets are in a supersaturated environment and grow efficiently by vapor deposition. Riming involves ice particles settling through and colliding with cloud droplets, which then freeze onto the particles. Note that for a given liquid water content, the higher the CCN concentration (such as in polluted air), the smaller the cloud droplets and the lower the efficiency of this process. Ice crystal aggregation occurs most readily under conditions of high concentrations of ice crystals, relatively warm air (near 0°C), and with complex, dendritic ice crystal structures such that crystals can readily interlock.

Concentrations of ice crystals do not always correspond to the concentrations of IN. Several mechanisms of ice multiplication have been proposed that explain many, but not all, differences between IN and ice crystal concentrations.

**Types of Cloud Seeding**

*Hygroscopic seeding* is used in warm or mixed-phase clouds. Large hydroscopic particles (salt powders and hygroscopic flare-produced particles; see image below) are injected into a cloud to increase the concentration of “collector drops” that can grow into raindrops by collecting smaller droplets and enhancing the formation of frozen raindrops and graupel (snow-like ice) particles. This method of seeding may also be effective in wintertime orographic clouds because it may counteract the negative influences on precipitation of high concentrations of CCN in polluted airmasses.

*Glaciogenic seeding* involves the injection of ice-producing materials into a supercooled cloud to stimulate precipitation by ice particle growth. The objective of glaciogenic seeding is to introduce seeding material that will produce the optimum concentration of ice crystals for precipitation formation. That concentration depends on particular features of the clouds and background aerosol concentrations. Recent experiments and basic physical modeling suggest that the window of opportunity for precipitation enhancement by glaciogenic cloud seeding is limited to:

- clouds that are relatively cold-based and continental;
- clouds having top temperatures in the range of -10°C to -25°C;
- the time available for precipitation formation, as illustrated at right.

The temperature window is critical: at cloud temperatures colder than -25°C, natural ice crystal concentrations can be high, and seeding could produce too many small ice crystals, resulting in an “overseeded” cloud. Alternatively, seeding materials are less effective in nucleating crystals above -10°C.

Timing is also important. If winds are weak, sufficient time may exist for natural precipitation processes to occur efficiently. Stronger winds may prohibit efficient natural precipitation, so seeding could speed up precipitation formation. But if the wind is too strong, seeded ice crystals will not have enough time to grow to precipitation before they are blown over the mountain crest and evaporate in the sinking subsaturated air on the lee side. Normally National Weather Service model forecasts and synoptic analyses of winds and temperatures are used to determine if conditions are optimum for seeding clouds.

The temperature window is determined by the Lagrangian time scale ($t_L$) for the development of precipitable particles.

The seeding process

Most cloud-seeding operations use silver iodide (AgI), which has a crystalline structure similar to ice. Its ice-nucleating ability depends on the mode of generation, which typically is by acetone generators in which AgI is suspended in acetone. The acetone is burned, producing a smoke of IN. This method allows generators to be located on the ground where they can use natural turbulence to carry IN into the cloud.

**Looking Ahead**

The application of glaciogenic cloud seeding to orographic clouds has been shown to increase concentrations of ice crystals in clouds, reduce supercooled liquid water content, and rapidly promote precipitation. However, further refinement of modeling and forecasting abilities would help optimize the cloud seeding process. One model currently being evaluated by the author is the RAMS high-resolution mesoscale model, which can predict wind speeds, cloud water contents, natural precipitation amounts, transport and dispersion, activation of seeding material, and the amount of precipitation enhancement by seeding. In addition, the role of background aerosol concentrations on precipitation formation will be an important area of investigation.

Contact William Cotton at cotton@atmos.colostate.edu.
The Colorado River Basin is experiencing significant demands upon its available water supply and these pressures are only expected to become more intense in the future. Population over the next 20 years is expected to increase by 39 percent in the Lower Basin states (California, Arizona, and Nevada) and 26 percent in the Upper Basin states (Colorado, Utah, Wyoming, and New Mexico), representing millions of additional people who will be dependent upon the Colorado River for water.

The current level of development and use of Colorado River system water is also becoming a concern. The Lower Basin states are effectively using all of their Compact apportionment now, and the Upper Basin states will be using their full apportionment in the future due to rapidly increasing uses.

Adding to pressures on the available Colorado River water supply, the basin remains in the throes of one of the worst droughts on record. The years 2000 to 2004 were particularly severe, with Lake Powell inflows ranging between 25 and 62 percent of average and Lake Powell dropping to 33 percent of its capacity. Even with one year of near-average inflow, lakes Powell and Mead are still only about half full. Sustained droughts have become much more serious and difficult to withstand with the increased development of the Colorado River. And more uncertainty has been introduced into drought management due to new tree-ring studies of past severe drought and new theories on future effects of a warming climate on Colorado River streamflow.

As a result of these circumstances, Colorado River water managers have been engaged in planning for shortages in the Lower Basin and evaluating coordinated operations of lakes Powell and Mead. The goals of these efforts are to improve system efficiency, to delay and reduce Lower Basin shortages, reduce risks of Upper Basin use curtailment according to the 1922 compact, and better meet the needs of system users within current law.

Augmenting the supply of Colorado River water has become a high priority in the effort to meet future needs. All feasible means of doing this are being evaluated, including winter cloud seeding.

Upper Basin Seeding Efforts
Wintertime cloud seeding is not new to the Upper Basin states. Utah, Colorado, and Wyoming currently

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Most professional cloud seeding organizations now believe the effectiveness of these programs is in the range of a 5 to 15 percent increase in precipitation.

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Don A. Ostler – Upper Colorado River Commission
Cloud seeding is one of several options under consideration by the Colorado River Basin states for augmenting water supplies in the basin. How much “new” water could it provide?

In spring 2006, the Upper Colorado River Commission contracted North American Weather Consultants Inc. to evaluate the current status of cloud seeding and the feasibility of using the method to enhance streamflow in the Colorado River region.

A 2005 report by the Bureau of Reclamation (Hunter et al., 2005) identified areas within Arizona, Colorado, Utah, and Wyoming where new operational winter cloud seeding programs could be developed and existing programs enhanced to provide additional runoff in the Colorado River Basin (see figure and table). Criteria for new programs included elevation above 9,000 feet, a mountain barrier at least three miles wide west to east, and location largely or wholly outside any designated wilderness areas. Operational programs with a straightforward goal of increasing streamflow are distinguished from more costly research programs that seek to advance knowledge.

How Much Water? At What Cost?

Carefully designed and conducted orographic seeding programs are considered the most physically and economically feasible and are generally estimated to achieve 5 to 15 percent increases in precipitation. Streamflow model simulations were performed for Colorado, Utah, and Wyoming by the National Weather Service’s Colorado River Forecast Center. The center predicted that an average increase of 650,500 acre-feet of runoff into Lake Powell for April through December could be gained from the proposed new cloud-seeding programs, assuming a 10 percent increase in October through March precipitation. Another 576,500 acre-feet of additional runoff was projected by augmenting existing programs for the same period and under the same conditions. With an additional 154,000 acre-feet of annual runoff that could come from new seeding programs in Arizona, the total estimated average potential for additional runoff in the Colorado River Basin is nearly 1.4 million acre-feet per year.

Developing new operational programs and augmenting existing ones in the four Upper Basin states has a preliminary cost estimate of around $7 million annually, at an average cost of $5 per acre foot. Fifteen percent of the total estimated

...see Feasibility, page 32

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**Technical Feasibility**

Don A. Griffith and Mark E. Solak – North American Weather Consultants Inc.

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**Existing Target Areas**

<table>
<thead>
<tr>
<th>Colorado</th>
<th>Utah</th>
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<tbody>
<tr>
<td>1. Upper Arkansas *</td>
<td>11. Fishlake Mtns. *</td>
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<tr>
<td>5. Beaver Creek</td>
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<tr>
<td>6. Grand Mesa North</td>
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<td>7. Grand Mesa South</td>
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<td>8. San Miguel Mtns.</td>
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<td>9. Western San Juans</td>
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<td>10. Eastern San Juans</td>
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**Potential Target Areas**

<table>
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<tr>
<th>Colorado</th>
<th>Utah</th>
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<tr>
<td>19. Central Rockies</td>
<td></td>
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<tr>
<td>Wyoming</td>
<td>Arizona</td>
</tr>
<tr>
<td>25. Wind River Mtns.West</td>
<td>27. Chuska Mts.(AZ/NM)</td>
</tr>
<tr>
<td></td>
<td>29. San Francisco Peaks</td>
</tr>
</tbody>
</table>

* Portion of area outside Colorado River Basin
Similar to how dewdrops form on cooled surfaces on the ground, cloud drops form on pre-existing aerosol particles in cooled ascending air streams. Polluted air provides many of these cloud drop condensation nuclei (CCN). Cloud water is comprised of many water drops 10-20 microns in size that are small relative to the range of droplet size in a cloud, float in the air, and are too small to combine into raindrops. Rain might be enhanced by seeding such clouds with two- to five-micron hygroscopic particles (relatively large compared to many aerosols) that nucleate large cloud drops, and then can become embryos of rain drops.

Small drops are also slower to freeze into ice crystals and are less efficiently collected by the ice crystals that do form,
so they produce less snow. Therefore, cloud seeding to augment precipitation is most effective in “super-cooled” water clouds, clouds that are composed of small water drops that remain liquid at subfreezing temperatures. Because super-cooled clouds of small drops are slow to freeze, precipitation can also be enhanced by seeding with ice nuclei, such as silver iodide, that initiate the ice crystals that subsequently collect the remaining cloud water into snowflakes.

**Pollutant Seeds Have Opposite Effect**

Cloud seeding for enhancing precipitation is the opposite of inadvertent suppression of precipitation caused by small CCN aerosols from smoke and urban particulate air pollution. We “seed” the clouds negatively with pollution aerosols on a much grander scale than we do positively with silver iodide and large hygroscopic particles. Thus, we can learn much about how to intentionally enhance rain by observing how we inadvertently suppress it.

The recently acquired ability to detect the composition of clouds from weather satellites revealed tracks of super-cooled small drops in clouds downwind of major urban and industrial areas over many parts of the world (see image opposite, left). The same satellite technique was used to show how cloud seeding with silver iodide has the opposite effect of converting the small super-cooled cloud drops into falling snow (see image opposite, right).

The western United States is particularly vulnerable to the effects of pollution, because much of its water comes from pristine oceanic air masses that become polluted by the major urban areas during their trek inland. When the polluted air ascends the mountain ranges it forms new clouds with reduced drop size, which dissipate when they pass the ridge line and are forced to descend on the lee side. The short lifetimes of clouds mean that pollution-induced slowing of the conversion of cloud drops to precipitation translates to a net loss of water on the ground. Consequently, we would expect urbanization and the resulting added aerosols during the last century to have caused a reduction in mountain precipitation with respect to coastal and upwind lowland precipitation, defined here as the orographic enhancement factor, Ro.

**The Evidence**

This hypothesis was validated, as reductions of 10 to 25 percent in Ro were recorded during the past decades in much of the mountain ranges of the western United States, including the California Sierra Nevada, the Cascades east of Seattle, the Wasatch Mountains east of Salt Lake City, the Sandias east of Albuquerque, and parts of the Rocky Mountains west of Denver and Colorado Springs (see Givati and Rosenfeld, 2004 and Rosenfeld and Givati, 2006). The estimated loss of precipitation at the central Sierra Nevada alone is estimated at 4x10^6 cubic meters per year (3.2 million acre-feet per year [afy]). A new study by Rosenfeld documented similar effects over Israel, with losses of usable water to the Lake of Galilee amounting to about 1x10^6 m^3 per year (81,000 afy), approximately six percent of the overall water potential of Israel.

These alarming findings prompted the California Energy Commission to support cloud physics aircraft measurements of pollution aerosols and their interactions with the potential rain clouds over California. These measurements, which took place during the latter part of the winters of 2005 and 2006, confirmed that urban aerosols are ingested into potential rain clouds and suppress their precipitation (Rosenfeld, 2006). Model simulations of these processes provide additional support and insights.

**Testing Ro Sensitivity**

Cloud seeding for precipitation enhancement is being conducted extensively in the western United States, but assessment of its efficacy requires a randomized seeding scheme, yet to be conducted here in a scientific manner that benefits these new insights. Experimental randomized cloud seeding with silver iodide in northern Israel, which was reported to enhance rainfall there by 13 to 16 percent, has continued operationally since 1975. Givati and Rosenfeld (2005) analyzed the orographic enhancement factor over the hills of northern Israel for the whole period of 1950 to 2002, during which time Ro decreased by 15 percent despite the reported positive seeding effect over the hills there. When separating the time series to seeded and see Pollution, page 33
Weather Modification and the Law

George W. Bomar – Texas Department of Licensing & Regulation

Weather is a key component of our shared natural environment. Any attempt to alter it for the benefit of some has important ramifications for others nearby. Thus, we find the practice of weather modification is regulated in most regions of the United States, particularly in the West, where cloud seeding has been employed over the years for the enhancement of rain and snow, and, to a lesser extent, the suppression of damaging hail. Regulation is also essential because history is replete with instances of purported “rainmakers” who took money from desperate farmers and ranchers battling drought, only to be revealed as charlatans. Government efforts to screen potential practitioners of weather modification are aimed at protecting the public from such exploitation. Moreover, state regulation is justifiable because governments regulate the allocation of water from waterways to users, and cloud seeding traditionally has been used as a means to augment water supplies.

**Regulation in the Public Interest**

State regulation of weather modification is designed to ensure that practitioners of the science 1) are competent, and 2) have the resources to compensate anyone harmed by those practices. Individuals or organizations seeking to conduct weather modification operations must secure a license and/or permit and demonstrate that the individuals in charge of the operations have the requisite training and work experience. Most states require those making day-to-day decisions about cloud seeding to possess academic degrees in meteorology or closely related fields. To show proof of financial responsibility, the purchase of liability insurance or the posting of a bond is often required. An integral part of licensing and permitting is the requirement that weather modification plans be published in newspapers in “Notices of Intention.” Such notices inform the public when and how weather modification activities are to be conducted and specify target areas (where the impact of the activity is aimed) and operational areas (where equipment used in the operations is to be located). The notices also inform residents how to obtain additional information or express their views on the proposed program.

Those holding licenses or permits for weather modification almost always must provide data and other information about their activities, usually on a periodic basis, to the appropriate state regulatory agency. All are required to report annually to the National Oceanic and Atmospheric Administration.

**Who owns the right to use the extra water that is produced?**

Few Court Cases

Since weather modification technology was first developed and employed in the years following World War II, relatively few lawsuits have been filed in U.S. courts claiming that the use of the technologies is harmful. Litigation is filed prior to the onset of cloud seeding in order to prevent it, or afterward, when damage or loss to crops or other property result from the weather. When filing a suit to prevent a weather modification program, potential victims must show “irreparable harm” is in prospect: something that is unique and irreplaceable is about to be destroyed or damaged. Victims of weather gone awry who believe weather modification contributed to their misfortune can sue the individual or company that caused the undesirable change in weather.

Despite approximately a dozen court cases filed since 1950, none have resolved the most important issues surrounding the practice of weather modification. Very few judicial opinions have addressed the property rights of landowners to rainfall from clouds above their land or upwind of their property. In the past 25 years, only two cases have addressed injunctions prohibiting cloud seeding or liability for alleged negligent cloud seeding. Since 1950, no plaintiffs in the United States have alleged deprivation of precipitation in a tort case involving cloud seeding. One law professor with vast experience in weather modification practices has described the history of case law on weather modification as “sparse and contradictory.”

**Why the Laws Are Cloudy**

Ample reasons exist why U.S. courts have never adequately defined the law as it relates to the relatively new area of weather modification. With litigation being slow and expensive, events subsequent to the alleged incident, such as the abrupt end to a drought, may cause plaintiffs to lose interest in resolving all the issues in their original complaint. Furthermore, the task of a judge is only to decide the facts or law necessary to dispose of the case, not to issue an essay about novel legal issues that transcend the particular case.

Many problems with weather-modification law may be attributed to inadequate understanding of how clouds produce rain and how seeding them modifies the process of rain production. The confusion will be reduced as new research answers those questions about the efficacy of cloud seeding that continue to daunt weather modification friends and foes alike. Once the applicable scientific principles are understood fully, a rational application of law to weather-modification practices can be achieved, helping to...
ascertain, for example, in tort litigation if a cloud seeder caused a flood or drought, or was in other ways negligent.

One legal issue heretofore ignored in U.S. courts is responding to the question, “Who owns the right to use the extra water that is produced in cloud seeding?” Should the cloud seeder be treated like other professionals (such as investment counselors, engineers, and surgeons) who provide services for pay, but the benefits and risks stemming from those services belong to their clients? The cloud seeder, holding a license or permit issued from a regulatory authority, has the right to attempt to modify the weather, but the right to use any extra water rests with the property owner on whose land the additional water falls.

**Did My Neighbor Get My Water?**

One of the most complicated issues pertaining to weather modification is the perception, unsubstantiated as yet, that increasing rainfall in one area will result in a corresponding diminution in adjacent areas, particularly downwind. If landowners have a legal right to naturally occurring rainfall, would they then have a case if they could demonstrate that cloud seeding elsewhere was responsible for a rainfall reduction in their vicinity? Atmospheric physicists view any deprivation of rain suffered by downwind landowners as de minimis, a harm too trifling to be compensated and arguably too much a scientific challenge to substantiate satisfactorily. The amount of atmospheric water manipulated by cloud seeding is a tiny fraction of the total water volume in the air on a given day in any particular region.

**More Research Yields Clearer Laws**

It is abundantly clear that the technology exists to modify the weather. Moreover, it seems certain that more effective strategies for altering atmospheric processes to benefit society are in the offing. Society would benefit immensely if damage from drought, floods, and severe storms could be reduced, even eliminated. To reap these practical benefits, however, requires a substantive investment in basic scientific research on clouds and their response to seeding. Such a commitment could eventually move us to a point of demonstrating efficacy of seeding beyond a reasonable doubt. Such progress would be invaluable to our legal system in developing and refining laws and regulations governing all aspects of weather modification.

Contact George Bomar at gbomar@license.state.tx.us.
After several years of well-below normal snowpack in the mountains of Wyoming and less than average summertime precipitation, conservation districts in the state began to consider avenues to augment increasingly limited water supplies. In summer 2004, noting the long-term existence of cloud seeding programs in nearby western states, Area V of the Wyoming Association of Conservation Districts asked the Wyoming Water Development Commission (WWDC) to fund a feasibility study on increasing Wyoming water supplies through similar means.

The Commission approved and the legislature funded a $100,000 study, and a request for proposals was issued. Three mountain ranges were specified for inclusion: the Medicine Bow Range in the southeast, the nearby Sierra Madres in the south-central, and the Wind River Range in the west-central part of the state (see map). Watersheds potentially affected include the Green, Wind-Bighorn, and North Platte rivers. Additional water in the Wind-Bighorn Basin would eventually flow north into the Missouri system. Runoff increases in the North Platte Basin would eventually reach water-short western Nebraska. Augmented flows in the Green River Basin would feed into the Colorado River Basin, a possibility that has caught the attention of some Lower Basin states’ water managers.

Weather Modification Inc. (WMI), a North Dakota-based firm, was selected to conduct the feasibility study. WMI in turn subcontracted with the National Center for Atmospheric Research (NCAR) to numerically model the airflow over the mountains and recommend an initial design for an operational program. Numerous meetings were conducted in communities in and near the proposed project areas to gauge public opinion and to engage state, federal, and tribal entities. The study, completed in January 2005, found ample indication that supercooled cloud water is often not converted to precipitation, and a plan to implement a pilot program was devised.

Studies are essential to improve the physical understanding of cloud and precipitation processes and the effects of seeding.

The Wyoming Project is Born

After vigorous discussions by the state legislature over the funding proposal developed by WWDC, an appropriation of $8.8 million was approved, and the Wyoming Five-Year Weather Modification Pilot Project was born. The program is unique in several ways. First, funding for the full five-year period was appropriated at once, ensuring project continuity. Second, the state recognized the value of independent project evaluation. WMI makes the seeding decisions and conducts all seeding operations, while NCAR designs and evaluates the program. Third, WWDC acknowledged early on that local, state, federal, and tribal interests must be involved and engaged in the program from the outset. Unlike strictly operational cloud seeding projects, the Wyoming Pilot Project also includes plans for detailed analytical and predictive modeling of clouds and precipitation, as well as atmospheric aerosol and cloud physics measurements. These studies provide evidence that can establish the cause-and-effect of seeding. Few programs include such efforts because of their cost, but their inclusion is essential to improve the physical understanding of cloud and precipitation processes and the effects of seeding on these processes.

A technical advisory team involving the following agencies and sub-agencies provided input into project design, safeguards, and operations: Medicine Bow-Routt, Shoshone, and Bridger-Teton national forests; the U.S. Forest Service’s Capital City Coordinator and Rocky Mountain Research Station; U.S. Geological Survey; Bureau of Land Management; USDA Natural Resources Conservation Service; National Weather Service; Wyoming’s State Engineer’s Office, Department of Environmental Quality, Game and Fish Department, and Department of Transportation; and the University of Wyoming Department of Atmospheric Science. This team has contributed significantly to the project, and team members have also learned much about cloud seeding technology.
Because of differences in climate, topography, amount of wilderness area, and the presence of tribal lands, the three mountain ranges were grouped into two target areas. One target, the Medicine Bow and Sierra Madre Ranges (MB-SM), contains only limited wilderness area, no tribal lands, and lies wholly within the Medicine Bow-Routt National Forest. The second, the Wind River Range, contains vast wilderness areas, is nearly one-third tribal lands, and includes land in both the Bridger-Teton and Shoshone national forests. Initial efforts consequently focused on the simpler MB-SM area.

**Getting Ready**

Almost all locations suitable for ground-based seeding in this area lie within the Medicine Bow-Routt National Forest, so an environmental analysis was required before the Forest Service would issue special-use permits for siting the equipment. Winter 2005-2006 was to have been the first season for seeding in the five-year project, but the environmental analysis quickly expanded beyond the scope originally envisioned, even in the “simpler” target area. WMI retained the services of Arcadis-Greystone, who performed a biological assessment, prepared a biological evaluation and management of indicator species report, and consulted with the Fish and Wildlife Service regarding ten federally listed threatened and endangered species.

While environmental analysis was underway, an instrumented aircraft, weather balloons, and microwave radiometers probed the clouds over and near both potential targets, gathering important aerosol, thermodynamic, and microphysical background data. A new high-performance computer was assembled at NCAR to begin high resolution numerical modeling of airflow, clouds, and precipitation.

Natural snow and soil samples were collected and analyzed by the Desert Research Institute of the University of Nevada for silver content, the primary component of the silver-iodide seeding agent proposed for the program. Approval to conduct airborne seeding was obtained for the MB-SM target area, and limited test seeding was conducted over the Medicine Bow Range. The Sierra Madre was not seeded at all, in case ongoing environmental studies show additional background chemistry (silver) measurements are needed in an unseeded region.

**The Green Light at Last**

Finally, special-use permits for siting equipment were issued by the Medicine Bow-Routt National Forest in August 2006 for the 2006-2007 season, just weeks before winter weather began to affect the preferred generator sites at higher elevations. WMI crews sprang into action, quickly deploying ground-based facilities at approved locations in the MB-SM. Several snowfalls caused delays, but by early December 2006, all 12 ground-based sites in the two ranges were established. Though this was several weeks after the scheduled November 15 start date, the generators are to be operational for the remainder of the 2006-2007 winter season, through March.

Seeding is scheduled to begin in a randomized manner designed by NCAR to account for natural storm variability and other statistical errors, but high-resolution precipitation gauges to be used for evaluation were still being deployed in early January. Preliminary test seeding began in January to test equipment and practice the procedures that will be used to effectively randomize the seeding. Many seasons of data will be required for results to be statistically meaningful.

Progress is somewhat slower in the Wind River target area. Although a special-use application for siting ground-based generators near the Wind River Range was submitted to the Bridger-Teton and Shoshone National Forests in June 2006, as of December, WMI was unaware of any formal Forest Service action on the application. The project shifted focus slightly, and WMI began siting ground-based seeding apparatus around the southern perimeter of the Wind River Range on state-owned and private lands not requiring Forest Service approval. Five sites are in place, allowing initial seeding tests to begin in the southern Wind River Range during the 2006-2007 season. Additional sites on federal lands in the Wind River Range remain a possibility, pending permit approval.

Contact Bruce Boe at bboe@weathermod.com.
Motivated by a United Nations projection that approximately one third of the world population will live under severe water stress by the middle of this century, politicians and water managers have begun to explore precipitation enhancement by cloud seeding as one means to augment water resources. In addition, ample evidence that human activities can alter atmospheric processes on scales ranging from local precipitation patterns to global climate strengthens the physical basis for deliberate attempts to alter the weather.

More than 150 operational weather-modification programs, primarily cloud-seeding activities aimed at enhancing precipitation or mitigating hail fall, take place in 37 countries; at least 66 operational programs are being conducted in 11 states across the United States. Many programs operate without any scientific quantitative assessment or evaluation of the seeding experiments. Although strong evidence exists that cloud seeding could enhance precipitation under certain atmospheric conditions in certain areas, equally strong evidence shows that current cloud seeding technologies do not transfer to other conditions and areas. In fact, glaciogenic seeding may actually reduce precipitation in some situations. Furthermore, some operational cloud seeding programs are ongoing in areas where experiments have shown seeding will not work.

**Microphysics and Dynamics Matter**

The potential for increases in rainfall using cloud seeding is strongly dependent on the natural aerosols, microphysics, and dynamics of the clouds that are being seeded. Microphysics refers to the size and concentration of water droplets and ice particles inside clouds. Dynamics refers to the forces affecting the movement of air in and around clouds. The microphysics are dependent on background aerosol levels, because it is the aerosol particles that attract water vapor to form cloud droplets, and in cold clouds, ice particles. Furthermore, the types and concentrations of aerosol particles can be influenced by trace gases (i.e., air pollution).

Given these dependencies, the microphysics of clouds and seeding effects can differ significantly from one geographical region to another, and even during and between seasons in the same region. In some instances, clouds may not be suitable for seeding, or the frequency of occurrence of suitable clouds may be too low to warrant the investment in a cloud-seeding program. Both factors need to be evaluated and preliminary studies conducted on atmospheric aerosols and pollution levels, and on the microphysics and dynamics of naturally forming clouds, prior to commencing a larger seeding experiment. In many operational programs these studies are lacking.

If the targeted measurements and additional data show sufficient evidence for clouds to be positively affected by cloud seeding, the seeding techniques should then be evaluated using a randomization procedure to statistically demonstrate that the seeding method works and to quantify any possible increases. This approach is similar, for example, to what is commonly done in medical trials with a new drug.

The dilemma as highlighted in the 2003 report of the National Research Council is that while little funding is available for physical measurements and understanding of weather modification processes, some are willing to spend funds to apply these technologies without knowing the effect it will have in their region. We do know that human activities can affect the weather, and that seeding will cause changes to a cloud. However, in many instances we still are unable to translate these induced changes into verifiable changes in rainfall, hail fall, and snowfall or to employ methods that produce scientifically credible, repeatable changes in precipitation.

**Why is Verification Difficult?**

Factors that contribute to the difficulty of verifying seeding effects include...
uncertainties about the natural variability of precipitation, associated background aerosol and microphysical characteristics of the atmosphere and clouds, inadequate understanding of the interactions between the microphysics and dynamics in clouds, inadequate targeting of seeding material, the inability to measure these variables with the required accuracy or resolution, and the detection of a small induced effect under these conditions.

Quantitative scientific proof is scanty, and the problem is compounded by extravagant claims, growing environmental concerns, and economic and legal factors. Agencies often are under pressure to meet short-term operational needs rather than setting a priority to achieve long-term scientific understanding and assessment. The scientific basis of weather modification concepts is not in question. Rather the absence of adequate understanding of critical atmospheric processes has led to a failure to produce predictable, repeatable, detectable, and verifiable results.

**We Have Made Progress**
Despite the lack of scientific proof, our scientific understanding has progressed on many fronts in the last twenty years. Recent experiments using hygroscopic seeding particles in mixed-phase (water and ice) clouds have shown encouraging results, with precipitation increases attributed to increasing the lifetime of the rain-producing systems. There are strong suggestions of positive seeding effects in winter orographic cloud systems. Satellite imagery has highlighted the role of high concentrations of aerosols in influencing clouds, rain, and lightning, thus drawing the issues of intentional and inadvertent weather modification closer together.

*see Understanding, page 33*
According to the United Nations World Water Assessment Programme (UN/WWAP, 2003), over the next 20 years the average global water supply per person is expected to drop by one-third, and by 2050, two to seven billion people will experience severe shortage of water. Water conservation schemes and desalination might minimize the shortage but would have little if any effect on the only input in the global water budget: rainfall.

Cloud seeding technologies increase the efficiency of the rain process under certain atmospheric conditions. Thus, they may be used to effectively increase water resources and help alleviate or prevent severe water shortages or drought. Societal need and recent technological advances provide an impetus for developing systems and technologies that monitor and manage atmospheric events such as hurricanes, orographic precipitation, and drought, and warrant the creation of a national weather modification program (NWMP). An NWMP was developed, presented to the scientific community, and proposed to Congress. The program would administer the resources for all applied research and development efforts directed toward optimizing current cloud-seeding technologies in order to help provide sustainable water supplies and minimize atmospheric hazards.

Congressional legislation to establish the NWMP (the Hutchison Bill, S517, in the Senate and a companion bill introduced by Congressman Udall) stalled in the 2006 Congress, and will be re-introduced in 2007. If passed, this legislation would support and extend existing research efforts and could lead to such benefits as relief from drought or severe water shortage, increased ability to generate hydroelectric power, and reduced destruction from hurricanes.

The proposed 10-year NWMP encompasses a comprehensive agenda of applied research and development efforts that optimize existing technologies used to manage “treatable” atmospheric processes and conditions, and to allow the development of relevant innovative technologies. The NWMP encompasses many lessons learned during the past 60 years, the recommendations of high-level researchers, and the near-term needs of the weather modification community. Its mission would concentrate on three areas: 1) monitoring atmospheric water resource management parameters; 2) applied research and development of the scientific basis of seeding technologies; and 3) public outreach and professional development, fostering cooperation between NOAA and other federal agencies, state agencies, universities, relevant commercial organizations, private groups, and the general public. The NWMP implementation plan calls for interdisciplinary development of monitoring capabilities and technologies based on well-understood winter orographic systems. Software modules would simulate the introduction of seed materials in the best available physical and numerical models (especially in the case of severe storm modification efforts), verifying outputs and transforming these models to work in operational and academic settings. In this way, relevant seed strategies could be developed to enhance the likelihood of their operational success. The NWMP also aims to develop: better dispersion techniques; higher-yield cloud seeding agents; physical, chemical, and statistical evaluation method developments; and improved cloud seeding program evaluations. These efforts will require reliable data, which may be obtained through carefully designed cooperative efforts.

Contact Tom DeFelice at defelicet@imsg.com.

Reference

The American Society of Civil Engineers’ (ASCE) Standard Practice for the Design and Operation of Precipitation Enhancement Projects, published in 2004, provides a useful overview of the topic and is intended to inform water managers and others who may be considering such a project. The roughly 50-page publication does not provide specific standards so much as a description of how cloud seeding (“precipitation enhancement”) works from both scientific and practical perspectives.

The first two sections cover the historical and scientific background of cloud seeding. U.S. cloud seeding experiments date back to the 1940s, when dry ice was used as the seeding agent. The current state of the technology is addressed by four major organizations: ASCE, the Weather Modification Association, American Meteorological Society, and World Meteorological Organization. Sections on cloud condensate, the growth of precipitation, and concepts of precipitation augmentation provide an informative tutorial on how precipitation forms and what factors influence its formation.

The bulk of the document focuses on project design, which should consider the geographic and temporal scope of the project, the method of seeding, selection of the seeding agent, data collection, siting of equipment, and legal and environmental concerns. The geographic extent of the project should include both target and control areas with very similar geography, climatology, and use. Seeding can be performed by both aerial and ground-based methods; the advantages and disadvantages of each are addressed. Typical seeding agents include silver iodide, dry ice, organic substances, and hygroscopic agents such as finely ground salt particles.

Data collection is critical both for determining the timing of seeding and evaluating its effectiveness. Real-time data used for decision-making are available from several networks and use radar, satellites, instrumented observatory stations, rawinsondes (balloon-borne instruments), gauges, computer models, and specially designed instruments such as for measuring the supercooled liquid water content of clouds. Data from precipitation and stream gauges, remote sensing techniques, snow chemistry, and cloud models are used to evaluate the results of seeding activities.

see ASCE, page 34

WHERE IS WEATHER MODIFICATION OCCURRING?

This map of current weather modification programs in the western United States illustrates the number and geographic range of projects underway. Sponsors range from state and local water agencies to power companies and private ski resorts. Modified from graphic provided by the North Dakota Atmospheric Water Board.
Rocky Flats Cleanup Aided by Improved Understanding of Radioactive Transport

The cleanup of the Rocky Flats Environmental Technology Site (RFETS), completed in 2005 ahead of schedule and under budget, was aided by new understanding in the movement of radioactive compounds. The federal Superfund site, located about 16 miles from Denver, was contaminated with large amounts of plutonium, uranium, and other high-level hazardous waste.

In 1989, the Federal Bureau of Investigation and the Environmental Protection Agency raided the facility based on alleged environmental and safety concerns, including violations of the Resource Conservation and Recovery Act and the Clean Water Act. Operations were immediately suspended and never resumed. The sudden closure meant large amounts of plutonium and other materials in various stages of processing and storage had to be dealt with, in addition to all the waste and poor environmental practices that were the basis for the raid. Original estimates were that cleanup would require $36 billion and take 65 years.

The site was renamed RFETS in 1995, following DOE’s cessation of nuclear weapon production. The same year, Kaiser-Hill won the contract to manage the cleanup. In 2000, the company and DOE agreed on an accelerated closure plan to be completed by the end of 2006. In fact, Kaiser-Hill declared physical closure of the site in October 2005 at a cost of around $30 billion less than earlier estimates.

RFETS once contained more than 800 structures in a 385-acre industrial area, surrounded by a 6,000-acre buffer zone. Although a large portion of the cleanup involved demolishing the buildings and the packaging, off-site transport, and storage or disposal of “weapons-usable” material (some of which could be used for nuclear reactor fuel), environmental cleanup of the site also was a key component.

In an article published last September in Physics Today, Clark and others described the evolution in understanding of the transport of plutonium in the surface water and shallow groundwater at the site that occurred during the remediation process. Originally, scientists thought that the elevated concentrations of plutonium must be due to aqueous sorption-desorption processes, but geochemical models predicted little movement. Site monitoring showed that plutonium and americium had similar spatial distribution in surface soils, with about 90 percent of the total inventory occurring in the upper five inches but with wide variations in concentration. Upon further study, researchers discovered that “plutonium and americium form insoluble oxides and colloids that adhere to small organic and mineral particles in the soil,” the article said. Wind and surface water were transporting contaminated particles over the site; wind patterns, surface topography, vegetation, and soil erodability significantly affected this distribution. Scientists switched to erosion and sediment-transport models and got much better results.

According to Clark and others, researchers used the process-oriented Water Erosion Prediction Project (WEPP) model developed by a consortium of federal agencies (see Southwest Hydrology, Jul/Aug 2006) to model hillside erosion and sediment deposition in streams. Output from WEPP was used as input to

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HEC-6T, developed by the U.S. Army Corps of Engineers, to model stream channel sediment erosion and deposition. The coupled models were used to simulate the transport of contaminants during storm events, the amount of contaminated sediments in surface water, pathways of contaminant migration, and potential effects of various management scenarios on cleanup activities.

As a result of improved understanding of how the contaminants were moving across the site, Clark and others state that the parties involved were able to come to agreement on the terms of the cleanup, and erosion control technologies were the primary tool used.


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**GRACE Monitoring Global Water Shifts**

*From temperatures.com*

For the first time, scientists have demonstrated that precise measurements of Earth’s changing gravity field can effectively monitor changes in the planet’s climate and weather. This finding comes from more than a year’s worth of data from the Gravity Recovery and Climate Experiment (GRACE), a two-spacecraft, joint partnership of NASA and the German Aerospace Center.

Results published in the journal *Science* show monthly changes in the distribution of water and ice masses could be estimated by measuring changes in Earth’s gravity field. The GRACE data measured the weight of up to four inches of groundwater accumulations from heavy tropical rains, particularly in the Amazon basin and Southeast Asia. Smaller signals caused by changes in ocean circulation were also visible.

Launched in March 2002, GRACE tracks changes in Earth’s gravity field. GRACE senses minute variations in gravitational pull from local changes in Earth’s mass. To do this, GRACE measures, to one micron, changes in the separation of two identical spacecraft in the same orbit approximately 137 miles apart.

GRACE maps these variations from month to month, following changes imposed by the seasons, weather patterns, and short-term climate change. These maps are up to 100 times more accurate than existing ones, substantially improving the accuracy of many techniques used by oceanographers, hydrologists, glaciologists, geologists, and other scientists to study phenomena that influence climate.

“Measurements of surface water in large, inaccessible river basins have been difficult to acquire, while underground aquifers and deep ocean currents have been nearly impossible to measure,” said Dr. Byron Tapley, GRACE principal investigator at the University of Texas Center for Space Research in Austin, Texas. “GRACE gives us a powerful new tool to track how water moves from one place to another, influencing climate and weather.”

Dr. Michael Watkins, GRACE project scientist at NASA’s Jet Propulsion Laboratory in Pasadena, California, said the results mark the birth of a new field of remote sensing.

“The GRACE gravity measurements will be combined with water models to sketch an exceptionally accurate picture of water distribution around the globe. Together with other NASA spacecraft, GRACE will help scientists better understand the global water cycle and its changes.”

Visit www.tempsensor.net, the University of Colorado Real-Time GRACE Data Analysis Site (geoid.colorado.edu/grace/index.html) and NASA-JPL (grace.jpl.nasa.gov).

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**Testicles Shrinking in Las Vegas Bay**

The U.S. Geological Survey, in cooperation with the U.S. Fish and Wildlife Service, recently released a four-page report, “Investigations of the Effects of Synthetic Chemicals on the Endocrine System of Common Carp in Lake Mead, Nevada and Arizona.” The report summarizes a number of investigations over the last decade concerning the potential of endocrine disruption in fish in the lake. Water discharged into Lake Mead via Las Vegas Wash includes residential-irrigation runoff, stormwater runoff, subsurface flow, and tertiary treated sewage effluent, collectively carrying a cocktail of chemicals. The characteristics of fish from Las Vegas Bay were compared to other, more remote areas of Lake Mead. Major findings to date are:

- Studies conducted in 1995 and 1999-2000 showed that male carp from Las Vegas Bay have low levels of androgen and smaller testes compared to male fish from reference sites in Lake Mead.
- The same and other studies also showed the presence of higher levels of synthetic chemicals in water, sediment, and fish from Las Vegas Bay compared to reference sites.
- Commonly used products, such as triclosan (an antimicrobial drug) are being accumulated in fish from Las Vegas Bay.
- Some of the chemicals present in Las Vegas Bay have been shown by laboratory studies to cause endocrine disruption in male fish.

Since the 2000 study was completed, regional drought caused lake levels to drop to historic lows. New studies are planned to assess the potential affects of drought-induced alterations on lake hydrology. In addition, baseline information is being collected to monitor changes in contaminant distribution and the potential for endocrine disruption that may occur due to the redistribution of wastewater inflow, as municipal dischargers in the Las Vegas Valley have been considering plans to divert their wastewater from Las Vegas Wash to other locations.

USGS Fact Sheet 2006-3131 is available at pubs.usgs.gov/fs/2006/3131/.
Managers, continued from page 18

have significant, active, winter cloud-seeding programs. In some cases these efforts have been going on for over 30 years. Current annual expenditures for Upper Basin operational cloud-seeding programs have reached approximately $2.6 million. These operations have benefited not only specific Upper Basin states but also the entire basin.

Lower Basin states are now collectively attempting to add funding to Upper Basin cloud-seeding efforts to enhance and extend existing programs. During water year 2007, an estimated $270,000 will be added by the Lower Basin for these efforts. In general, Upper Basin states have expressed a willingness to consider additional funding to enhance and extend existing efforts, provided weather modification is adequately controlled and monitored to ensure that no Upper Basin state or local interests are harmed, such as from impacts from operations in above-average years.

The Effectiveness Debate
The scientific community is currently debating the effectiveness of winter cloud-seeding programs. Uncertainty arises primarily from the difficulty of statistically demonstrating and predicting precise amounts of increased snowpack from a certain level of effort. Some scientific organizations have decided not to support the idea that cloud seeding will increase water supplies unless there are direct, measured, and statistically verified increases over natural events. For many practical reasons, this is a difficult fact to tease out of the data. However, many scientific organizations do conclude there is increased precipitation from cloud seeding when it is properly conducted. A significant preponderance of indirect statistical information implies that snowfall and runoff will increase under proper conditions. Existing seeding operators have gained sufficient data from their efforts to allow confidence that cloud seeding is effective and justifies continued funding. Most professional cloud seeding organizations now believe that the effectiveness of these programs is in the range of a 5 to 15 percent increase in precipitation over the target areas.

Results of a winter cloud seeding preliminary feasibility study funded by the Upper Basin and conducted by Don A. Griffith of North American Weather Consultants Inc. (see page 19) agreed with this predicted increase in snowpack over selected target areas from properly designed and conducted cloud-seeding efforts. Estimates of the amount of additional water that might be generated from all cloud-seeding efforts in the basin ranged from about 600,000 acre-feet to 1.6 million acre-feet per year during average weather conditions. During drought, less additional water would be generated from seeding, so it is important to seed during wetter times and store additional water in reservoirs. A portion of these predicted increases is already contributed from existing operations, but a very significant additional amount was predicted to be gained from new efforts. The cost of developing this water was estimated to range from $4.50 to $11.50 per acre-foot. These costs are extremely low compared to any other feasible means to augment the flow of the river. Although scientific debate about the exact amount of increase generated from cloud seeding remains, the result would be the most cost-effective water that can be developed, even if estimates are off by an order of magnitude.

With proper design, controls, safeguards and monitoring, the Upper Basin states will likely consider additional cloud seeding. However, because of the difficulty in quantifying the specific effect of cloud seeding, any water generated will be considered “system water” and not specifically allocated to any state or entity. The water may be used by any state, but only within that state’s Compact apportionment and consistent with state water law. Just as a high tide floats all boats, increased runoff will benefit all states, primarily through increased reservoir storage that will help the states get through periods of drought.

Contact Don Ostler at dostler@uc.usbr.gov.

Feasibility, continued from page 19

cost is designated for effectiveness evaluations, including statistical studies and physical measurements such as the detection of silver in snow.

Ways to Proceed
Design studies are recommended to customize new operational winter cloud-seeding programs in the four states according to site-specific factors such as climatology, topography, the presence and frequency of seedable conditions, social considerations, and existing state regulations. Existing programs could be enhanced by new or supplemental seeding equipment or by extending the operational periods.

Federal funding should be sought to support research programs, which could be piggybacked onto operational programs, to evaluate the effectiveness of various types of seeding and impacts on streamflow. The basin states should also coordinate among themselves to share costs and administration of both new and existing programs.

Because they do not require large permanent infrastructure, cloud-seeding programs can be relatively quickly implemented, suspended, or terminated. Routine, year-after-year cloud-seeding programs could help stabilize and bolster water supplies, even though the total volume of increase will vary over wet and dry years. Establishing routine programs is recommended because predicting a wet or dry year in advance is difficult, conditions can change mid-season, additional wet-year precipitation can be stored for use during dry periods, and commitment to a long-term program helps provide stability and acceptance by funding agencies and the public.

The complete report is available at www.nawcinc.com/Colorado%20River%20Seeding.pdf. Contact Don Griffith at dgriffith@nawcinc.com.

References


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unseeded conditions they found that the trend line of $Ro$ shifted upward by 12 to 14 percent for the seeded rain time series compared to the unseeded time series. The sensitivity of $Ro$ to both seeding and pollution effects was greatest in the hilly areas with the greatest natural orographic enhancement factor and practically nonexistent in the low-lying areas where no orographic enhancement occurs.

The double-sided sensitivity of clouds to the damaging effects of pollution aerosols and potential corrective effects of cloud seeding provides another powerful tool for assessing the potential for enhancement of orographic precipitation. Areas that have experienced significant reductions in the trends of the orographic enhancement factor are likely manifesting the sensitivity of the clouds to aerosols, and hence could benefit from cloud seeding.

**Satellites Offer Great Opportunities**

The multispectral capabilities of recently commissioned satellites have provided new insights into the impacts of aerosols in reducing cloud drop size and in slowing the process of precipitation formation. These satellite capabilities can provide further insights into the efficacy of cloud seeding for rain enhancement. They also can be used to direct seeding operations to the clouds that likely will be most responsive to the process. Given the severe shortage of water in the southwestern United States, the time is right to start a new generation of cloud seeding research so the region can benefit from the new methodologies and insights it will produce.

Contact William Woodley at williamwoodley@cs.com or Daniel Rosenfeld at daniel.rosenfeld@huji.ac.il. For additional reading, see www.earth.huji.ac.il/staff-details.asp?topic=3&id=149.

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- Rosenfeld, D., and A. Givati, 2006. Evidence of orograpic precipitation suppression by air pollution induced aerosols in the western USA, J. Applied Meteorology, 45, 893-911.

**Future Directions**

Capitalizing on these advances and especially adding new remote and in situ observational tools to existing or new experiments could yield substantial new insights and at last simultaneously provide the necessary physical and statistical data on the efficacy of cloud seeding to enhance precipitation or mitigate hail. Some especially promising areas include:

- **Hygroscopic seeding to enhance rainfall.** The small-scale experiments and larger-scale coordinated field efforts proposed by the WMO (2000) could serve as a starting point for such efforts.

- **Orographic cloud seeding to enhance precipitation.** A randomized program that includes strong modeling and observational components and employs advanced computational and observational tools could substantially enhance our understanding of seeding effects and winter orographic precipitation.

- **Studies of specific seeding effects.** These could include studies of initial droplet broadening, the formation of drizzle and rain associated with natural hygroscopic seeding, and anthropogenic sources of particles.

- **Improving modeling.** Special focus is needed on modeling cloud microphysical processes.

Contact Roelof Bruins of roelof@ucar.edu.

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Operational aspects of cloud seeding are covered next. Key project personnel include meteorological staff, pilots specifically trained in cloud seeding, a director of operations, and support personnel. Decision-making requires close coordination and communication among these and others, such as local weather officials. Safety considerations include protection of personnel from hazards related to microwave radiation, seeding agents and dispensers, severe weather, and aircraft safety. In addition, operators must monitor for conditions that warrant suspension of operations, such as flooding, severe weather, avalanche conditions, or full reservoirs.

The final section briefly addresses evaluation of cloud seeding projects. Although much knowledge is to be gained over the long term from project evaluation, a strong evaluation requires target areas to be randomly seeded or not, so as to develop two unbiased classes of storms for comparison. Unfortunately, most sponsors of cloud seeding projects want to maximize the immediate benefits and not forego any opportunity to enhance precipitation, thus randomized programs are rare. Alternative approaches are to compare the target area to a nonseeded control area, or to compare storm measurements from within and outside of the project area prior to and during the project to see if the relationship changed during the seeding program. Both direct and indirect measurements are used for evaluation. Direct measurements include precipitation and radar data, whereas indirect measurements may include crop yield changes, stream runoff data, or chemical analyses using various tracers.

The document concludes with a glossary of terms and an extensive list of references. Although anyone seriously considering initiating a cloud seeding project would need to consult with trained scientists and practitioners as to the feasibility and cost of the method in the desired area, Standard Practice provides water managers and others with a strong base of information about how the process works, decisions that would need to be made, and other important considerations.

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Alley Receives USGS Communication Award

William M. Alley, chief of the USGS Office of Ground Water, was awarded the Shoemaker Award for Lifetime Achievement in Communication in 2006, according to the electronic newsletter of the Association of Ground Water Scientists and Engineers of the National Ground Water Association. Alley “was recognized for the collection of USGS circulars that covers principles and issues related to ground water, as well as many fact sheets and magazine articles. Alley was instrumental in conceiving and coordinating this set of publications and was an author of many of them,” said the announcement.

The Shoemaker Awards were established in 1997 to honor Eugene Shoemaker, “whose abilities as both a scientist and a communicator inspired his colleagues and the public around the world,” according to the USGS. The periodically awarded Distinguished Achievement Award is considered a lifetime award that honors an individual’s standing in his or her professional field, skill and enthusiasm for conveying traditional and groundbreaking scientific concepts, and expertise in more than one communication medium.


ACWA Director Honored by NWRA and WestCAS

Steve Hall, executive director of the Association of California Water Agencies (ACWA), was honored with awards from the National Water Resources Association (NWRA) and the Western Coalition of Arid States (WestCAS) in December.

Hall was recognized for his exceptional career in representing, supporting, and assisting water users in California and the West in general, and received NWRA’s Lifetime Achievement and Water Buffalo awards. The Lifetime Achievement award was in particular recognition of Hall’s tremendous contribution to NWRA and its members during his nearly 13 years with ACWA.

The Water Buffalo award is a special and relatively new award given to individuals who are respected by their peers for their knowledge and force of personality in the water business. Commissioner John W. Keys III is the only other individual to receive the award.

Hall was also recognized with a Lifetime Achievement Award from WestCAS in recognition of his and ACWA’s support for WestCAS and its efforts on the Safe Drinking Water Act and Clean Water Act. The WestCAS board of directors noted that Hall personified their motto: “The Voice of Water Quality in the West.”


Westerhoff Receives Busch Award

The Water Environment Research Foundation (WERF) Endowment for Innovation in Applied Water Quality Research recently presented the Paul L. Busch Award to Paul Westerhoff, an environmental engineering professor at Arizona State University. Westerhoff was selected for his research investigating the fate of commercial nanomaterials in drinking water and wastewater treatment plants, and their potential human toxicity.

The award comes with a $100,000 research grant that will aid Westerhoff and his team as they attempt to provide fundamental knowledge of nanomaterial interactions to help control them in wastewater treatment plants. This research aims to improve operations of existing plant processes and catalyze research opportunities on the beneficial use of nanotechnology in diagnostic tools and treatment processes.

Nanomaterials—less than a billionth of a meter wide—are becoming increasingly common in manufactured goods and are found in products as diverse as cosmetics.

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and stain-resistant paints. Little scientific information is currently available on their fate in water and wastewater treatment plants, whether they are present in biosolids or effluent, or their potential impact on the treatment processes.


Scanlon Selected as Birdsall-Dreiss Lecturer

Bridget Scanlon, senior research scientist at the Bureau of Economic Geology, University of Texas at Austin, will be the 2007 Birdsall-Dreiss Distinguished Lecturer, announced the Geological Society of America’s Hydrogeology Division, which sponsors the lecture by providing transportation expenses. Scanlon will present one of two talks as she visits various institutions and meetings this year; the lecture topics are ecological controls on water cycle responses to climate variability, and impacts of land use and land cover change on water resources.

Originally from Ireland, Scanlon joined the Bureau of Economic Geology in 1987. She leads a research group whose primary objective is to assess sustainability of water resources, including both quantity and quality, within the context of climate variability and land use/land cover change. Studies integrate physical, chemical, and isotopic analyses and numerical modeling. Much of the research focuses on impacts of climate variability and conversion of natural ecosystems to agriculture on groundwater recharge in semiarid regions. The group also investigates the impacts of natural and anthropogenic contamination, including nitrate and arsenic, on water quality.

Visit gsahydrodiv.unl.edu.

Johnson New Reclamation Head

Robert Johnson became the 20th leader of the U.S. Bureau of Reclamation when he became commissioner last fall. With Reclamation since 1975, Johnson most recently served as the director of the Lower Colorado Region, where he oversaw the management of the lower 700 miles of the Colorado River, Hoover Dam, and numerous other Reclamation activities in southern Nevada, southern California, and Arizona. In that position, he was closely involved with the first water-sharing agreements between Arizona, California, and Nevada.

Johnson also played a major role in securing California’s Quantification Settlement Agreement, which addressed California’s over-reliance on Colorado River water. In addition, he helped develop and implement the Lower Colorado River Multi-Species Conservation Program, a coordinated, comprehensive, long-term multi-agency effort to conserve and work toward the recovery of endangered species, and protect and maintain wildlife habitat on the lower Colorado River.

Visit www.usbr.gov.

Verrie Pearce Mourned

Verrie F. Pearce, a flood-control expert with a nearly 40-year career at the USGS, died in November at age 79, reported the Sacramento Bee. A civil engineer, he was known for his work in flood protection and control in California. Following his retirement from the USGS in 1980, he worked as a private consultant, and after heavy rain flooded the city of Roseville, he designed a flood-warning system of sensors and bridge gauges for the city, which ultimately expanded into an extensive system that recently received the nation’s highest federal rating of flood-control protection, said the newspaper.

According to the Bee, Pearce “was an authority on recording water depths and flows who traveled all over the world taking measurements in rivers and streams prone to overflowing. He kept meticulous records that officials used to predict flood patterns and develop prevention plans.”

Watersheds: Connecting Weather to the Environment

Sara Espinoza – NEETF and Joseph P. Lamos – UCAR/COMET

Most Americans believe they know more about the environment than they actually do: just 12 percent can pass a basic quiz on energy awareness; about 80 percent are influenced by incorrect or outdated information; and only 41 percent can correctly define the term “watershed” in a multiple-choice format. To bridge this environmental information gap, the National Environmental Education & Training Foundation (NEETF), in partnership with the American Meteorological Society (AMS), is turning to broadcast meteorologists—a trusted public source of daily scientific information—for assistance.

The premier professional society for broadcast meteorologists in the United States, AMS believes that weathercasters are an underutilized public resource, and would like to see them become more central in improving science and environmental reporting at their stations. AMS foresees an evolution of the broadcast meteorologist into a “station scientist” who can expertly cover the weather, watersheds, and other environmental issues for the station.

Although broadcast meteorologists are experts in the atmospheric sciences and the art of broadcasting, they often have a more limited background in hydrology, water quality, and watersheds. To provide the background necessary to cover these topics on the air, NEETF partnered with the Cooperative Program for Operational Meteorology, Education & Training (COMET®) to develop a series of online environmental education courses aimed at providing basic watershed and environmental information to incorporate into local weathercasts. Online education materials complement NEETF’s Earth Gauge™ program to provide free environmental science information to the broadcast meteorology community for use on-air.

The initial course, “Watersheds: Connecting Weather to the Environment,” was released in September 2006. This online course is organized into six short units of instruction, each approximately 20 minutes long, and divided into six to eight small lesson elements. Overall, the course uses a narrative style to convey watershed science, and models how weathercasters can communicate watershed and hydrological concepts to the public. Central to the course content is the theme that one’s backyard is in a watershed; key information and data are provided by the EPA, USGS, NOAA, and other government agencies through their websites. The lessons focus on how these Web resources can be used to better educate the public about watershed science.

By incorporating this course into the AMS continuing education program, it is hoped that broadcast meteorologists will earn points toward their certification and inform and educate their audiences. While intended for broadcast meteorologists, the course is also an excellent primer for land use managers, teachers, community leaders, and others interested in learning more about watersheds.

Over the next year, NEETF and COMET will add a module that addresses smart growth issues and interactions between weather and the built environment. In addition, a course on weather and public health is planned.

The watershed course, funded by the U.S. EPA’s Office of Wetlands, Oceans, and Watersheds, is free and accessible on the COMET Program’s MetEd website, meted.ucar.edu/broadcastmet/watershed/.

Contact Sara Espinoza at sara@neetf.org. Learn about the AMS initiative at www.ametsoc.org/stationscientist.
PG&E Apologizes to Tribe, Moves Facility

Pacific Gas and Electric (PG&E) issued a formal apology to the Fort Mojave Indian Tribe last fall for the construction of a water treatment facility on sacred land, and promised to move the facility to a different location, return the land to the tribe, and include the tribe in future activities of the company, according to the Mohave Daily News. The facility had been built to treat chromium-VI-contaminated groundwater from PG&E’s Topock Natural Gas Compressor Station near Needles. It was an interim facility to prevent the contamination from reaching the Colorado River while a permanent, long-term treatment facility could be designed and constructed, according to the newspaper.

With this action, the tribe dropped a lawsuit filed against state and federal agencies in 2005 for “building the plant in the middle of their sacred area without consultation,” reported the Daily News. The California Department of Toxic Substances had ordered PG&E to take action to prevent the plume from reaching the Colorado River, and allowed PG&E to build the facility on the land without consideration for the tribe’s concerns.

The tribe expressed satisfaction that the issue was resolved outside the courts, even though the impact to its lands cannot be reversed. Courtney Coyle, a tribal attorney, told the Daily News that had it gone to court, “the judge probably wouldn’t have ordered the land to be returned to the tribe, or to pay for a tribal cultural person to monitor future projects.”


Three Companies Pay $2.1M for San Gabriel Cleanup

In November, the U.S. Environmental Protection Agency announced it had reached separate settlements requiring companies that allegedly contributed to groundwater contamination at the San Gabriel Valley Superfund site near Los Angeles to reimburse EPA $2.1 million and the California State Department of Toxic Substances Control (DTSC) $16,000 for past cleanup costs. Rathton Corporation and Chemed Corporation will reimburse $1.8 million to EPA and $14,000 to DTSC. The Saint-Gobain Corporation will reimburse $376,000 to EPA and $2,000 to DTSC. EPA previously received approximately $10 million from prior settlements relating to the Puente Valley Operable Unit (PVOU) in Area 4 of the Superfund site.

An editorial in the San Gabriel Valley Tribune noted that the payments are proportional to “a few cents out of a $4 bill for the PVOU,” according to the San Gabriel Basin Water Quality Authority.

Other potentially responsible parties are implementing groundwater cleanup programs for the PVOU that are estimated to cost over $50 million over the next ten years. The work parties are designing a groundwater cleanup system to pump out contaminated groundwater. The extracted groundwater will be treated and may be provided to a local water supply distribution system or discharged to surface water.

The EPA listed several sections of the 170-square-mile San Gabriel Valley as Superfund sites in 1984, including multiple areas of groundwater contaminated by volatile organic compounds. The contaminated groundwater underlies numerous cities and towns; forty-five water suppliers in the valley use San Gabriel Basin groundwater to provide 90 percent of the drinking water for over one million residents.


Tetra Tech Wins $15M

In October, Tetra Tech Inc. announced the signing of a $15 million contract with the U.S. Environmental Protection Agency to provide technical support to its Pacific Southwest Region (Region 9) Water Division as it implements core water programs, including those associated with the Clean Water Act, Marine Protection and Sanctuaries Research Act, and Safe Drinking Water Act. The contract has a four-year period of performance and will include time and materials and fixed-price tasks.

EPA Region 9 includes Arizona, California, Hawaii, Nevada, the Pacific Islands, and Tribal Nations. The Water Division is responsible for providing clean and safe surface water, groundwater, and drinking water and protecting and restoring aquatic ecosystems. Tetra Tech is a 7,500-person consulting company providing engineering and technical services.

Visit www.tetratech.com and www.epa.gov/region9/.
after the book was in press. The chapters in the West commanded our attention only relevant, even though multi-year drought issues regarding climate variability—still one highlight is a cogent section on of the four major sections of the book.

Water and Climate in the Western United States, a book impressive in its breadth, takes on a confluence of topics related to climate variability, change, prediction, and modeling, and the roles and influences of institutions, economics, and law on the ability to use climate knowledge to improve water management. Editor William M. Lewis Jr. has assembled an all-star cast of climatologists; hydrologists; legal, economic, and policy scholars; and water managers to meet this task, and the effort provides a nice blend of policy, hydrology, and climate science. The book is partly based on a workshop held in 1999 in Boulder, Colorado, and the conclusions of various working groups punctuate each of the four major sections of the book.

One highlight is a cogent section on issues regarding climate variability—still relevant, even though multi-year drought in the West commanded our attention only after the book was in press. The chapters on hydrologic prediction give a reasonable sense of the strengths, weaknesses, prospects, and practicalities of dynamic and empirical approaches to using climate information in hydrologic modeling. Chapters written by water managers are especially valuable for their historical perspectives, insights on the constraints on water management, and the challenges of management, given uncertainties introduced by climate and society. The managers collectively assert that adaptation to climate variability, policy considerations, and engagement with stakeholders will provide the robustness needed to meet future challenges. The chapter on economic strategies for adapting to projected climate change impacts on water resources highlights some actions pioneered in California that are becoming more common since the ongoing drought, including water banking, water transfers, short-term market arrangements, and creative water pricing.

The tour de force of the book is an informative and fairly comprehensive chapter on the complex legal, policy, and institutional issues facing water managers and stakeholders. The chapter’s author concludes that attention to actual or anticipated water supply shortages, often precipitated by severe droughts, creates opportunity for water policy reform.

A major shortcoming of the book is the lack of a stronger editorial presence to provide a synthesis of the array of topics covered. One senses little or no interplay between the workshop participants and the chapter authors. The structure of the book and its association with the workshop is never explicitly mentioned until the final chapter, which does not serve well its function to pull the multidisciplinary strands of the book together in a satisfying way. Nevertheless, the attempt to blend management concerns, needs, and critiques with academic approaches to major water and climate issues is a refreshing goal. Although the book’s jacket claims it will appeal to academics and policymakers alike, policy makers may find the technical chapters on linkages between prediction of climate and hydrology a difficult read.

Will you want to own a copy of Water and Climate in the Western United States? You bet. Is it the “go to” reference that will allow you to clear reams of books and articles from your bookshelf? No way. Much has changed in the three years since the book was released and eight years since the workshop on which the book was based; thus, the book provides a snapshot in time of its subject. There are now more compelling success stories on using climate in hydrologic prediction; there have been notable changes in water policy, drought, and climate change preparedness in western states, as well as improved understanding of drought variability and observed climate changes in the West. Of course, much is frustratingly the same, even in light of multi-year drought and increased demands on water supplies, and this opens a window of opportunity for an updated volume on these always engrossing topics.

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RockWorks 2006

Clint Carney – Nebraska Public Power District and Colorado School of Mines

Software Review courtesy of International Ground Water Modeling Center and Colorado School of Mines

RockWorks 2006, the latest version of subsurface visualization software from the Golden, Colorado-based RockWare Inc., provides a large array of tools useful for site characterization in many earth science disciplines. For geologists, hydrogeologists, and geophysicists involved in water-resources investigations, the software package is particularly useful for developing hydrostratigraphic models that facilitate construction of groundwater flow and transport models.

The software’s Borehole Data Manager window provides a centralized database management interface through which borehole data, including lithology, stratigraphic contacts, geophysical data, geochemical measurements, fracture information, and groundwater levels, can be used to create maps, cross sections, fence diagrams, single- or multi-log plots, and three-dimensional surface and solid models. Other capabilities useful to water resources investigations are available in the RockWorks Utilities window. This interface facilitates creation of contour maps of water levels and drawdowns, as well as Piper and Stiff diagrams. Utilities include statistical analyses and control of display options.

In addition to visualization of the subsurface for conceptual model development, RockWorks 2006 provides useful ways to create grids that can be used for modeling. For example, solids models created in RockWare can be exported as ASCII XYZ files, which can then be imported into various groundwater modeling interfaces for defining model units and layers. Water resource investigators will like the new Well Construction interface. This addition allows for detailed well construction information to be stored in a database format. With this data, RockWorks 2006 can be used to plot well construction diagrams alongside 2-D and 3-D strip logs, allowing the user to identify the formation or lithology accessed by the screened intervals. Well features such as screen depth and length, casing length, and construction materials can be included in the well construction diagram.

Among several enhancements over the 2004 version, RockWorks 2006 implements the Microsoft Access database format for storage and management of borehole information. This new format increases the user’s ability to query borehole information and link data from various tables within the database. Checks on data integrity within the database have been improved (for example, checks on consistent layer elevations). RockWorks does not require Access to be installed for operation of the software, however: the option to import and manipulate data in a spreadsheet format remains.

Additional enhancements include an improved tool layout for creating borehole strip logs and the capability to edit all graphics created in RockWorks. In addition to the export capabilities for grids, RockWorks 2006 now has more user-friendly options for exporting data to AutoCad and ArcGIS programs.

RockWorks 2006 comes with an extensive help menu and several tutorials that help introduce the new user to the software’s major features. The RockWare website provides additional technical support.

The software can be purchased online at www.rockware.com.
MARCH 2007


March 19-22  Association for Environmental Health and Sciences. 17th Annual AEHS Meeting & West Coast Conference on Soils, Sediments, and Water. San Diego, CA. www.aehs.com/conferences/westcoast/


March 22-23  University of California at Santa Barbara. First Western Forum on Energy and Water Sustainability. Santa Barbara, CA. www2.bren.ucsb.edu/~keller/energy-water/forum_agenda.htm


APRIL 2007


April 11-13  Arizona Riparian Council. 21st Meeting - Climate and Riparian Areas: Connecting the Dots. Casa Grande, AZ. azriparian.asu.edu/


April 22-26  Montana Tech. 15th Annual Mine Design, Operations, and Closure Conference. Fairmont (Butte), MT.


MAY 2007


May 15-19  ASCE-Environmental and Water Resources Institute. World Environmental and Water Resources Congress. Tampa, FL. content.asce.org/conferences/ewri2007/
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