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THE UNITED STATES AND MEXICO: WEATHER TECHNOLOGY, WATER RESOURCES AND INTERNATIONAL LAW

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A visitor to El Paso on a hot, dry day in June was heard to comment incautiously: "If I owned West Texas and Hell, I would rent West Texas and live in Hell." There are others, including many of us who reside in those states of Mexico and the United States along the border, who have been rather free with our adverse statements about the heat and lack of precipitation here. You will have to fend for yourselves on the temperature; I bring you a message of cautious hope about the precipitation.

Weather modification technology has made important advances during the past few years.¹ Precipitation enhancement techniques have been greatly improved;² there are operational cold fog dispersal systems;³ promising approaches have been taken in combating warm fog;⁴ lightning⁵ and hail suppression

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1. For official reports on weather modification, see Advisory Committee on Weather Control, Final Report (1957); D. Gilman, J. Hibbs & P. Laskin, Weather and Climate Modification (Report to the Chief, U.S. Weather Bureau) (1965); L. Hartman, Weather Modification and Control, S. Rep. 1139, 89th Cong., 2d Sess. (1966); J. Lackner, Precipitation Modification (Report for U.S. National Water Commission) (1971); Panel on Weather and Climate Modification, National Academy of Sciences, Weather and Climate Modification (1965); Special Commission on Weather Modification, Weather and Climate Modification (Report to National Science Foundation) (1965).

Among the leading texts on weather modification are L. Battan, *Harvesting the Clouds: Advances in Weather Modification* (1969); L. Battan, *Cloud Physics and Cloud Seeding* (1962); B. Mason, *Clouds, Rain and Rainmaking* (1962).

2. American Meteorological Society, *Statement on Weather and Climate Modification* (1967), in Proceedings of First Nat'l Conf. on Weather Modification ii-iv (1968); I. Gutmanis & R. Gillis, *Weather Modification: Programs and Prospects*, 2 Environment Reporter, Monograph No. 8, 3 (1971).

3. Beckwith, *Impacts of Weather on the Airline Industry: The Value of Fog Dispersal Programs*, in Human Dimensions of Weather Modification 195 (W. Sewell ed. 1966); R. Fletcher, *Operational Applications of Fog Modification*, in Proceedings of Int'l Conf. on Weather Modification, Canberra, Australia 255 (1971); Ramsey, *Operation Fog Cutter*, United Mainliner 4 (May, 1964).

4. Air Transport Ass'n of America, *Airline Warm Fog Dispersal Test Program At Sacramento, Cal.* (1968); Hindman, *Meteorological Conditions Favorable for the Artificial Dissipation of Warm Fog*, in Proceedings of Third Nat'l Conf. on Weather Modification 54 (1972); Jiusto, Pilié & Kocmond, *Fog Modification With Giant Hygroscopic Nuclei*, 7 J. Applied Meteorology 860 (1968); MacCready, *Warm Fog Modification*, 1 WMA 11 (1969); St.-Amand, Clark, Wright & Finnegan, *Warm Fog Modification*, in Proceedings of Int'l Conf. on Weather Modification. Canberra, Australia 259 (1971).

5. Fuquay, *Weather Modification and Forest Fires* 309 (1967). On lightning generally, see Taylor, *Lightning-Agent of Change In Forest Ecosystems*, 68 J. Forestry 477 (1971); Uman,

have been under experimentation;⁶ and much theoretical work and some field experiments in severe storm modification have been undertaken.⁷ Some projects in the United States might have international ramifications.⁸ There are three types of intentional weather modification⁹ which have been conducted or are planned by the United States which I believe would interest Mexican

Everything You Always Wanted to Know About Lightning But Were Afraid to Ask, Saturday Rev., May 13, 1972, at 36.

Weather modification has been used to combat forest fires not only by suppressing lightning, but also by dampening timber lands. Harpster & Douglas, *Weather Modification-A Fire Control Tool*, WMA 244 (1971).

6. Dennis, *The Theory and Practice of Hail Suppression*, 2 WMA 147 (1970); Goyer, Howell, Schaefer, Schleusner & Squires, *Project Hailswath*, 47 Bull. Am. Meteorological Soc'y 805 (1966); Henderson, *An Operational Hail Suppression Program in Kenya*, 1 WMA 30 (1969); Schickedanz & Changnon, *The Design and Evaluation of the National Hail Research Experiment in Northeast Colorado*, 3 WMA 160 (1971); Schleusener, *Lessons from Project Hailswath*, in Fifth Conf. on Severe Local Storms 24 (Oct. 1967); Swinbank *The National Hail Research Experiment*, in Proceedings of the Int'l Conf. on Weather Modification. Canberra, Australia 203 (1971).

7. Tornado control, yet in its infancy, is talked of in Henderson & Carley, *The Airborne Seeding of Six Tornadoes*, in Proceedings of Third Nat'l Conf. on Weather Modification 241 (1972). For discussion of hurricane modification, see text at notes 50-58, *infra*.

8. For articles dealing with weather modification and international law, see Corbridge & Moses, *Weather Modification: Law and Administration*, 8 Natural Resources J. 207 (1968); Goldie, *Science, Policy and the Developing Frontiers of International Law*, 4 Akron L. Rev. 114, 116 (1971); Hassett, *Weather Modification and Control: International Organizational Prospects*, 7 Texas Int'l L.J. 89 (1971); Oppenheimer & Lambright, *Technology Assessment and Weather Modification*, 4545 S. Cal. L. Rev. 570, 587, (1972); Samuels, *Prospective International Control of Weather Modification Activities*, 21 U. Toronto L.J. 222 (1971); Taubenfeld & Taubenfeld, *Some International Implications of Weather Modification Activities*, 23 Int'l Organization 808 (1969); Taubenfeld, *Weather Modification and Control: Some International Legal Implications*, 55 Calif. L. Rev. 493 (1967); See also R. Davis, *The Legal Implications of Atmospheric Water Resources Development and Management* §§14.1-15.2 (1968); T. Malone, *Current Developments in the Atmospheric Sciences and Some of their Implications for Foreign Policy*, paper presented at Joint Meeting of the Policy Planning Council, Dep't State and Special Panel of Comm. on Science and Public Policy, Nat'l Academy of Sciences, Washington, D.C. (1968); Moses & Corbridge, *Legal Structures for International Supervision of Weather Modification Techniques* (Int'l Conf. on Water of Peace Paper No. P/635, 1967); Taubenfeld, *The International Lawyer and Weather Modification*, in *Human Dimensions of the Atmosphere* 99 (W. Sewell ed. 1968); Taubenfeld & Taubenfeld, *The Law and Weather Modification*, in Proceedings of First Nat'l Conf. on Weather Modification 190 (1968); Weiss, *The International Legal and Political Implications of Weather Modification*, in Proceedings of Third Nat'l Conf. on Weather Modification 232 (1972).

9. Inadvertent weather modification caused by pollution is not within the scope of this paper. It is, however, a matter of great concern to meteorologists and other knowledgeable persons. See S. Brubaker, *To Live On Earth 87-96* (1972) (Mentor paperback edition); Presidential Council on Environmental Quality, *Man's Inadvertent Modification of Weather and Climate*, 51 Bull. Am. Meteorological Soc'y 1043 (1970). See also Changnon, *Lesson from the La Porte Anomaly*, in Proceedings of Int'l Conf. on Weather Modification. Canberra, Australia 193 (1971); Changnon & Huff, *Urban Effects on Daily Rainfall Distribution*, in Proceedings of Second Nat'l Conf. on Weather Modification 215 (1970); Hobbs & Radke, *Cloud Condensation Nuclei from Industrial Sources and Their Influence on Clouds and Precipitation*, in *id.* at 237; Huff & Changnon, *Inadvertent Precipitation Modification by Major Urban Areas*, in Proceedings of Third Nat'l Conf. on Weather Modification 73 (1972); Langer, *A Study of Automobile Exhaust As A Source of Ice Nuclei*, in Proceedings of Second Nat'l Conf. on Weather Modification 242 (1970); Mohen & Vonnegut, *Weather Modification and Air Pollution*, *id.* 228; Schaefer, *New Field Evidence of Inadvertent Modification of the Atmosphere*, *id.* at 163.

and American lawyers and environmentalists. The first is snowpack augmentation to increase stream runoff. The second is drought relief rainmaking, and the third is hurricane treatment.

SNOWPACK AUGMENTATION

The major snowpack augmentation program now planned in the United States is a part of Project Skywater—the Bureau of Reclamation's atmospheric water resources program.¹⁰ The Bureau has selected the Upper Colorado River Basin area as one of its primary target areas. Along with other researchers, the Bureau's personnel and contractors have been carrying out experiments in the laboratory and in the atmosphere to obtain information as to how clouds over the western slopes of the Rocky Mountains might best be treated in order to enhance snowfall.¹¹ They have lately embarked on a pilot program in the San Juan Mountains of southwestern Colorado.¹² The Upper Colorado Basin was chosen by the Bureau of Reclamation for early attention because of the need for water in the arid American southwest and the anticipated success of snowpack augmentation along the Rockies.¹³

Roughly seventy-five percent of the annual runoff of the Upper Colorado River Basin originates in that thirteen percent of the area of the basin lying above nine thousand five hundred feet elevation. Atmospheric moisture moving from the west encounters the orographic barrier of the Rocky Mountains, is thrust higher, cools, and then drops precipitation. The high elevation area receives thirty-eight inches average precipitation annually, half of it during the winter months. This produces a runoff of about thirteen inches. The twenty-five inches annual loss represents a substantial part of what the losses would be even with additional precipitation from weather modification activities.

10. The basic planning document for the Bureau of Reclamation program is Office of Atmospheric Water Resources, Plan to Develop Technology for Increasing Water Yield from Atmospheric Sources (1966). For a discussion of the legal effects of snowpack augmentation, see Howe, *Legal Moguls: Ski Areas, Weather Modification, and the Law*, 33 U. Pitt. L. Rev. 59 (1971).

11. See, e.g., Office of Atmospheric Water Resources, 2 Project Skywater: 1968 Ann. Report 267 (1969). (Report to Bureau of Reclamation).

12. Office of Atmospheric Water Resources, Project Skywater: 1971 Annual Report 5-6, 31 (1972). An interdisciplinary team has made a technology assessment report on snowpack enhancement in the Upper Colorado River Basin. It considers the San Juan project and discusses the proposed basin-wide Winter Orographic Snowpack Augmentation program. Stanford Research Institute, Technology Assessment of Winter Orographic Snowpack Augmentation In the Upper Colorado River Basin: The Impact of Snow Enhancement (1972) (2 vols.).

13. *Id.* at 99-105.

According to the Bureau of Reclamation, we may assume that eighty-five percent of any precipitation resulting from snowpack augmentation will appear as runoff. If a fifteen percent precipitation augmentation can be brought about by wintertime snowmaking, Bureau calculations indicate that there would be an annual yield of one million eight hundred seventy thousand acre-feet of additional streamflow.¹⁴ If that water were permitted to flow downstream and normal losses occurred, a million and a half acre-feet of water would be available at the Mexican border.

Two of these figures are key matters of concern: the fifteen percent increase in precipitation through weather management techniques and the million and a half acre-feet of runoff at the international boundary resulting from use of such technology. How is the first figure arrived at? What are the international law ramifications if this water resource becomes available?

Nature forms snow when suspended cloud droplets either freeze because temperatures have dropped to forty degrees below zero centigrade or suitable nucleating particles are present. The most common nucleating particles become efficient around fifteen degrees below zero centigrade. Ice crystals are formed around nuclei. They grow at the expense of water vapor and water droplets and some become heavy enough to fall in relation to the surrounding air. Snow pellets or graupel may be formed by riming or several crystals may clump together to form a snowflake.¹⁵

Clouds may not become cold enough, and nature may not provide adequate nuclei for the formation of ice crystals from cloud droplets. In 1946, Vincent Schaefer discovered that upon dropping dry ice through air containing super-cooled water droplets he could cause the formation of ice crystals.¹⁶ Use of this technique of weather modification involves the problem of putting enough dry ice at the right place in the cloud. So,

14. Kahan, *Weather Modification Potential for Water Supply In the Colorado River Basin*, in Proceedings of Second Nat'l Conf. on Weather Modification (1970); see also Hurley, *Augmenting Upper Colorado River Basin Water Supply by Weather Modification*, Paper presented to Am. Soc'y Civil Engineers Annual Meeting, New York, N.Y., Oct. 1967. See II Stanford Research Institute, *supra* note 12, at 125-38.

15. For discussions of cloud formation, see H. Byers, *Elements of Cloud Physics* (1965); R. Feagle & J. Businger, *An Introduction to Atmospheric Physics* 79-109 (1963); F. Hare, *The Restless Atmosphere* 31-38 (rev. ed. 1966). The ice crystal process of precipitation formation is examined in J. Day, *The Science of Weather* 139-41 (1966); S. Petterssen, *Introduction to Meteorology* 65-66 (1958). See generally N. Fletcher, *The Physics of Rainclouds* (1962).

16. The early history of scientific weather alteration is recounted in D. Halacy, *The Weather Changers* 81-87 (1968).

scientists looked for a way of stimulating precipitation by adding artificial nuclei when insufficient natural nucleating particles were present. Bernard Vonnegut discovered that silver iodide becomes effective as an ice crystal nucleus at around minus four degrees centigrade.¹⁷ Freezing is accompanied by the release of the heat of fusion. This results in increased buoyancy and the growth of the cloud into altitudes with lower temperatures and pressures. Seeding the cloud with silver iodide thus alters its microphysics and triggers precipitation.

Snowpack augmentation in the mountains can be carried out by using burners or generators placed on the ground above the nine thousand foot level. Silver iodide and acetone solution is burned in the generators and air currents carry the plume from the burners into the clouds. To be effective, the proper amount of nucleant must be placed in the right part of the cloud at the correct time. This requires good meteorological information from which the cloud seeders can work and a great deal of theoretical study and laboratory and field experiments. Researchers working in the area have undertaken carefully planned experiments in which control areas are set up with characteristics like seeded areas and target area seeding is done on a randomized basis.¹⁸ The estimate of a fifteen percent annual increase in precipitation resulting from treating winter clouds is based on the results reported by these experimenters.¹⁹ This hypothesis will be tested by the San Juan project.

The Bureau of Reclamation calculations may prove to be over optimistic. Ecological and political reasons may prohibit operations to the extent technically possible or throughout the entire high runoff area.²⁰ Supplemental water generated may not

17. Vonnegut's work is discussed, *id.* at 87-92.

18. For reports on the long-term experiment conducted at Climax, Colorado by Colorado State University, see Chappell, *Cloud Seeding Affects on Precipitation Intensity and Duration of Wintertime Orographic Clouds*, in Proceedings of Int'l Conf. on Weather Modification, Canberra, Australia 121 (1971); Grant, Chappell & Mielke, *The Climax Experiment for Seeding Cold Orographic Clouds*, *id.* at 78; Mielke, Grant & Chappell, *Elevation and Spatial Variation Effects of Wintertime Orographic Cloud Seeding*, 9 J. Applied Meteorology 476 (1970); Mielke, *Randomized Orographic Cloud Seeding Results for Eight Wintertime Seasons at Climax, Colorado*, in Proceedings of Second Nat'l Conf. on Weather Modification 66 (1970).

19. Office of Atmospheric Water Resources, Project Skywater: 1970 Ann. Report 1-6. 91-153 (1971). See also Kahan, *supra* note 14; Hurley, *supra* note 14.

20. Ecology and weather modification are considered by C. Cooper & W. Jolly, *Ecological Effects of Weather Modification: A Problem Analysis* (Rep. to Bureau of Reclamation, May 1969); Ecological Soc'y of America, Ad Hoc Weather Working Group, *Biological Aspects of Weather Modification*, 47 Bull. Ecol. Soc'y Am. 39 (1966); Rango, *Possible Environmental*

become available for downstream use.²¹ Should this harvest of a million and a half acre-feet of streamflow become available at the Mexican-American boundary, weather modification will have helped solve the problems associated with the obligation of the United States to make deliveries of water from the Colorado River to Mexico.

Not all the American states in the basin have used their share of the water from the river.²² At present, the quantity of water required by the 1944 Mexican-American treaty can be delivered to Mexico. Should the American states take all the water they are entitled to, there could well be a quantity problem unless the river flow were supplemented.

Colorado River water quality has been a source of contention between Mexico and the United States.²³ This problem might be minimized by dilution of saline waters in the river through the introduction of less contaminated water to the stream.

In 1968, in the Colorado River Basin Project Act, Congress declared:

that satisfaction of Mexican treaty rights constitutes a national obligation which shall be the first obligation of any water augmentation project. . . . Accordingly, the States . . . shall be relieved from all obligations which may have been imposed upon them by . . . the Colorado River Compact so long as . . . means are available and in operation which augment the water supply of the Colorado River system in such quantity as to satisfy the

Response to Weather Modification, in Proceedings of Second Nat'l Conf. on Weather Modification 411 (1970); see also R. Berkman & K. Viscusi, *Damming the West: The Nader Task Force Report on the Bureau of Reclamation* 76-83 (1971).

For a report on a Bureau of Reclamation sponsored study of the potential ecological impact on the area encompassed by the San Juan seeding project, see Teller, *Current Studies In The Ecological Effects of Weather Modification in Colorado*, in Proceedings of Third Nat'l Conf. on Weather Modification 226 (1972).

Attitudes toward weather modification are reported in Haas, *The Many Views of Planned Weather Modification*, paper prepared for Third Nat'l Conf. on Weather Modification (1972); Haas, Boggs, & Bonner, *Science, Technology and the Public: The Case of Planned Weather Modification*, in *Social Behavior, Natural Resources and the Environment* 151 (W. Burch ed. 1972); Haas, *Response to Planned Weather Modification: Implications for Urban Resource Management*, 1970 Western Resources Conf. 251; Haas, *Sociological Aspects of Human Dimensions of the Atmosphere*, in *Human Dimensions of the Atmosphere* 53 (W. Sewell ed. 1968);

21. For a study of how upstream states might lay legal claim to the supplemental water, see Pierce, *Legal Aspects of Weather Modification—Snowpack Augmentation in Wyoming*, 2 Land & Water L. Rev. 273 (1967).

22. Allocation of the waters of the river was finalized in *Arizona v. California*, 373 U.S. 546 (1963).

23. See *Agreement with Mexico on the Lower Colorado Salinity Problem*, 52 Dep't State Bull. 555, 637 (1965); Sepulveda, *The United States and Mexico: Areas of Dispute in Mexican-American Relations*, 17 Sw. L.J. 98, 102 (1963).

requirements of the Mexican Water Treaty together with any losses of water associated with the performance of that treaty.²⁴

In the hearings leading to enactment of the act, there are many references to weather modification as the means whereby this national obligation might be met.²⁵

PRECIPITATION ENHANCEMENT

During the drought of the spring and early summer of 1971, desperate water users in the southwestern United States and Florida sought federal assistance in the form of a drought relief precipitation enhancement program. Extensive cloud seeding was done in Florida by the National Oceanic and Atmospheric Administration;²⁶ and, in the southwest, by the Bureau of Reclamation.²⁷ The Bureau called its program Project Arid Lands. Summer cumulus clouds were treated with silver iodide in order to enhance rainfall. Aircraft were used to put the material in place. Pyrotechnic ordnance developed by the navy was fitted to the planes and ignited at the proper time for the seeding agent to be effective.²⁸

It is difficult to evaluate the success of the project. Rain fell after seeding flights. However, without control areas and using randomized seeding, there is no sure way to ascertain whether there might not have been equal precipitation without the seeding.²⁹ On the other hand, the consequences of the seeding on legislators can be evaluated. They liked it. Arizona wishes to have

24. 43 U.S.C. § 1512 (Supp. 1972).

25. *Hearings on H.R. 3300 Before the Subcomm. on Irrigation and Reclamation of the House Comm. on Interior and Insular Affairs*, 90th Cong., 2d Sess., pt. 2, at 704, 760, 785, 818, 857, 861, 900-04, 909-11, 929 (1968). Weather modification streamflow augmentation was also noted in the conference committee report on the bill. H.R. Rep. No. 1861, 90th Cong., 2d Sess. 20 (1968).

26. The seeding was requested by the governor. Letter from Reubin Askew, Governor of Florida to Robert White, Acting Administrator of NOAA, Feb. 3, 1971.

27. Letter of C. R. Baskin, Chief Engineer, Texas Water Development Bd. to Ray Jay Davis, Aug. 13, 1971; letter of C. M. Smith, Director of Emergency Services, State of Arizona, to Ray Jay Davis, Aug. 5, 1971.

28. For discussion of the use of pyrotechnics, see St.-Amand, Finnegan & Burkhardt, *Understanding of the Use of Simple and Complex Ice Nuclei Generated from Pyrotechnics and Acetone Burners*, 3 WMA 31 (1971); see also St.-Amand, Burkhardt, Finnegan, Donnan & Jorgensen, *Pyrotechnic Production of Nucleants for Cloud Modification - Part I—General Principles*, 2 WMA 25 (1970); St.-Amand, Burkhardt, Finnegan, Wilson, Elliott & Jorgensen, *Pyrotechnic Production of Nucleants for Cloud Modification - Part II—Pyrotechnic Compounds and Delivery Systems for Freezing Nucleants*, 2 WMA 33 (1970); Vetter, Finnegan, Burkhardt, St.-Amand, Sampson & Kaufman *Pyrotechnic Production of Nucleants for Cloud Modification - Part III—Propellant Compositions for Generation of Silver Iodide*, 2 WMA 53 (1970).

29. According to one study, early results from the Arizona seeding were inconclusive. Osborn, *Comments by A Hydrologic Engineer on Cloud Seeding In Arizona*, in *Proceedings of Third Nat'l Conf. on Weather Modification* 146 (1972).

the project repeated in 1972. Its legislature has considered a bill appropriating \$250,000 for use by cities, towns and counties for cloud seeding.³⁰ Senator Bellmon of Oklahoma recently introduced a bill in Congress seeking \$4,000,000 for drought relief seeding in Arizona, New Mexico, Texas, Oklahoma, Colorado and Kansas. An additional \$3,000,000 would be appropriated for use in the northern Great Plains states.³¹

There are other attitudes. Weather modification has had the image of an impotent rapist. There are the skeptics who assert that weather technologists are charlatans. They cannot alter precipitation, but they are expert at fleecing the gullible.³² There are others whose jeremiads foretell artificially induced floods, droughts and other pestilence—all wrought by cloud seeders raping the atmosphere.³³ In point of fact, weather modifiers are neither impotent, nor are they atmospheric rapists.

Precipitation patterns can be altered if the right conditions exist and the treatment is appropriately done. But conditions are not always right; not all clouds respond well to efforts to harvest them.³⁴ Seeding methodology, which has come a long way, still is in need of much refinement.³⁵

The charge that artificial precipitation brings on flooding has been the basis for one lawsuit in the United States.³⁶ The action against the weather modification organizations and its sponsor failed for want of proof by the plaintiffs of causation.³⁷ The order of increase in precipitation caused by artificial nucleation would not normally be enough to induce flooding. Should natural precipitation give indication of prospective flooding, seeding would be—indeed has been—abandoned.³⁸

30. S.B. 1028, 30th Ariz. Legisl., 2d Reg. Sess. (1972).

31. S. 3515, 92nd Cong., 2d Sess. § 201 (d) (1972).

32. In view of the centuries of hokum by confidence men who milked the public with unfounded claims of an ability to produce rain, this is not altogether surprising. For a look at one such character, see Lyons, *Weather or Not*, 8 Ariz. Q. 5 (1952).

33. Legislation in Pennsylvania and West Virginia talks in terms of man-made droughts and floods. Pa. Stat. tit. 3, § 1114 (Supp. 1970); W. Va. Code Ann. § 29-2B-13 (1969).

34. Government weather modifiers in Australia conduct a weather modification school in which they point out which types of clouds should be seeded. Fifth Course of Instruction in Cloud-Seeding Techniques 13a-d, 22a-h, 23a-e (1970).

35. The Bureau of Reclamation has conducted a series of conferences among its personnel and contractors to keep them abreast of new developments. Office of Atmospheric Water Resources, Proceedings: Skywater Conferences I-V (1967-69).

36. *Adams v. California*, No. 10112 (Super. Ct. Sutter County, Cal., April 6, 1964).

37. Mann, *The Yuba City Flood: A Case Study of Weather Modification Litigation*, 49 Bull. Am. Meteorological Soc'y 690, 708 (1968).

38. Interviews at Weather Modification Ass'n Meetings, Feb. 1970.

A board of inquiry which investigated the allegation that cloud seeding played a role in the

Man-made rainshadow is one fear of those who cry rape at the cloud seeder. Curbstone logic asserts that if you take out precipitation by seeding, you withdraw an equivalent amount of downwind precipitation. This "robbing Peter to pay Paul" allegation rests on the analogy of the rivers of the skies with the streams on the land. But the two are not analogous. Nature is an inefficient precipitator; only a small part of the water vapor in clouds falls to the ground. The amount of water vapor is only one of many factors leading to precipitation.³⁹

Studies on the extra-area impact of cloud seeding are somewhat limited. Evidence, though, tends to show that treatment of orographic clouds results in an increase in precipitation downwind outside of the target area.⁴⁰ Summer cumulus seeding has been shown by some projects to bring about an increase in precipitation outside of the intended target area.⁴¹ There are also showings of a negative affect.⁴²

Let us *assume*, for purposes of discussion, that the drought relief summer cumulus seeding by the United States near the international border will *increase* precipitation in Mexican territory downwind from the operations. In most instances, precipitation enhancement would be welcomed by the Mexicans. It might, however, be harmful to some interests. Tomato growers in Florida feared cracks in their produce from rainfall at the wrong time. Federal scientists cooperated with them and did not seed when the danger of harm existed.⁴³ It is likely the United States would show concern for similar problems in Mexico.

1972 Rapid City, South Dakota flood, found that no causal relationship could be established between injection by scientists of 350 pounds of salt into clouds downwind of a storm that several hours later dropped up to fourteen inches of rain in the Rapid Creek drainage. The board, however, recommended that all weather modification projects should contain automatic shut down procedures which would be used to stop seeding in the event of any potentially dangerous meteorological conditions. It was the view of members of the board that weather modifiers must avoid even the appearance of contributing to flood situations. P. St-Amand, R. Davis & R. Elliott, Preliminary Report On Rapid City Flood of 9 June 1972 to the South Dakota Weather Control Comm'n (1972).

39. Kahan, *Weather Modification Effects on Man's Environment*, 1967 Western Resources Conf. 82, 86-88.

40. Elliott, Brown & Grant, Transactions of Seminar on Extended Area Effects of Cloud Seeding, Santa Barbara, Calif., Feb. 15-17, 1971. See II Stanford Research Institute, *supra* note 12, at 99-102.

41. In Victoria precipitation maps made of areas downwind from a seeding target area in which summer cumulus clouds are treated shows significant increase in precipitation. Interview with Ian Searles and John Wylie, Cloud Seeding Officers, Victoria Dep't of Agriculture, Agricultural Aviation Section, in Horsham, Victoria, Nov. 18, 1970.

42. See, e.g., Flueck, Part V-Statistical Analyses of the Ground Level Precipitation Data: Project Whitetop (1971).

43. Letter of Donald Frier, Engineer, Bureau of Permitting, Florida Dep't of Air & Water Pollution Control to Ray Jay Davis, Aug. 13, 1971.

Suppose, though, that there is seeding in the United States and that Mexican interests are inadvertently adversely affected. Does international law provide for any relief? No treaties between the two countries deal with weather modification. Nor are there any determinations by international tribunals about weather modification that could serve as precedents governing such a case. It is necessary to turn to more general principles.

The *Trail Smelter* case⁴⁴ espouses the view which would probably be adopted by an international judicial agency in the eventuality of harmful artificial rainfall. This case involved injury to interests in Washington state from Canadian air pollution. A joint arbitration commission found that:

[U]nder the principles of international law . . . no State has the right to use or permit the use of its territory in such a manner as to cause injury by fumes in or to the territory of another or the properties or persons therein, when the case is of serious consequence and the injury is established by clear and convincing evidence.⁴⁵

Injuries caused by a silver iodide plume which brings on an unwanted rainstorm and injuries caused by fumes seem to be parallel.

In most of the litigation in the United States over weather modification, plaintiffs have contended that they had been or would be deprived of precipitation by virtue of the activities of the defendants. Except in one instance,⁴⁶ plaintiffs have not been able to demonstrate any such loss.⁴⁷ Proof of causation would be similarly difficult if Mexico were to assert that atmospheric water resources management in the United States had or would decrease Mexican precipitation. Let us *assume*, though, that summer cumulus seeded in conjunction with Project Arid Lands has reduced or will *inhibit* rainfall south of the border.

An examination of the rules of law governing the conduct of

44. *Trail Smelter Case* (United States v. Canada), 3 Rep. Int'l Arbitral Awards 1964 (1949), 3 U.N. Rep. 1904, 35 Am. J. Int'l L. 684 (1941).

45. *Id.* at 716. See also *Case Concerning Factory at Chorzow* (Germany v. Poland) (1928), reprinted in 4 A. McNair & H. Lauterpacht, Ann. Digest of Pub. Int'l L. Cases—Years 1927 & 1928, 260 (1931).

46. *Southwest Weather Res., Inc. v. Rounsaville*, 320 S.W.2d 211, and *Southwest Weather Res., Inc. v. Duncan*, 319 S.W.2d 940 (Tex. Civ. App. 1958), both *aff'd sub nom.* *Southwest Weather Res., Inc. v. Jones*, 160 Tex. 104, 327 S.W.2d 417 (1959).

47. *Samples v. Irving P. Krick, Inc.*, Civil Nos. 6212, 6223 and 6224 (W.D. Okla. 1954); *Adams v. California*, No. 10112 (Super. Ct. Sutter County, Cal., April 6, 1964); *Slutsky v. City of New York*, 197 misc. 730, 97 N.Y.S.2d 238 (Sup. Ct. 1950); *Pennsylvania Natural Weather Ass'n v. Blue Ridge Weather Modification Ass'n*, 44 Pa. D.&C.2d 749 (1968); *Auvil Orchard Co. v. Weather Modification, Inc.*, No. 19268 (Super. Ct. Chelan County, Wash., 1956).

upstream riparian nations on international rivers points the direction that an international tribunal might follow in deciding upon the rights of an upwind country to seed clouds. Here, the leading authority is the *Lake Lanoux Case*.⁴⁸ France planned to dam Lake Lanoux whose waters feed the Carol River which flows into Spain and is used there for irrigation. The French, however, contemplated supplementing Carol River flow to compensate for the diversion at the dam. Spain objected to French plans both on the ground of a prior bilateral treaty and on the international law principles limiting the conduct of upstream nations in developing the water resources of an international river. An arbitral tribunal to whom the matter was taken approved the project. The tribunal wrote:

As a matter of form, the upstream State has, procedurally, a right of initiative; it is not obliged to associate the downstream State in the elaboration of its projects. If, in the course of discussions, the downstream State submits projects to it, the upstream State must examine them, but it has the right to give preference to the solution contained in its own project, provided it takes into consideration in a reasonable manner the interests of the downstream State.⁴⁹

The United States, as the upwind country in our drought relief rainmaking illustration, would not be subject to a Mexican veto in undertaking Project Arid Lands if this case were adopted as a precedent. But, should the Mexicans suggest some alternative project, as, for example, a joint seeding effort on both sides of the international boundary, the United States would have to consider it. The Americans could, however, prefer their own project, if they would take into consideration Mexican interests. Rainshadow in Mexico would, it seems to me, require alteration of the American project or compensation for any losses caused.

HURRICANE TREATMENT

Early in the history of scientific weather modification, it occurred to the research team at General Electric which had pioneered cloud seeding that it might be possible to treat severe tropical storms and thereby mitigate the enormous losses associated with many of them. As a part of the company's Project Cirrus, dry ice was used to seed a storm over the Atlantic east of Florida on October 13, 1947. Visual observation showed an

48. *Lake Lenoux Case (France-Spain)*, 25 I.L.R. 101 (1957), 53 Am. J. Int'l L. 156 (1959).

49. *Id.* at 170.

alteration of the appearance of the cloud deck that had been treated.⁵⁰ This hurricane later altered its track and came over land causing significant losses. On the advice of counsel, General Electric withdrew from the hurricane modification business.⁵¹

More recent work on hurricanes has been a part of Project Stormfury, a joint operation of the United States Navy and the National Weather Service. They have seeded Hurricane Esther on September 16, 1961 and Hurricane Debbie on August 18th and 20th of 1969. The potential value from their activities can be seen in a look at the \$1.42 billion losses suffered from Hurricane Camille which preceded Debbie. The theory of the Stormfury seeding is to affect the heat balance in the eye wall of storms by massive silver iodide treatment. This, it is hoped, will slow the winds which are responsible for much of the damage done by hurricanes. In the case of Debbie, the winds fell from ninety-eight to sixty-eight knots after the seeding on the 18th. They reintensified the next day. On the 20th they were reduced by fifteen percent.⁵²

The extent to which silver iodide treatment might mitigate hurricane losses is not known. There have been too few cases from which to generalize. It is unclear as to how weather modification techniques will change the precipitation associated with such storms. Should weather engineering efforts reduce rainfall as well as winds, there will be harm as well as benefits flowing from hurricane suppression. An illustration of this may be seen in the case of Hurricane Inez of 1966. It threatened the Gulf Coast of the United States, a threat that, fortunately, did not materialize. Instead, it brought with it a great deal of rainfall which filled the reservoirs of the Mexican altiplano. A substantial portion of the runoff from Mexico in the Lower Rio Grande Basin is associated with tropical storms.⁵³

Let us *suppose* for purposes of discussion that the United States decides to seed a hurricane in the Gulf of Mexico; that the

50. "Project Cirrus"—*The Story of Cloud Seeding*, Nov. 1952 G-E Rev. 8, 22-23.

51. A Rosenthal, H. Korn & S. Lubman, *Catastrophic Accidents in Government Programs* 30 (1963).

52. Gentry, *Modification Experiments on Hurricane Debbie, August 1969*, in *Proceedings of Second Nat'l Conf. on Weather Modification* 205 (1970). See also N.Y. Times, Aug. 18, 1969, at 22, col. 4; Aug. 19, 1969, at 24, col. 6; Aug. 20, 1969, §C at 27 col. 3; Aug. 21, 1969, at 26, col. 3.

On hurricane seeding, see generally Dep't of the Navy & ESSA, *Project Stormfury, Annual Reports* (1965-68).

53. Roberts, *We're Doing Something About the Weather!*, 141 Nat'l Geographic 518, 545 (April 1972).

suppression effort *reduces* the winds from the storm; that rain which otherwise would have fallen over Mexican territory does not fall there. In this case the United States has harmed Mexico. What are the obligations of the United States?

It would first seem clear that the American government should notify Mexico of its proposed hurricane experiment. In the *Corfu Channel Case*,⁵⁴ the International Court of Justice entered an award for Great Britain against Albania essentially because of the failure of Albania to give warning of a danger that it knew of. Mines had been laid in the Corfu Channel, an international waterway within Albanian territorial waters, and Albanian authorities were aware of their presence and of the entry of British ships into the area. Nevertheless they failed to warn the British and the losses complained of occurred. The court noted that:

[A] general notification to the shipping of all States before the time of the explosions would have been difficult, perhaps even impossible. But this would certainly not have prevented the Albanian authorities from taking, as they should have done, all necessary steps immediately to warn ships near the danger zone, more especially those that were approaching that zone. . . . In fact, nothing was attempted by the Albanian authorities to prevent the disaster. These grave omissions involve the international responsibility of Albania.⁵⁵

Corfu Channel seems to indicate that a nation who knows of a dangerous condition ought to extend notice of that condition to those who may be harmed by it.

When Stormfury was set up, the United States realized that other nations might be affected by our activities. We established seeding areas in the Atlantic, Caribbean Sea and Gulf of Mexico. Seeding criteria were established that included refraining from seeding storms that on the course and at the speed at the time of seeding would have passed over land within forty-eight hours. Notes to this effect were given by the State Department to countries that might be affected.⁵⁶ During the next few years, the seeding opportunities so limited our activities that we treated only one hurricane. Therefore, the criteria was liberalized so

54. [1949] I.C.J. Rep. 4, 22, 43 Am. J. Int'l L. 558 (1949).

55. *Id.* at 571.

56. Interview with Harry Hawkins, Alternate Director, Project Stormfury, at China Lake, Cal, April 12, 1972. It is difficult to give notice of the actual seeding operations. The planes are airborne before the decision is made in Washington as to whether to seed or not. *Id.*

seeding could take place within twenty-four hours of potential passage over land. That lead to the seeding of Debbie.⁵⁷

Fear of causing damage by hurricane modification efforts, or of being accused of doing so, has been a factor in the proposed move of Stormfury to the Western Pacific. There are fewer nations involved, greater expanses of island-free ocean and twice as many storms as in the present area. The Philippine Republic is anxious for us to move into their area, Japanese cooperation has been secured and the Nationalist Chinese have agreed. With the thaw in relations between the United States and the Peoples Republic of China it is clear that the mainland Chinese should also be considered. Earlier in April of this year, Stormfury personnel were told that the move to the Pacific had been postponed by a directive from the highest level of government.⁵⁸ So for the time being, Stormfury will remain where it is.

What would international law say should the United States suppress a hurricane and thereby deprive Mexico of some rainfall? There are international agreements concerning control by a sovereign over ocean waters and their resources that lie off-shore from its territory.⁵⁹ Stormfury seeding may well take place beyond such an area of control. Other agreements exist which deal with allocation of resources contained in the high seas.⁶⁰ Although these agreements do not deal with a potential resource that would migrate over the land of a country, their concept of conservation of resources might be used in looking at any Mexican claim. The difficulty is that the Americans would assert that they are only incidentally depleting a renewable resource. The aim of storm modification and its real thrust is protection of the human environment.

Other possible analogies which might be considered are the

57. *Id.*

58. *Id.*

A successful precipitation enhancement program conducted in the Philippines with American assistance contributed toward enthusiasm by the Philippine government over weather modification. St.-Amand, Reed, Wright & Elliot, *Gromet II: Rainfall Augmentation in the Philippine Islands* (1971).

59. For discussion of the law regarding off-shore resources, see Brooks, *Deep Sea Manganese Nodules: From Scientific Phenomenon to World Resource*, 8 *N.R. J.* 401 (1968); Friedmann, *Selden Redivivus—Towards A Partition of the Seas?*, 65 *Am. J. Int'l L.* 757 (1971); Murray, *A Discussion of the World Court's North Sea Judgment*, 19 *Am. Univ. L. Rev.* 470 (1970); Pardo, *Development of Ocean Space—An International Dilemma*, 31 *La. L. Rev.* 45 (1970).

60. On fishing and whaling, see Alexander, *National Jurisdiction and the Use of the Sea*, 8 *Natural Resources J.* 373 (1968); Eisenbud, *Understanding the International Fisheries Debate*, 4 *Nat. Resources J.* 19 (1971); Griffis *The Conservation of Whales*, 5 *Cornell Int'l. L. J.* 99 (1972).

agreements concerning ocean pollution⁶¹ and the 1963 Limited Test Ban Treaty.⁶² These agreements deal with adversely affecting the quality of the oceans and the atmosphere. The impact of such activities can be felt by interests on land in countries other than the homeland of those responsible for the harm. Again, the argument would be advanced that the analogy of these instances to hurricane modification is not close enough. An international agreement dealing specifically with high seas severe storm modification is called for.⁶³

CONCLUSION

As this paper has progressed, the law has been looking murkier and murkier. I trust that it has, however, been more effective in illuminating some of the legal problems associated with the transnational effects of weather modification than was the proverbial lighthouse in coping with the fog. The story has been told of an Indian who watched the lighthouse and who penned these lines:

Lighthouse, him no good for fog. Lighthouse, him whistle, him blow, him ring bell, him flash light, him raise hell; but fog come in just the same.⁶⁴

61. For material on pollution of the ocean environment, see Hardy, *International Control of Marine Pollution*, 11 *Natural Resources J.* 296 (1971); Schacter & Server, *Marine Pollution Problems and Remedies*, 6 *J. Am. Int'l L.* 84 (1971).

62. See discussion in Brown, *International Law and Marine Pollution: Radioactive Waste and Other Hazardous Substances*, 11 *Natural Resources J.* 221 (1971).

63. The World Peace Through Law Center, a private organization, has had a draft protocol on weather modification prepared. Samuels, *Draft Protocol on Weather Modification*, World Peace Through Law Center, Pamphlet Series, No. 15.

Senator Pell has introduced a resolution in the Senate which urges the administration to seek treaty arrangements with other nations which would provide for the cessation of research, experimentation and use of weather modification activity as a weapon of war. S. Res. 281, 92nd Cong., 2d Sess. (1972). "Sen. Pell has expressed concern over 'unofficial and unconfirmed' reports that the United States has put its weather modification expertise to use as a weapon of war in Southeast Asia." Purrett, *Weather Modification As A Future Weapon*, 101 *Science News* 254 (1972).

64. Quoted from Prosser, *Lighthouse No Good*, 1 *J. Legal Educ.* 257 (1948).