PROOF OF LEGAL CAUSATION IN WEATHER MODIFICATION LITIGATION: REINBOLD V. SUMNER FARMERS, INC., AND IRVING P. KRICK, INC.

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1. INTRODUCTION

In 1974 there was a "bumper crop" of weather modification litigation. There were only a dozen or so cloud seeding lawsuits tried during the preceeding twenty-five years of artificial weather alteration (Davis, 1974a). Two cases were filled and disposed of in 1974; one case was filed, but has not yet come to a hearing; and another case which had been initiated in 1972 was tried last year. Perhaps no statistical significance can be drawn from moving from an average of one case every two years to four cases in a single year, but happily-employed lawyers and expert witnesses undoubtedly found comfort in the increased volume of litigation. Fortunately for weather modifiers and their insurers, the 1974 crop of cases yielded no defeats.

The year opened with the filing in January of the complaint in Montana Wilderness Association v. Hodel, a case which challenged the issuance of an operational permit for the seeding in the Hungry Horse area of Montana. In the winter the sponsor called off the project because there had been adequate precipitation for the sponsor's needs. In the summer the court dismissed the case as moot because there no longer was any "case or controversy"--a constitutional prerequisite, without which the federal courts could not exercise their jurisdiction.

In May a group of Texans who had opposed issuance of an operating permit for a seeding project in the western part of the state instituted an action designated as Farmers and Ranchers for Natural Weather v. Atmospherics, Inc. In June a hearing was held at Littlefield, Texas on the motion of the plaintiffs for a temporary injunction ordering a halt in the seeding. They argued that, under the position adopted by the Texas courts during litigation in the 1950's, landowners were entitled to whatever precipitation would naturally fall over their property. Experts for the defendants testified that there had been no diminution of precipitation resulting from the seeding; their lawyers argued that passage of regulatory legislation in Texas subsequent to the earlier litigation had superseded the language in those cases and authorized issuance of the permit. The judge ruled for the defendants.

Also, in June, an administrative claim was filed, as a class action with the Department of the Interior, seeking recovery under the Federal

Tort Claims Act for wrongful death and property loss suffered by the victims of the June 9, 1972, Rapid City, South Dakota flood (St.-Amand, Davis and Elliott, 1973). The theory of the action is that employees of the Bureau of Reclamation had contributed to the flooding through their seeding. This case has not yet been processed through the bureaucratic mill. When it is considered, the government obviously will argue that the seeding was done by a contractor or grantee of the Bureau of Reclamation, and that it did not contribute to the flood.

In November a jury trial was held at Caro, Michigan in the case of Reinbold v. Sumner Farmers, Inc. and Irving P. Krick, Inc. The judge ruled against the claim for an injunction; the jury entered a verdict against the plaintiff's claim for damages. Reinbold involved several interesting points. A class action had been initiated originally, and at the November trial there was ample indication that, in the event of a victory by the plaintiff, a long line of his neighbors was waiting to file their own claims. The case was heard by a jury, a rare event in weather modification litigation. Since there is no statute dealing with weather modification in Michigan, the legal rulings were based on common law. And the decision in Reinbold ultimately turned on the issue of legal causation. Although causation has been the key to defense victories in a number of prior weather modification cases (Davis. 1974a), the importance of that issue was more clearly recognized in Reinbold than it had been in most earlier litigation. Both sides focused their testimony on questions concerning legal causation. Future litigants--and it is as certain as death and taxes that there will be future litigation about cloud seeding--can profit from a discussion of the factual and legal setting in which the causation question was considered and an analysis of proof of legal causation in the case.

2. FACTS

The Irving Krick organization first did cloud seeding in Michigan during the 1950's on behalf of the Boyne Mountain ski area. Their work involved providing forecasts and doing snow-making for a rather small target area.

The next contact that the Krick organization had with Michigan was in 1963 when they ran a precipitation enhancement project in the Midland area on behalf of Dow Chemical Company, a client for whom they had done forecast work in Texas. The Midland project was designed to increase streamflow so that the industrial effluent from Dow's operations would be diluted enough to bring Dow within the state pollution control law.

During 1971 and into 1972 there was a drought in Michigan which adversely affected crops. John Baker, the county agricultural extension agent from Gratiot County, recalled the 1963 seeding and traveled to Palm Springs, California to discuss with Dr. Krick the possibility of operating a rainmaking project for central Michigan. After this initial contact, a contract was negotiated between Irving P. Krick, Inc., of Texas, one of five corporations through which Dr. Krick and his associates do business,

and the central Michigan farmers. Sumner Farmers, Inc., an organization of farmers, was a party to the contract as a sponsor of the weather modification project. The target area involved Gratiot, Montcalm, and Isabella counties (Krick, 1972, 1975).

Michael Irwin Reinbold is a thirty-one year old farmer who, along with his father and brother, operates a farm in Almer Township, Tuscola County, Michigan. They own and rent about seven hundred and seventy acres. The county seat, Caro, is southeast of Bay City which is at the tip of Saginaw Bay on Lake Huron. The Reinbold farm is about fifty miles east of the Gratiot County line, the closest part of Krick's target area.

One of the twenty-two ground-based silver iodide generators used in the project was located at Holland, a city near Lake Michigan in the western part of the state. This generator was one hundred forty-five miles from the Reinbold farm. At midnight on July 11, 1972 the Holland generator was turned on. It was operated until eleven o'clock that morning. The AgI output was 0.5 gm/hour. A total of 5.5 grams of AgI was emitted.

Between two and four in the afternoon of July 11 a severe storm with hail and rain together, and accompanied by high winds, struck Tuscola County. According to Mr. Reinbold, on July 11, he saw a strange cloud to the west all by itself. It was small (not like a thunderhead) oval with a little peak, and grey. It was lightning and thundering, so he quit cultivating his fields. The accompanying winds came from all angles and blew water into his house. The excessive precipitation from the storm drowned Reinbold's planting of oats, corn, wheat, sugar beets, beans and soybeans. This greatly reduced his crop yields and as a consequence his 1972 income was reduced below what it would have been had the storm not taken place. Reinbold did recover $2,000 on a wind insurance policy, and he received a federal loan which needed to be only partially repaid. He had no hail insurance in 1972. Overall he calculated his unreimbursed loss from the storm at $37,500.

3. PLAINTIFF'S COMPLAINT

Farmers in Tuscola County were aware of the central Michigan seeding project. There had been accounts about it in the area newspapers, at least one of them learned about it through business contacts in Gratiot County, and a group of them had visited John Baker to complain about the seeding. They got little comfort from him. Their delegation objected because of a storm on June fifth. The seeding for the summer 1972 project did not start until June fourteenth.

Reinbold did some reading in local libraries about cloud seeding, employed Leo Maki of Caro as his attorney, and through him filed a complaint against Sumner Farmers, Inc., and Irving P. Krick, Inc., on November 7, 1972. The complaint was filed in the local Michigan state court, the Circuit Court for the Fortieth Judicial Circuit. It was assigned to Judge James P. Churchill in Tuscola County at Caro, and was given the file number 2734. Reinbold asked for $37,500 in damages, an

injunction against further seeding, and an order declaring the suit to be a class action.

In order to prevail in an action for damages, the plaintiff must allege and prove that (1) he has suffered a loss, (2) the conduct of the defendant caused that loss, and (3) the defendant's conduct constituted a nuisance, amounted to a trespass, was negligent, or was of such a nature that it could be characterized as an ultrahazardous activity and would give rise to strict liability. The first count of Reinbold's complaint alleged the loss, causation, and strict liability. The next three counts alleged nuisance, trespass, and negligence; and each count incorporated by reference the allegations of loss and causation.

Trespass to real property involves intentionally causing something to enter the property. In earlier times trespass did not cover the emission of small particles, such as silver iodide crystals. It did cover throwing water onto the land of another person. There were, of course, no cases dealing with causing rain. Some of the more modern cases have allowed the action for intrusion by air pollutants. Trespass might have been a viable theory in this case (Davis, 1970).

The law of nuisance involves balancing the weight of the plaintiff's interests against those of the defendant. When the defendant acts intentionally (as did Krick), there is substantial harm to the plaintiff's right to the use of his property, and the balance of interests is struck in the plaintiff's favor, the plaintiff will prevail. But in striking that balance the court must consider the value of the seeding project as against the harm from it. The balance, thus, might have been struck in Krick's favor (Davis, 1970).

Negligence is carelessness. To prove negligence Reinbold needed to establish that Krick's conduct fell below the standard of care of his profession. The law requires that persons who hold themselves out to be experts conduct themselves as would other members of the same profession. To win on a negligence count, Reinbold would have to establish that, in the eyes of other experts, Krick's conduct was careless. To do that he would have to introduce such testimony from such experts (Prosser, 1971).

Because the negligence, trespass, and nuisance theories all, to some extent, involve proving fault by a defendant, most plaintiffs would prefer to proceed on an ultrahazardous activity theory which requires no proof of fault. To use such a theory a plaintiff must show that the activity is of an abnormally dangerous nature, something like blasting, operation of an atomic power plant, or fumigation with cyanide. The law of some states specifically rules that weather modification is not an ultrahazardous activity (Ackermann, Changnon, and Davis, 1974; Davis, 1974b). Two state statutes treat cloud seeding as though it is ultrahazardous. Michigan has no statute.

On February 10, 1973, Krick, through his attorney, Richard G. Smith, answered the complaint. Mr. Smith was selected by the Insurance Company of North America which carried legal liability insurance for Irving P.

Krick, Inc. Under the terms of the policy the company had the right and the obligation to defend its policy holder. Mr. Smith, whose office is in Bay City, Michigan, is a former judge. Sumner Farmers, Inc., answered the complaint on February 21st. Their attorney, Jefferson Arnold, was from Gratiot County.

Both answers denied fault and objected to the strict liability theory; both denied causation; and both stated that the plaintiff would have to prove any losses. They objected to the motion to declare a class and to the request for injunctive relief. In one respect their answer differed. Sumner Farmers asserted that, if Krick did cause harm, he was acting apart from any instructions as an independent contractor and that Sumner Farmers had no authority over such acts and would not be responsible for them.

4. APRIL 1973 HEARING

The plaintiff's motion, to enjoin the seeding, asked both for a temporary injunction to cover the time between a summary hearing and a full-dress hearing on the merits and for a permanent injunction to be awarded after the full-dress hearing. This sort of motion is commonplace. In many instances the parties accept the decision in the temporary injunction hearing (or can afford no further litigation expenses), and the lawsuit terminates there. Some weather modification cases have ended in that fashion. Dr. Krick believed after the hearing in this case on the temporary injunction that the plaintiff would pursue the matter no further. Although such was not the case, the importance of this part of the proceedings cannot be overlooked.

In preparation for the hearing, the lawyers began their discovery procedure. Modern trials are no longer conducted like card games in which neither side knows what is in the hand of the other party. Rules of procedure permit the lawyers to take depositions from the parties and to ask interrogatories of them. Mr. Smith took Mr. Reinbold's deposition on April 3, 1973. After the hearing, and before the trial, written interrogatories were asked by the attorneys of both Krick and Reinbold.

The hearing on the temporary injunction was held on April 13, 1973 before Judge Churchill. After hearing the testimony from the parties, he denied the motion for the temporary injunction. He also denied the motion to treat the case as a class action. The consequence of his decisions was to permit the central Michigan project to continue. Although the other farmers (including Reinbold's family) clearly had an interest in the rest of the case and in its outcome; they decided against a class action or joint suit and Reinbold proceeded alone. Had Reinbold won, they could not have automatically recovered; but their chances for successful negotiations with the insurance company would have been very good.

5. NOVEMBER 1974 HEARING

The trial of the case was at one time set for April 1974, but was delayed until November. It took place on six days: Wednesday, November 13 through Friday, November 15, and Tuesday, November 19 through Thursday, November 21. The presiding judge at the trial was Norman A. Baguley of Lapeer, Michigan. Judge Baguley is the other circuit judge in the 40th Judicial Circuit of Michigan. Judge Baguley is a naval aviator. He had not always had happy experiences with forecasters.

In the trial of the Yuba City flood case in California the attorneys for the parties decided to submit their case to a judge, rather than a jury, for his findings of fact. They felt that the technical issues involved in weather modification litigation could not readily be explained to jurors (Mann, 1968). The defendants' constitutional right to a trial by jury was exercised, and at the first day of the trial a jury was selected within a few hours. Six jurors and two alternates were seated. Later one of the alternates was used. Five of the jurors were women; the lone male was a high school principal with an MS degree, who had some knowledge of physics. The women serving were: a librarian, a typist, a retired farm wife, and a business man's wife.

At the trial the major witnesses for the plaintiff were Mr. Reinbold who testified as to the storm and his losses, Bernard DeWitt who was the expert on Michigan weather, and J. Vern Hales who was used to trace the silver iodide plume. Testifying for the defense were Dr. Krick and Dr. Pierre St.-Amand as experts. Other major defense witnesses were John Baker (the Gratiot County extension agent) and William Bigelow (the president of Sumner Farmers, Inc.). They both gave evidence relating to the increase in crop yields resulting from the central Michigan project.

At the conclusion of the testimony, Sumner Farmers moved for a directed verdict in its favor. Since the plaintiff consented to the motion, it was granted. The judge reserved making public his ruling on the motion for a permanent injunction. The case for damages against Irving P. Krick, Inc., was submitted for consideration to the jury. The judge instructed the jury as to the law they were to apply. Although Michigan has been a leader among the states in environmental legislation (Sax, and Conner, 1972), it has no weather modification control law. Two bills were proposed in 1974; neither were passed. Consequently, Judge Baguley based his instructions to the jury on the common law of Michigan. The jury returned a verdict in favor of the defendant, Irving P. Krick, Inc.

On November 21, 1974 formal judgement was entered by the judge on behalf of the defendants. There has been no appeal from the judgement.

6. LAW OF CAUSATION

The prestigious American Law Institute, an organization composed of

leading practicing lawyers, law teachers, and judges, has undertaken to formulate a series of so-called "restatements" of the law. In their Restatement (Second) of the Law of Torts (1965), the members of the Institute have expressed their views as to what American common law requires for proof of causation.

> "In order that a negligent actor shall be liable for another's harm, it is necessary not only that the actor's conduct be negligent toward the other, but also that the negligence of the actor be a legal cause of the other's harm." Sec. 430.
>
> "The actor's negligent conduct is a legal cause of harm to another if (a) his conduct is a substantial factor in bringing about the harm. . ." Sec. 431.
>
> "(T)he actor's negligent conduct is not a substantial factor in bringing about harm to another if the harm would have been sustained even if the actor had not been negligent." Sec. 432 (1).

Thus in the law of negligence there is the requirement that the plaintiff prove that "but for" the defendant's conduct there would have been no injury to the plaintiff. It is also necessary to prove a causal relationship between the injury to the plaintiff and the actions of the defendant when using the ultrahazardous activity, trespass, and nuisance theories of tort liability.

While it is not necessary for the defendant to prove that his activities have not been a substantial factor in the plaintiff's loss, it is usually sound trial tactics for the defendant's lawyer to introduce into evidence testimony that tends to establish that the plaintiff's loss would have happened even if the defendant had done nothing.

In Reinbold the causation question broke down into two issues: (1) Did the silver iodide released at Holland between midnight and eleven in the morning reach the Caro area between two and four in the afternoon? (2) If so, did it effect such a change in the Caro weather that but for the silver iodide particles the severe storm described by Reinbold would not have taken place?

7. ANALYSIS OF PROOF OF CAUSATION

The presentation of technical discussion occupied most of the trial period. Only the general thrust of the arguments is reported here, not necessarily in the order in which the information was presented. Considerable time was spent in examination and cross examination of Mr. Reinbold, neighboring farmers and associates on the severity of the storm and the extent of his losses. We will not dwell on the latter point, but will consider only those factors related to proof of causation.

Mr. Reinbold's description of the storm has already been cited. A

Mr. Jack La Valley, a pilot familiar with meteorology, who owns a farm near the Reinbold place, also described the storm. The hazy, hot day began to cloud up at about 1330. The sky to the west, north and part of the south became overcast. He could tell that they were in for a severe storm. It rained and hailed intermittently. The wind blew. Some of the larger hailstones were of golfball size. A rain gauge was filled with hail to a depth of five or six inches. The hailswath was about 5 by 6 miles in area.

Mr. de Witt, a former Air Force meteorologist and pilot, now a consultant in meteorology and aircraft accident investigation, discussed the storm in the framework of the daily weather forecast and in the climatology of the state. The forecast for the day had held no clue that such a storm might take place, foretold scattered thundershowers with a 10% chance of rain. A book on Climatology of the United States (Visher 1954) was produced to demonstrate that the storm was greater than what would be expected on the basis of climatology. Less than once in a century would one expect to find a rainfall of 3 inches in one storm. The storm in question had filled a five-inch rain gauge to the top. It was not surprising that the storm had not been forecast, because it was so much greater than what one could expect on the basis of climatology that the forecasters would have been constrained from predicting it.

Dr. Krick described his techniques for cloud seeding. On the Michigan project, he had 22 ground-based generators distributed in and around the target area. These generators produce silver iodide particles by eroding silver iodide electrodes with an electric spark; a fan expels the aerosol. Each generator releases one-half gram of silver iodide per hour, yielding some 6×10^{14} particles active as freezing agents, at $-20^{o}C$, per gram of silver iodide. Krick intended that the material take effect 30 to 40-miles downwind of the release point; beyond that distance the concentration of the plume would fall below useful limits. Based upon analysis of current weather information by his staff, located at Palm Springs, California, selected generators are turned on at specified times and turned off at other specified times. The generator locations are chosen so that the silver iodide plumes arrive at such a place and in adequate quantities as to cause the clouds to rain upon the target area. This is a complicated procedure because one must consider the winds at a variety of altitudes, the lifting rate of the air, the contribution from convection and the time required for the clouds to develop rain and for the rain to fall. The intention is to produce a gentle rain from a Bergeron-Findeisen process. The seeding rates are selected to insure augmented rainfall but to avoid spectacular dynamic growth of clouds. Usually no attempt is made to seed isolated clouds; some type of weather system is chosen that will yield rain and the seeding is tied to the arrival of this system over the target area. Evaluation is made by comparing the rainfall, as measured by rain gauges, located outside of the target area with that measured within the target area. No temporal randomization is attempted because it is an operational project and the loss of seeding opportunities would not be justified.

Examination of Dr. Krick as to the probable wind regime and trajectory of the seeding agent was preceded by general questions as to meteorology

and winds. He was asked if upper level winds could approach the ground to altitudes of a few hundred feet. He replied that this was possible. He then was asked about the winds at Holland on the day in question and he replied that the winds would have been from the south to southeast during the night at velocities of 0 to 11 knots. The upper winds were taken from observations at Flint. These observations showed a temperature inversion with base at the ground and top at about 1,000 ft AGL and a wind from 265° at 16 knots at 3,000 ft. MSL.

Krick produced two figures that showed the trajectory of the plume as he and his staff calculated it, Fig. 1. Crucial to Krick's argument was the presence of the temperature inversion. He contended that the wind changed from the southerly flow to the westerly flow at, or above, the inversion top and that the seeding agent was trapped below the inversion until the inversion broke sometime between 1030 and 1100. After that time, the AgI could be moved up and eastward to the limits shown in Figure 1 by 1400. He contended that the plume by that time was being entrapped in a number of small clouds and was being mixed vertically over the target area. Some considerable loss of nuclei was certain to occur by scavenging. The nuclei never got much beyond the boundary shown in Figure 1.

Krick also discussed the surface weather map for the day. The map for 0700 local time shows that warm moist air from the Gulf of Mexico and from the Atlantic was being carried northward and northeastward by the surface winds across the Plains States and on up into Canada. Many of the reporting stations, all the way from the Gulf Coast, were showing overcast or partially cloudy skies at 0700. The upper level winds, at 500 mb were out of the west at about 20 to 30 knots. A temperature inversion was widespread over the Michigan Peninsula; the area around Holland was covered by stratus clouds. The radiosonde data indicated that, once the inversion broke, convection was possible to altitudes as great as 45- to 50-thousand feet; the maximum temperature for the day was between 85°F and 90°F, amply warm to start the convection.

Radar maps were produced that showed the development of clouds over a large part of the eastern and central United States during the day. The storm over Almer Township was clearly visible as were a large number of clouds with tops adequately high to produce heavy rain and hail. No large clouds were noted in the space between Holland and Almer Township. The large clouds reported by the radar were scattered over the central United States as far west as the Rocky Mountains. The cloud over Almer Township appears to have been a member of a set of clouds that caused a good deal of trouble over most of southern Michigan on that day.

Dr. J. Vern Hales discussed the plume trajectory as he calculated it, Figure 1. His calculations were quite detailed up to 0800 hours. Dr. Hales made his calculations according to the techniques set forth in Turner's workbook (Turner, 1969). for describing plumes from chimneys and similar sources. The theory on which this technique is based considers the plume to be a distribution of material describable by two normal Gaussian distributions, one vertical and one horizontal. The rate at which the plume spreads, at several standard deviations from the center, is about

1,000 ft. per hour. Hales calculated the fraction of the agent to be found above 200 ft and 500 ft above the ground. He did this until 0800 and then assumed that the westerly winds carried the seeding agent to the east. He contended that the winds could have been blowing at this speed and in this direction at some altitude between 200 and 500 ft. AGL, on the basis of testimony by Krick that such a thing was possible. The plume emitted up until 0800 would, according to Hales, have arrived at the Reinbold farm right on schedule to be ingested into the storm cloud.

Dr. Hales estimated that the concentration of AgI particles arriving at the Reinbold farm would have been from 390 to 2,800 particles per cubic meter of air at cloud base and diluted by motion through the cloud mass the concentration would be between 32 and 92 per cubic meter of cloud.

Dr. Hales was asked if he had an opinion as to whether this concentration of nuclei would cause increased precipitation at the Reinbold farm. At this point a discussion as to his qualifications as a weather modifier was launched by Attorney Smith. Dr. Hales has a doctoral degree in meteorology, has practiced meteorology professionally, has taught meteorology and cloud physics at the graduate level and has once worked with clearing supercooled fog at airorts in Utah. He had also made a critique of an early project by Dr. Krick in Utah and had served as a consultant to the President's Advisory Committee on weather control in the mid-fifties. He had never actually conducted a rain augmentation program but had kept in close touch with publications on the subject and with friends throughout the world who were experts in the field.

Mr. Smith then objected to Dr. Hales qualifications on the basis of lack of practical experience in the area of weather modification. He was overruled by Judge Baguley.

Dr. Hales then said, "Well, my opinion is that there is a preponderance of evidence that the Krick silver iodide contributed to the violence of the storm". The presence of the silver iodide may well have caused small clouds to become big ones and start the storm. The very paucity of silver iodide nuclei might have been responsible for making the hail worse. Freezing the clouds would have released 13% more energy. The very fact that the storm was so severe was evidence that it was not natural and that the probability of it occurring naturally compared to the probability that the silver iodide made it so fierce, caused him to think that Krick's silver iodide was indeed responsible.

Subsequently, the Summary Report on Weather Modification for Fiscal Years 1969, 1970, 1971, prepared by the Department of Commerce, was cited as authority that the Krick AgI might have made the hail worse. The discussion on page 53 said: "The number of hail embryos introduced is very critical; too few might actually produce more large hailstones and increase hail damage".

Upon further examination, Krick averred that he had been asked a general question about the gradual transition of upper level winds to those at lower levels, that he had indeed pointed out that it was possible to have a uniform gradient in wind velocity with, of course, changes in direction caused by frictional forces at the surface. He emphasized,

however, that he was not then speaking of the conditions over Michigan on 11 July 1972, or of conditions in the presence of an inversion, because he was not then answering that question. Winds often change direction and velocity at the top of an inversion. It is not common for a gradual change in either velocity or direction with altitude to occur when an inversion is present. Therefore, he contended that his version of the plume trajectory was more correct than that of Dr. Hales, Indeed, had he wanted to seed the clouds over Almer Township on that day, he would have turned on a generator at Clio, see Figure 1.

During the examination of several witnesses, excerpts from the Storm Data and Unusual Weather Phenomena reports prepared by the National Weather Service were read into the record. These showed clearly that storms of that magnitude had occurred in a number of places in Michigan over a period of years before and after the event and that on one or two occasions, the amount of hail and rain dropped exceeded that of the storm of 11 July 1972. On 16 July 1972, for example, crop damage was estimated at over 1/2-million dollars in Bay County. Hail ranging from pea-size to one and one-half inches in diameter and to golfball size, caused damage in southeast Midland, west central Bay, Northern Saginaw and central Tuscola counties. The largest single loss was in Tuscola County where a 3-mile wide, 20-mile long strip of hail reached up to 6-inches in depth, closed roads and broke many windows in homes. Grains, beets, corn and beans all suffered damage from the hail. There were no cloud seeding operations in Michigan on that day.

Dr. St.-Amand was asked to give a short discussion of how clouds developed and how weather modification worked. Water condenses upon particles in the atmosphere and cloud droplets form at altitudes equal to or greater than the level of condensation. These particles were less numerous over the ocean away from land and very numerous over continental areas. Water did not freeze unless some particles that resembled ice were present in the air to cause it to freeze. Such materials exist naturally, again these nuclei were scarce in maritime air and quite abundant over the continents. These consisted of mineral material such as some clays, effluvia from manufacturing processes, exhaust from engines, steel mills, foundries, etc. Most of these agents cause water to freeze at temperatures below, say, -10 or -12 degrees Centigrade. Most any solid material would cause water to freeze at some temperature, but the advantage of silver iodide was that it would work at -3 or -4 degree C, some 3- or 4-thousand feet lower in the cloud than would the natural materials. This gives a considerable advantage to those wishing to invoke the freezing process in clouds with tops too low to glaciate naturally, but would make only a trivial difference in tall continental clouds with high updraft velocities that have already attained full growth. Thus, smaller clouds can be made to grow by release of heat of fusion and additional head of condensation. The nuclei normally present in the air would outnumber the nuclei put into the clouds by a process such as Krick's. The contribution to cloud growth by the doses used by Krick were not of much importance. On the other hand, marginal clouds could be made to yield additional rainfall by introducing snowflakes that would grow more rapidly than unfrozen drops and would serve to start a collision-coalescence process.

Asked about the plume tracing he pointed out that Turner's handbook, page 7, had a caveat against extending the techniques expressed in the book beyond a kilometer or two and hence extrapolation to the order of 200 kilometers was not justified. The inversion would trap the material below it, as indeed the handbook specified, and that until inversion broke, transport to the east was not likely. Of the two versions of the plume, that by Dr. Krick seemed more reasonable, but the situation was more complicated than either proponent had indicated.

Turbulence caused by convection, on a scale larger than that upon which Turner's treatment was based, would cause more rapid lateral and vertical dispersion of the plume, than Turner's method would indicate. Small clouds would have ingested a good deal of it, have scavenged some into drops, dissolved much of that material, and upon evaporation of the drops would have left the material in a colloidal size too small to cause freezing at any useful temperature. Moreover, 90% of Krick's material would have been dissolved in drops of the size found in updraft cores of large thunderstorms, leaving only 10% that would be effective at all. Thus the calculation showing the concentration of the plume at the Reinbold farm would have to take account of the activity of the nuclei as a function of temperature. If this were done, the number of particles to be considered would be small indeed, and in a cloud of that type would have added only a minute amount of freezing to that which was produced by natural nuclei. It was not possible, given the information used, to make an accurate estimate of the concentration of AgI particles over Almer Township. It was unlikely that any had arrived by the time the storm was well developed. Even if the particles produced by Krick's generator had arrived there in time to be ingested into the storm, the numbers would have been so few in comparison to the numbers of natural nuclei not produced by Krick, that no effect measurable in any way, or even detectable, would have been produced. The statement in the NOAA Summary Report had been taken out of context, a fuller discussion which might have led to the opposite conclusion was available on the following page, the document was not a scientific dissertation on the amelioration of hail and therefore should not be taken seriously. In no case with which he was familiar had seeding of clouds ever resulted in increased hail. The hypothesis that the storm was unnatural was untenable; many such storms had occurred in Michigan and elsewhere and indeed would, on that day, have been expectable on the basis of the sounding and the weather maps.

Ancillary to the main arguments about causation was testimony as to the effectiveness of Krick's operation at making rain. Dr. Hales expressed the opinion that the project was not well designed. Mr. W. Bigelow, one of the farmers, and the Gratiot County Agricultural Extension Agent, Mr. John Baker, testified that they felt the project was worthwhile because the agricultural yield from the area had just about doubled in the years that Krick had been seeding. The economic benefits were great enough to encourage them to continue with the work. Dr. St.-Amand said that in comparison to other projects operated elsewhere, that the standards of care and the quality of the techniques were quite acceptable. From the point of view of safety, the techniques that Krick used were far more conservative than what was customarily done elsewhere without untoward results.

Some inquiry into a longstanding disagreement between Krick and Hales was pursued, involving a report prepared by Hales concerning cloud seeding done by Krick in Utah in the mid-fifties, to augment winter rainfall and snowpack, using a method similar to that which he uses in Michigan. Krick had judged his results on the basis of measurements from snow courses, rain gauges and streamflow. Hales had prepared his report on the basis of rain gauges. These were so located that much of the precipitation that might have arisen from seeding might not have been detected. The seeding by Krick was stopped, but since then, weather modification has been carried on by others over a large part of the state, using techniques similar to those used by Krick, with apparently satisfactory results. The matter was never resolved; this affair has been cited as evidence of controversy concerning cloud seeding.

ANALYSIS OF THE TESTIMONY:

It was necessary, to prove the case for causation, to show that Krick had actually seeded the clouds, inadvertently or otherwise, over the Reinbold farm and that, but for his seeding agent, the cloud would not have been as fierce. In order to demonstrate that the cloud was, indeed, extraordinarily destructive, and therefore unnatural, and hence the result of interference with natural processes by the defendant, the testimony based on climatology was invoked. The tracing of the plume with the object of showing that the material had arrived at the farm in time to start the storm was necessary. Some mechanisms relating the hailfall to the ingestion, by the cloud. of Dr. Krick's silver iodide was necessary.

The defense took the point of view that the storm was a natural event. Such storms had occurred before Dr. Krick began to seed clouds, occurred when he was not seeding and would likely occur in the future.

That the storm was natural seemed in little doubt in view of: the weather maps and soundings that showed the potential for such storms was present; and of the radar maps that showed that thunderstorms did indeed occur in places where Krick's agent could not have been reasonably expected to be. The Severe Weather Reports listed enough storms within the preceding few years to indicate that the climatology book cited did not reflect that true condition of the present climate in Michigan, at least insofar as applied to local, severe, summer storms.

The seeding agent did not reach the Reinbold farm at all; if it did reach it, it did not do so in time to affect the cloud; if it had reached it in time to affect the cloud it was too dilute to do so; it had no effect whatsoever upon the cloud, but that if there were any effect it would have been to ameliorate the storm by reducing the hail, although even that was extremely unlikely.

The plume calculated by Hales, up to 0800 hours, was similar to Krick's version because it was based on lower level winds derived from Krick's testimony. These winds, although not of impressive accuracy, near the ground over the whole of the trajectory, were probably as close as could be had. The higher level winds were based on actual observation. These

winds gave Dr. Hales a solution that fitted his needs rather well if he were permitted to begin an eastward movement at 0800. Under this condition enough material had accumulated to the north of Holland to make a reasonable number of nuclei available. Had they begun to move eastward earlier, asindeed would be expected if Hales were correct in his assumption as to the vertical distribution of the wind, part of them would have blown well past the Reinbold farm and they would have been even more dilute. Had they started eastward later, they would not have arrived in time. By accepting the lower level winds as Krick predicated them, the plaintiff gave up the opportunity to dispute the wind data.

The only trouble with Hales' solution was that the temperature inversion did not break soon enough. Hales is an expert on inversions, and has done considerable research on them, his own clear explanation of inversions to the jury made it clear that the material had to be retained below the inversion. The matter of whether the wind changed smoothly and continuously with altitude was the key to the possibility of having the material begin its eastward hegira at 0800. It is well known that winds do not as a rule do this and that there is generally a discontinuity in both speed and direction at or above an inversion top rather than beneath it, although wind changes are, of course, possible at any altitude.

One of the more effective exhibits in the trial was the display of a small vial containing 5.0 grams of silver iodide, approximately the total output from the Holland generator between midnight and 1100 on 11 July 1972. One-fifth of an ounce of a dense, fuzzy, yellow powder did not appear to a scientific laymen to be very impressive, and only by the wildest stretch of imagination could anyone have been convinced that this specimen could have caused a hailstorm, much less done anything else of importance.

The evidence on causation broke down in that it was not at all clear that the plume had reached the farm. The numbers of nuclei were below that encountered in nature. The windspread nature of hailstorms on that day and the lack of a sound and credible theory for the causation of hail by the material were serious bars to establishment of causation.

The testimony as to the effectiveness of Krick's cloud seeding was not germane to the issue of causation but was directed toward the question of whether an injunction should have been issued. The farmers and the farm agent were so enthusiastic in expressing their opinions as to the economic benefit that little doubt was left as to the desirability for continuing the work.

8. CONCLUSIONS

From this recital it is possible to draw several conclusions. The first is that causation will be a key issue in any weather modification litigation in which the plaintiff seeks recovery of damages for his losses. A defendant can win such a lawsuit by prevailing on that point alone.

A second conclusion is that even though testimony from nonexperts in meteorology is admissible (American Law Reports, 1974b), the use of expert testimony is essential for the defendant. Testimony from persons

who are expert in the specific matters for which their testimony has been sought is most persuasive to jurors as well as to judges. These expert witnesses should neither "talk down" to jurors, nor should they use technical jargon which is unfamiliar to the average lay person.

Official records and written reports are also admissible in evidence and can be considered by a jury (American Law Reports 1974a). Cloud seeders would do well to reflect upon the fact that their prior assertions of effectiveness can and will be used against them by litigants. Through use of the pre-trial discovery process, lawyers can obtain copies of all records and reports applicable to activities in questions (Davis, 1968). One of the more troublesome issues is that material published anywhere in the literature, scientific or otherwise, can be introduced. A great deal of older information may not be applicable and published reports prepared by committees and others called in to assess the state-of-the-art may be invoked. This latter material is rarely sound enough or exact enough to be used reliably, but it could be difficult to convince a judge or jury that such information were not of the same quality as a revelation from the Almighty, especially if the authors are not available for cross-examination. Carelessly done scientific work, by the defendant, or by others, may be very damning. No good scientist should have to be reminded that he should be very precise in what he says and be quite sure of his information. The degree of review and criticism given by the scientific community to the work of its members is as naught compared to the intense scrutiny of an attorney whose client may have a great deal to lose or gain. Only the facts developed in the course of a trial may be used in considering the verdict--if one side does not develop the information in court it is not considered.

Perhaps a warning sounded by James Russell Lowell is in order: "Don't ever prophesy--unless you know." And to that might be added: "Don't ever state a 'fact' in a record or report--unless you are prepared to live with that 'fact'--as part of the proof of legal causation in weather modification litigation." It pays to remember that the Devil can quote scripture.

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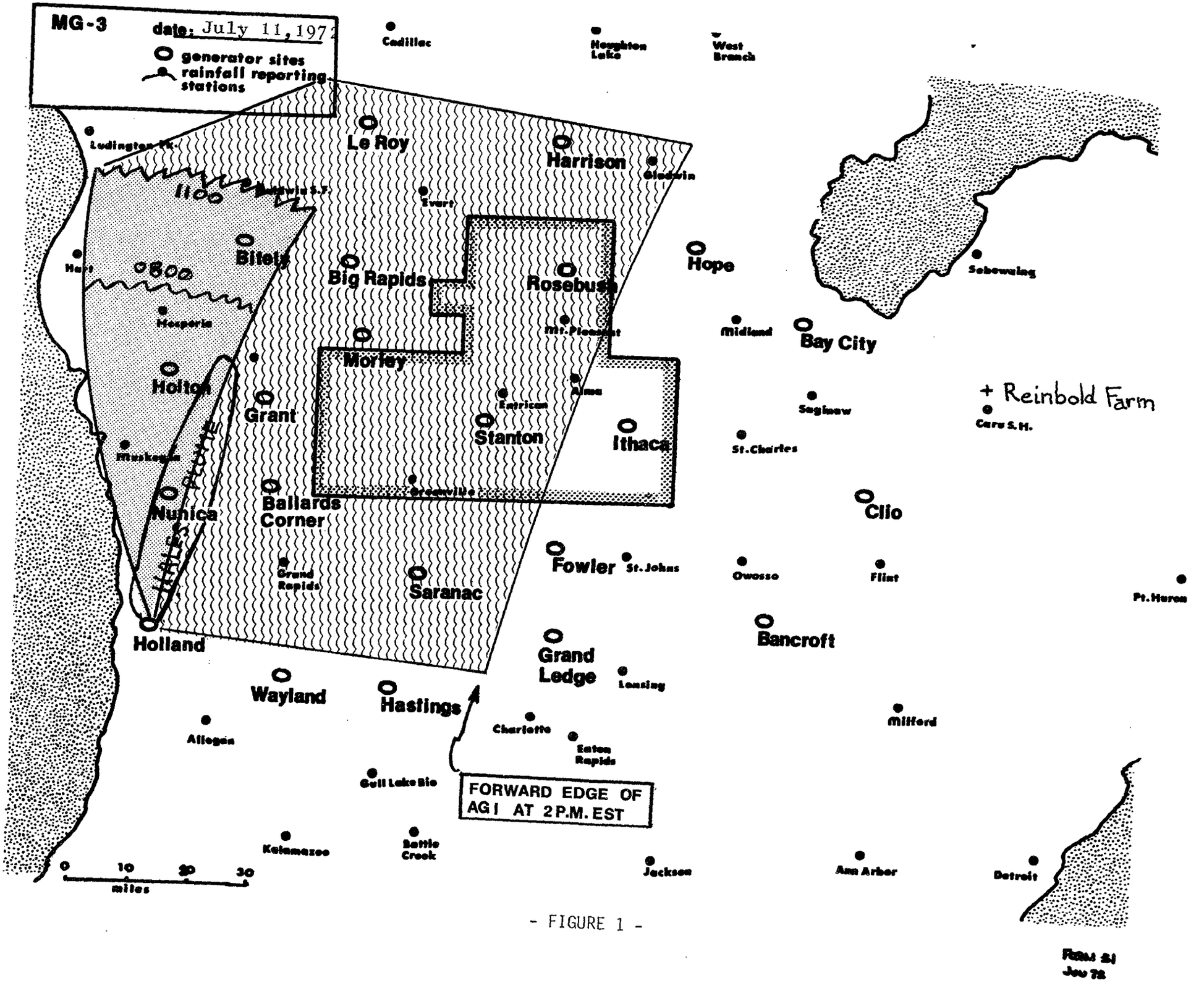
MG-3
date: July 11, 1972
generator sites
rainfall reporting stations
Cadillac
Houghton Lake
West Branch
Ludington PK.
Le Roy
Harrison
Gladwin
Evart
Hart
Bitely
Big Rapids
Rosebush
Hope
Sebewaing
Hesperia
Mt. Pleasant
Midland
Bay City
Morley
Holton
Alma
Grant
Entrican
Saginew
Stanton
Ithaca
Muskegon
St. Charles
Greenville
Nunica
Ballards Corner
Clio
Fowler
St. Johns
Owosso
Flint
Pt. Huron
Grand Rapids
Saranac
Holland
Bancroft
Grand Ledge
Lansing
Wayland
Hastings
Milford
Charlotte
Allegan
Eaton Rapids
Gull Lake Bio
FORWARD EDGE OF AG I AT 2 P.M. EST
Kalamazoo
Battle Creek
Jackson
Ann Arbor
Detroit
0 10 20 30
miles
+ Reinbold Farm
Caro S. H.

- FIGURE 1 -

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FIGURE 1

- CAPTION -

Composite drawing of the plumes of silver iodide as calculated by Dr. Hales and by Dr. Krick. Krick estimated that the material would be carried northward and slightly to the west because of an offshore component of wind near the lake (dotted overlay). The extent of the plume at 0800 and at 1100 are shown in smaller dots. He estimated that by 1030 or 1100, the plume would no longer be constrained by the inversion, would begin to move easterly under the influence of a wind from 265°, and would have reached the eastern boundary shown by 1400. Dr. Hales' plume was calculated only until 0800, at which time, by his calculations, 76% would have been above 200 feet AGL and 45% would have been above 500 feet AGL. The winds somewhere between these altitudes would have been blowing from 265°, according to his hypotheses, and would have arrived over the Reinbold farm (shown with a +) at just about 1400.

Lack of detailed winds aloft, below the top of the inversion, makes the choice between the two treatments dependent upon the concepts that the material is trapped below the base of the inversion and that the lower level winds do not change smoothly and gradually with height in the presence of the inversion. Hales assumed that the material was transported easterly once it reached some altitude between 200 and 500 feet, based on unimpeded vertical diffusion of a Gaussian plume. Krick contended that the material was confined below the base of the inversion and rose as the base of the inversion rose. Detailed knowledge of the behavior of the inversion base prevented more detailed calculation of the vertical distribution until the inversion disappeared.