The application of modern environmental systems methods to the resolution of environmental controversy in the courtroom and the scientific literature has stimulated interest in applying the methods of general systems science to consideration of the environmental impact of such other toxicants as radionuclides, mercury and the polychlorinated biphenyls (PCBs).

§8.40 The Project Rulison Litigation[13]

During the summer of 1969, individuals supported by the American Civil Liberties Union commenced an action against the Atomic Energy Commission to prevent the detonation of a nuclear device in an underground natural gas stimulation experiment called *Project Rulison,* a part of the Atomic Energy Commission *Plowshare* Program to encourage the peaceful use of nuclear devices.

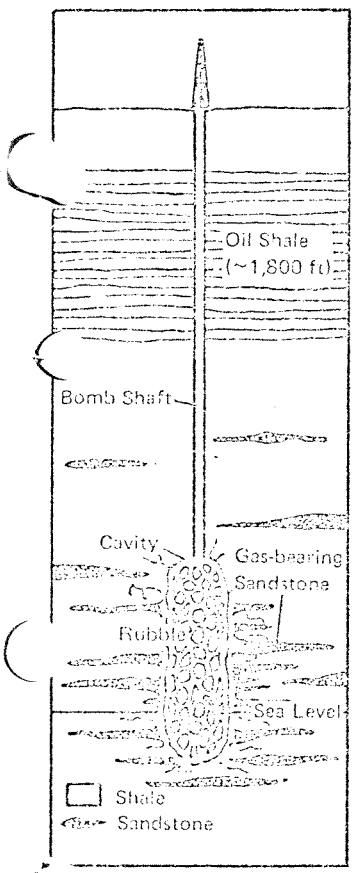
Project Rulison was a low-level underground nuclear explosion to be detonated in Western Colorado more than a mile below the surface. The purpose of the test was to study the commercial feasibility of releasing natural gas trapped in sand and shale lenses of low permeability and discontinuities that would be uneconomical to develop with conventional fracturing techniques. The nuclear explosion would create a subsurface cavity into which natural gas would flow and be pumped out. Six months after the nuclear blast, the Atomic Energy Commission intended to begin measuring the amount of gas collected in the cavity as a result of the nuclear explosion by "flaring"—burning the radioactive gas at the surface well head.

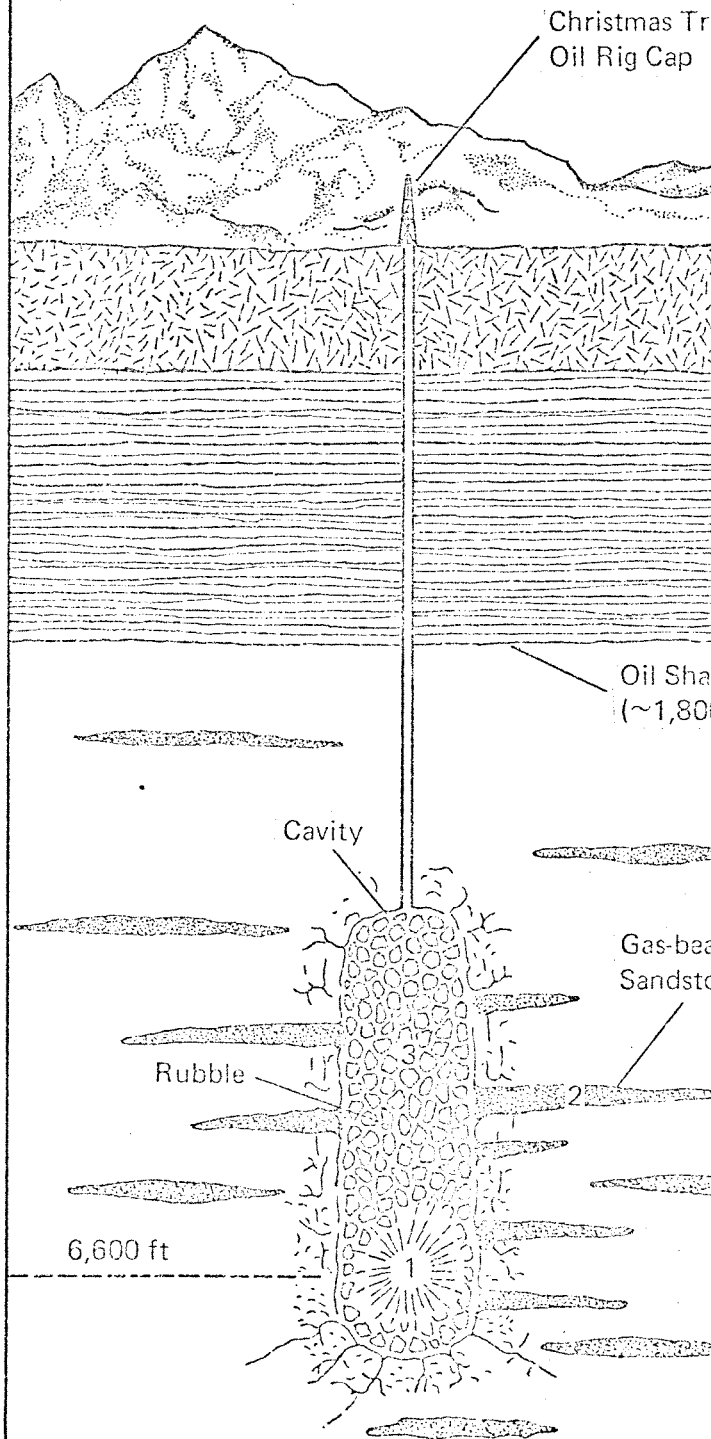
§8.41 The Project Rulison Complaints. *Project Rulison* provided the first direct confrontation among the several current theories urged in support of citizen action to protect the environment from the operations of federal agencies. Three separate suits were filed. In the first action, supported by the American Civil Liberties Union, individual property owners and residents near the site, relied on conventional legal theories to establish standing. Their complaint alleged that the underground nuclear detonation would infringe the rights of the plaintiffs and those similarly situated under the *due process* clause of the Fifth Amendment of the United States Constitution; that the detonation had not been authorized by Congress; that the Atomic Energy Commission was

exceeding its statutory authority; and that the explosion would create a nuisance. Individual plaintiffs alleged direct, personal, private injury and special damage, and sought injunctive relief to protect their personal property rights. The ACLU supported action sought to restrain detonation of the underground nuclear device as its principal request for relief, and the ACLU application for a temporary restraining order had already been denied when a second action was filed by the Colorado Open Space Coordinating Council. The title of that action in itself indicates the contrast in theories.

> COLORADO OPEN SPACE COORDINATING COUNCIL, on behalf of all those entitled to the protection of their health and safety and of the health and safety of those generations yet unborn, from the hazards of ionizing radiation resulting from the distribution of radioactive materials through the permanent biogeochemical cycles of the

Author Vanarone





Biosphere as a result of the defendants conduct of *Project Rulison,* and
on behalf of all those entitled to the full benefit, use and enjoyment of the national, natural resource treasures of the State of Colorado without degradation resulting from contamination with radioactive material released as a result of the defendants conduct of *Project Rulison,* and all others similarly situated,

Plaintiffs,

—against—

AUSTRAL OIL COMPANY, INCORPORATED and CER GEONUCLEAR CORPORATION,

Defendants

U.S. ATOMIC ENERGY COMMISSION, BUREAU OF MINES, U.S. DEPARTMENT OF INTERIOR, and LOS ALAMOS SCIENTIFIC LABORATORY,

as their several interests may appear

The shift in emphasis in the Colorado Open Space Coordinating Council (COSCC) action from an emotional outcry against the the underground nuclear blast itself to a reasoned demand for care in the release of radionuclides to the environment led to a Court order restraining the "flaring" of the radioactive natural gas following the blast until the hearing and determination of the action brought by COSCC. By amending their complaint, the ACLU, on behalf of Crowther and the other individuals concerned personally with the blast, remained in the action. Subsequently, the District Attorney of the Ninth Judicial District of the state of Colorado attempted to bring an action in the state court on a public nuisance theory, but that action was summarily transferred to the U.S. District Court and consolidated with the COSCC and ACLU actions at the request of the Atomic Energy Commission. The action filed by COSCC was a class action on behalf of those present and future generations entitled to protection from the hazards of ionizing radiation that might result from Project Rulison. The COSCC complaint asserted that the release of any radioactive material into the environment would violate the rights retained by the People under the Ninth Amendment of the United States Constitution and protected under

the *due process* and *equal protection* clauses of the Fifth Amendment of the United States Constitution—rights to the full benefit, use, and enjoyment of the natural resources of Colorado free from radionuclide contamination resulting from Project Rulison. The COSCC complaint alleged that the defendants had not demonstrated to the plaintiffs or the environmental science community any evidence as to the environmental impact of Project Rulison (the Project Rulison litigation was brought before the National Environmental Policy Act) and that the release of certain radionuclides as a result of Project Rulison would cause serious, permanent, and irreparable damage to the natural resources of the State of Colorado and represent a threat to the life and property of the people of the State of Colorado. COSCC claimed that adequate administrative remedies did not exist and there was no adequate remedy at law. The COSCC complaint asked for a temporary restraining order preventing detonation of the nuclear device until the defendants had "shown good cause supported by substantial evidence" that the detonation would not contaminate the environment with radionuclides or pose a hazard to the health and safety of present and future generations of the people of the State of Colorado.

As in the litigation against DDT, the COSCC complaint alleged that after release from the underground chamber, the radionuclides, in particular tritium, would follow complex pathways throughout the Regional Ecological System and could ultimately result in serious, permanent, and irreparable damage to the natural resources and environment of the Regional Ecological System and represent a threat to the public health, safety, and welfare of the people residing in the Regional Ecological System. Proving the allegations of the complaint would require systems methods. Trial began 12 January, 1970, in the United States District Court in Denver before Judge A. A. Araaj.

§8.42 SYSTEMS MODELS FOR REGIONAL IMPACT ANALYSIS. The initial step in the action by COSCC to prevent the proposed release of radionuclides from Project Rulison was to describe the interacting physical and biological processes and material transport systems comprising the area described in the complaint as the Colorado Regional Ecological System. The Atomic Energy Com-

mission had already carried out some systems studies as part of its safety evaluation program and the central issue of the litigation became the adequacy of the Atomic Energy Commission system model and the analysis and evaluation of the hazards which depended upon that model.

Prior to presenting testimony from Dr. Loucks as to the inadequacy of the systems methods utilized by the Atomic Energy Commission, it was necessary to carefully define the entire effort of the Atomic Energy Commission, its consultants and contractors in the area of environmental concern, in order to provide the expert witnesses and attorney for COSCC with something definite in the record to criticize, while at the same time limiting the extent of AEC rebuttal testimony. Of course, there is little likelihood that any responsible court will declare any reputable scientist a hostile witness in the absence of outright advocacy by the witness, even where the expert is an employee of or consultant to one of the parties to the action. This reluctance to declare expert witnesses hostile witnesses is most evident where the witness is a University Professor acting as a consultant to a government agency. The attorney who is faced with challenging the determination of a federal agency supported by demonstrably competent scientific evidence must assume that any recognized authority on the specific subject matter of the litigation is probably an employee of, or a consultant to, the agency involved in the determination. Attempting to challenge an agency determination on the grounds that it is not supported by a fair preponderance of the substantial credible scientific evidence without calling the agency experts first for the purpose of defining the extent of their competence and testimony is to risk substantial, permanent, and probably irreparable damage to the scientific reputation of the scientific witness who has the temerity to oppose the opinions of his scientific peers who are obviously more knowledgeable on the specific matter in question because of their selection by the government agency as "independent" experts or consultants.

In the Project Rulison litigation, this difficulty was overcome by counsel for COSCC first calling the ecologist responsible for the preliminary determination that there would be no ecological damage from the Project and then calling the scientist who acted as the consultant and independent authority for the scientific conclu-

sion relied upon by the Atomic Energy Commission that there would be no ecological damage from Project Rulison at the time of the blast or thereafter. Even at the risk of overqualifying the agency expert, counsel must elicit all the relevant qualifications of the Agency expert prior to calling any opposing expert.

THE WITNESS: [Dr.] Vincent Schultz... Pulman, Washington Professor of Zoology, Washington State University.

DIRECT EXAMINATION OF AEC EXPERT

Q. And [what] particular academic discipline [do] you now specialize in?

A. Radiation ecology, statistical ecology, and population dynamics.

MR. EARDLEY: I will stipulate to his qualifications.
MR. YANNACONE: As what?
DR. SCHULTZ Why don't we just say ecology, for the record, if you like.

Q. In the course of your regular professional activities have you had occasion to investigate and evaluate ecological studies specifically in connection with the operation of the Nevada Operations Office [of the Atomic Energy Commission] as set forth in NVO No. 40, Revision No. 2?

A. You're throwing numbers at me. Now, if you're asking whether I have had the opportunity to evaluate ecologically the Nevada research test site and [sites] all over the United States, the answer is yes.

Q. Fine. Now, in the course of your regular activities as such, have you been an employee of or consultant to the Atomic Energy Commission?

A. The answer is also yes and no. For six and a half years I was ecologist with the Atomic Energy Commission, the Division of Biology and Medicine, Environmental Science Branch....

Q. Now, Doctor, in the course of your regular professional activities have you had occasion to see this bulletin—, [the Project

Rulison Postshot Plans and Evaluation?]

A. Yes.

Q. Have you had occasion to specifically review Appendix B, "Biological Considerations"?

A. Yes, sir.

Q. Have you had occasion to look at the portions which deal with the meteorological and the atmospheric monitoring?

A. I have read the entire report.

Q. And are you satisfied that this report fairly and accurately represents the entire substance of the work that will ultimately be used to evaluate the ecological effects of Project Rulison?

A. What ecological effects are we talking about?

Q. That's what I was about to ask you.

A. If you have read the last page, you will see that I stated that "there will be no ecological effect from Project Rulison."

Q. Okay. And in quotation marks it says, "Panel concluded that, 'ecological effects in the natural environment, distinguished from that of man and his domestic species, are not anticipated, e.g., on the population and their winter ranges,'" is that correct?

A. Yes, sir.

Q. Now, Doctor, would you please, for the record, so we will have a frame of reference, tell us what you as an ecologist for the Atomic Energy Commission consider ecological effects?

A. Well, I would say an ecological effect is a time effect.... I can probably explain it better with a little example: one in which we consider effects on the structure and functions of an ecosystem. Do you understand what we mean by an ecosystem?

Q. You tell us what the AEC considers it [to mean].

A. I didn't know whether you wanted every word defined in [my] presentation or not. But the AEC considers—whoever

the AEC is—I consider it the sum total of the physical and biological components and environment, [and by ecological effects]... I would say non-repairable effects, if you want it in laymen's terms.... If for example there was an accident of some type, and I'm not referring to Rulison, [and] half of a deer population was destroyed. As a result of the biotic potential [of the] species and what we know about deer, there would not be an ecological effect. This population would come back to, quote, normal, if you like. Changes in successional patterns [such as], say, up at Woodwell's, [who] has been involved with this [on] Long Island [at] Brookhaven National Laboratory, would be an ecological effect. If one leaf were killed this would not be an ecological effect in my definition.

Q. **And is it your considered professional opinion, then, without any testing or any further research, that the flaring of the tritium in the form of tritiated water [vapor] from the Project Rulison cavity and its release into the Rulison regional transport systems will produce no ecological effects.**

A. Yes, sir. If I may comment on this, I very rarely make definite statements, as I am trained also as a statistician, and I doubt very many ecologists do, but I am so positive about this situation that I made it, and it is, oh, probably only the second positive statement I have made since I got married when I said, "I do," to the minister.

Q. **Doctor, what is it about the environmental characteristics of tritium in the region of Project Rulison that enables you to achieve this degree of positiveness in your statement?**

A. Well, I believe, first, one reason, because of the safety procedures that the AEC is involved with. You want to consider an accident case or—

Q. **No, I want to consider the sustained release of tritium.**

A. I say this on the basis [of] the levels we are dealing with as far as tritium is concerned, extensive knowledge of radiation studies that have been done on effects on ecosystems [and] on individual species have shown that fairly high levels are needed to have any ecological effects, and we are not dealing

with that ballpark figure at Rulison, if I can assume that the figures that were given to me are correct, and I do.

Q. This is what we would like in the record now. What figures were given you?

A. Well, 10,000 curies I believe was the latest, the accident, if the total amount came out, 10,000 curies.

Q. In other words, it is your considered professional ecological opinion that even if you released 10,000 curies, or 94 percent of that, [which is what] I think the maximum possible probable accident [is supposed to be], this would have no ecological effect on the regional transport systems as you understand them?

A. In the region, yes, sir. Now, we are not talking about on a square meter of ground, obviously. You have to talk about the deposition pattern and a few other things before you can draw a conclusion.

Q. Have all these been considered?

A. Yes, sir.

Q. And are they all included in this exhibit,...

A. Oh, absolutely not.

Q. Then where do you find them when you look for them?

* * *

A. Not in there. You want to talk about ecological [effects]? There have only been a few studies that have been involved with tritium, and they haven't been published, but we are talking about a pollutant in the environment... ionizing radiation. There are a lot of studies with gamma radiation, as you are probably aware, and they have not done any specifically with tritium. You don't look at every single isotope in the world to understand principles in ecology and effects of pollutants. You would never get through in my general opinion.

Q. In other words, you're basing your opinion on extrapolation from studies based on transport systems and considerations of isotopes that have been studied, such as Cesium-137.

A. No, not entirely, we have a report by Rhoades, Platt, *et al.* They were probably seeing effects on ...sagebrush, at six to eight hundred rads, and we are not talking about those types of figures in this situation.

Q. Is there any study that you can point to with respect to the evaluation of the transport systems for tritium in any complete regional transport system?

A. Talking about entire ecosystems?...The answer is no.

Q. There are some rather complete studies, are there not, published by the Atomic Energy Commission or sponsored by the Atomic Energy Commission, with respect to the transport of certain nutrients and certain radioisotopes throughout entire ecosystems?

A. [In] my general opinion as a scientist, through the entire ecosystem you are asking for something maybe only God could do. [But] within reason, there have been some fairly definitive studies on transport through an ecosystem of cesium.

Q. And from these studies, are you able to evaluate transport characteristics for the entire system?

A. No, not entirely. One can't base all conclusions on specific studies. I often tell my students there is no substitute for biological innovation, know-how, and common sense, and that's involved in this situation, also. That's a quote, incidentally, from Simm and Row, and I don't want to steal it.

MR. YANNACONE: Thank you. You are excused.

DIRECT EXAMINATION OF PLAINTIFF'S EXPERT:

A. ...Orie Loucks...Madison, Wisconsin....I'm Professor of Botany and Forestry at the University of Wisconsin. My academic discipline includes both of those areas, but, in addition, the past year and a half I have been working as a systems analyst in environmental problems....

I took an undergraduate Bachelor's degree in Forestry at the University of Toronto; a Master's degree in Forestry at the University of Toronto...in 1955; and I completed the

Ph.D. in Botany with a minor in Meteorology at the University of Wisconsin in 1960.

Q. Since that time have you been regularly engaged in ecological research, teaching, and administration?

A. Yes.

Q. And the past year and a half have you been doing specific work in systems ecology?

A. Yes.

Q. In the course of your regular professional activity have you ever had occasion to work with the Atomic Energy Commission or any of its affiliates?

A. I have served as a consultant on occasion to the AEC.

After preliminary qualification of the witness, testimony was elicited establishing the principles which determined the completeness of a systems model.

Q. So that we understand what we are talking about, what do you mean when you use the phrase "systems ecology"?

A. Systems ecology to me is the investigation of the system that is acting on biological materials in the natural environment, and it has three major components: These are the atmospheric transport system as it influences biological materials; the water transport system, the redistribution of water from the atmosphere to the surface, to the vegetation, and to the groundwater; and thirdly, the biological transport system itself, where we have movement of many materials by grazing and predation activities.

Q. Doctor, would you tell us what you mean by the phrase "transport system"?

A. By a transport system, I mean the system in the environment that involves a movement, transfer, or exchange of material from one point to another or from one form to another, as in the transformation of carbon dioxide by photosynthesis.

Q. All of these transport systems are functions of time and some of them are functions of distance, aren't they?

A. That's right, and functions of other properties of environmental systems.

Q. Now, Doctor, tritium is a biologically active material, is it not?

A. It can be in certain systems, yes.

Q. Would you please tell us the basic elements of the atmospheric transport system of a biologically active material?

A. The basic elements of this transport system include the circulation of the atmosphere, particularly the circulation of the lower atmosphere, and, in the case of tritium, we are primarily concerned with the water components in the atmosphere. This transport system includes such features as the lateral flow of air, including the flow of water vapor over a landscape where it may encounter areas of high topography which can result in cooling of the air and a resultant condensation of the water vapor, where it enters the water transfer system.

Q. All right, Doctor, would you summarize briefly the elements of the water transport system as they influence a biologically active material such as tritium.

A. The water transport system is much more fully understood than the atmospheric transport system, and we do have a computer simulation capability for predicting the movement of water through the land system from the moment that precipitation strikes the surface. The water is then redistributed to a number of variables within the model. I am describing the Stanford watershed model developed at Stanford University over the past ten years. [With] this model and its simulation capability, one is able to determine how much of the water from any precipitation input will be immediately evaporated; how much will become surface flow and move toward a stream and down a channel; how much will infiltrate into the soil and become accessible to plant roots; how much will be absorbed by the plant roots and transpired to the atmosphere; and how much may enter the groundwater to appear, with a considerable time lag, in a stream fed by groundwater....

Q. Is there a single published scientific paper that briefly covers some portions of the Stanford model...?

A. I have a paper here published by a colleague of mine at the University of Wisconsin. He and I, together with two others, are part of a systems group investigating the enrichment of waters, lakes, and streams in Wisconsin, and we are utilizing the Standford watershed model as the basic predictor capable [of] following [the] flow of water through this system.... Dr. Huff's primary research has been the investigation of the use of the Stanford watershed model as a means of predicting the transport of radioactive aerosols down the stream [by means of] materials picked up at the surface of the ground.

The Stanford watershed model predicts what the flow in the stream will be for some hours after the precipitation, and the hydrologic transport model that Dr. Huff has described is used to predict the concentration of radioactive materials that will be in that peak flow of water or that will be present in the water at any point after a storm or over a period of months.

Q. For the record, Doctor, would you identify that paper by title or publication.

A. The title of this paper is "A Numerical Model of the Hydrologic Transport of Radioactive Aerosols from Precipitation to Water Supplies," by Dale D. Huff and Paul Kruger, and it was published in Geophysical Monographs, No. 11, [in]... 1957.

The paper was then offered as evidence.

MR. EARDLEY: Just a moment, I object...I haven't read the paper yet, but I would object on the general ground that...he is offering this paper which deals with a subject with which he has not yet indicated he has any expert knowledge.

MR. YANNACONE: I will continue [to] qualif[y] [the witness], your Honor.

MR. SEARLS: I want to enter the further objection that it is hearsay as to these defendants [Austral Oil and CER

Geonuclear] with no right of cross-examination of the two authors of the paper.

Q. Doctor, in the course of your regular professional activities, have you had occasion to investigate the systems characteristics of streams?

A. Yes, sir.

Q. Have you had an occasion to make an independent scientific judgment of the effect and validity of the Stanford Model as to stream flow?

A. Yes, sir.

Q. Have you, in the course of your regular professional activities, had occasion to rely upon and utilize this model as the basis for work that you have published under your own name?

A. Yes, I have.

Q. Has the work that you have published under your own name been evaluated in the usual scientific sense through the process of publication?

A. Yes.

Q. What was the title of your publication?

A. The paper of primary interest here is entitled "Systems Models for Describing Changes in Ecosystems."...The authors are Donald G. Watts and myself, [Dr.] Watts being another colleague in the systems group at the University of Wisconsin. [The paper was] published in February of 1969 by the Institute for Environmental Studies at the University of Wisconsin.

Q. Doctor, under whose auspices was this paper prepared and published?

A. This paper was supported by the U.S. Public Health Service in part, by the University of Wisconsin Graduate School in part, [and] by the Federal Water Pollution Control Administration in part.

Q. Was it accepted by them as a fair return on their financial investment?

A. Yes.

MR. EARDLEY: Oh, just a moment. I object to that question. It calls for a conclusion by the witness about the state of mind of somebody else.

MR. YANNACONE: I will withdraw the question and rephrase it.

Q. Did you get all your grant money...? Did the agencies pay for it completely?

A. The agencies supported all of the work here, yes.

Q. And [they] paid all the money they were supposed to?

A. Yes, and continued the project to [include] current work that we are doing.

Q. Is the project continuing now?

A. Yes.

Q. Under the same auspices and support?

A. Yes.

Q. You have submitted that [paper] as a report to those funding agencies, haven't you?

A. Yes.

MR. YANNACONE: I ask the Court to take judicial notice of the fact that it is pretty obvious the agencies were satisfied.

THE COURT: All right.

At this point, the attempt was made to introduce published papers into the record as evidence, and, after objections and questioning by opposing lawyers, trial counsel for COSCC asked the following questions elaborating the extent of Dr. Louck's personal research and its relevance to radionuclides directed toward demonstrating that systems analysis is an integrative science requiring direct participation by individual scientists of specialized competence in many disciplines.

Q. Now, with respect to that paper[14] and the water transport system we have under consideration, are there elements of the

work done in that study that relate to the transport of biologically active materials such as tritium in a system such as the Rulison regional transport system?

A. The continuing objective of the systems studies at Wisconsin is to investigate the transport of nutrients—nitrogen and phosphorus—from various sources on the landscape to lakes and streams. It is the consensus of our group and of other groups across the country that a simulation capability of the carrier material, water, is the best means of achieving good prediction of a transported material, such as nitrogen or phosphorus.

We have also applied this technique to investigation of the transport of DDT. Any other material that enters water can be modeled and simulated by the techniques that Professor Dale Huff published in his paper.[14]

Q. In other words, then, in the course of your regular professional activities at the University of Wisconsin you participate in and collaborate with and conduct discussions on matters of mutual interest with Dr. Huff?

A. Yes, sir.

Q. And in the course of your regular professional activity, have you had occasion to make an independent professional judgment of the reliability and validity of the material contained in the Huff paper you have just described?

A. I have.

Q. Now, Doctor, is there anything inconsistent between the Huff-Kruger[14] paper and the paper you have prepared with Dr. Watts[15]...?

A. No, there is nothing inconsistent. They are directed to two very, very different but somewhat related activities, and they would have to be studied carefully to see the common denominator that runs through them.

Q. Is the material contained in each of those studies relevant to the basis of your opinion and discussion of the water transport system for a biologically active radioactive material, such as tritium, in the Rulison Regional Transport System?

A. Yes, I view it as an immensely relevant foundation to further discussion of the movement of tritium.

MR. YANNACONE: I now ask they be marked in evidence.

Further cross-examination by counsel for the AEC and other defendants sought to demonstrate the incompetence of Dr. Loucks and the immateriality of his testimony because of insufficient investigation of radioactive materials.

CROSS EXAMINATION BY MR. EARDLEY [AEC]

Q. Doctor Loucks, what courses did you take in college or since college which led you to an understanding of the major functions of these radioactive nuclides?

A. I am presently engaged in work that is primarily concerned with systems analysis of materials moving through the environment. Most of my preparation has led up to this activity. In developing this experience we have relied very heavily on the systems studies carried out at Oak Ridge National Laboratory, which I have followed closely for the past fifteen years. It has been one of the leading centers in the development of systems analysis of biological systems. And it is from that association that I have some experience with the movement of radioactive materials in systems. As a systems analyst, I cannot appear as a specialist in research in radioactive materials themselves, per se, but on their movement in complex systems.

Q. Now, what practical personal experience have you had in tracing the movements of radioactive substances in the ecology?

A. My personal experience in that area has been in the utilization of the published literature from Oak Ridge National Laboratory on the movement of these materials in biological systems, and which we are presently adapting through the systems analysis group at the University of Wisconsin.

MR. YANNACONE: I'm going to object. This is properly cross-examination. I am nowhere even halfway through my direct examination....

MR. EARDLEY: Your Honor, we are talking about now the

introduction of two documents here which, if he is an expert in this field, I would object to because there's no way I can cross-examine him about stuff that he has not, you know—that he is not knowledgeable about.

MR. YANNACONE: Let me withdraw the offer and continue the qualifications.

THE COURT: All right.

Q. In the course of your regular professional activities have you had occasion to investigate the analysis of systems and transport mechanisms in the atomosphere, in water and in biological systems, alone and in conjunction with others?

A. I have.

Q. Is it possible for any single individual at this time, with competence in any single academic discipline, to consider all of the elements of a water, atmospheric, or ecological transport system in the natural environment?

A. This is not possible for any one individual.

Q. [Are these considered] as a general rule, by the Systems Method?

A. Yes.

Q. And is this a method pioneered by the United States government at the Cambridge Radiation Laboratory and the Manhattan Project during World War II?

A. Yes.

Q. Have you had occasion to participate on some of these teams that do this type of research over the past ten years?

A. Yes.

Q. Now, in the course of preparation of the...paper ["Systems Models for Describing Changes in Ecosystems"],[16] have you had occasion to discuss the entire paper with your co-author, Dr. Watts?

A. I have.

Q. Is Dr. Watts a member of the faculty of the University of Wisconsin?

A. He is.

Q. What is Dr. Watts' peculiar specialized discipline?

A. He is associate professor of statistics, but his training at the Master's and Ph.D. level was in electrical engineering.

Q. In other words then, Doctor, to prepare that paper, which includes elements of a number of disciplines including, as not the least of which, statistics and ecology, required the...services of at least two people, is that correct?

A. It did.

Q. Of differing disciplines?

A. Yes.

Q. Are each of you capable of reporting the results contained in that paper?

A. Yes.

Q. Are you capable of standing cross-examination on that paper?

A. Yes, I am.

MR. YANNACONE: I [now] offer that paper in evidence.

This attempt to introduce published papers into the record as evidence met with objections and led to extensive *voir dire* by attorneys for the Atomic Energy Commission and the Austral Oil Company. These objections were met by elaborating the extent of the independent research conducted by the witness and its relevance to the systems analysis of radionuclide distribution, further establishing that systems science is an integrative operation requiring direct participation by representatives of many intellectual disciplines.

DIRECT EXAMINATION (Continued)

Q. Now, Doctor, in the course of your consideration of the transport system involved in the distribution of biologically active materials, have you had occasion in the course of your regular professional studies to rely upon the work of people at the Oak Ridge National Laboratory?

A. Yes, I have.

Q. Are these individuals full-time employees of the Atomic Energy Commission?

A. Yes, they are.

Q. Can you name them?

A. Dr. Jerry F. Olson [and] Dr. Robert O'Neil, both of Oak Ridge National Laboratory; Dr. Jerry S. Kline of Argonne National Laboratory, whose specialty is tritium; and Dr. Stanley I. Auerbach at Oak Ridge National Laboratory.

Q. Now, Doctor, in the course of your regular professional activities, have you ever had occasion to appear in a judicial proceeding before?

A. Yes, I have.

Q. And did you appear in one for me as a witness when I called you back in May of this year?

A. Yes.

MR. EARDLEY: Your Honor, I object to this line of testimony. What difference does it make whether he has appeared with Mr. Yannacone before?

MR. YANNACONE: Subject to connection, we have a number of documents that we have to get in and we're going to meet the same set of objections.

THE COURT: Go ahead.

Q. Doctor, did you appear at this hearing today pursuant to subpoena?

A. Yes.

Q. Did you receive that subpoena in this courtroom?

A. Yes.

Q. Did you receive a telephone call from me telling you that you were going to get a subpoena?

A. Yes, I did.

Q. Did you receive a telephone call from me telling you that I had requested the Atomic Energy Commission to produce you as

A. Yes.

Q. Now, Doctor, in the course of the preparation for the prior proceedings we participated in together, we collaborated for a number of months, did we not?

A. Yes.

Q. During the preparation of this proceeding, in view of the fact that you were formerly a consultant for the Atomic Energy Commission, we have not collaborated in the preparation of the testimony, have we?

MR. EARDLEY: Now just a moment, Your Honor. This is going too far.

THE COURT: The objection is sustained.

Q. Now, Dr. Loucks, with respect to the consideration of a system of transport mechanisms [in] air, water, [and] biological [systems] involving the distribution of biological active material, are the elements of the systems analysis itself independent of the nature of the material?

A. The primary transport processes you mention by which there is exchange in the system are the same regardless of the material that may be moving through the system.

Q. In other words, then, Doctor, to properly describe a system we describe two elements, the first of which are—

MR. EARDLEY: I am going to object. He's leading the witness right down the path.

MR. YANNACONE: He is a consultant for the Atomic Energy Commission, Your Honor, on matters that I haven't had a proper opportunity to prepare. He is here under subpoena.

THE COURT: Well, you said, as I understand you, you collaborated for months.

MR. YANNACONE: On DDT, Your Honor.

THE COURT: So the objection is sustained. Proceed.

The direct testimony then considered in more detail the characteristic of the individual regional ecological systems operative within the Colorado Regional Ecological System.

Q. Doctor, will you discuss the basic elements of the water transport system in two aspects, the first being that portion

which is variant, and a function of the transport mechanism, and [the second] that which is dependent upon the chemical and physical properties of the material to be transported?

A. Yes, the primary transport system is the movement of the water through the system itself. I listed seven or eight variables into which incoming water precipitation can be partitioned. The processes whereby it goes through this partitioning are such processes as evaporation, infiltration, gravitational flow, absorption by plants, and related transformations. This is essentially the system for material that is the carrier system. In addition, we have the transporting material, a material that may be in the water, for example, nitrogen, DDT, or tritium, but each of these materials will go through the processes at some rate that is somewhat different than that of the water.

Q. **In other words, then, Doctor, once you have adequately described the water transport function in the water transport systems, and then the physical and chemical properties and the biological activity of the material, you can utilize your systems model and come up with some predictable statements about the distribution of the biologically active material, is that correct?**

A. If the chemical and physical properties are well-enough known, one can make the adjustment in the system to achieve a prediction of the flow of the carried material. In many cases the properties are not well-enough known to make this prediction, however.

This characterization of the physical transport systems was followed immediately by characterization of the biological transport system.

Q. **Doctor, would you describe for us the biological transport system as an element of a systems analysis as it affects the transport of a biologically active material such as tritium?**

A. The biological transport system consists of plant roots which absorb water from the surface layers of the soil; water, which enters the conducting system of the plant and in the leaves,

and may be either transpired into the atmosphere or may, at that point, react with carbon dioxide and through photosynthesis become implaced in sugar molecules in the leaf which in turn can become implaced in starch or cellulose molecules of the plant tissue. The transport system continues then through what is referred to as another trophic level, another partitioning of the movement of materials upward through the food web when grazing animals, and this may include mice as well as cattle, feed on that herbage and utilize primarily the carbon and water that has been mixed in sugars and cellulose. But to the extent that tritiated water may have been a part of the water incorporated in sugar molecules, it can continue to be a component of cellulose entering the digestive tracts of the animals feeding in the next trophic level.

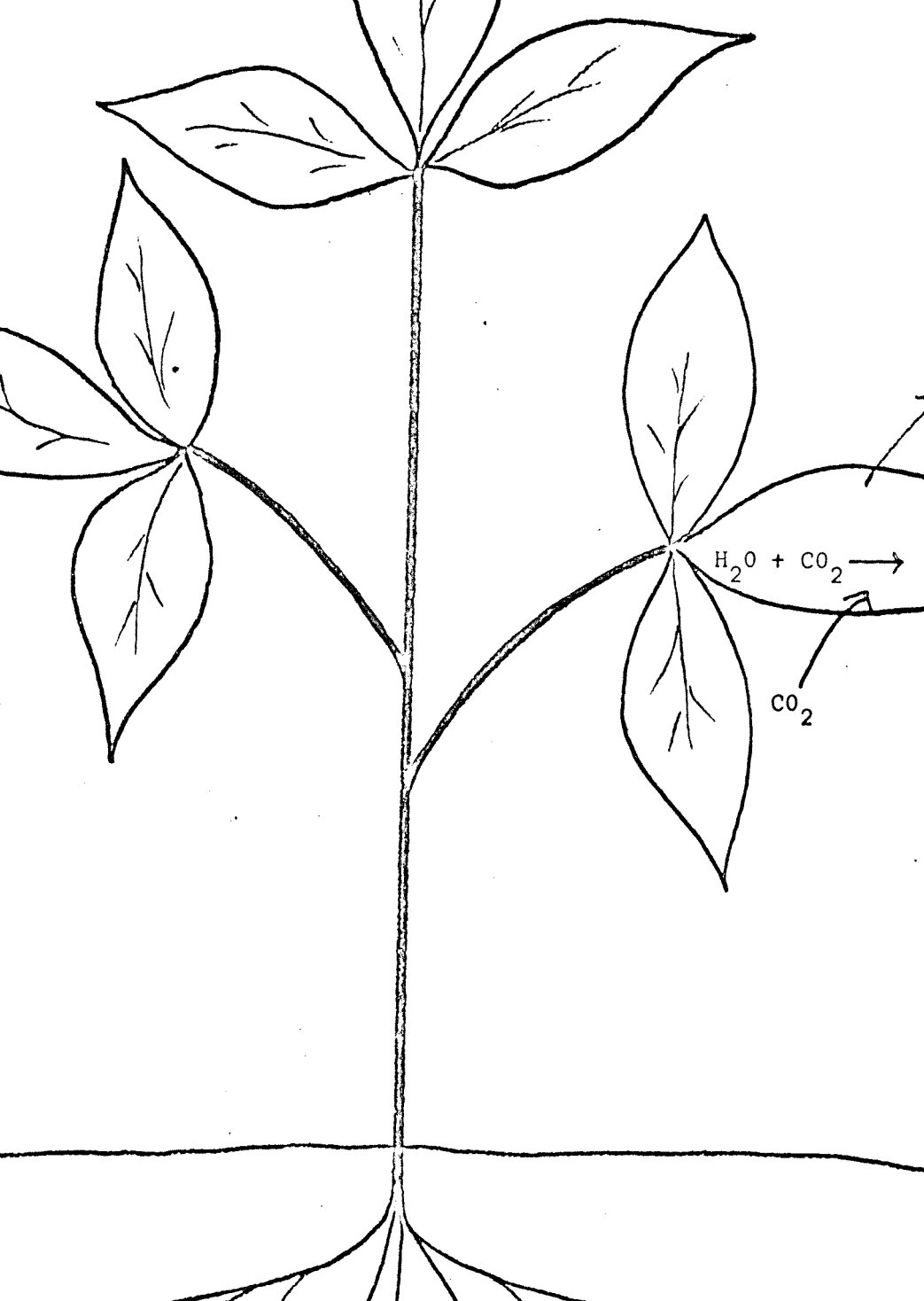
Considerable evidence was introduced on the photosynthetic process in primary producers, the role of water in the photosynthetic process, and the potential for the incorporation of tritium in the formation of plant sugars during the photosynthetic process. After establishing the characteristics of the trophic level of the primary producers, the witness proceeded to consider higher trophic levels in the system.

Q. Now, Doctor, in the course of your review of the government's little pamphlet on tritium, is there any evidence indicating the way in which tritium enters the plant world as such?

A. There is really a very cursory treatment of the potential for tritiated water to be taken up in the sugar cellulose molecules ....This paper is a review of the existing literature at the time that the review was made, and the author is able to simply cite what had been done up to that time and he points out that there seems to be...an incomplete reversibility of tritiated water vis-a-vis the ordinary water molecule indicating a selective uptake in cellulose.

Q. All right, now, Doctor, in the course of your regular professional education, you became involved in the subject of botany, did you not?

A. Yes.


$H_2O + CO_2 \longrightarrow$
CO_2

Q. You have a degree in it, don't you?

A. Yes.

Q. You [supervise] a number of Ph.D. candidates in it, don't you?

A. Yes.

Q. Now, Doctor, would you please for the record explain very briefly the mechanism of the fixation of energy in green plants and the place of water vapor, tritiated or otherwise, in this process?

The Court permitted Dr. Loucks to use a chart.

A. This is essentially the photosynthesis reaction where we see the uptake of carbon dioxide combined with water, for which, as we see from this review, there is just a little evidence of selective substitution of tritiated water, but so

little evidence that we simply have to view this as a void, as a gap in the knowledge... that we have to view the potential for selective substitution of tritiated water at this role in the equation as substantially unknown at this time. We have an input then of energy to bring about the synthesis of carbon dioxide (CO_2) and water (H_2O)—sunlight at appropriate wave lengths. To balance the equation, we want to take 6 $CO_2 + 6\ ^3H_2O$ (tritiated water) which will give as bigger molecules, then, $C_6H_{12}O_6$, plus the release of oxygen, $6O_2$.

Q. And that's the basic photosynthetic reaction, is it not?

A. This is the basic photosynthetic reaction which requires water as a substrate. The secondary reactions that are of some interest are the reduction of sugar, $C_6H_{12}O_6$, to starch or cellulose, as the case may be, as a storage or growth material in the plant.

The same sugars, of course, are the building blocks of the more complex molecules which the review by Jacobs[17] points out do take up tritium and retain it, particularly DNA.

Q. Now, Doctor, what is the basic constituent of cellulose?

A. Sugar in reduced form.

Q. Now, Doctor, when the green plants are grazed by the next trophic level above, what happens?

A. Of course, all the contents of the green plant are immediately ingested and any water in the plant, which might include tritiated water not found in cellullose, will then move into the water circulation of the grazing animal. On the other hand, the sugars, starches, and cellulose can be broken down by the grazing animal and utilized as building materials in the tissue of that animal.

Q. In other words, then, Doctor, there are two separate processes and mechanisms involved within this grazing animal, one for the water which is not bound in the green plant and is [simply] carried [by it], and the other which is bound in the chemical elements of the green plant?

A. That's right.

Q. Doctor, how much of this material that is ingested is retained by that grazing animal?

A. It would depend on the age of the grazing animals. What we are concerned with here is that, in general, about fifty per cent of the energy intake, that is, the energy contained in the bonds of those sugars or cellulose molecules, will be utilized in respiration, that is, essentially in the release of heat to maintain body warmth and activities of the grazing animal.

Of the remaining fifty per cent, a portion will be excreted and a portion will be utilized in the building of tissues so that we have then in the grazing animal the reduction of approximately fifty per cent of the sugars or cellulose, the $C_6H_{12}O_6$ equivalent, the reduction of this material to its components, carbon dioxide and water, and these are returned then to the atmosphere...And a portion of the remainder remains with the grazing animal; that [portion] which is not excreted.

Q. When the grazing animal is preyed upon, eaten, or otherwise consumed, does the same process repeat?

A. Yes, the same process repeats as we move through each predator-prey level referred to as a new trophic level, and we have the same utilization of approximately fifty per cent of the intake in simply burning off the intake and the storage of a portion, a major part, of the remaining intake.

Q. Doctor, in the course of your regular professional activities, have you had occasion to investigate the phenomenon commonly referred to as biological concentration?

A. Yes.

Q. Have you had occasion to investigate the phenomenon with respect to biologically active materials such as DDT?

A. Yes.

Q. Doctor, in the course of your regular professional activities, have you prepared documents for publication on the basic phenomenon, the biological concentration of DDT?

A. Yes, I have.

Q. And did you do this alone or in concert with others?

A. Well, because, again, the study of biological concentration or magnification of a transported material in a complex system extends beyond the capabilities of any one scientist, this kind of research is acknowledged in almost all laboratories I know of as being the responsibility of a combination of scientists, and in the case of the DDT study and manuscript we have now submitted for publication, the combination of people working on it included...

MR. EARDLEY: Just a moment, I would like to have Mr. Yannacone explain how DDT got into this cavity. Otherwise, I think it is immaterial.

Q. Doctor, in the course of your regular professional activities, have you had occasion to investigate the concentration or biological magnification of biologically active substances in regional transport systems?

A. Yes, I have.

Q. Have you had occasion to deduce any general principles with respect to the process of biological magnification and concentration as a result of this study that are essentially independent of the physical and chemical properties of the biologically active material under consideration?

A. Yes, we have arrived at evidence of significant time lags in the development of the magnification and in the expression of the magnification that seems likely to be independent of the material.

Q. Now, Doctor, so that we can understand the process of modern ecological research in ecological systems today, would you please tell us the place of the consideration of the actual transport of particular radionuclides throughout a regional transport system and the ultimate mathematical systems description of that transport system?... Would you outline briefly for us the elements of ecological research in systems today—modern ecological systems research—and indicate the role the general data regarding the place radionuclides and other biologically concentratable materials play in the systems study [so] that the general systems [characteristics] may be determined?

A. Well, we have to look at the biological transport system the same way that we look at the water transport system and recognize that the primary transport through the system is of energy, and that there are certain processes, approximately a dozen processes, involved in the exchange and transfer of energy in this system, we have to distinguish the analysis of the energy from the analysis of the transported material, such as tritiated compounds, in the biomass of these materials, which may not be transferred at the same rate as the transfer of energy itself. This is the primary conclusion that we arrive at from analysis of DDT [transport]. We find that the physical and chemical properties of the material will determine its rate of concentration, its rate of magnification, in the biological transport system.

Q. **Doctor, in order to properly determine the systems characteristics of the trophic level biomasses in a complex ecosystem such as the ones that you have [considered] in your systems papers, with respect to your systems analysis [of] the transport of the biologically active material DDT, did you have need to rely upon information with respect to the transport of radioactive materials and radionuclides in similar ecosystems?**

A. Yes, as I have indicated, our understanding of these systems to a great extent today rests on certain research begun in the early 1950s, particularly at Oak Ridge National Laboratory, and continuing to this time. However, the taking-up of this technique of systems analysis by other groups studying biological systems across the country has led to certain innovations in the technique that are now independent of the original work that focused primarily on radionuclides.

Q. **Well, the passage of radionuclides through an ecosystem, by virtue of the very physical properties of radionuclides, are easy to spot, aren't they?**

A. They are easy to spot and they are the material that has given rise to most of our present conception as to the nature of [material] movement in ecosystems.

Q. **And as Dr. Schultz indicated, much of the work that has been done depends upon the studies with Cesium-137 and I-131 and fallout products such as Strontium-90?**

MR. EARDLEY: Now, Your Honor, would you instruct Mr. Yannacone to let the witness testify? He hasn't been sworn and he has been doing all the testifying here.

MR. YANNACONE: I am not competent to testify.

THE COURT: I think he is just hurrying it along...Go ahead, the objection is overruled.

A. Yes. All those materials, all those radionuclides, have been used in the investigation of ecosystems and that isotope Dr. Schultz in particular mentioned, Cesium-137, has been particularly important.

Q. In the systems studies, is it possible to indicate qualitatively any of the criteria determining the time which it takes a given biologically active material to attain dynamic equilibrium at any given trophic level?

A. Yes, in the analysis of DDT, we had sufficient data available that we were able to show that the time lag involved in reaching equilibrium levels of DDT at the top of the trophic system, at the top of the food web...

Q. By the way, what is the top of the food web?

A. The top of the food web is represented by the top carnivore. That is, a species that preys primarily on other carnivores and which itself is rarely preyed upon. The Peregrine falcon is one of our best examples, also the bald eagle...To the extent that we [human beings] utilize meat in our diet, we are a top carnivore, but to the extent that we shift and become vegetarians we are less of a top carnivore. The time lag involved in achieving equilibrium levels with a contaminant such as DDT can be shown from an analysis of a system of differential equations that describe the changes in that system as at least equal to the lives of the longest lived species in the system. That is, you cannot get equilibrium at the top of the system until you have reached equilibrium all the way up through the system, and this is a function of the longevity, and in some of our top carnivores, such as the bald eages, we have time lags of thirty or forty years.

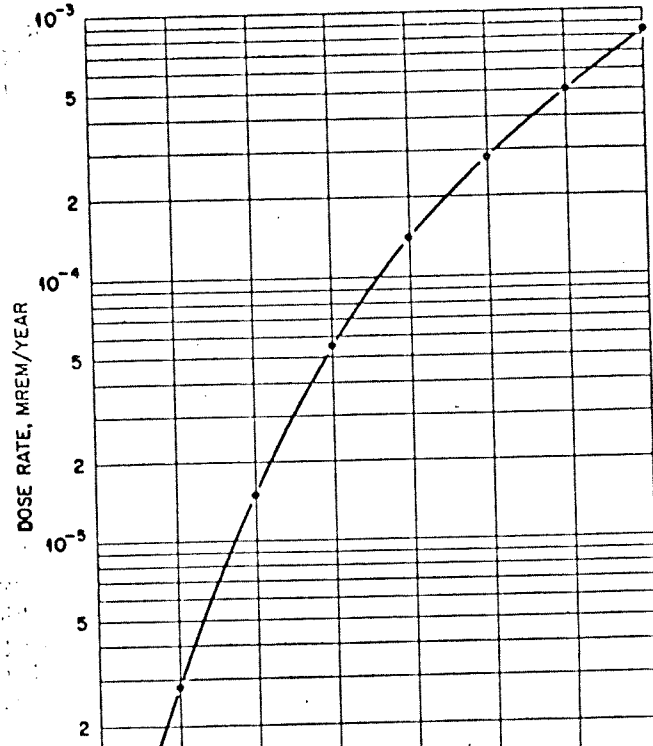
Q. I show you a graph which is entitled "Dose Rate to Body Tissue of the Worldwide Population from Tritium as a Result

of the Ingestion of Drinking Water and of Inhalation and Skin Absorption of Water Vapor...

Now, Doctor, I want you to look at that graph and indicate whether or not that indicates from purely a mathematical point of view any points at which dynamic equilibrium of tritium in the trophic level occupied by man may be reached?

A. This is worldwise accumulation and for the year 1970...it shows two times ten to the minus six millirems per year. By 1985 it is ten to minus four millirems per year. By the year 2000, it is ten short of ten to the minus three millirems per year, indicating a continuing buildup which clearly is not reaching an equilibrium level.

First the graph, not the entire paper in which it appeared, was offered into evidence and admitted without objection.



§ 8.43 TESTING THE COMPLETENESS OF DESCRIPTIVE SYSTEMS MODELS. The early testimony developed a relatively general outline of the physical and biological components of a Regional Ecological System Model. Direct examination then proceeded to compare the systems studies of the Atomic Energy Commission which had been offered to support the safety evaluation of the proposed general release of tritium into the Central Colorado Regional Ecological System.

Q. [By Mr. Yannacone] Now, Doctor, is it possible to describe the regional transport systems in order to predict the transfer and distribution of a biologically active toxic material such as tritium? Yes or no?

A. [By Dr. Loucks] It's possible to make a description, yes.

Q. And without the development of an adequate systems model [is it possible to predict the transfer and distribution of a] biologically active toxic material such as tritium?

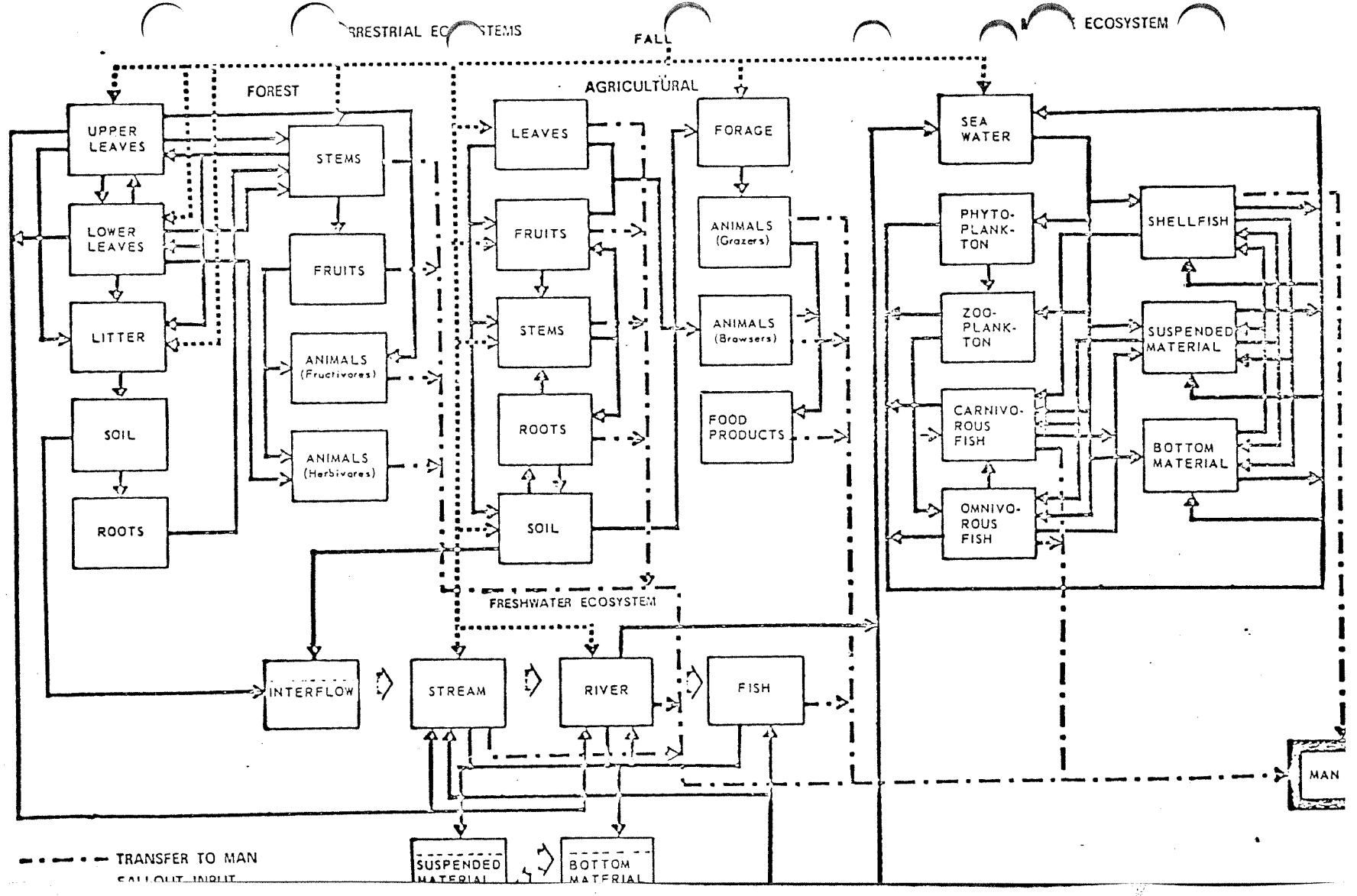
A. No. You cannot possibly make a satisfactory prediction without a complete descriptive model of the transport [of] material through the systems.

Q. Doctor, at this time can you, with a reasonable degree of ecological certainty, based on the data contained in the technical discussions of over-the-site safety programs for underground nuclear detonation[35] and in the exhibit *Project Rulison Postshot Plans and Evaluations*,... adequately predict the transfer and distribution of the material tritium throughout the Rulison regional transport system?

A. I do not think so.

Q. Now, Doctor, would you elaborate on your answer as to why you cannot?

A. I would like to contrast the completeness of the systems description in these two documents with one in a paper entitled *Systems Analysis of a Coupled Compartment Model for Radionuclides Transfer in a Tropical Environment*, by Stephen V. Kaye and Sidney J. Ball, both of Oak Ridge National Laboratory, ...


FALL
FOREST
AGRICULTURAL
UPPER LEAVES
LOWER LEAVES
LITTER
SOIL
ROOTS
STEMS
FRUITS
ANIMALS (Fructivores)
ANIMALS (Herbivores)
LEAVES
FRUITS
STEMS
ROOTS
SOIL
FORAGE
ANIMALS (Grazers)
ANIMALS (Browsers)
FOOD PRODUCTS
SEA WATER
PHYTO-PLANK-TON
ZOO-PLANK-TON
CARNIVO-ROUS FISH
OMNIVO-ROUS FISH
SHELLFISH
SUSPENDED MATERIAL
BOTTOM MATERIAL
FRESHWATER ECOSYSTEM
INTERFLOW
STREAM
RIVER
FISH
MAN
SUSPENDED MATERIAL
BOTTOM MATERIAL
TRANSFER TO MAN

Q. Do you know either of those authors?

A. Yes, I know Dr. Kaye.

Q. Now, have you on prior occasions reviewed and considered his work in your work?

A. Yes.

Q. Doctor, let's lay a proper foundation for that paper.... Without quoting therefrom, would you indicate briefly the subject matter of that Kaye paper?

A. This paper is concerned with the feasibility and safety, particularly the safety, of the proposed sea-level canal in Panama, and it offers a systems model that they use to answer some questions with respect to the redistribution of radionuclides that may be expected in the tropical environment if and when the blast for the sea-level canal is set off.

Q. And is that a systems model that was prepared by, through, or under the aegis of the Atomic Energy Commission?

A. Yes, it is.

Q. Have you examined the model as purely a systems model?

A. Yes, I have.

Q. Is the substance of that paper fairly representative of the basic elements of compartmentalized systems models as now being developed under the aegis of the Atomic Energy Commission?

A. Yes, it is.

Q. Now, would you indicate where, if anywhere, in the *Postshot Rulison Memorandum,* and the *Preshot Memorandum,* there appears any reference to systems modeling or systems considerations for the purpose of predicting the ecological effects?

A. In the *Preshot Memorandum* there is a Chapter 15, "Environmental Safety," by R. G. Fuller, ecologist for Battelle Memorial Institute. In Chapter 15 there is a system model, Figure 15.2, "Generalized Materials Transfer Program," which has some similarity to a figure in the paper by Mr. Kaye, Figure 1, entitled "Preliminary Diagram of En-

vironmental Pathways for Transfer of Radionuclides to Man in a Tropical Environment."

MR. EARDLEY: Your Honor, I want to object to this line of questioning. If, as I gather, he is about to testify that there isn't a proper model—a proper model has not been prepared for this problem at Rulison—it seems to me that he can so state and tell us the reasons. I would ask no more when I compare what's wrong with a lawyer's brief, and say, "Well, let me show you what a good brief looks like." I don't think we have to go to some other model. If he is an expert, as he purports to be, he can tell us, without comparing, what the defects are in our study.

THE COURT: Seems to me that the objection is well taken.

Q. Doctor, in the course of your regular professional activities have you had occasion to evaluate systems models with respect to water transport?

A. Yes.

Q. Doctor, in the course of your regular professional activities have you had occasion to take and review the systems model set forth in [the *Pre-Shot Memorandum*]?

A. Yes, I have.

After consideration of the Atomic Energy Commission Systems Model, the direct examination of the witness turned to those elements of the systems study which did not represent adequate support for the Atomic Energy Commission safety evaluation.

Q. Doctor, can you with any reasonable degree of ecological certainty evaluate that model, first of all with respect to its capability as a fair and adequate description of the Rulison regional transport system, based on other data in the same documents?

A. This systems model represents a relatively advanced description of the system at Rulison, but it is deficient in several major respects. The information is simply not yet available to provide a fully satisfactory description of the regional transport system around Rulison; the model provided here

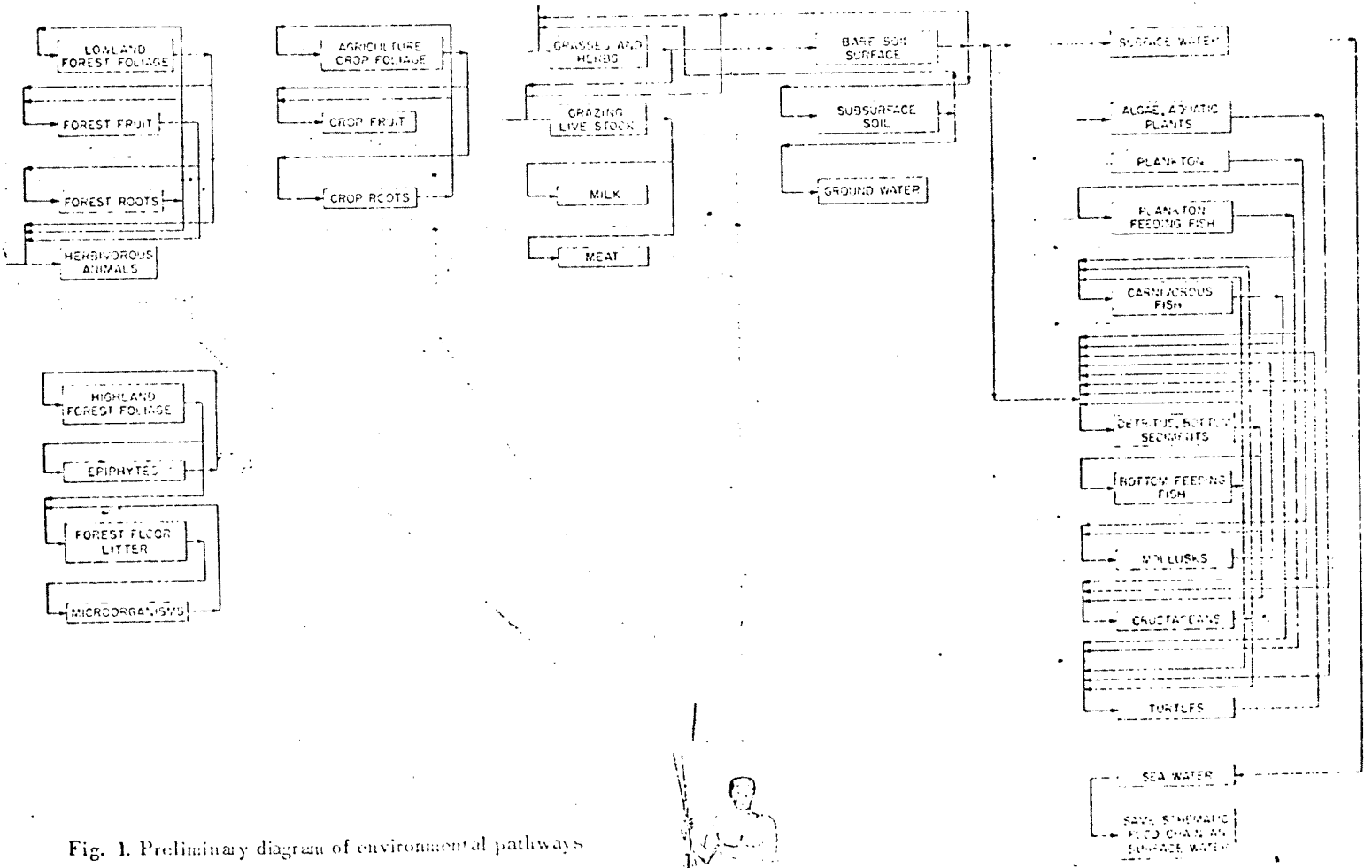


Fig. 1. Preliminary diagram of environmental pathways for transfer of radionuclides to man in a tropical environment.

represents the state of the art as of two or three years ago....

Well, in certain laboratories across the United States and in Canada, there have been some major innovations in the description of terrestrial ecological systems as described here primarily in incorporating the atmospheric and water transport systems. If you examine the [Pre-Shot] model...you will see that it is primarily a model of the biological transport system and the redistribution of materials in that biological system to the environment. It does not provide an adequate model of the uptake of materials in the environment into the biological materials.

As often happens during litigation involving complex technical issues, an experienced Trial Judge enters the dialectic process and seeks to clarify the position of the parties and occasionally recapitulates the evidence in the record to that point in the trial.

THE COURT: Aren't the dotted lines merely to show that part which results from the fallout and then it gets into the system, and then the solid line gives the pathway or transfer into the system? Is that correct?

DR. LOUCKS: The solid line represents the transfer between variables within the system.

THE COURT: Yes, but on the fallout, it has to start someplace. It falls out as shown by the dotted line, as I understand this. I'm not arguing about it....I'm just trying to understand it.

DR. LOUCKS: [That's the way the AEC is presenting it, but] I say that the fallout and uptake by the plant represents a series of processes such as infiltration, absorption, and uptake through the leaves, evaporation, both from the surface and vicinity of the plants, and then from the leaves themselves through transformation. These are all processes involved in that uptake, and the complete system and the complete description of the transport system from the point source represented in the plans for the postshot evaluation ought to be incorporated in the model.

Q. Now, Doctor, have you in the course of your regular professional activities had occasion to investigate the elements of the transport mechanisms that are so summarily represented by

dotted lines in this figure entitled "Generalized Materials Transfer Program of the Preshot Evaluation Report"?

A. Yes.

* * *

Q. [By Mr. Yannacone] What elements in your study do not appear in the [Generalized Materials Transfer Program]?

A. There are none of the elements [of our study] showing relationship to the various water variables and the water transfers in the AEC study.

The questioning continued to develop the ramifications of a safety evaluation that had been based in part on an incompletely described system model. The central issue was whether the AEC studies did in fact represent the "state of the art" in environmental systems methods at the time they were done, and if they did not, was the omission likely to result in underestimation of the potential health hazard to any of the people living in the vicinity of the proposed release. Objections by AEC defense counsel were frequent, but several major points were established. The first dealt with the feasibility of a more complete predictive model, and the second with the independence of system characteristics from the absolute quantities of tritium transported.

The hearing examiner concluded with the following findings of fact:

Q. Do you have with you any examples of the relationships that exist and are summarized by that dotted line?

A. Well, the best model of this relationship is in...the report by [Dr.] Donald G. Watts and myself. In a color chart at the back of the report, entitled "Water Variables and Water Transfer Functions," we have described in a block diagram similar to the one in [the Pre-Shot Evaluation Report] the exchanges that go on in the movement of water from the point at which it reaches the surface [as] precipitation to its subsequent redistribution by evaporation to the atmosphere or into root zone storage or stream flow into pools, lakes, or reservoirs.

Q. Now, would you elaborate for the Court and tell us what those elements that don't appear [in the AEC study] consist of...?

A. Well, they consist of the transformation of precipitation to surface water and surface flow. The transformation by infiltration of precipitation of water at the surface to water in the root zone. These are separate compartments that are similar to the transfer of a radioactive material, for example, in [the "Generalized Materials Transfer Program"] from upper leaves to lower leaves, this is a transfer that is sufficiently important to have been included in this figure and the processes involved in infiltration and redistribution of water in the soil profile and to the plant roots are of equal consequence in simulating the system as a whole and predicting the tritium uptake by plants.

Q. Are you telling us, Doctor, that the ["Generalized Materials Transfer Program"] in Defendants' exhibit considers only stems and leaves in that subsystem and ignores the root stem and the ground infiltration to the roots?

A. As inputs. It does provide for materials in the soil and in the soil water as outputs from the biological systems.

Q. Doctor, unless you have fully identified all the inputs and outputs of a given regional transport system, can you adequately develop a model on which you may base predictions?

A. No, you cannot make a model that will give you satisfactory predictions unless you have included all of the major variables and transfer systems through which the material must move to reach the biologically important materials.

Q. After these have all been identified, before you can use the model for predictive purposes, is it still necessary to perform field observations and assemble field data with respect to the particular regional transport system involved?

A. This is one of the most important points. It is strongly evident from both exhibit[s] that these reports acknowledge that we do not now have the information to express quantitatively the transfers between these compartments. These

models, incomplete as they are, show only the description, the kinds of transfers that will have to be taken into consideration to give you a predictive model. I haven't counted the total number of transfers that will have to be estimated here, but they are in the order of 30 or 40, each of which must have a transfer coefficient determined for it before a simulation of that system and a prediction of biological magnification or flow through the system can be achieved with any quantitative accuracy.

Q. **All right Doctor, assuming that we know the actual amount of tritium released as tritiated water vapor plus a little bit of tritiated natural gas at the wellhead during the flaring process, on the basis of the information contained...in the "Pre-Shot" and the "Post-Shot" evaluation reports, can you determine the distribution and transfer of tritium throughout the Rulison Regional Transport System?**

A. No, you cannot.

Q. **...Doctor, what is the relationship of the atmospheric transport system which we haven't discussed in the detail and this type of water model?**

A. The water model itself begins with the precipitation input, so that any characteristics of the topography in this region that will influence the precipitation will then influence the water transport system...determining flow, so there is this coupling of the atmospheric transport system to the characteristics of the drainage basin.

Q. **Is it possible to determine the actual quantitative tritium input to the Rulison Regional Transport System with respect to its water transport system unless it's atmospheric transport system from ground zero to the point where the inputs [are shown] in the water models has been accurately determined or described?**

A. No, you would have to begin with a full description and analysis of the atmospheric transport system from the point source.

The discussion of biological aspects of a regional systems model

was centered largely around the systems study offered by the AEC as part of their safety evaluation program. The criticisms were really ones of scale or precision, rather than error. With the examination of the AEC systems model complete, therefore, counsel began asking about the regional systems which control the biological system, carry waste materials such as radionuclides, and which had not been considered in the AEC safety evaluation model.

Q. Doctor, would you outline briefly for us what are the elements of an adequate description of the Rulison atmospheric transport system, and would you refer to the ["Pre-Shot Evaluation Report"] and indicate what if any differences there are?

A. I would like to draw a diagram in support of this answer... [and]...discuss first of all the induction of precipitation by orographic effects over a plain that is followed downwind by some local elevation, perhaps 1000 feet. We may have horizontal flow of air carrying a volume of water, but as it moves over this topography the air naturally is forced upward. As it is forced upward it is cooled because of the adiabatic lapse rate of temperature, on the order of three degrees Fahrenheit for 1000 feet.

This cooling by upward motion frequently results in the induction of cumulus clouds at some point near the top of the hill, and if the atmospheric system is unstable, with air at that point having a dew point near the ambient air on the plain, the cloud will build in sufficient size so that we get rain. Orographic rainfall of this type is what occurs all summer long in the mountain systems, and is what accounts for the differences in the forest composition that are described in Appendix B, "Ecological Considerations," of [the "Pre-Shot Evaluation Memorandum"]. The differences, of course, in forest composition that I am talking about, are the presence of alpine fir and Englemann spruce, both species with relatively high demands for water. They occur on the upland in the White River National Forest, the so-called Battlement Mesa, south and east from the ground zero site, whereas at lower elevations in the Battlement Creek area you have species such as piñon pine that are tolerant to droughts and will survive with very little water.

So, if I may draw a specific cross section of the Battlement Creek and adjacent topography, we have the high topography in the White River National Forest at approximately 10,000 feet elevation, and we have the Battlement Creek Valley with a point at which flaring will be done somewhere in the vicinity of 6500 feet. Thus we have a difference in elevation of 3500 feet, which under normal adiabatic lapse conditions would give a temperature difference of ten degrees magnitude, which clearly is sufficient to bring about considerable cooling and, therefore, considerable condensation of water vapor as air masses move from the west to east over the Battlement Mesa plateau. The differences in [species] composition which are recorded in Appendix B indicate a major difference in precipitation, and this difference is predictable as a function of the topography, the temperature differences, and the regional flow conditions.

Now, since this precipitation is induced locally, over a difference of approximately two and half miles, we can expect that tritiated water released into the atmosphere at the flare point will be precipitated in the immediate vicinity when showers occur.

Now, as long as there is stability in the air mass, and there is no shower occurring, the tritiated water of course will be dispersed over a considerable distance, but the primary time for testing for contamination in this area must be when you are getting local precipitation induced as a result of the orographic effect.

I might point out that the report also shows that there will be a considerable release of heat from the flaring, and the heat itself will initiate updrafts that will reinforce the buildup of cumulus clouds and shower activity on this upland.

Now, since the shower activity will not be initiated until close to the top of the mountain, the continuation of that shower into the next valley is really the site at which most of the contamination would be expected to occur. This is in the Plateau Creek Valley, and I would point out that although the post-shot plans and the evaluation documents show the location of residences in the Battlement Creek Valley system,

it does not take into consideration the distribution of residences in the Plateau Creek area, the area where a system model of the regional atmosphere transport system predicts much or most of the contamination would take place.

The central issue at this point in the trial was whether the Atomic Energy Commission System Study for Project Rulison did in fact represent the "state-of-the-art" in environmental systems science at the time it was done and if it did not, were the inadequacies likely to have increased the potential hazard to the health of the people of the Colorado Regional Ecological System. In spite of frequent objections by the attorneys for the Atomic Energy Commission and the Austral Oil Company, several major points were established. The first dealt with the feasibility of a more complete predictive model, and the second with the independence of systems characteristics when considered from an analytical and conceptual point of view, from the absolute quantity of the environmental toxicant transported.

Q. **Now, Doctor, can you with a reasonable degree of scientific certainty indicate what, if any, studies will be needed before the actual transfer, transport, and distribution of tritium as released during the flaring process of Project Rulison can be accurately predicted in a quantitative sense?**

A. It is my opinion from analysis of these two [AEC] documents, and my understanding of ecological systems, that we would require a major program of study relating specifically to tritium and its activity, and its differences from water in movement through the atmospheric, water, and biological transport systems.

The model I envisage would be approximately twice as complex as [that presented by the AEC]. This isn't impossible. There are groups at several locations across the country that are dealing with models that are this complex, but these are people that are primarily concerned with water and nutrient transport, and the Atomic Energy Commission probably has not had access to those particular kinds of studies [which] allow us to examine the extent of infiltration of the water coming down on Battlement Mesa, its infiltra-

tion and subsequent reappearance in the stream water in the valley of Plateau Creek, and the potential contamination of those reservoir systems.

It seems to me that this is the kind of program which if carried out could give us the assurance that the proposed post-shot plans and evaluation could be carried out safely, and I am very much struck by how far short of an adequate program the materials in the [Post-Shot Plans and Evaluation] are.

Q. Doctor, can you state with a reasonable degree of scientific certainty that the actual qualitative system description that is derived from the studies you have performed is invariant with respect to [its] systems relations subject only to modification of rate constants and transfer coefficient functions with respect to the chemical and physical properties of the toxic materials that are biologically active being transferred through the system?

A. Yes.

MR. SEARLS: I object for the further reason, Your Honor, that he has no knowledge of the amount and quantity of tritium which will be released in this particular reentry.

Q. Doctor, does the actual amount of tritium to be released go the qualitative description of the system or only the quantitative predictability of the system?

A. No, the characteristics of the system and the characteristics of the material moving through the system will determine the essential properties of where that material will turn up at other points within the system and this is independent of the total load entering the system.

Q. In other words, then, Doctor, the water transport system, once it is described for the Rulison regional transport system, will still be the Rulison regional transport system for water, in spite of the fact that you might introduce tritium, Cesium-137, or I-131 into the water system?

A. Yes, and it will still be the same system if you double the quantity of material or change the levels in any way.

A. That's right.

MR. YANNACONE: Your Honor, I must object on the grounds that Mr. Fuller, who testified here on the first trial as the ecological evaluator of this particular Rulison shot, testified to the sum and substance of all the data he had on the ecology of Project Rulison, and this witness testified that he was shown the transcript and examined that testimony.

THE COURT: Well, he could have said that. He could have said that in response to this answer. The objection is overruled.

Q. Now, let me ask you this. I suppose that listening to you, it must be quite expensive to prepare one of these models, as you term them?

A. Yes, it is....I have been involved in bringing together just such a proposal right now at the University of Wisconsin, and this kind of study will cost approximately $4 million over a four-year period.

Q. And let's assume that for the sake of the questions to follow that no one really knows how much, if any, radioactive nuclides are going to come out of this chimney. Do you always, in your work, insist upon a model which costs up to $4 million when you do not even know whether there is going to be any dangerous hazard resulting?

A. We are always influenced by the number of other examinations that model will have to answer for that investment, and in this case we have nuclear reactors being sited all over the country which will also release tritium, and the model developed for the Rulison site would be at least a pilot scale model that would have some application at sites around the shore of Lake Michigan and Vermont and particularly the sites where tritium would be released into the estuaries along the Atlantic Coast. These areas are going to be different in some respects, but we would not have to repeat this investment at all the other sites. The same kind of study is needed to assure safety with respect to material like tritium, regardless of the circumstances, so I don't think that that price should be identified solely with the Project Rulison.

Q. Well, would a study at Rulison bear upon future detonations of different sized and different types of nuclear bombs at different depths and different materials, issuing different types of radionuclides?

A. Any search that improves our understanding of the full transport system through which any of these materials will be moved, will help. Some of these other shots will be under conditions of different topography; different kinds of patterns of precipitation through the year and they would obviously have to be supplemented by local studies. So we would benefit greatly by carrying out this kind of investigation at Rulison, but it would not give us all the answers...for other detonations.

Q. So what might be involved is simply an educational, but not for Rulison, [a] practical, project?

MR. YANNACONE: I'm going to object unless [information is] added to the record [as to] whether there are going to be more shots in Project Rulison with the same type of regional...

THE COURT: Objection sustained.

Q. I understood you to testify that if there was no rainfall that this, as you understood it—and I don't really know how much you understand about Rulison...

MR. YANNACONE: I'm going to object to that. [Dr. Loucks] understands a lot more, apparently, about the system mechanics of Rulison than anybody who has published anything about it.

* * *

THE COURT: I sustained the objection to that. I understood you to say that if there was no rainfall there would be this, as you understand, I suppose this material down there, whatever it may be, is coming up through a long stack to be flared at the top. Now, do you know what flaring means? It's going to be burned, and I understood you to state that if there was no rainfall, the tritium would be dispersed over a wide area. Now, is that fair?

MR. YANNACONE: I must object unless we specifically talk about tritium in the form of HT, a gas, or HTO, tritiated water vapor.

THE WITNESS: I testified that tritiated water was released by flaring and would be dispersed downwind from whatever direction the wind may be originated. But, in this area the wind is frequently west to east and you have this high topography at the ground zero site and to the extent that the atmosphere is clear, this water vapor would move downwind a little perhaps, settling, but most of it to be ultimately precipitated at some site, perhaps in the Front Range of the Rockies or farther east on the Great Plains.

Q. That would be a very wide dispersion, would it not?

A. That would be a wide dispersion.

Q. You have just finished testifying that if the air were clear, and I presume that means no precipitation, that this tritium, if there is tritium coming up through the chimney, will be carried presumably by the winds into the Rocky Mountain area—that's considered quite an area—and I am asking you whether or not you have enough familiarity with the properties of tritium to know how much above the natural background there would be an increase in radiation.

A. No, I don't have that kind of information. That's the kind of information that I would hope will be obtained to satisfy the degree of...

Q. Now, assuming that under such conditions and such dispersion there would be no detectible damage to the ecology or to man, would you as a scientist believe that an expenditure of $4 million dollars or thereabouts would be justified?

MR. YANNACONE: I am going to object to the assumption in the question that there would be no detectible damage. There is no foundation for asking this witness now a question in that form unless Mr. Eardley is willing to specify what he considers damage, or, let the witness do it.

THE COURT: Overruled. He may answer it.

A. Well, Your Honor, I find that question extremely difficult to

answer. I can't accept that assumption, but if I must accept it, and somehow you are able to assure me that there are no detectible effects, then really that kind of investment is apparently not justified.

Q. **So if as a matter of practice at Rulison they were to shut off the gas during rainfall, during precipitation, there wouldn't be any need for this expensive model, would there?**

A. We have no means of predicting when there is going to be a build-up of precipitation downwind from a source of heat buoyancy. As air moves up over this topography...

Q. **Precipitation means rain to me. What does it mean to you?...Does it include snow and...**

A. Yes, snow, and it can develop on this high topography in fifteen minutes.

Q. **Well, are you suggesting that we can't turn this thing off in fifteen minutes?**

MR. YANNACONE: I'm going to object. There is a time lag factor as the exhibit indicates that the cross examiner has totally ignored.

MR. EARDLEY: Well I'm certainly ignoring it. I don't understand it.

THE COURT: Overruled. Let's go.

A. There is a major time lag for the horizontal transport from the flaring site to the point at which precipitation will start, and you can't turn it off until the precipitation is taking place and, meanwhile, there is this indeterminate quantity of tritium that would be carried down from this shower.

Q. **With respect to tritium, are you familiar enough with the properties of that [substance] to have any idea as to how much tritium will come up through the pipe in the form of water vapor, and how much in the form of gas?**

MR. YANNACONE: I'm going to object. This testimony is already in the record. We must take as an assumption what the defendants have told us will be delivered from that pipe top.

THE COURT: Objection is overruled.

A. I have read the testimony of Dr. Carter and Mr. Fuller and these documents and...

Q. When did you first see this document that is called "Tritium" which was mentioned in the discussion?

A. I saw the document first this morning, but I have known about it and discussed it over a period of time. And I expected to be able to use it during part of my testimony.

Q. Even though you didn't see it until this morning?

A. That's right.

Q. Well then, do I understand that you don't know what portion of the tritium will come up in the form of water vapor and in the form of gas?

A. No, we simply have the statements by Dr. Schultz and the testimony that there will be about ten thousand curies.

Q. Wouldn't it make a difference insofar as the ecology is concerned, whether this came up in the form of water vapor or gas?

MR. YANNACONE: I'm going to object, Your Honor. There is ample testimony in the record that...

THE COURT: I don't care what the testimony is in the record. He's cross examining the witness and frankly, counsel, I'm beginning to lose my patience with your interrupting here and suggesting to the witness the answer, trying to put it in the form of an objection. Proceed.

MR YANNACONE: Your Honor, I respectfully take exception to that. I don't have to put words in the mouth of this witness.

THE COURT: Well, you have been doing it, sir. Proceed, Mr. Eardley.

A. I see no reason why it will make any difference if the gas is being flared and you have the kind of contribution of tritiated water that is produced by burning the gas and that which originated as water vapor.

Q. Don't you think that water vapor is heavier than gas?

A. Does the question imply that the gas might be released unburned?

Q. It might be released as a gas, yes... Let us assume we have got two pipes, one discharges tritium as a gas and the other discharges tritium as water vapor. Now, water vapor has a different weight than gas, doesn't it?

A. Yes.

Q. It's heavier, isn't it?

A. Yes.

Q. And it would be deposited—it would drop to the ground much sooner, would it not?

A. I don't believe so, no.

Q. The same amount of wind would still go as far?

A. The currents, the eddys, and circulation in the atmosphere will mix them both. Ultimately there will be some precipitation, but the eddy structure in this valley is going to be such as to mix them both.

Q. Have you ever seen vegetation that had received tritiated water?

A. No.

Q. Have you ever seen tritiated water?

A. No.

Q. Have you ever seen the animals that have eaten tritiated food?

A. No.

Q. You made a statement, and I'm sorry that I wasn't able to copy it down, that there were some cases where the information wasn't developed fully enough to determine its effect in the systems. Do you remember that question?

A. I was saying that to complete the prediction of the movement of material through these complex systems, we must know the processes whereby there is transformation at various locations in the systems such as evaporation or

photosynthesis. And that to achieve prediction, we must know the physical and chemical characteristics of the material, like tritium, in that process...particularly the biological characteristics of tritium and its action in processes like photosynthesis [which are] not adequately known at this time.

Q. Well, if it isn't adequately known—what is the real value of the system?

A. We want to be able to predict how far and to what extent tritium will be brought down over these uplands downwind from the flaring site; in what quantities.

Q. You made a statement that food value—I think we were talking about animals, cows—would be reduced in some chain by fifty per cent. Do you remember that?

A. This is normal respiration in the body.

Q. How much tritiated food does a cow have to eat in order to achieve some sort of an imbalance with nature which will cause some deleterious effect?

A. This is what I believe we must know before we can be satisfied as to the safety of the site. We don't know it at the present time.

Q. ...Are you aware of the full extent of the monitoring that will take place or that is proposed to take place at Rulison?

A. Yes, I have read it in the post-shot plans and evaluation.

Q. And you are then aware of the fact that they are going to monitor water, vegetation, et cetera...at close distances and at far points from Rulison?

A. Yes.

Q. And is it your testimony that this will not sufficiently protect the ecology of the area?

A. That's my testimony.

Q. Why? Explain why that is.

A. Because the model to which they expect to relate the values obtained does not faithfully enough follow the full transport

by which this material is moved through the system and, for example, it does not indicate the need to monitor immediately during a shower downwind from the flaring site. This is the period [during which it] will be most essential to have estimates of the content of tritium entering the terrestrial system.

Q. Let's assume a rainfall, and that tritiated water is deposited within a quarter of a mile, a mile away—you have no idea how much radiation that would cause to the vegetation there?

A. No.

Q. Or whether it would do any damage to vegetation?

A. No. This is the information we need.

During cross examination, counsel for the Atomic Energy Commission tried to raise doubts as to the utility of a quantitative predictive model examining the movement of tritium in Western Colorado, suggesting that the total proposed release would have to be known in order to develop the models, and that this would require measurement of the total natural gas yield from the experiment which would require "flaring" of the radioactive natural gas from the underground chamber.

CROSS EXAMINATION BY MR. SEARLS

Q. Don't you consider the actual monitoring to be more accurate than predictions made prior to the reentry?

A. No, I think—

Q. Answer yes or no.

MR. YANNACONE: I am going to object [unless] the question can be answered yes or no—

A. No.

Q. [By Mr. Searls] In other words, you think predictions made prior to reentry can be more certain than monitoring that might take place after the venting to the air?

A. I didn't say they would be more certain. I say that we must

have predictions that we can have some confidence in as part of the assurance that monitoring will be satisfactory.

Q. Can monitoring be made more certain than predictions made prior to the reentry?

A. Certainly, but it is after the fact.

REDIRECT EXAMINATION

MR. YANNACONE: Let the record show I would like to apologize to the Court if I have inconvenienced it in any way by way of outburst.

Q. Doctor, if I try and put any words in your mouth, you will spit them out, won't you?

THE COURT: Counsel, that remark is absolutely uncalled for and I am telling you your right to practice in this court is going to be withdrawn if you keep making snide or sarcastic remarks.

Q. Doctor Loucks, with respect to the $4 million systems model, will it be valuable for regional transport systems similar to the area around the Rulison Regional Transport System?

A. Yes, it will.

Q. Are there other such areas in the State of Colorado?

A. Yes, sir.

Q. Are there other such areas along the Mesa Verde formation where we can assume that further underground detonation to stimulate gas wells will occur?

A. Yes.

Q. Now, Doctor, would you refer to [your diagrammatic representation of orographic precipitation] and indicate... whether precipitation can occur as a result of the flaring process itself?

A. Yes, this relates to the heat released by the flaring process, which in itself creates an updraft, a vertical movement of air, which will move an air mass with its water content, included in it tritiated water, released vertically through the at-

mosphere some distance. [The Post-Shot Evaluation] estimates this up to 300 meters, which would result in a lowering of the temperature around that air mass, and this in itself over horizontal topography can result in the induction of local showers.

Q. In other words, then, the precipitation that occurs in the orographic form the orographic shower, as it were, occurs after the tritiated material enters the cloud or the horizontal-lateral movement of the atmosphere, and at some point removed [from the site of release], when the elevation is high enough so that the adiabatic lapse rate causes the dew point of the air mass to be exceeded?

A. That's right.

Q. In other words, stopping the flaring when the rain cloud...

MR. EARDLEY: Just a moment, this is going to be another leading question. When we get to flaring I would like to have him ask a question and not tell the witness.

THE COURT: All right.

Q. Doctor, what do you understand by flaring?

A. As I understand it, this is the burning of the tritium as it escapes from the stack, so as to produce tritiated water [vapor].

Q. Now, does the burning of this gas, this triatiated gas, do anything to the radioactive properties of the tritium.

A. No.

Q. Now, Doctor, assuming...the tritiated gas comes out, some of it as gas, some of it as water vapor following burning or as water vapor coming up out of the pipe, does it make any difference in your opinion with respect to the potential for the development of orographic showers downwind of that release?

A. No, it would not matter what the origin of the tritiated water was.

Q. ...Without burning [the tritiated gas] to make it tritiated

MR. SEARLS: I object because, first, he's not an expert on tritium, and in the second place, he has not shown he has done any monitoring of the character which he is asking him to testify.

MR. YANNACONE: I will qualify further.

THE COURT: No, I'm going to permit him to answer the question. The objection is overruled.

A. One, you would have to look at the atmospheric circulation of this area and hydrologic circulation of this area in some detail before one could determine how big a monitoring program it would be. It would obviously be substantial but probably less than a complete study.

Q. Would the monitoring program outlined in any of the exhibits you have examined be adequate in the absence of a full systems description?

A. No, I do not believe that any of the monitoring programs as described in these documents is adequate.

Q. Now, Doctor, in the course of your preparation for this hearing, did you have occasion to read [this] portion of...the testimony?

> **Q. Mr. Fuller, what is your function, if any, with respect to Project Rulison?**
>
> A. Battelle [Memorial Institute] was given the opportunity for being responsible for making an ecological survey of the area around Project Rulison to ascertain whether in our opinion any adverse ecological consequences would result from the project.
>
> **Q. Did you conduct the survey?**
>
> A. I did.
>
> **Q. Would you briefly outline the extent of the survey?**
>
> A. Yes. On consultation or taking into account the assumptions that are made by those expert in the field of containment and nuclear detonation...

Q. Now, Doctor, assuming that [testimony] in addition to all the other assumptions that Mr. Eardley and Mr. Searls ask you to

make, does that in any way change your opinion?

A. No.

Q. **Now, Doctor, assuming a substantial and extensive monitoring program based upon a model similar to the one you have described as incomplete here, will this furnish usable data for accurate prediction of any of the distribution transfer or transport mechanisms of tritium following flaring or distribution of a second project similar to project Rulison?**

A. No, in general a large-scale monitoring program does not result in any considerable degree of predictive capability. It allows a limited degree of prediction under certain situations, on occasion, but it avoids the question of understanding the system well enough so that you have good predictability.

MR. YANNACONE: I have no further questions.

Counsel for the AEC, Mr. Eardley, again tried to raise doubts as to the utility of a quantitative predictive model for examining movement of tritium in western Colorado environment. In this instance he was suggesting that the total proposed release would have to be known in order to develop a model:

CROSS EXAMINATION BY MR. EARDLEY

Q. **One thing that is difficult for me to understand since this model business is brand-new to me—I have never heard of it until today—is, if you don't have any idea what's going to come into the atmosphere, how can you predict by any means what the ecological effect of that substance is about whose possible nature and quantity you have no idea?**

A. We have learned through the last twenty years of use of DDT that we simply cannot introduce these kinds of materials into the environment if we don't have the basis for predictions. We can get it by appropriate studies. We can develop this predictive capability without having contaminated the environment.

THE COURT: He asked how do you do that?

Q. **When you have an unknown, how do you arrive at a known?**

A. By investigating the physical and chemical and biological characteristics of the material moving through the system under laboratory conditions so that you get individual rate functions or process equations that can be utilized in the system as a whole.

Q. Now, if we wanted to spend $4 million dollars to have you go out to Rulison, what would be your assumption in making a model as to how much tritium was going to come up? You would have to know that, wouldn't you?

A. Not while you develop the model. Once you have a functioning model with the physical and chemical and biological characteristics of tritium operating in the transfer process, then, simply in the computer you can say we will put in 500 curies and see where it comes out. Then, we would put in 10,000 curies and see where it ends up in the environment, It's got to go somewhere and we would know where it's going to be.

MR. EARDLEY: No further questions.

CROSS-EXAMINATION BY MR. SEARLS:

Q. Have you made any laboratory tests of tritium?

A. No, I have not.

MR. SEARLS: That's all.

REDIRECT EXAMINATION

Q. Are you familiar with some of the literature with respect to the [environmental effects of] tritium?

A. Yes.

Q. Are there laboratory studies with respect to tritium that you know of that are adequate to plug into a model for the purpose of modeling the physical and chemical properties and biological properties of tritium?

A. There has been some work but there is no major program investigating these characteristics that would be suitable at this time for plugging into these rate function equations.

Q. Now, Doctor, as I understand your model, once you have got it

in a descriptive form, then all you need to add to it to get a quantitative answer is the exact amount of tritium being released at a point? Is that what you're trying to explain?...- After you have developed a model, but when you don't know the amount of tritium that's going to be released into the region that you have just modeled, what does the model tell you, if anything?

A. The model will give you the estimated response. That would be the levels of tritium at certain points in that region and different materials in that region as a function of some specified input and we could simply look at where the tritium would be and in what concentration, given some input of 10,000 curies or some smaller amount, it would be possible to actually determine what the level of input is, presumably in this kind of model.

Q. **When the amount of tritium to be released in the system [modeled] is known, what can the model [tell us] when you put this number in?**

A. It tells us what the concentration and the loading of the environment, both over short periods and cumulatively over an extended period of time, will be.

Q. **And if the model fairly and accurately represents the transfer systems, then whatever amount of tritium is released, a small or a large amount, you can tell where it's going and where it's going to end up, is that right?**

A. That's right.

MR. YANNACONE: I have no further questions.

Your Honor, since I am leaving for a large portion of the case, I would again like to apologize to the Court for any outbursts. It is a privilege and an honor to practice in this District and I am sorry if I have caused the Court any inconvenience.

§8.49 THE PROJECT RULISON DECISION. The Court issued its memorandum opinion and order on 16 March 1970, supporting the plaintiff COSCC on most points of law, but finding in favor of the Atomic Energy Commission on most issues of fact. The systems testimony was the exception, and the court wrote,

"The plaintiffs' challenge to the defendants claim that the planned release of radionuclides will not present a threat to health is on two levels. At the one level, they challenge the assertion that the plans themselves provide adequate protection for health and safety. At the other level, they claim that although the plans may be adequate in terms of the AEC standards and other accepted standards, the standards themselves do not provide adequate protection for health and safety.

"The only significant evidence introduced by the plaintiffs in challenging the adequacy of the plans was through the witness, Dr. Orie Loucks. Dr. Loucks is a Professor of Botany and Forestry at the University of Wisconsin who has been working as a systems analyst in environmental problems. His opinion is that the AEC has made an inadequate ecological study, that distribution and resultant concentration of the radionuclides cannot be predicted, and that therefore the potential threat from the release is not accurately predicted in the plans. He thinks that a major sutdy is necessary of tritium, its activity and movement through the atmosphere, water, and the biological transport systems. Such a study would cost $4 million and would take about four years.

"Defendants countered by offering the opinion of Dr. Vincent Schultz, formerly of the Division of Biology and Medicine of the AEC and currently a Professor of Zoology at Washington State University. His opinion is that the release of tritium from the Rulison flaring is of such an insignificant amount that no detectable ecological effect will result. This opinion is in agreement with the results of the AEC study found in Exhibit N, Appendix B.

"The Court is not in a position to evaluate a scientific controversy of great sophistication, and this controversy as to methodology is certainly more sophisticated than the conventional problems with which we are faced. However, we fortunately need not make such an evaluation to decide the issues presented in this case. The question that we must resolve here is whether or not the evidence establishes that the plans for the release and flaring of the gas are inadequate to provide a reasonably certain and rational basis for predicting that no danger to health and safety will result therefrom. The controversy as to the necessity of a com-

plete ecological analysis of tritium distribution need not here be resolved if in fact an accurate prediction can be made from the information provided by the defendants' studies."

Judge Arraj concluded his decision by stating that:

"...plaintiffs have failed to show the probability of irreparable damage if the flaring is not enjoined, and have failed to establish a right to the specific injunctive relief sought."

However, he then qualified the decision by emphasizing:

"...This opinion, our findings, conclusions and ruling apply only to the specific factual situation presented by this letigation. We approve only of the flaring of the gas from the one well in the Rulison unit in which a nuclear device was detonated on September 10, 1969. We are not here and now approving continued detonations and flaring operations in the Rulison field. Such determination must be made in context of a specific factual situation, in light of contemporary knowledge of science and medicine of the dangers of radioactivity, at the time such projects are conceived and executed.

"Further, although we have found that the plans for the flaring do provide reasonably for the health and safety of the public and that the specific plans for surveillance are reasonable, we determine that the Court should retain jurisdiction in order to insure that the plans we today approve as reasonable are in fact reasonably and safely executed."

The final action of the decision was to dismiss the complaints and order that:

"...defendant Glenn Seaborg or his responsible agent comply fully with the information and data dissemination plan outlined in Appendix A to this opinion, insuring the distribution of such data to the Rulison Open File as indicated, the Colorado State Public Health Department, and also to this Court, when they first become available." [18]

As a result of the brief introduction of modern methods of environmental systems science into the Project Rulison litigation,

the Court retained jurisdiction of the post-shot release plans and required more extensive "off-site" monitoring of radiological safety data than had been proposed initially in the Project Rulison post-shot plans, and there was some assurance that this monitoring would now be organized environmentally to follow atmospheric, hydrologic, and biological transport systems.

§8.50 Brief Statements of Systems Characteristics

A more common participation by environmental systems scientists in legislative and judicial processes involves preparation of a general statement describing the Regional Ecological System and indicating its primary response characteristics. Such a statement involves a substantial amount of preparation, for usually the systems scientist will be called upon to develop and present flow charts and the general form of the equations necessary to develop a mathematical model. An overall conceptual model should be presented, and although solutions to the mathematical model are not usually possible, the legislative or judicial body considering the proceeding should be encouraged to utilize the conceptual model, the flow charts, and the general mathematical model as a structured means of considering the Regional Ecological System as a whole and of evaluating the probable impact of any proposed action within the system, as well as an indication of alternative futures for the Regional System.